

Links between livestock production, the environment and sustainable development

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Summary

This study examines the prospects for strong growth in the supply and demand for animal products worldwide, especially in developing countries, where 80% of the world's population lives. Based on scientific publications, statistics and field observations, it reviews greenhouse gas emission levels from livestock, the ability of ruminant livestock systems to sequester carbon and the capacity of the livestock industry to meet the challenge of sustainable development and to share its benefits while minimising impacts to climate change. Special attention is paid to the situation of the 800 million livestock farmers in the world living at the extreme end of poverty. The study underlines the importance of improving livestock productivity and the interdependence of the economic, environmental and social components of sustainable development. It highlights how, in the least developed countries and most lower-middle-income countries, the pressure exerted by animal diseases hampers efforts to improve livestock productivity. Poor livestock farmers have not sufficiently benefited from development policies and need support to adopt technological advances to meet the challenges of sustainable development and poverty reduction.

Keywords

Development policy – Environment – Greenhouse gas – Livestock production – Livestock productivity – Poverty reduction – Sustainable development.

Introduction

Importance of livestock for human well-being and the future of our planet

World economic growth and the massive development of non-agricultural industries and services have reduced the monetary share of livestock production in the global economy. Nevertheless, this has not diminished the importance of livestock for human well-being and the future of our planet. Grasslands occupy more than one-quarter of the world's land surface, and one-third of cultivated land worldwide is used to produce cereals, oilseeds or feed-crops for animals (1). Almost one-fifth of the world's population – 1.3 billion people – derive income from livestock production (2) and 2 billion people use animals to work the land or to transport goods (3). For 800 million poor farmers living on less than US\$1.25 a day, animals have particular attraction because they generate income, provide numerous benefits and represent capital that can be mobilised to cope with agricultural crises or life events.

Changing lifestyles have significantly reduced direct contact between humans and farm animals; nevertheless, in biological terms, human and animal health remain inextricably linked. Two-thirds of human pathogens are pathogens that also affect animals, and the incidence of emerging zoonotic diseases is on the rise, thus increasing the threat of human pandemics.

Prospects for strong growth in animal production worldwide

Humans have a strong natural behaviour to consume animal products. For most people, an improvement in the quality of life goes hand in hand with increased consumption of animal products. In the most developed countries, where per capita consumption of animal products is very high, recommendations aimed at stabilising or reducing demand for such products mean that growth in the consumption of milk and meat is on the wane. Conversely, in developing countries, where 80% of the world's population lives, demand for animal products is soaring and, over the coming

years, is likely to increase further because of rising household purchasing power (especially among those exiting poverty and entering the middle class) and demographic growth.

Focus and objectives of the study

Thanks to advances in science and technology, animal husbandry has the capacity for continued growth and increased production worldwide. Today, the main challenge is to achieve sustainable growth that is able to satisfy needs and contribute to the well-being of present generations of people and animals, as well as to share the benefits of growth and preserve the natural resources and ecosystems on which future generations will depend.

This study accepts that increased production and consumption of animal products is inevitable in developing countries. Using data from scientific publications, statistics and field observations, it examines the conditions for sustainable growth in livestock production in least developed countries and in lower-middle-income countries¹, where 87% of poor people live and where livestock farmers live in extreme poverty.

Exaggerated accusations and environmental impacts revised downwards

In 2006, the report *Livestock's long shadow* (4) made a number of serious accusations about livestock, often alleging that they are the main culprit for: water pollution; lowering water tables (because animals compact the soil as they move around); soil degradation; acid rain; diminished wildlife and biodiversity; deforestation; and hazards to human health. It also blamed livestock for helping to degrade coastal areas and destroy coral reefs, as well as being responsible for 37% of anthropogenic emissions of methane (CH₄), 65% of anthropogenic emissions of nitrous oxide (N₂O) and 18% of total anthropogenic greenhouse gas emissions. These accusations were levelled particularly at extensive livestock systems.

Very few people have read all 390 pages of the report. Short excerpts containing the most serious allegations were widely quoted in the press, but the benefits of livestock and the improvement measures cited in the report were not reported, thus helping to demonise livestock production in the eyes of the public and of decision-makers in least

developed countries, lower-middle-income countries and development agencies. This led to a collapse in aid and national financing for the poorest farmers (see below, in particular Fig. 10), which weakened animal production and aggravated the impact of livestock on the environment and climate change (5) (Box 1).

Box 1

The greenhouse effect and greenhouse gas emissions from agriculture

Two-thirds of the sun's rays reaching the Earth's surface are absorbed. Under the effect of reverberation, the remaining one-third is returned to space in the form of infrared rays. However, the gases referred to as greenhouse gases, which accumulate in the lower atmosphere, act as a filter and block the passage of some of the infrared rays, which are then returned to the Earth and contribute to its warming.

Two-thirds of the greenhouse effect results from the absorption of heat by water vapour and clouds, while one-third results from the interaction of 40 or so greenhouse gases, including: carbon dioxide (CO₂), methane (CH₄), ozone (O₃), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). The main greenhouse gases are naturally present in the atmosphere but, since the beginning of the industrial era, human activity has significantly increased their concentration.

According to the Intergovernmental Panel on Climate Change (IPCC), in 2010–2011, agricultural production was responsible for 5 to 5.8 Gt CO₂-eq, or around 12%, of total anthropogenic greenhouse gas emissions, and the entire agriculture, forestry and other land uses (AFOLU) sector is responsible for 10 to 12 Gt of CO₂-eq, or almost one-quarter of total anthropogenic greenhouse gas emissions (6).

CO₂-eq: carbon dioxide equivalent; Gt: gigatonne (1 GT = 10⁹ tonnes)

Since 2006, estimates of greenhouse gas emissions from livestock have been revised sharply downwards several times. In 2014, an analysis conducted according to recommendations from the Intergovernmental Panel on Climate Change (IPCC) concluded that greenhouse gas emissions from livestock worldwide represented around 28% of CH₄ emissions, 29% of N₂O emissions and 9% of total anthropogenic greenhouse gas emissions (7). These new estimates, far lower than in the *Livestock's long shadow* report, were compared with the estimates sent periodically by developed countries to the United Nations Framework Convention on Climate Change (UNFCCC), which confirmed their validity.

In addition, many studies have demonstrated that the allegations against livestock production were exaggerated or unfounded, highlighting in particular the low impact

¹ The country classification is based on that used by the OECD Development Aid Committee for granting aid. In 2013, there were 49 least developed countries, 34 of them in sub-Saharan Africa, and 40 lower-middle-income countries, all of which had a gross national income per inhabitant between US\$1,006 and US\$3,975. They included India, Nigeria and Pakistan.

of livestock production on deforestation (Box 2) and the benefits of pasture land for air quality, the regeneration of water resources and the maintenance of wildlife and biodiversity (see below).

However, the studies that might have restored the reputation of livestock farming did not enjoy the same media attention as the *Livestock's long shadow* report, and alarmist messages prejudicial to the implementation of sustainable livestock development continue to be broadcast.

Evaluating emissions and the capacity of livestock systems to sequester carbon

The instructions of the IPCC state that estimates of greenhouse gas emissions must include all sources, as well as all sinks of greenhouse gases associated directly or indirectly with a product or service. An evaluation of the contribution of livestock production to greenhouse gas emissions therefore entails a balance-sheet approach that takes into account the offsetting allowed for carbon sequestration.

