# The global impact of cattle: A socio-economic, food security and environmental perspective.

by:

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## Abstract

*Cattle have been the focus of an intense debate between those concerned about the possible negative effects on global warming, land degradation, food competition and human health, and those who are positive toward the possible role of cattle in maintaining global socio-economic and environmental sustainability. Here we reviewed the pros and cons in view of a projected increase in demand for animal-based foods and therefore in cattle numbers. Analyses of cattle numbers and foods from various literature sources suggest gross overestimation towards 2050. Nevertheless, the importance of cattle to the global socio-economy, world trade and human sustenance, particularly in the developing world, is shown to be indispensable. Also, animal-based foods are shown to be vital to human health and development, and contrary to many claims to the opposite, there is very little evidence that animal-based foods are associated with serious non-communicable diseases, if consumed in recommended portions. With respect to global warming, cattle are responsible for a significant portion of methane emissions. However, the atmospheric accumulation of methane from cattle is overestimated due to methane's short lifespan, recent calculations of enteric fermentation and methane's warming potential, in addition to the role of cattle in carbon sequestration and being a sink. Since carbon sequestration has more potential than emission reduction in limiting global warming, photosynthetic capacity should be maximised. This is promoted by conservation of the world's grasslands and using cattle and other herbivore livestock as grazing stimulants to enhance photosynthesis. Also, in crop production, by using cattle to provide organic fertiliser and graze cover crops in regenerative methodology, soil organic carbon and soil health are improved, to the eventual benefit of soil storage of atmospheric carbon. It is concluded that whereas concerns about animal welfare, zoonosis and antimicrobial resistance should be addressed, the call for a reduction in global cattle numbers because of the perceived negatives is unwarranted. A reduction in cattle numbers will limit carbon sequestration and largely defeat the objective of limiting global warming.*

## 1. Introduction

Currently there is an intense debate between those against the use and expansion of animal-based protein, and those not unduly concerned in the use of such to combat global hunger. Typical concerns against animal-based protein relate to rising greenhouse gas (GHG) emissions, land and resource use, perceived negative effects due to animal welfare, antimicrobial resistance (AMR), zoonosis, environmental concerns and human health. These concerns are raised at a time when it has been projected that food requirements will increase by 50–70% towards 2050 and, from a livestock perspective, at least a doubling in demand for meat and even more for dairy. These anticipated increases are due to the rise in the global population and the demand for animal-based protein increasing at the expense of staple foods as per capita income in transition and developing countries increase. The livestock sector is also well-positioned for this challenge since it occupies approximately 30% of the ice-free terrestrial surface of the earth and 80% of agricultural land. In 2010, it contributed more than 40% of the global value of agricultural output, employed 1.3 billion people and supported 600 million smallholder farmers in transition and developing countries.

While most people recognise the importance of dealing with animal welfare, AMR and zoonosis, many believe that the concerns raised above can be either offset or that the concerns are misplaced. They are of the opinion that GHG emissions can be limited by production efficiency, dietary and supplementary means, carbon sequestration, grazing management and other means. They also do not regard animal needs as being in direct competition with human foods as herbivore livestock primarily use materials which cannot be digested by man and often to that effect occupy spaces which cannot be cultivated. In addition, they regard animal-based foods as vital to human development because of nutrient density and high bioavailability and do not subscribe to the notion that animal-based foods are a threat to human health.

Given the intense debate, and the importance thereof, concerning the matters highlighted above and others such as social, cultural, economic and political impacts of livestock production, the question is whether an increased production for animal-based protein is attainable without negative consequences. Therefore, in this paper we have focussed on beef and dairy cattle, reviewing some of the most recent research on the contribution of cattle to the economy, social wellbeing, and food security as well as environmental concerns.

## 2. Abundance and distribution of cattle

### 2.1 Population statistics

Between 1800 and 2006 cattle (non-cattle bovines not included) constituted 32–37% of herbivore livestock species and in numbers increased from approximately 420 million to 1.4 billion. On a biomass basis cattle constitute roughly 70% of herbivore livestock species which include cattle, buffalo, sheep and goats, illustrating the overwhelming influence which cattle could have on land use, natural resources and the environment.

However, there is no consensus as to the global population of cattle (see Annexures 1 and 2). According to the FAO (Annexure 1), the global herd is increasing monotonously on a year-on-year basis. When considering individual country statistics and also consulting various sources, there are some marked discrepancies (Annexure 2), questioning the absolute numbers and the steady increasing trend. These growth discrepancies are highlighted in Table 1. Not only does the growth rate vary much from year to year within a given country, but it also varies much among different countries. The countries listed in Table 1 are the ones with the largest herds. For example, the cattle population change in Brazil varies between -2.5% (2013) and +10% (2020). Russia saw an increase of 21.8% in 2013 and a decline in practically all the years thereafter. China's herd also fluctuated between growth rates of -12.1% and +19.8%. These large discrepancies in both the absolute size of the global herd, as well as the relative change between years and countries, are disconcerting given the importance of cattle in a global context and the weight placed on the FAO statistics to determine policies with a global reach and significant local impact.

**Table 1: The year-on-year percentage change in cattle population**

| Country | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| **Brazil** | -0.3% | -2.5% | 7.6% | 2.8% | 0.9% | 1.4% | -0.9% | 3.6% | 10.0% |
| **India** | -0.9% | 2.1% | -3.1% | - | - | -0.5% | 0.0% | - | - |
| **China** | 3.4% | 5.6% | 5.7% | -11.2% | -4.6% | 0.5% | -12.1% | 19.8% | 4.6% |
| **Russia** | -2.1% | 21.8% | -19.2% | -4.6% | 0.5% | -0.5% | -1.6% | -1.1% | -0.6% |
| **United States** | -1.6% | 2.8% | -3.6% | 2.9% | 1.0% | 1.3% | 0.6% | -0.3% | -0.3% |
| **EU*** | - | 1.0% | 1.9% | 1.0% | 0.0% | -2.3% | -1.5% | -0.8% | -0.9% |
| **Ethiopia** | - | - | -1.8% | - | - | 2.4% | 2.8% | -1.8% | - |
| **Argentina** | -1.4% | 0.6% | -1.5% | 2.7% | 0.6% | 1.3% | 0.7% | 0.0% | -1.3% |
| **Pakistan** | - | - | 6.4% | - | - | 3.7% | 3.8% | - | - |
| **Mexico** | - | - | 3.8% | - | - | -6.2% | 9.4% | - | - |
| **Australia** | 0.6% | -0.4% | 3.2% | -6.2% | -8.8% | 4.8% | -0.4% | -9.2% | -2.1% |
| **Bangladesh** | - | - | 5.3% | - | - | 0.4% | 0.8% | - | - |
| **Colombia** | - | -7.9% | 4.5% | - | - | - | - | - | - |

Sources: see Annexure 2.
EU* - EU excluding the UK.

### *2.1.1. Country trends*

Cattle numbers for countries with >20 million cattle are shown in Tables A1 and A2 (of Annexure 2) and the countries with the ten largest herds are shown in Figure 1. These ten herds comprise approximately 60% of the global cattle population. Brazil has the most cattle in the world and the number is increasing, largely driven by exports, with the total population recorded as 253 million in 2020.

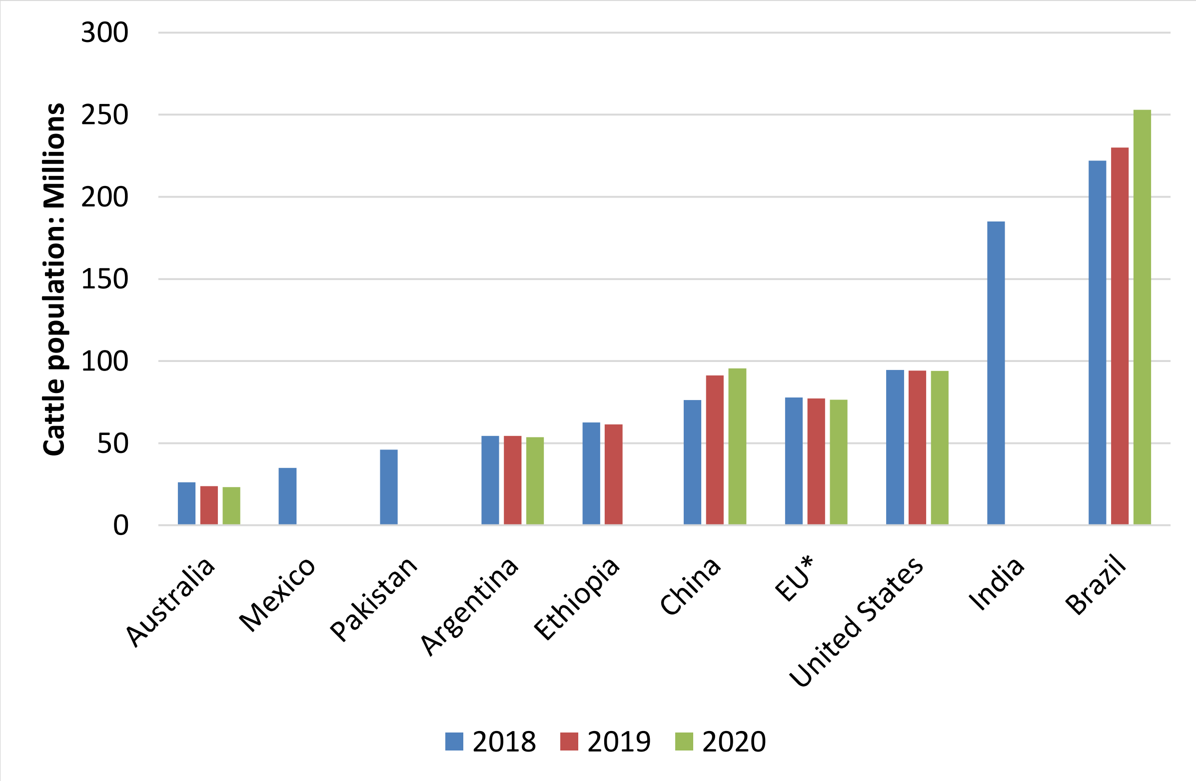



**Figure 1: Countries with the ten largest herds in the world.**
*EU excluding the UK

When considering the trend since 2009 as depicted in Tables A1 and A2, the herds in some countries increased (such as Brazil, China, Ethiopia, Pakistan and Colombia) while herd sizes remained unchanged in India, the USA, EU, Argentina, Mexico and Bangladesh, and declined in Australia, Russia and Sudan. There is no marked difference between developed and transition or developing countries as there is representation of the trends of increase, constant and decrease in all of these nations. In earlier publications there were indications that increases in production in developed countries resulted primarily through increased efficiency, whereas in developing countries it resulted primarily through increasing numbers; the implication being that more pressure could be put on resources and degradation of land in developing countries. While this may be true for Ethiopia and possibly a limited number of other developing countries, in general the trends in Table 1 do not support the conclusions in the earlier publications. However, this does not negate the interpretation that efficiency of beef production has not made vast strides in particular countries. For example, in 2007, beef production systems in the USA required 69.9% of the animals, 81.4% of the feedstuffs, 87.9% of the water and 69.0% of the land to produce one billion kg of beef compared to 1977, and waste output was reduced to 81.9% manure, 82.3% $CH_4$ and 88.0% $N_2O$. Or in dairy, as another example, milk production in the USA increased by 24.9% between 2007 and 2017. This was achieved by 25.2% less cows resulting in a reduction in methane emissions of 19.1% and 18.5% in nitrous oxide.