Box 2

The impact of livestock production on worldwide deforestation is declining

The rate of deforestation has diminished on every continent, from 16 million hectares in the 1990s to less than 10 million hectares in 2012. The most spectacular results have been achieved in Brazil, where government measures have curbed deforestation and the spread of sugar cane plantations (for bioethanol production) and soy (for animal feed). According to Nepstad *et al.* (8), deforestation in Brazil has been reduced by 70% since 2008 and stood at around 0.45 million hectares in 2012.

In 2012, the two main regions affected by deforestation were equatorial and southern Africa, with 3 million hectares of forest destroyed, and Indonesia, with 2.1 million hectares of forest destroyed. In Africa, deforestation is widespread and often caused by poor peasants gathering fuelwood and who need agricultural land to plant crops. In Indonesia, deforestation stems from industrial planting of crops such as oil palm and from the timber trade. In Brazil, residual deforestation is caused by small farmers clearing trees to extend their crops onto more fertile land. The departments responsible for forest protection now rely on mixed crop/livestock farming to maintain soil fertility and ensure the sustainable development of agriculture on land already cleared, thereby avoiding further slashing and burning.

Source: Malhi *et al.* (9), Nepstad *et al.* (8) and Margono *et al.* (10).

Assessment of the environmental impact of greenhouse gases is generally based on a life-cycle analysis. For the low-input/low-output livestock systems adopted by many poor farmers (see Box 3), life-cycle analysis may be confined to assessing the greenhouse gases emitted directly by animals and their dung, because such systems consume no fossil fuels and use virtually no inputs.

Box 3

The main greenhouse gases generated by agriculture

Carbon dioxide (CO₂) represents around 70% of anthropogenic greenhouse gas emissions. It is produced mainly by burning fossil fuels (oil, coal) and biomass. Photosynthesis helps to offset CO₂ flows. On balance, the net flow of CO₂ emissions is very low (11).

The volume of **nitrous oxide (N₂O)** emissions is much lower than for CO₂, but its ability to trap heat is 298 times greater than that of CO₂. Agricultural N₂O (from animal effluents, crop residues and agricultural fertilisers) is produced in the soil or in liquids when an aerobic biological process turns ammonia into nitrates and the nitrates are then turned into nitrogen gas (N₂) by anaerobic denitrification.

Methane (CH₄) is produced mainly by enteric fermentation, a stage in the ruminant digestion process, and by irrigated rice crops. Its ability to trap heat is 25 times greater than that of CO₂.

In most regions of the world, N₂O is the main source of agricultural greenhouse gases. CH₄ is the main source of agricultural greenhouse gases in only a few regions: Latin America, Eastern Europe, Central Asia (owing to large-scale rice growing) and in the Organisation for Economic Co-operation and Development (OECD) countries of Oceania.

The **calculation of greenhouse gas emissions** takes into account the global warming potential of the main gases. Estimates must include all sources and all sinks of greenhouse gases associated directly or indirectly with a product or service. The total volume of emissions of these gases is expressed as a CO₂ equivalent (CO₂-eq), using the formula:

$$\text{kg CO}_2\text{-eq} = \text{kg CH}_4 \times 25 + \text{kg N}_2\text{O} \times 298 + \text{kg CO}_2$$

Types of livestock greenhouse gas emissions

Enteric fermentation

According to Gerber *et al.* (12), because enteric fermentation produces heat-trapping methane, cattle account for a total of 71% of the greenhouse gases generated by the livestock sector, and small ruminants for around 7%. Pigs and poultry, which provide more than three-quarters of the world's meat, together produce less than 20% of greenhouse gases. The estimates of Caro *et al.* (7) are comparable, although they apportion a slightly higher share of livestock emissions to cattle (74%) (Fig. 1; Box 4).

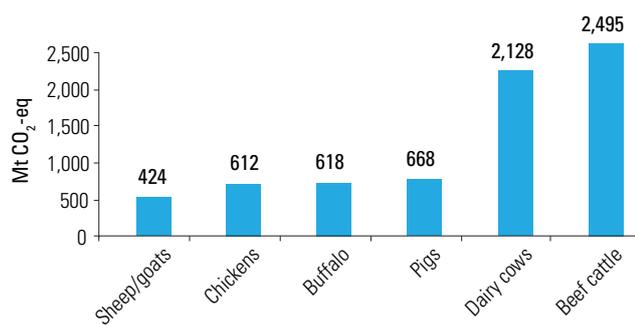


Fig. 1
Estimated global greenhouse gas emissions by species, in metric tonnes of carbon dioxide equivalent (Mt CO₂-eq), 2011
 Source: Global livestock environmental assessment model (GLEAM), cited by Gerber *et al.* (12)

Box 4
Enteric fermentation

Ruminants have a very special digestion process called enteric fermentation, which takes place in the rumen under aerobic conditions, enabling them to transform cellulose-rich food into milk or meat with a high nutritional value.

During the digestion phase, bacteria break down the plant matter into fatty acids, CO₂ and CH₄. The fatty acids are absorbed into the bloodstream, while non-fermented food and microbial cells pass through the intestine and the gases (including methane) are removed by eructation.

The quality of feed is very important. When rations contain less cellulose, more energy and proteins and are more digestible, the part played by enteric fermentation in digestion is reduced, as are methane emissions.

In extensive livestock systems animal dung produces little methane

In extensive livestock systems, animal excrement is dropped on the ground. The CH₄ generated by dung is negligible when there is no storage in a confined space and no anaerobic fermentation (11, 13). According to IPCC standards (13), at an average temperature of 25°C, the average level of CH₄ produced by dairy cattle manure is 98 kg a year in North America, where animal dung is often processed in liquid form, but only 1 kg a year in Latin America and Africa, where ruminant livestock systems are usually extensive (Table I).

In extensive livestock systems N₂O emissions are less than the global average

The volume of N₂O emissions depends on manure storage conditions, temperature, type of soil, rainfall and other factors. In faeces the nitrogen is largely organic. It must first be mineralised in an aerobic environment and then denitrified in an anaerobic environment (in a confined space or in the soil) before becoming a source of N₂O. When dung is deposited on the ground in areas with heavy rainfall, mineralisation can be rapid but, in dry regions, it breaks down much more slowly and the faeces can remain intact on the ground for months.

There are very few studies concerning N₂O emissions from pastoral farming systems in arid zones. The few results available vary widely. Gerber *et al.* have estimated that N₂O emissions from animal dung account for around 33% of total emissions from cattle in sub-Saharan Africa (12). According to an estimate of greenhouse gas emissions in Australia, under climatic conditions similar to those in sub-Saharan Africa, in 2012, the amount of N₂O emitted by

Table I
Emissions of enteric CH₄ and CH₄ from cattle and pig manure in the major world regions (13)

Region	Kilograms of enteric CH ₄ per animal/year			Kilograms of CH ₄ from animal manure per animal/year (25°C)		
	Dairy cows	Other cattle	Pigs	Dairy cows	Other cattle	Pigs
Sub-Saharan Africa	46	31	1	1	1	1
Latin America and the Caribbean	72	56	1	1	1	1
East Asia and the Pacific	68	47	1	26	1	6
South Asia	58	27	1	5	2	5
Middle East and North Africa	46	31	1	2	1	5
North America	128	53	1.5	98	2	39
Western Europe	117	57	1.5	75	21	27

animal dung on the ground was three times smaller than the amount produced by grassland fires, ten times smaller than that produced by crop fertilisers, and represented only 3% of the total N₂O emissions from livestock (14).