### *2.1.2. Comparison with herbivores pre-industrialisation*

During the Late Pleistocene (LP) era, which is approximately 10 000 years ago, wild (mega-) herbivore methane emissions were like that of livestock today (138.5 vs 147.5 Tg $CH_4$ /year);

the estimate for cattle alone being 75.8 Tg $CH_4$ /year. Thereafter there were sharp declines in wild herbivores during the terminal Pleistocene when hunter-gatherer humans invaded their habitat. Further reductions were through the massive hunting in the 1800s, the Great Plains kill-off of Bison in the 1860s, anthropogenic interventions with fenced livestock farms which demised the large springbok and other herds passing through the Karoo of South Africa in the late 1800s, and the African Rinderpest epizootic of the 1890s which also affected domestic herbivores that were rapidly increasing at the time because of agricultural activities. The combined methane emissions of wild and domestic herbivores during the 1800s until about 1900 varied between about 75 and 85 Tg $CH_4$ /year, the modern-day collective number being approximately 160 Tg $CH_4$/year. It can be deducted that methane emissions during the last two centuries were lower only because of the abnormal extirpations, since the LP estimation was similar; therefore, the atmospheric methane burden by cattle today is probably no more than by wild mega herbivores during the LP.

The rapid decline of mega-herbivores after the LP resulted in widespread ecological changes due to the loss of their ecological functions, as driven by their unique combinations of traits. However, with the rapidly increasing domestic herbivore numbers post-LP, herbivore species richness through introductions in many parts of the world potentially counteract some losses. By analysing traits such as body weight, diet, fermentation type, habitat type and limb morphology, results showed that extinction-driven biodiversity contractions of LP-trait combinations have been offset through the introduction of primarily domestic herbivores by ~39% globally. Analysis of the trait overlap revealed that characteristics of introduced species were overall more like those of the LP than those of the current native-only (wild herbivore) characteristics. This is because 64% of introduced species are similar to extinct rather than extant species within their respective continents. Many introduced herbivores restore trait combinations which have the capacity to influence ecosystem processes, such as wildfire and shrub expansion in drylands. Although the introduced herbivore species post-LP have long been a source of contention, such as for example contribution to land degradation, the findings indicate that they may, in part, restore biodiversity and ecological functions reflective of the past several million years before widespread human-driven extinctions. This is a substantial positive for cattle husbandry if well-managed.

## 3. Socio-economy

### 3.1 Contribution to agro-economy

Livestock provides more than half of the value of agricultural output in developed countries through production and trade, but proportionally less in medium income and developing countries. As a group, the latter nevertheless amounts to approximately one third; the world average being about 40%, with the world average having remained constant over time. Specifically with respect to cattle, beef in developed countries accounted for 27% of total meat production in 2007 and 19% in developing countries. Recently, beef production remained constant, for example, between 2016 and 2021 at <70 million metric tons. The constant value again casts doubt on the consistent increase in cattle numbers as estimated by the FAO. Beef’s share of total meat production has declined from 32% in 1990 to 21% in 2020. The bulk of production, and therefore consumption, now comes from pork and chicken (76%).

Globally livestock is a significant asset of more than $1.4 trillion. In transition and developing countries the impact of livestock is staggering: livestock production and marketing are essential to the livelihoods of more than one billion poor people in Africa and Asia, which is one seventh of the global population. Beef production and marketing in West Africa supports 70 million people; dairy supports 124 million people in South Asia and 24 million in East Africa, whereas small ruminants support 81 million people in West Africa and 28 million in southern Africa. Estimations also show that more than 80% of poor people in Africa and up to 66% of poor people in India and Bangladesh keep livestock.

## 3.2 Contribution to social wellbeing

Whereas cattle and other livestock products in developed countries are sold in well-defined value chains with predicted and futures markets and prices, the value of livestock in poor and developing countries is much more than the market price of the product. It also reflects the challenges that livestock keepers face such as constrained finances, access to information and services, as well as landlessness. The following benefits can be listed: (1) Livestock is used to accumulate wealth and in pastoral communities are often the only major asset. Small and large animals constitute a "savings account" used to purchase agricultural inputs, invest in other income-generating activities, or pay for expenses such as education, weddings, medical bills and funeral costs. (2) Livestock contribute to staple food production by providing manure, contributing to land preparation and providing ready cash to buy planting materials or fertiliser or to hire labour for planting, weeding or harvesting. The contribution of livestock can thus increase the area of land cultivated, the yields and productivity achieved, the feed produced from crop residues, and, through enhanced nutrient recycling, the sustainability of the farming systems. (3) Although draft power use in general is decreasing globally, in regions such as Sub-Saharan Africa, it continues to contribute significantly to food production. Draft power enables more land to be cultivated, allows farmers (especially women) to escape the burden of manual tillage, permit land to be cultivated before the rains have softened the soil, thereby increasing timeliness of farming operations. (4) Livestock can provide a buffer in times when harvests fail or other disasters strike. (5) In many societies, small ruminants are often owned by women, who may also control any income obtained from their sale. (6) Improving women's access to inputs and services has the potential to reduce the number of malnourished people in the world by 100–150 million. The combined impacts of meeting nutritional needs and providing income make livestock a powerful force for the poor.

# 4. Food security

## 4.1 World trade

The rapid growth in global demand for livestock products, which has occurred over the last quarter century, has been characterised as "the Livestock Revolution" and is expected to continue. It is largely driven by increases in per capita income, population growth and urbanisation in developing countries. Demographic changes, urbanisation and economic growth in the developing world, particularly in emerging (transition) countries in Latin America and Asia, are rapidly changing food consumption patterns in that part of the world. Developed countries achieved the food transition process in a time period of over more than a century. Emerging and other developing economies are now following a similar eating pattern but at a considerably accelerated rate; the transition is reduced to 20 years in emerging countries and 40 years in other developing countries.

Table 2 shows export prospects of beef and dairy towards 2026 of major exporting countries, predicting a substantial growth in the market of 19.5% and 22.5%, respectively.

**Table 2: Key countries exporting beef, veal and dairy products and exporting prospects**

| | Exports 2016 (000 tonnes cwe)** | Projected export growth 2016–2026 (000 tonnes cwe)** | Exports 2016 (000 tonnes)# | Projected export growth 2016–2026 (000 tonnes)# |
|---|---|---|---|---|
| | **Beef and veal** | | **Dairy products** | |
| Argentina | 230 | 463 | 424 | 17 |
| Australia | 1 913 | 300 | 195 | 108 |
| Canada | 619 | 100 | | |
| Brazil | 1 893 | 633 | | |
| EU^ | 462 | -138 | 1 946 | 715 |
| India | 1 655 | 275 | | |
| New Zealand | 621 | -91 | 2 418 | 548 |
| USA | 1 413 | 188 | 885 | 145 |
| ROW* | | | 1 955 | 224 |
| Total | 8 806 | 1 730 | 7 823 | 1 757 |

^EU including the UK; *ROW = Rest of the world; **CWE = Carcass weight equivalent; #Dairy products are whole and skimmed milk powder.

Argentina, Australia and Brazil are expected to be the dominating countries in beef and veal with significant exports also from the USA and India, whereas Europe and New Zealand's influence will decline. Although much of the trade occurs within developed countries, a major portion goes to transition and developing countries. In concert with import and export, meat production in transition and developing countries will continue to be dominated by China and Brazil, the former benefitting from economies of scale as production moves towards increasingly commercial enterprises, and the latter from resource abundance and a devalued currency.

In dairy, New Zealand and the EU dominate the market (Table 2). The EU is projected to show export growth in the four main dairy export products, namely cheese, butter, and skimmed milk and whole milk powder. Export expectations from other key exporting nations are more conservative. However, New Zealand is expecting to see whole milk powder exports rise by 22% between 2016 and 2026, thereby maintaining a 53% share of the overall global market. The major share will go to China and south-east Asia and the growth is expected to continue.

## 4.2 Demand for meat and milk

It has been projected that a doubling in meat production, even more in beef production per se and a quadrupling in milk production between 2003 and 2050 will be required to meet the increasing demands of the global population by 2050. The question arises if the demand can be met as it will require sharp increases in cattle numbers and productivity. The projection for global numbers is an increase from 1.5 billion in 2000 to 2.6 billion in 2050, which would require an annual increase for developed countries of 0.6% between 2005 and 2030 and 0.2% between 2030 and 2050 and a corresponding increase in developing countries of 2.0% and 1.3%, respectively. This is unrealistic since (1) the number in 2000 was still <1.3 billion as implied in Section 2.1 and shown in Figure A1 (A), and (2), if the numbers of the FAO as depicted in Figure A1 (A) in Annexure 1 are accepted, extrapolation from the linear regression equation we compiled indicates a cattle population of only 1.76 billion in 2050, and from the polynomial regression equation only 1.47 billion. Thus, taking into consideration the inaccuracies in country numbers, environmental influences and other uncertainties, it seems unlikely that cattle numbers will exceed approximately 1.6 billion by 2050.

In addition to the argument pertaining to the size of the global herd, beef production has largely stagnated at <70 million metric tonnes per annum between 2016 and 2021. It is accepted that productivity in terms of efficiency and carcass weight can increase. Carcass weight increased from 160 kg in 1961 to 215 kg in 2019 according to the FAO (216 kg as calculated in Figure A1 (B)) and it is projected to increase to 227 kg in 2050, which is unrealistic as most cattle in developing countries with the largest expected increase in cattle numbers, are not fattened, but slaughtered in a lean condition, even emaciated. In concert with this statement, the polynomial regression equation we compiled predicts a decrease in carcass weight to 201 kg by 2050. Thus, beef production by 2050 as calculated from the regression equations in Figure A1 (A) can probably vary between 72 and 87 million metric tons, and therefore will unlikely meet the predicted doubling in demand by 2050.

Similarly, the required milk production is unrealistic since current production levels per cow in developed countries are becoming difficult to exceed without major implications to animal health and welfare, and high investments in genetic improvement and feed stocks will be required in developing countries. Production levels in selected developing countries (Bangladesh, India, Jamaica, Peru, Senegal, Tanzania and Thailand) vary between 250 and 3000 kg/cow/year, and for the continents it ranges as follows: Sub-Saharan Africa (excluding South Africa) at 250, South Asia at 1 000, Near East and North Africa at 1 300, Central and South America at 1 700, South East and East Asia at 2 800, Russian Federation at 3 000, Eastern Europe at 3 900, Oceania at 4 400, Western Europe at 6 100, EU27 at 7 300 and North America at 8 800 ℓ/cow/lactation.

The per capita demand must be considered in the context of the dichotomy of abundance in the developed world and low consumption in the developing/poor countries, although vast changes are expected with increasing affluence as poor countries rise during the transition phase. For example, the per capita demand for meat in China increased dramatically from 3.6 kg in 1961 to 52.4 kg in 2002. In developed countries, the demand for meat and milk (including dairy products) was predicted to increase from 78 kg and 202 kg per capita per annum from 2002 to 83 kg and 203 kg, respectively per capita per annum in 2015. The corresponding figures for developing countries were 28 kg meat and 44 kg milk per capita per annum from 2002 to 32 kg meat and 55 kg milk per capita per annum in 2015. In general, the annual demand for meat is expected to increase by between 6 and 23 kg per person worldwide by 2050, and the absolute increase will be greatest in Latin America, the Caribbean, East and South Asia and the Pacific, with demand doubling in Sub-Saharan Africa. As argued above, these demands will have to be met primarily by pork and chicken, as beef (and also sheep and goat meat) production is unlikely to increase to the projected requirement. In fact, the demand for beef may already be declining in Europe: EU consumption of beef reached a high in 1985 at 25 kg per capita per year, but from then has steadily declined to 16 kg (carcass equivalent). This is low compared to other major beef consuming countries in the world (e.g. 35 kg in Australia, 37 kg in the USA, 41 kg in Brazil and 59 kg in Argentina).