Capacity of ruminant livestock systems to sequester carbon and prevent greenhouse gas emissions

Carbon sequestration on pasture land

Grazing land acts as a carbon sink that can sequester a large proportion of greenhouse gas emissions from livestock. According to Ronald and Debbie (15), cattle grazing land captures 20% of the CO₂ released into the atmosphere by deforestation and agriculture worldwide. In Europe, grasslands are net sinks of CO₂, storing 500 kg to 1,200 kg of carbon per hectare. In addition, good pasture management and hedgerow maintenance offset 24% to 53% of emission levels, depending on the production system (16, 17). Leip *et al.* (18) demonstrated that plant consumption by animals reduces the amount of reactive nitrogen available in the soil by 30% to 40%, thereby limiting the production of N₂O.

Consumption of coarse agricultural by-products prevents biomass burning

In many African countries there are formal contracts between livestock owners and arable-land farmers under which animals are led onto croplands immediately after the harvest to eat the coarse residues of crops (corn, millet and sorghum stubble, leguminous haulm, etc.) and, in exchange, to fertilise the soil. Animal consumption of agricultural residues that would otherwise have been burned can prevent the emission of 15 kg to 25 kg of CH₄ per hectare from field residues².

Contribution to reducing bush fires and protecting shrub savannah

By reducing the savannah ground cover, ruminants prevent or reduce the severity of periodic bush fires, thereby preventing the destruction of trees and shrubs by fire and the emission of at least 13 kg of CH₄ per hectare of burned savannah (Box 5).

In tropical regions where annual rainfall exceeds 500 mm per year and where grasses compete with shrubby vegetation for soil use, the presence of animals weakens grass cover and the intensity of bush fires. First, this promotes shrubs and, second, it also promotes the replacement of shrubs

² One kilogram of burned corn stover emits 2.7 g of CH₄ and 1 ha of corn stover represents 10 t of dry matter; 1 kg of burned grass savannah emits 2.3 g of CH₄ and 1 ha of savannah represents around 6 t of dry matter. When assessing greenhouse gas balances, the emissions from dung on the ground should be offset against the crops they fertilise (13).

with non-fire-resistant woody plants, thereby boosting the establishment of shrub savannah and carbon storage capacity.

Draught power

In all least developed countries and middle-income countries, animals provide a cheap source of renewable energy. They help with farm work and transportation and play a key role in the rural economy. Two billion people use animals to work the land or to transport goods. In some countries, a huge proportion of animals are used for their labour. In Bangladesh, 90% of adult cattle are used for both farm work and transportation (3).

In 2009, 60% of India's land was ploughed by animals, 20% by hand and 20% using tractors. The power provided by India's 83 million draught animals, fed mainly on agricultural by-products, has been estimated at 30,000 megawatts – the equivalent of 50% of India's power generation capacity. Without draught animals, ploughing would require five times as many tractors and the use of 20 million tonnes of diesel fuel, which would release 60 million tonnes of CO₂ (19, 20).

Methods for calculating greenhouse gas emissions should be adapted for extensive livestock production

All researchers point to the particularities of calculating carbon emission and sequestration and the huge differences arising from farming methods, soil types and climate. This wide variability makes it risky to use local observations as the basis for constructing models for calculations on a

Box 5

Production of greenhouse gases by bush fires

Fire contributes to climate change in many ways. It releases very large quantities of CO₂, CH₄ and, to a lesser extent, N₂O. Fires generate emissions of hydrocarbons and reactive nitrogen, which reacts to form ground-level ozone, a powerful greenhouse gas. In addition, large fires produce a variety of aerosols and smoke that play a role in preventing certain kinds of radiation from leaving the atmosphere. Lastly, they reduce the Earth's surface albedo for several weeks, which contributes to global warming.

In the savannah covering around one-eighth of the Earth's surface, the impact of bush fires on global warming differs widely, depending on whether the fires affect woody layers or grass cover. Reducing the intensity of bush fires by grazing usually leads to an increase in tree and shrub cover, creating CO₂ sinks in soil and biomass.

wider scale. Furthermore, in tropical countries there is little understanding of carbon sequestration capacity and the types of greenhouse gas emissions prevented by livestock. It is vital to take them into account and this warrants more detailed assessments in the regions concerned.

In least developed countries and middle-income countries, the technical difficulties of estimating greenhouse gas emissions are compounded by the diversity of livestock's economic and social functions. Udo and Steenstra (21) note that estimates invariably attribute all greenhouse gas emissions to consumable animal products and overlook the non-consumable outputs that benefit poor farmers (livestock are a source of labour and manure, and they represent capital that can ensure the survival of a household during a farming crisis) (see below). While this method of calculation is fine for developed countries, it is unsuitable for countries where animals provide numerous services and social functions for hundreds of millions of poor farmers, and where crops often account for less than half the total value of animal production.

Combined effect of improved livestock productivity on human well-being and the environment

Strong correlations between productivity, poverty and the impact of livestock on climate change

Improving productivity³ makes it possible to produce equal amounts of outputs using fewer inputs (fewer animals, less cattle feed or less grazing, and, generally, less labour). The effects of improved productivity are wide-ranging. They may be economic, through better use of investments and inputs. They may also be environmental because, at the same level of production, greenhouse gas emissions and the pressure of livestock on natural resources diminish. Finally, improved productivity requires better animal husbandry, welfare and health, which in turn reduces the impact of zoonoses.

A statistical analysis of a series of variables representing poverty reduction and enhanced livestock performance (intensive growth) in the world's major regions shows strong positive correlations (the variables vary in the same direction). Poultry are an exception, because increasingly they are produced intensively by 'rich' farmers and the correlation with poverty reduction (0.2) is weak. The analysis also shows strong negative correlations (the variables vary

in the opposite direction) between the series of variables representing livestock performance and greenhouse gas emissions. In other words, any improvement in livestock performance corresponds to a reduction in greenhouse gas emissions (Table II).

Improved agricultural productivity is the main driver of poverty reduction

In the 19th Century, improved agricultural productivity underpinned growth in the major economies (including the United States [USA], Japan and Europe) and, more recently, in the major emerging countries (24, 25). No country has succeeded in alleviating rural poverty without improving the productivity of its agricultural sector (26, 27).

In countries where agriculture is the main source of employment and income for poor people, agricultural growth contributes significantly more to reducing poverty than growth in other sectors, partly because it is difficult to transfer the income generated in one economic sector to another. As a result, poor people derive greater benefits from growth if it occurs in their own sector (28, 29). In addition, agriculture is highly labour intensive. Growth in agriculture helps to provide jobs for low-skilled workers, create wealth, and deliver commodities to promote growth in local manufacturing and non-agricultural jobs (30, 31) (Fig. 2).

Montalvo and Ravallion (32) showed that, in China, improved agricultural productivity has been the main driver of poverty reduction. They conclude that the idea that the secondary sector (manufacturing) and tertiary sector (services) have played a role in fighting poverty is debatable because of the lack of data demonstrating the influence of these two sectors on growth (Box 6).