The dichotomy of developed versus developing countries is best illustrated by the per capita demand for meat at the extremes of developed and developing countries, such as 125 kg meat in the US, 146 kg in Denmark, 59–60 kg (beef alone) in Argentina, 13.3 kg/annum in Sub-Saharan Africa and 3.5 kg/annum in Ethiopia. Excluding Ethiopia, these figures equate to per capita consumption of 165 g/day, 200 g/day, 80 g/day and 20 g/day, respectively, reflecting a tenfold difference from highest to lowest. To put these numbers in perspective, recommendations for meat intake from an essential nutrient intake point of view range from 50–100 g per capita per day to 100–110 g per capita per day according to the World Cancer Research Forum, and even 150 g per capita per day. Therefore, to meet the demand for animal protein and associated nutrients, production as far as possible given the limitations of livestock production increases, and imports to developing/poor countries, should be escalated not reduced.

## 4.3 Contribution to human health

Diets of many in poor and middle-income countries, and even those of some populations in rich countries, tend to be low in high-quality protein, iron, vitamin A, zinc, calcium and other nutrients. While there is considerable variation across different types of animal source foods (meat- or dairy- or egg-based), the majority are dense in both energy and multiple micro- and macronutrients — some of which are rarely found in plant source foods (e.g. vegetables, grains, legumes and nuts), such as vitamins B12 and D. Plant source foods do contain essential micronutrients, but for some, such as iron, the captured form makes it less readily absorbable by the human body. For others, such as carotenoids (for production of vitamin A), larger food quantities are needed to meet the need. Most animal source foods also contain high-quality proteins, comprising all essential amino acids. Diets without animal source foods must typically include a wider variety of foods and in larger quantities to provide all amino acids and may require supplements for certain vitamins.

Infants, young children, adolescents, and pregnant and lactating women, have higher nutrient requirements per kg bodyweight and are more vulnerable to nutrient deficiencies and associated negative health outcomes if they consume insufficient amounts of key micronutrients. As animal source foods tend to be dense in many nutrients, relatively small amounts can be eaten to meet multiple requirements — making these helpful additions to the diets of vulnerable people groups, particularly young children (from 6 months of age). There is also some evidence of associations between animal source food consumption and reduced risks of stunting and improved micronutrient status, growth and/or cognitive performance. It should, however, be noted that it is difficult to make unequivocal conclusions in studies such as these as numerous other impacting factors cannot always be controlled. The same applies to an analysis of evidence on health implications of animal source foods discussed in the next paragraph. The most acceptable way is to rely on studies using collective investigations with a meta-analysis methodology, and reviews.

Considering that recent studies show an association between consumption of unprocessed red meat and processed meat and adverse health consequences, including increased risk for cancer, cardiovascular mortality and stroke, dietary guidelines have generally endorsed limiting meat intake. There are many contradictory studies though, which did not find significant associations between unprocessed red meat and mortality or major cardiovascular disease (CVD). Some studies did, however, find that a higher intake of processed meat was associated with higher risk of mortality and major CVD. Regarding cancer, various authors reported that diets restricted in red meat have little or no effect on cancer mortality and incidence, and in an overall conclusion it was stated: "The magnitude of association between red and processed meat consumption and all-cause mortality and adverse cardiometabolic outcomes is very small, and the evidence is of low certainty".

A summary of association results between the intake of milk and dairy products and human health reveals the following: the assumption that saturated fat can lead to increased plasma cholesterol which is associated with risk of CVD, and since full-fat dairy products contain saturated fat, most dietary guidelines recommend the consumption of low-fat dairy products. However, the evidence for a link between dairy consumption (including full-fat products) and CVD shows neutral, or even modest beneficial, effect. It was concluded that the observational evidence does not support the hypothesis that dairy fat or high-fat dairy products contribute to obesity or cardio-metabolic risk, and furthermore suggests that high-fat dairy consumption within typical dietary patterns is inversely associated with risk of obesity. This is supported by a study which showed that higher intake of dairy (milk and yogurt) was associated with a lower body mass index, % body fat, waist circumference and waist-to-hip ratio, as well as lower systolic and diastolic blood pressure. Results furthermore suggest minimum or no risk for CVD and intake of cheese, and even a non-linear relationship with maximum cheese intake at about 40 g per day for maximum protection. Thus, it can be concluded that at relatively high intakes, there is little evidence that milk has any significant adverse effects on health and may be protective against CVD, metabolic syndrome and colorectal cancer. Whereas other dairy products certainly contribute to consumption of saturated fatty acids, evidence for either negative or positive effects on health is limited.

Deductions from the discussion on meat and dairy products per se, are that their contribution to the risk of metabolic diseases is low, and over-consumption resulting in obesity should rather be the concern. Eating energy-dense diets, in particular rich in carbohydrates and sugar, and excess animal source foods, combined with sedentary lifestyles, has resulted in obesity mostly in developed countries, but also in developing countries due to energy-protein imbalances. A highly likely outcome over time is that a significant number of obese individuals will become insulin resistant and develop metabolic syndrome, a cluster of risk factors that predispose the individual to both CVD and type 2 diabetes.

# 5. Environment

## 5.1 Greenhouse gas emissions

### *5.1.1. Methane emissions and the biogenic carbon cycle*

All food production systems have an environmental impact. Livestock production has been singled out as a major cause of climate change (global warming). The concern is primarily associated with ruminant livestock being a comparatively large source of methane ($CH_4$) emissions which have a much higher warming contribution (52 %) than carbon dioxide ($CO_2$ – 13%) and nitrous oxide ($N_2O$ – 35%). The main source of ruminant $CH_4$ is enteric fermentation. Enteric $CH_4$ contributes approximately 6% to global anthropogenic GHG emissions and 40% to all livestock emissions. However, $CH_4$ is an attractive amelioration target for short-term gains in global warming abatement, since it has a much shorter lifetime than $CO_2$ in the atmosphere of 8–12 years and therefore all countries must target $CH_4$ reduction.