According to Pica *et al.* (33), livestock sector development has a unique ability to reduce poverty and contribute to economic growth. Basing their observations on data from 66 developing countries, these authors found a statistically significant causal relationship between livestock development and economic growth in 36 of the 66 countries studied. In 33 countries, development in livestock production seems to be (or to have been) an engine of growth in per capita gross domestic product (GDP). Livestock productivity seems to be (or to have been) driven by growth in per capita GDP in only three countries. According to the authors, the unique ability of livestock productivity to reduce poverty and contribute to economic growth stems from its indirect benefits for the productivity and marketing of agricultural products (in the form of organic manure and transport) and for human health (by reducing zoonoses and improving nutrition), as well as from the use of animals to accumulate capital, making it easier to escape from poverty.

³ The term 'productivity' is used here in the physical sense (volume) and refers to the technical performance of livestock production.

Table II
Correlation between data sets concerning livestock performance, poverty reduction and greenhouse gas emissions in the major world regions

Series of variables studied			Correlation coefficient
Poverty reduction rate between 1981 and 2012 (Fig. 2)	and	Percentage of the intensive component of livestock growth between 1981 and 2012 (Fig. 5)	Cattle: 0.87
			Pigs: 0.64
			Poultry: 0.20
			SR: 0.77
Annual milk production per cow (Fig. 4)	and	GHG emissions per kg of milk (Fig. 3)	-0.68
Off-take ratio (Fig. 4)	and	GHG emissions per kg of meat (Fig. 3)	-0.78

GHG : greenhouse gas
 SR : small ruminants

Correlations calculated from World Bank data (World Development Indicators, 2014) (22) for the poverty rate; from Gerber *et al.* (12) for emissions per kilogram of meat and per kilogram of milk; from the Intergovernmental Panel on Climate Change (IPCC, 2006) (13) for milk production per cow, and from the Statistics Division of the Food and Agriculture Organization of the United Nations (FAOSTAT) in 2014 (23) for off-take ratios. The percentage of the intensive component of growth was calculated based on data from FAOSTAT in 2014 (23)

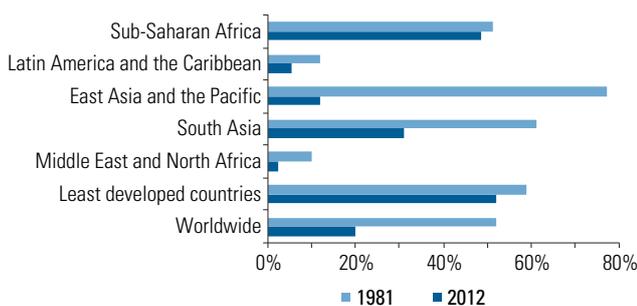


Fig. 2
Percentage of people in extreme poverty in developing countries of the world's main regions and in least developed countries, in 1981 and 2012

Source: World Bank, World Development Indicators (22)

Box 6
Intensive and extensive growth in livestock production

Poverty has been driven back in countries that have succeeded in improving livestock productivity. Conversely, it has stagnated in countries where growth in livestock production has been largely extensive (see Figs 2 and 5). This is because of the different characteristics of these two forms of growth. Improving productivity makes it possible to produce more by making better use of inputs and, in particular, by giving farmers a better return on their work. On the other hand, growth in extensive production requires greater use of inputs (more animals, requiring more pasture and more labour) but it fails to make better use of inputs and, in particular, does not give farmers a better return on their work. As a result, farmers' incomes stagnate. In other words, extensive growth may create jobs if new farmers enter the sector but it does not lead to a significant reduction in poverty.

Livestock's ability to help build wealth is crucial to reducing poverty. Experience in East Asia shows that rural household assets promote the creation of non-farm rural employment and facilitate the urban integration of households leaving farming (31).

Greenhouse gas emissions from livestock fall when productivity improves

According to Caro *et al.* (7), between 1961 and 2010, greenhouse gas emissions from livestock fell by 23% in developed countries where there were massive productivity gains. In developing countries where, at least in some regions, productivity gains were low, they rose by 117%.

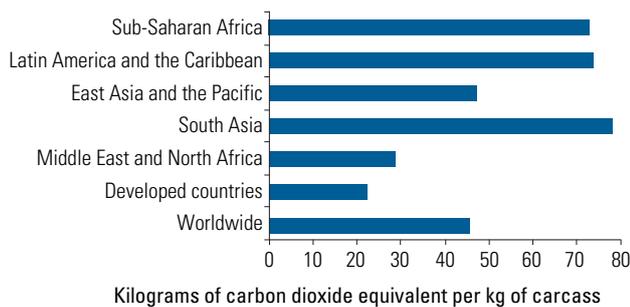
Higher productivity and lower greenhouse gas emissions from livestock in developed countries

The estimates that developed countries submit periodically to the UNFCCC confirm a continuing reduction in greenhouse gas emissions from livestock. In developed countries, emissions from livestock peaked in the 1970s. Since then they have fallen and the pace of decline accelerated in the mid-1990s (7). With the exception of poultry, production of which has soared worldwide, livestock numbers in developed countries are falling. Nevertheless, continuing productivity gains have led to steadily rising livestock production volumes. Between 1981 and 2012, the number of pigs in Western Europe fell by 4%, while output increased by 20%. During the same period, in North America, the number of cattle decreased by 22%, while beef production increased by 13% (23).

In 2011, greenhouse gas emissions in Canada, Australia, the USA and Europe (including land use change) were estimated at 20, 25, 26 and 32 kg CO₂-eq (carbon dioxide equivalent) per kg of carcass weight, respectively. In developed countries, CO₂-eq emissions for milk were 0.8 to 1.2 kg CO₂-eq per kg of milk (17, 34, 35). In Europe and the USA, improved performance was the leading factor in reducing greenhouse gas emissions from livestock.

Low productivity and higher greenhouse gas emissions from livestock in low-income countries

The situation in developing countries is very mixed. Emerging countries such as China and Brazil have improved productivity and achieved performances close to those of developed countries. Least developed countries and large middle-income countries, such as Nigeria and Pakistan, have low productivity levels, resulting in higher emissions (Figs 3, 4 and 5).



What is the outlook for livestock numbers and production levels by 2050?

Strong growth forecast for livestock production worldwide

Between 1961 and 2012, global meat production grew by a factor of four, from 71 million tonnes (Mt) to around 300 Mt, while milk production more than doubled from 344 Mt to 740 Mt (23). According to estimates by the Food and Agriculture Organization of the United Nations (FAO), in 2050, global meat production is expected to rise to 455 Mt (50% more than in 2012), milk production to 1,077 Mt (45% more than in 2012) and egg production to 102 Mt (45% more than in 2012) (36) (Figs 6 and 7).

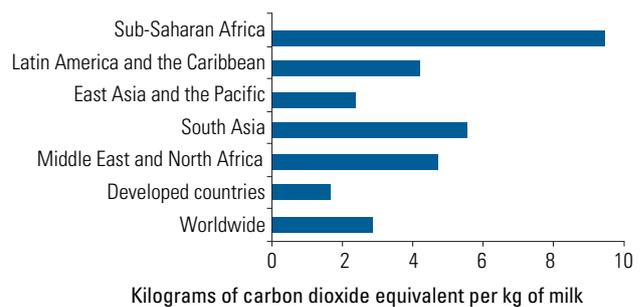


Fig. 3

Variation in the intensity of greenhouse gas emissions from dairy and beef cattle in major regions of the world

Source: Global livestock environmental assessment model (GLEAM), cited by Gerber *et al.* (12)

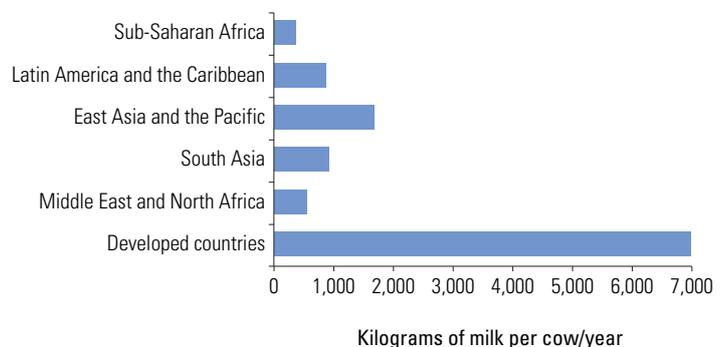
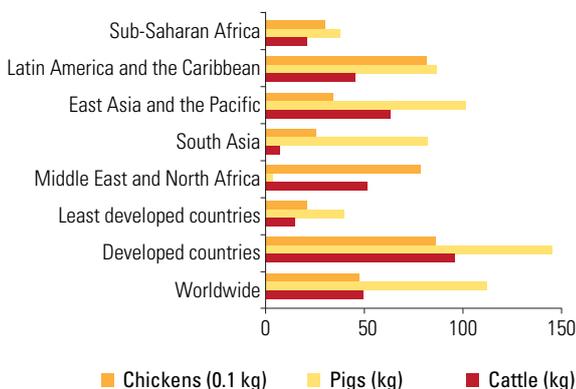


Fig. 4

Off-take ratio of meat and milk in major regions of the world

Off-take ratio calculated on the basis of data from FAOSTAT in 2014 (23). Milk production volume based on figures from the Intergovernmental Panel on Climate Change (13). The off-take ratio is calculated by dividing the amount of meat obtained from a species in a year (usually expressed in kilograms) by the average number of animals of that species for the same year. For cattle and pigs, it is expressed as kilograms of carcass weight and, for broilers, as 0.1 kilograms of ready-to-cook chicken weight

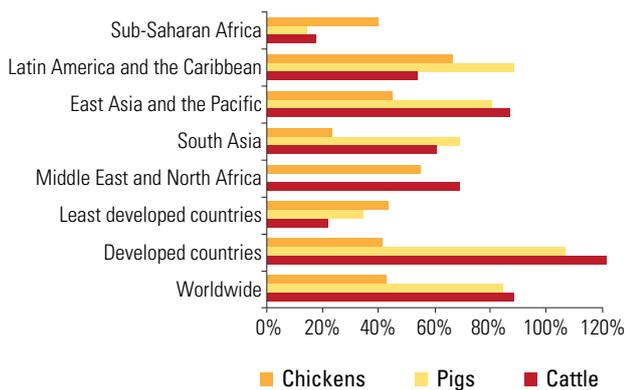


Fig. 5
Percentage of the intensive component in total production growth in major regions of the world and in least developed countries between 1981 and 2012

The percentage of production gains from the intensive component of growth (with productivity gains), between year A (start of the period) and year B (end of the period), is determined by the formula:

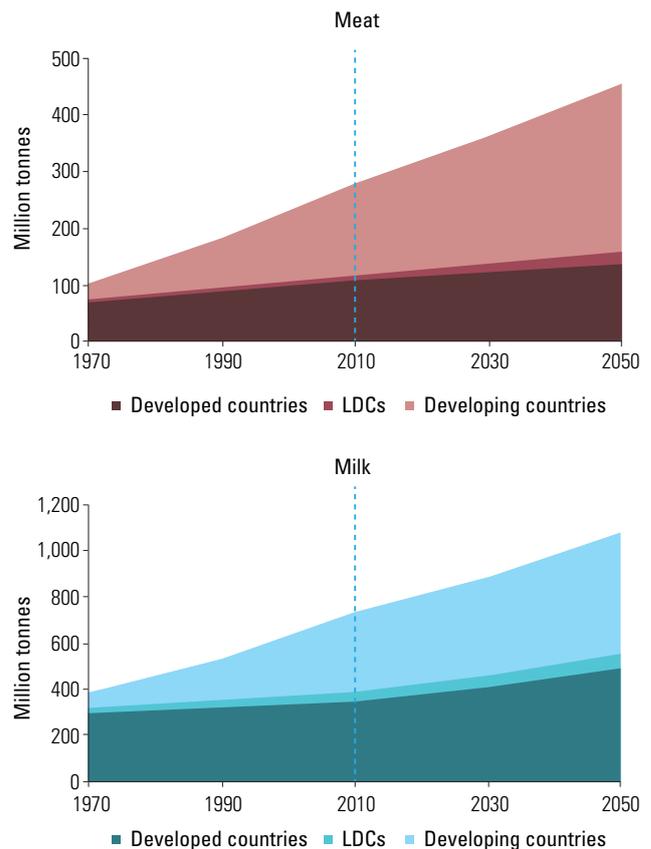
$$\text{Intensive growth (\%)} = \frac{\text{Production year B} - [(\text{Production year A} / \text{Numbers year A}) \times \text{Numbers year B}]}{\text{Production year B} - \text{Production year A}}$$

The FAO forecasts that, by 2050, growth in the main animal products is likely to still be greater than global population growth. By 2050, it is estimated that there will be 9.5 billion people on the planet (37). For meat, per capita annual consumption is expected to rise from 36 kg to 48 kg (+33% compared with 2012) and, for milk, from 101 kg to 114 kg (+13%).

Thanks to productivity gains, by 2050, greenhouse gas emissions from livestock are expected to decrease worldwide, except in least developed countries and some lower-middle-income countries

Average annual growth in meat production of 1.2% between 2010 and 2050 would be sufficient to achieve the forecasted volumes by 2050. Between 1981 and 2012, worldwide growth in the off-take ratio for pork (the main meat consumed) and chicken meat, far exceeded this value (Table III). If productivity were to continue to rise at this rate, it would be enough to meet the needs of the global population without increasing the number of animals.

The problem is that global averages mask major regional differences. Latin American and East Asian countries have already made substantial progress. Nevertheless, there is still plenty of scope for improving productivity (Fig. 4), especially in pork and beef production. In these countries, the decline in greenhouse gas emissions is expected to be boosted by household consumption of a growing proportion of monogastric meat.



LDCs: least developed countries

Fig. 6
Growth trend and outlook for meat and milk production from 1970 to 2050, in millions of tonnes

Source: FAOSTAT (23) for the period 1970 to 2010 and Alexandratos and Bruinsma (36) for 2010 to 2050

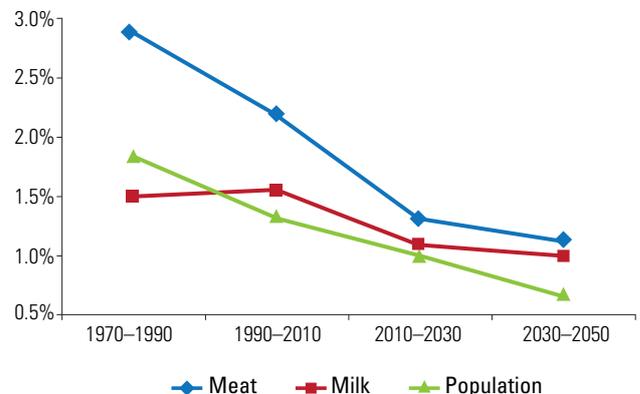


Fig. 7
Comparison of global trends in the annual growth rate of the population and meat and milk production, from 1970 to 2050