For mitigation purposes, it is more relevant to express GHG emissions (and $CH_4$) in relation to the amount of product produced, that is, to consider the contribution to food security at the same time. It also provides a measure of efficiency and partly reflects the amount of product produced in relation to the number of non-producing animals. For beef cattle the proportion non-producing animals (cows, heifers, etc.) are high compared to dairy cattle where the cow is also the producing animal. GHG emissions in kg $CO_2$ equivalent (e)/kg product in life cycle assessments for developed countries at the farm gate are: beef = 14–32 and milk = 0.84–1.4, and when grass burning, slaughtering and processing in the case of beef are added it is 25–35 kg $CO_2$e/kg and for milk the numbers increase to 1.3–1.5 kg $CO_2$e/kg after processing. The number for Sub-Sahara Africa is about 2.7 kg $CO_2$e/kg milk, illustrating the effect of low and inefficient production systems. Within the context of the anticipated increases in demand in the future it is imperative that efficient systems should be followed with high levels of production and turnover while not compromising the natural resources and the environment.

Factors which need to be considered when considering $CH_4$ emissions of cattle, and which have mostly not been taken into account as yet, relate to the IPCC acceptance of the global warming potential (GWP) of $CH_4$, the generally accepted number of $CH_4$ produced in enteric fermentation, and accounting in GHG emission calculations for the contribution of the animal itself as being a carbon sink and not merely a source of emissions. Being comparatively new in the literature, we discuss this in more detail.

In GWP, the conventional calculation (GWP100) accepts the GWP of $CH_4$ as being 28 to 34 times the warming potential of $CO_2$. Recently, this has been contested on account of a much lighter molecule weight of $CH_4$ than $CO_2$, a half-life of $CH_4$ in the atmosphere of 8.6 years and an exponential decaying rate which indicates that half of its effect realises in the first 8.6 years and three quarters at approximately 17.2 years, where after it filters progressively towards infinity (Figure 2). This results because $CH_4$ is removed from the atmosphere by chemical reactions, primarily with the hydroxyl radical and by chemical reactivity with soil. Photosynthesis through the biogenic carbon pathway plays a significant role (Figure 3). In contrast, for $CO_2$ the primary mechanisms for removal from the atmosphere involve absorption into the oceans and biomass, which can last up to 1 000 years, and its warming effect stays over a long time. Because of the regular removal of $CH_4$, and if more $CH_4$ is not added to the atmosphere than what is removed, the net result is a shifting warming effect, but on average at much lower levels than what is accepted in GWP100. In a study by Oxford atmospheric scientists a formula was developed which considers the changing nature of the warming effect. The authors used a finite period of 20 years to capture the decaying nature of $CH_4$ and calculated from the equation: $E^*t = 128 \times E_{CH4\,(t)} - 120 \times E_{CH4\,(t-20)}$, that if the cut-off point of 20 years is considered where ECH4 is $CH_4$ emissions for time *t* and time *t-20*, then the warming potential can be as low as 128 – 120 = 8 times that of $CO_2$. This approach has become known as GWP* and is progressively been applied in life cycle analysis (LCA) and other calculations.

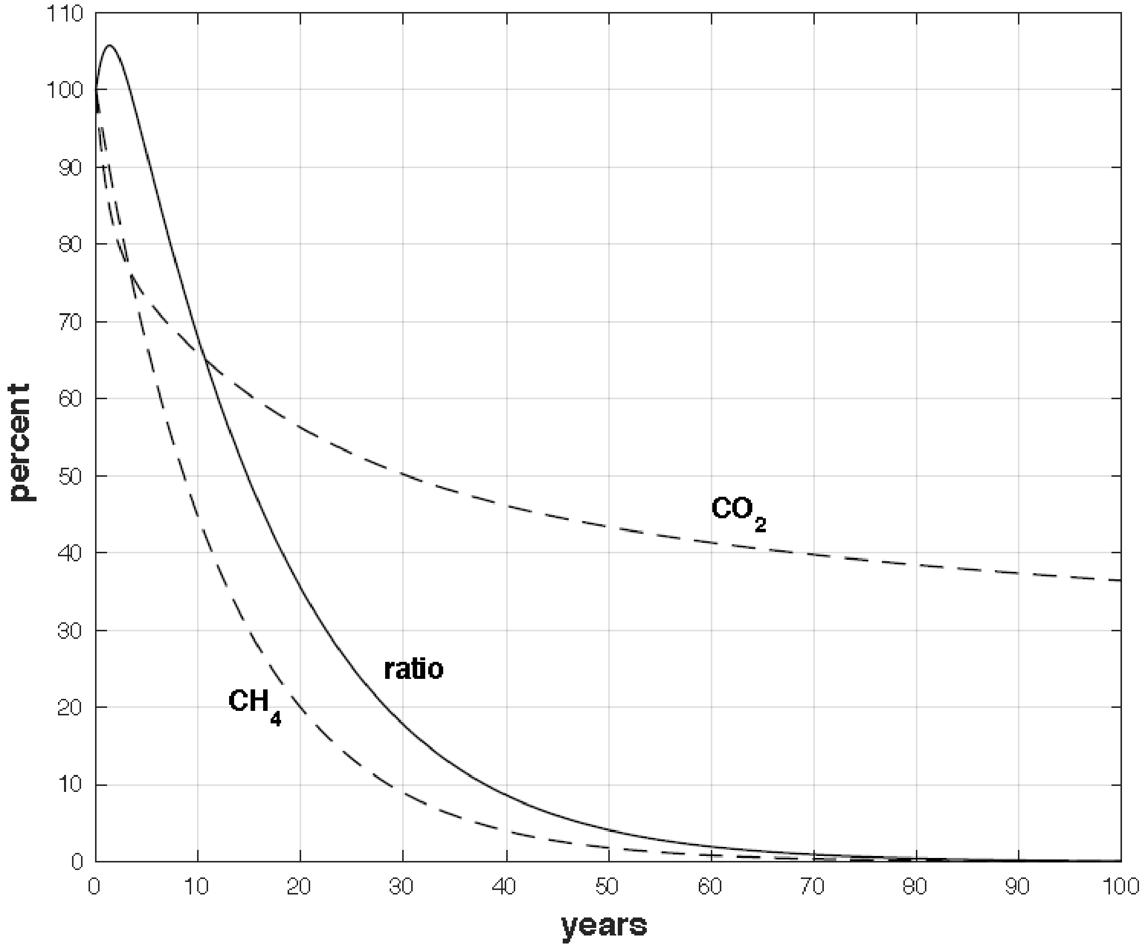
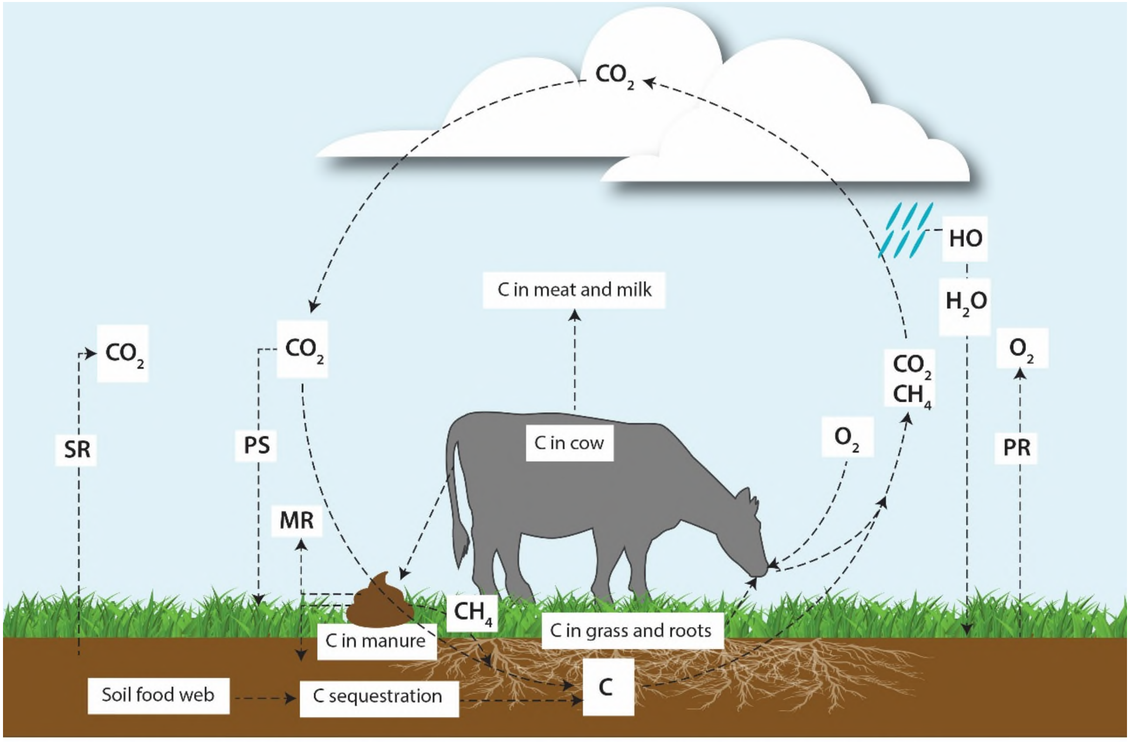