Source: Growth rate calculated on the basis of data from FAOSTAT (23) for the period 1970 to 2010 and from Alexandratos and Bruinsma (36) for 2010 to 2050

Table III
Average annual growth in the off-take ratio for meat from cattle, pigs, chickens and sheep/goats, in major world regions, between 1981 and 2012

Region	Cattle	Pigs	Chickens	Sheep/goats
Sub-Saharan Africa	0.2%	0.3%	1.3%	0.5%
Latin America and the Caribbean	0.9%	2.9%	2.7%	1.1%
East Asia and the Pacific	4.5%	2.8%	1.6%	4.0%
South Asia	1.1%	2.4%	0.7%	-0.1%
Middle East and North Africa	2.0%	-	2.1%	-1.0%
Least developed countries	0.6%	1.0%	1.5%	0.3%
Developed countries	0.8%	1.1%	0.9%	0.7%
Worldwide	0.8%	1.7%	1.3%	0.7%

Calculated on the basis of data from FAOSTAT in 2014 (23)

In developed countries, productivity gains have slowed but needs have barely increased. Under the terms of the Kyoto Protocol⁴, developed countries are required to continue reducing greenhouse gas emissions from livestock.

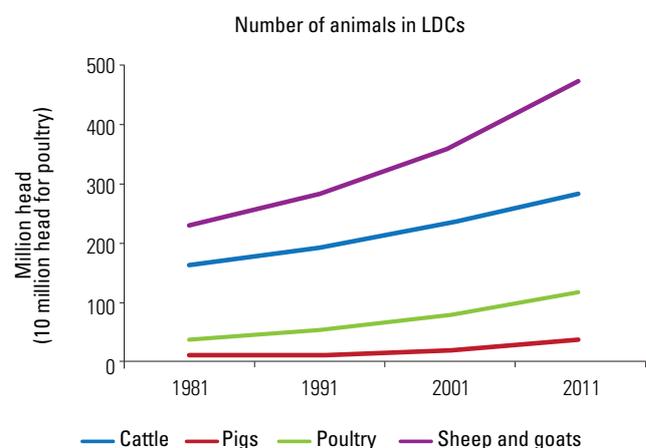
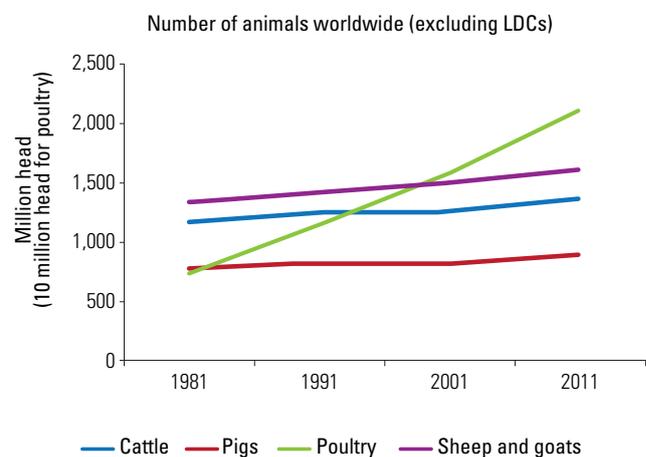
Least developed countries, especially those in sub-Saharan Africa, and large lower-middle-income countries such as Nigeria and Pakistan, are a special case. Although their consumption of animal products is relatively low (17 kg of meat and 44 litres of milk per capita in sub-Saharan Africa in 2011), demand is rising because of strong population growth and greater purchasing power. Productivity gains are very low owing to weak sectoral policies and pressure from animal diseases (Table III). As a result, in order to meet growing demand, imports are rising and growth in local production is largely extensive, achieved by increasing the number of animals, with few productivity gains (see Box 6 and Fig. 4). In least developed countries, cattle numbers have been rising twice as quickly as in the rest of the world and the number of sheep and goats, three times as fast (Fig. 8). Unless sectoral policies are adopted to achieve productivity gains, greenhouse gas emissions will continue to increase.

Conditions for improving livestock productivity

Government support is vital to trigger an improvement in agricultural productivity

Using meta-analyses, Latruffe (38) and the Organisation for Economic Co-operation and Development (OECD) (39) have shown that the most powerful determinants of productivity are the quality of government interventions (sectoral policies,

⁴ The Kyoto Protocol target for 2008–2012 requires a reduction in the emissions of six greenhouse gases (carbon dioxide, methane, nitrous oxide and three substitutes for chlorofluorocarbons) by at least 5% compared with 1990 levels.



LDCs: least developed countries

Fig. 8
Numbers of production livestock from 1981 to 2011
Source: FAOSTAT (23)

including those on animal health, research and development, and infrastructure), the quality of the natural environment (climate and soil fertility), market conditions (strength of demand) and the level of commercialisation of farms (commercial farming as opposed to subsistence farming). In the specific case of livestock, improving productivity also means improving the systems for preventing and treating animal diseases, especially transmissible diseases, to secure investments and product sales. With the exception of the level of commercialisation, the most powerful determinants of productivity are outside the control of livestock producers. This would explain, at least in part, the low productivity levels in countries where sectoral policies are weak and there is very little support for livestock production, and the high productivity levels in countries where livestock farming receives strong government support.

Animal diseases are a barrier to improving livestock productivity

Animal health is a prerequisite for higher productivity. Investment in animal husbandry, whether in nutrition, animal genetics or housing, may become profitable provided the risk of high-impact livestock disease has first been contained (40).

Direct effects of improved animal health on greenhouse gas emissions

Very few studies specify the direct effects of animal diseases on greenhouse gas emissions. One of the rare studies on the subject was carried out by researchers and field veterinarians in the United Kingdom (41). The study assessed the impact of 15 endemic diseases and physiological disorders of dairy cattle (mastitis, lameness, infertility, etc.) on greenhouse gas emissions. The results showed that, when animals are healthy, they produce an average of 3.8% more milk (7,831 litres compared with 7,539 litres a year) and, in parallel, emit 1.6% less CO₂. The adoption in the United Kingdom of a programme to reduce by 50% the impact of the 15 diseases studied would reduce emissions of CO₂ by 669 kilotonnes (kt) a year, equivalent to 5% of dairy cattle emissions. For the most important diseases, the programme would also have a positive effect on the profitability of livestock farming. In addition, performance gains would reduce the number of dairy cows by 83,000 (out of a total of 1.8 million). Conversion of the released pasture land to woodland would allow 207 to 1,077 kt CO₂-eq to be sequestered per year, depending on the type of woodland. Overall, livestock performance gains from improved control of the 15 diseases studied could reduce the carbon footprint from British dairy farming by 7% to 13%.

The above example concerns a developed country with a favourable animal health context. In countries where animal health conditions are dire, a programme to control animal diseases by reducing animal and production losses would have a much greater impact.

In least developed countries and most lower-middle-income countries, animal diseases lead to wasted resources and are a constraint on technological progress

In least developed countries, annual mortality rates in traditional village livestock systems average 20% to 22% of calves, 6% to 7% of adult cattle, 22% to 24% of lambs and kids, 15% of adult sheep and goats, 40% to 50% of piglets and 50% of chickens aged 0 to 6 months (World Organisation for Animal Health, unpublished data). Moreover, even when they do not kill, diseases weaken animals and affect their performance, resulting in animal production losses of up to 50% (42). Apart from wasting resources, the incidence and severity of animal diseases in least developed countries and most lower-middle-income countries make them a serious risk, which dissuades farmers from specialising in livestock and making the necessary investments to improve their productivity. It also cripples foreign investment.

Animal disease risk is preventing poor farmers from developing monogastric livestock farming

In 2012, three-quarters of global meat output was from pigs and poultry, which emit only small quantities of greenhouse gases (Fig. 1), while in least developed countries ruminants remain the main source of meat, accounting for 60% of total meat production in 2012.

Because of pressure from animal diseases, poor farmers are unable to participate in the development of monogastric livestock farming (Box 7). Wealthier farmers have the ability to reduce disease risk by isolating their animals from external pathogen threats and engaging the services of veterinarians. They manage to set up intensive livestock units for poultry and sometimes for pigs (in southern Asia), often near cities. As demand is strong, they can incorporate the costs of risk prevention and treatment into their production costs. On local markets, products from factory farms compete with those of poor farmers. In a context of poor animal health with inefficient Veterinary Services, animal disease risk is also a factor of social inequality and contributes to marginalisation of the poorest farmers.

Poor farmers do not derive enough benefit from development policies

Livestock enjoys significant support in developed countries

In developed countries, the agricultural sector receives support⁵ and strong productivity gains have been achieved thanks to substantial government assistance. The livestock

⁵ Agricultural support includes support for producers, support for consumers and support for general services such as research, infrastructure and agricultural training.

Box 7**Low-input/low-output livestock systems**

Poor livestock farmers usually employ low-input/low-output livestock systems, with ruminants capable of making use of vast expanses of arid land and coarse agricultural by-products, or with monogastric animals (poultry, pigs) that are able to find food for themselves: kitchen waste, crop residues, insects and wild grains.

For highly risk-averse poor farmers, low-input/low-output systems are of great economic interest because they require no investment and use very few inputs. Although the animals do not produce much, they do offer many benefits and represent capital that can ensure the survival of a household during a farming crisis and help it to cope with life events.

Low-input/low-output livestock systems are suitable for ruminants or hardy monogastric breeds. However, they do not allow the development of genetically improved and profitable monogastric livestock, which require feed rich in energy and protein. Good quality rations are expensive, and the genetic characteristics of the indigenous monogastric breeds, which are hardy breeds, make them unable to use such rations profitably⁶.

Genetically enhanced monogastric breeds, which perform much better, are also much less resistant to endemic diseases and require hygiene conditions that poor farmers are unable to provide.

share in agricultural GDP is very high, often close to 50%, and agricultural support is distributed equitably between crop and livestock production. In the late 1980s, support for farmers in OECD countries represented around 37% of the total value of agricultural products at the farm gate. Although support has dwindled since then, it was still worth US\$258 billion in 2012, or 19% of the total value of farm products (43).

In East Asia, institutional reforms and substantial government support have improved agricultural productivity and reduced poverty significantly

The countries of East Asia, which have provided strong support to agriculture, are those that have achieved the best results in reducing poverty. In China, poverty fell from 77% to 10% between 1981 and 2012.

In parallel with major sectoral reforms, China's support for agriculture had risen to 17% of the value of agricultural production in 2011. This exceptionally high level for a middle-income country accounted for 3.7% of national

GDP, far more than in the OECD countries (0.9% of GDP in 2011). The livestock sector was a major beneficiary of this support. Livestock production grew faster than crop production and contributed to the diversification of rural incomes. Growth in agricultural productivity has been compatible with maintaining a big rural population (50%) and a large number of farms. In 2012, there were 200 million farming households in China. The average farm size was 0.65 hectares (31, 44).

Weak sectoral policies and the collapse of government support for poor farmers in least developed countries and lower-middle-income countries

Despite its economic and social importance, livestock farming has been the biggest loser in both the changing international aid strategies and the economic policies of the poorest countries.

Up until the 1980s, the governments of most least developed countries provided significant support for livestock production. However, the introduction of structural adjustment policies in the 1990s led to the rapid withdrawal of public Veterinary Services from the field, even though there were not enough private operators capable of taking over. This led to the sudden cessation of many services provided to farmers (mass vaccination, veterinary clinics, etc.), with serious consequences for livestock sector performance (40).

In the early 2000s, the Poverty Reduction Strategy Papers (PRSP) initiative and the priority given to achieving the Millennium Development Goals resulted in a substantial rise in aid to institutions and the social sector (especially health and education), coupled with a sharp reduction in government support and international aid for infrastructure and the productive sectors, including agriculture. The share of official development assistance (ODA) allocated to the agricultural sector, which accounted for around 12% of total aid in the 1980s, fell to less than 4% of total aid in 2004 (Fig. 9).

Beginning in the 1990s, livestock production became the target of exaggerated or totally unfounded allegations by non-governmental organisations (NGOs) and some international organisations (see above). Livestock production in general, and pastoralism by the most vulnerable communities in particular, was held responsible for serious damage to the environment and human health. While these often highly publicised allegations did not reduce support for livestock farming in developed countries and emerging countries, they coincided with a collapse in international aid and national funding for the poorest farmers (Fig. 10). This led to growth in extensive farming to meet consumer demand,

⁶ In traditional village livestock farming systems in Africa, chickens achieve their sale weight at around six months. Half die before that age. Under intensive systems, genetically improved chickens achieve their sale weight at seven or eight weeks and less than 4% die before this age.

with no productivity gains, exacerbating the impact on the environment and climate change (5, 46).

In 2012, total ODA stood at US\$172 billion. Agriculture as a whole received US\$11.5 billion. The share of aid allocated directly to the livestock sector was US\$173 million (0.1% of total ODA), including US\$114 million for animal production (OECD Development Assistance Committee [DAC] code 31163) and US\$59 million for Veterinary Services (OECD-DAC code 31195). In 2012, the livestock sector received directly only 1.5% of the aid allocated to agriculture, which is completely disproportionate to the economic and social importance of livestock. The multilateral agencies that provide on average 22% of total ODA contributed 57% of the aid allocated to the livestock sector (45). Animal production also receives a small portion of aid for agricultural research, extension, policy and training. In least developed countries, where ODA often accounts for over 10% of GDP (22) and over 30% of the agricultural investment budget, the sharp reduction in government support has acted as a constraint on livestock productivity gains.