**Figure 2: The persistence of carbon dioxide and methane in the atmosphere as a function of time**
Note: The chart begins when a pulse of the gas is injected into the atmosphere. The legacy effect of methane is miniscule compared to that of carbon dioxide.

The biogenic carbon pathway (Figure 3) illustrates the integrated role of cattle in drawing $CO_2$ from the atmosphere through photosynthesis, the carbon of which is sequestered into plants and roots and is then captured in the soil. Methane from the cow is oxidised in the atmosphere by hydroxyl oxidation and other substances to $CO_2$.

In contrast to the $CH_4$–$CO_2$ relatively stable relationship in the biogenic carbon pathway, which has evolved over millions of years between rangelands and herbivores (Figure 3), the entering of the atmosphere of $CH_4$ with fossil fuel origin, peat and $CH_4$ trapped beneath ice masses in the polar regions – and now being released due to global warming – is 'new' to the atmosphere and results in accumulation because the rate of removal is exceeded.




SR = soil respiration; PR = Plant respiration; PS = Photosynthesis; HO = Hydroxyl oxidation; MR = Manure respiration

**Figure 3: The biogenic carbon pathway**

With respect to enteric $CH_4$, from results of calorimetry trials on a wide range of forages and forages plus supplements in Australia, methane production was regressed on gross energy intake (GEI). These Australian forages correspond to forages and forages plus supplements used in many countries in the world. The prediction equation has a $R^2$ of 0.93 and the estimate of methane production was 6.3% of GEI. This resulted in a mean relationship of metabolisable energy (ME) equal to 0.905 digestible energy (DE) instead of the usually accepted relationship of ME = 0.82DE.

The last pathway is accounting for the GHG emissions inclusive of the contribution of the animal being a carbon sink and not just a source of emissions. Currently, carbon accounting focuses almost exclusively on enteric and manure-based $CH_4$ emissions. The fact that livestock production also contributes to the sequestration of carbon is largely ignored. It is assumed that, in addition to enteric emissions, the carbon absorbed by the animal in the form of feedstock is oxidised and returned to the atmosphere. An important omission in carbon footprint assessments is the carbon cycles within the animal to enable physiological functions of maintenance, pregnancy, lactation and growth. The within-animal pool (Figure 3) completes the carbon cycle and needs to be considered as a virtual carbon sink.

The arguments above provide significant evidence that on average the GWP of $CH_4$ in the atmosphere is lower than until recently accepted if the implications of GMP* are accepted. Global cattle $CH_4$ emissions if Tier 2 calculated, should also be much lower towards 2050 than accepted in the literature for LCA calculations due to the cattle number arguments in Section 2.1, the lower enteric $CH_4$ production as shown by the Australian forage work, proof of a virtual carbon sink, and proof that in many countries the same productivity is maintained with less cattle than in the past. In fact, the evidence of a slowing down (even reduction) of cattle numbers towards 2050 as suggested in Sections 2.1, 3.1 and 4.2 may even result in a cooling down of the cattle-induced $CH_4$ in the atmosphere, if the predicted outcomes of GWP* and the reasoning above are accepted.