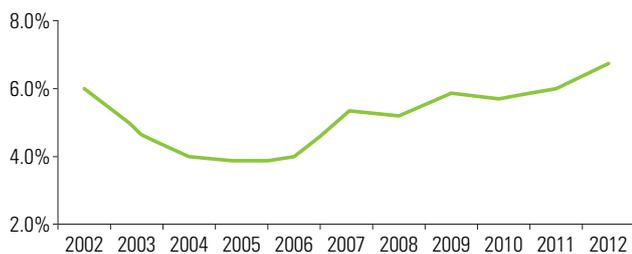


Fig. 9
Agricultural support as a percentage of total official development assistance from 2002 to 2012

Source: Development Assistance Committee of the Organisation for Economic Co-operation and Development (45)

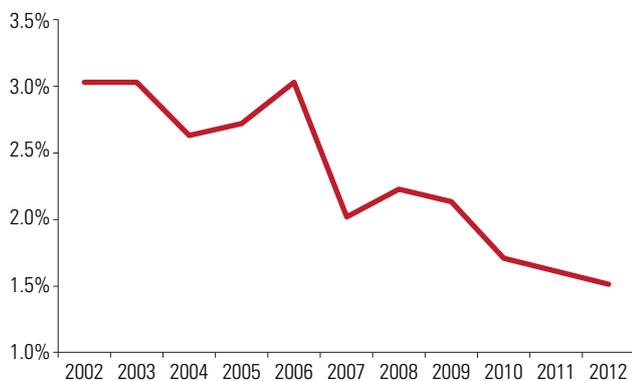


Fig. 10
Livestock support as a percentage of agricultural support

Source: Development Assistance Committee of the Organisation for Economic Co-operation and Development (45)

In most least developed countries and lower-middle-income countries, especially in Africa, aid guidelines often follow PRSP guidelines, as do national strategies, because these countries are required to have their PRSP approved before they are eligible for debt relief or financial assistance from the World Bank or the International Monetary Fund (IMF). A study of references to livestock in the PRSPs of 49 countries revealed that no PRSP explained coherently the importance of livestock for the economy and for poverty reduction (47). The PRSPs of countries where most of the population depends mainly on livestock for its livelihood (such as Niger or Tajikistan) touched on the subject only briefly. The few recommendations concerning livestock production were all general in nature, with no details of the activities to be carried out and no quantification of budgetary needs. According to the study's authors, this reflected not only the influence of World Bank and IMF consultants – because several PRSPs were drawn up in a language (English) other than the language of the countries concerned – but also the lack of any political will on the part of national decision-makers and experts to develop the livestock sector.

The same reluctance to finance livestock is found in Global Environment Facility (GEF) funding (48) (least developed countries have easy access to this facility under the Least Developed Countries Fund for climate change). Climate experts recommend giving priority to improving livestock productivity to reduce greenhouse gas emissions. Smith *et al.* (11) estimate that improved performance would reduce greenhouse gas emissions from livestock by 70% in low-income countries. Although agriculture plays a key role in the seven priorities cited in the UNFCCC guidelines for preparing National Adaptation Programmes of Action for climate change, the actions concerning agriculture relate to land preparation systems, irrigation, traditional crops, etc. None concern the livestock sector (49).

Conclusions

Counter-productive effects of allegations against livestock production

Livestock farming is subjected to an astonishing level of surveillance and many studies have endeavoured to assess its impact on the environment. No other agricultural activity has attracted so much attention. After exhausting the list of allegations against livestock farming in terms of soil degradation and deforestation, the most recent critical studies are now focusing on its impact on climate change.

In an increasingly populated world where the pressure of agriculture on natural resources is rising inexorably, it is only right to seek to safeguard ecosystem integrity, animal

welfare and the needs of future generations. However, instead of leading to reforms capable of offering sustainable production growth, with shared benefits, repeated allegations have penalised the poorest farmers by depriving them of the support they need to secure their production and lay the foundations for sustainable development.

Harmful consequences of growth driven solely by demand

All too often, the finding that demand is driving growth has resulted in reduced support for livestock. Demand is a powerful determinant of production and, in principle, strong demand leads to higher prices, which stimulate greater production. However, demand alone is not enough to improve livestock productivity, which also requires greater support for research, a better institutional framework, etc. In the absence of productivity gains, demand drives extensive growth, which pushes up animal numbers, exacerbates pressure on natural resources and is unable to reduce poverty.

The danger of one-criterion assessments and the advantages of ruminants

One-criterion assessments of the environmental impact of livestock frequently recommend replacing ruminants with monogastric animals, which emit fewer greenhouse gases and occupy less space. These recommendations do not stand up to a broader analysis that takes into account all the requirements of sustainable development.

Enteric fermentation enables ruminants to convert very coarse by-products, which cannot be used by humans and monogastric animals and might otherwise be burned, into proteins with a high nutritional value. They are the only animals capable of providing a livelihood for the often marginalised pastoral communities inhabiting the immense, arid expanses covering 16% of the Earth's land mass, where cold, drought or steep gradients preclude the cultivation of crops (1). Ruminants provide the draught power for farm work and transportation in remote areas. Consumable animal products are often the sole basis used for assessing the environmental impact of poor farmers, but in fact they are just one of the benefits offered by ruminants.

Although it is often recommended that monogastric livestock production be developed in order to preserve ecosystems, more often than not these animals are produced under landless systems that use rations produced intensively, far from livestock farms or even on another continent. However, in the case of ruminants, poor farmers use virtually no imported inputs and, in developed countries, 90% of ruminant fodder and grain is produced on-farm and does not require transport with a high carbon footprint. In all cases, ruminant dung returns to the soil

where it re-enters natural cycles that are difficult to quantify and nearly impossible to model because they are linked directly to specific local factors, such as soil type, climate and farming practices (17).

Ruminants have a relatively long life cycle and systems for farming them are better than those used for monogastric animals in that they respect the animals' natural way of life and welfare and avoid the use of antibiotics to counter the microbial build-up inherent in intensive farming systems. Although ruminants use pastures occupying 26% of the Earth's land mass (1), many studies have shown that ruminant farming systems have the capacity to offset much of their greenhouse gas emissions. In addition, natural pasture land is able to create an environment that helps improve air quality, regenerate water resources, maintain wildlife and biodiversity and improve the living environment by providing pleasant landscapes (15, 50). In addition, Leip *et al.* (18) have demonstrated that plant consumption by animals reduces reactive nitrogen availability in the soil by a full 30% to 40%, greatly limiting the production of N₂O.

Making scientific advances accessible to the poorest farmers, especially in Africa

Africa is the continent with the highest proportion of the population engaged in farming (60% of the working population). It is also the continent that provides the least support for agricultural productivity. For a number of years, sub-Saharan Africa has posted sustained economic growth of around 5%. This growth has been on the back of the extraction of raw materials and investment in infrastructure, as well as an increase in agricultural output (51). However, unlike the growth in Europe and North America in the 19th Century and in Asia in the late 20th Century, Africa's growth has not been built on improved agricultural productivity. It therefore provides very little benefit for the poor. Africa is the continent that has done the least to alleviate poverty (Fig. 2).

Africa is the future demographic giant. Population growth is expected to slow worldwide, except in Africa, where it is expected to remain close to 2% a year until at least 2050. Africa's population is set to more than double (+119%) between 2010 and 2050. With 4 billion inhabitants by 2100, it is likely to be the world's second most populous continent, after Asia (37).

Apart from the dramatic consequences of poverty for nearly half of all Africans, persistent large-scale rural poverty in this future demographic giant could have repercussions on the entire planet. Inadequate veterinary surveillance would pose a major threat to animal and human health in the rest of the world because of the persistence of transmissible animal diseases and the risk of emerging zoonoses. In addition, continuing dire economic vulnerability in

livestock production areas, which cover a large part of the continent from Senegal to Somalia and Mauritania to Kenya, could produce hotbeds of insecurity (which already exist), with serious consequences for the stability of the continent and for the rest of the world.

In all major countries, agricultural productivity gains have played a key role in poverty reduction and the unique ability of livestock farming to reduce poverty has been widely recognised. Erik Solheim, Chair of the OECD Development Assistance Committee, pointed out that there is no single solution for ending poverty but that the remarkable success stories of some countries show the way for others (52).

As well as the need for international solidarity, in view of the interdependence of the various economic, social and environmental processes required to ensure our planet's sustainable development, there is a need to rethink the marginalisation of livestock production in development policies.

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