### *5.1.2. Nitrous oxide*

The relationship between cattle and nitrous oxide ($N_2O$) is primarily indirect through their feed stocks. Nitrous oxide is emitted in comparatively small quantities from cattle manure and primarily following chemical N fertilisation and pesticide application of crops, cover crops and cultivated pastures. As chemical fertilisers, N application to agricultural crops has increased dramatically, from 10 Tg N/ha in 1961 to 77 Tg N/ha in 2016. Nearly half of the N fertiliser supplied is not used by crops and is lost to the ecosystem through volatilisation, runoff or leaching. These losses may lead to environmental pollution, such as the release of GHGs, negative infiltration of aquatic water bodies, soil acidification and biodiversity reduction. For example, due to the low N use efficiency of the crops and the extreme mobility of the reactive forms of N in either the gas or the soluble phase, the excess N applied has a high risk to be lost to the environment.

Nitrogen is released into the atmosphere during the processes of de-nitrification (reduction of $NO_3^-$ to $N_2$ by soil microbes) under anaerobic conditions, and nitrification (oxidation from $NH_4^+$ to $NO_3^-$) under aerobic conditions. The atmospheric level of N pollution by 2050 is expected to be in the range of 102–156% higher than in 2010 with the agricultural sector accounting for 60% of this increase. The lifespan of $N_2O$ in the atmosphere is 110–120 years and its GWP is 298 times that of $CO_2$ at GWP100, that is, about exactly as calculated by the IPCC over the 100 year period. Thus, although $N_2O$ concentration in the atmosphere is only 1/1 000 of $CO_2$, it is 5–6% of all GHG in the atmosphere and increasing at a rate of 0.25% per year. In 2018, $N_2O$ emissions from agriculture to the atmosphere were 7.718 Gg. Thus, its warming effect is substantial and increasing. In addition, $N_2O$ is one of the ozone-depleting substances in the atmosphere.

The implications are that agricultural practices need to limit N fertilisation and other chemical substance applications. Currently, the status is that developing countries remain in the phase of increasing N pollution (e.g. India), certain countries are in the transition phase (e.g. China), while others are in a phase of reducing pollution (e.g. the USA and the EU). To limit pollution by $N_2O$, practices of conservation and regenerative agriculture (CA and RA) in crop production should rather be implemented, which are discussed in the following sections. In these practices, cattle play a significant role. One aspect is the supply of organic N through manure as substitute for chemical N fertilisation.

### *5.1.3. Soils and carbon stocks*

Soil is involved in the biogeochemical cycles of C and N, and thus is key to climate regulation either by emitting GHGs or by sequestering C. By sequestering, soil can store vast amounts of C: the first meters of mineral soils contain between 1 500 and 2 400 Pg of organic C. This is about three to four times the amount of C in vegetation (450–650 Pg C) and 2–3 times the amount in the atmosphere (~829 Gt C).

In a study the potential of natural climate solutions (defined as conservation, restoration, and improved land management interventions on natural and agricultural lands) to increase carbon storage and avoid GHG emissions in the US, was calculated. The results showed the potential as being 1.2 ± 0.3 Pg $CO_2$e per year, which is the equivalent of 21% of the total net annual emissions of the US. In a similar study, it was estimated that natural climate solutions can provide 37% of cost-effective $CO_2$ mitigation required by 2030 for a >66% chance of holding global warming to below 2$^o$C. The potential for carbon removal from the atmosphere and storage in soil is clearly substantial and in which agricultural practices need to play a significant role. The role of cattle (and other herbivores) is through its essential link in the biogenic carbon cycle which channels carbon through the plant to the soil as illustrated in Figure 3.

### *5.1.4. Associations with rangeland*

Together grasslands cover 3.67 million km$^2$, which is 46% of all global rangeland types and it co-evolved with herbivores, soil biota and predators. The grasslands are one of the world's most extensive terrestrial biomes, covering more than 40% of the terrestrial surface of the earth and are central to the survival of modern-day livestock herbivores, their associated pastoralists and commercial farmers in addition to a diverse community of large wild mammals, the African continent being a prominent example where countless wild herbivores still graze such as in the Serengeti-Masai Mara complex. Although cattle habituate most biomes, the grasslands are the major home of cattle on all continents. India and some neighbouring countries are unique since significant numbers are kept in urban areas because of social, cultural and religious orientation.

The grassland biome is also an extremely important resource for soil carbon sequestration, even more than forests. Furthermore, it is important because many arid and semi-arid grass species have co-evolved with herbivores, thereby indicating the important role which cattle as the major herbivore in contemporary times must play in the quest to mitigate climate change, and to use and protect grasslands, and of course other rangelands which they inhabit.

There is a growing amount of evidence that GHG emissions associated with rangelands are primarily due to poor grazing management resulting in either inadequate use or bare ground and soil erosion, and that managing grazing effectively can, in fact, contribute to $CO_2$ removal from the atmosphere by enhancing soil carbon sequestration. In this context, results showed that moderate grazing enhanced soil organic carbon (SOC) in the upper 15 cm by 12% compared with no grazing. One explanation is that plants put more carbon below ground because of grazing than plants not grazed, through increasing root mass up to three times more in grazed grasslands compared to not-grazed grasslands. The response of plant roots to grazing is to produce more roots and exudate through the roots which feed the microbial population, thereby also improving soil health.

Effective grazing management requires some form of rotation as it is generally accepted that perennial (even annual) grasses require recovery periods after grazing to produce and develop new tillers and root systems, and replace nutrients lost in grazed tissue. Rotational grazing requires multi-paddocks through which livestock herbivores (cattle) are rotated in one or more cycles during a season. While there are differences of opinion regarding the intensity of grazing, relatively high to ultra-high density, quick rotation systems have shown increasing interest as these may advance photosynthesis and promote soil cover if correctly applied.

The grazing management system adopted should ensure high forage plant biomass (dead litter or living plants) as permanent soil cover, which is highly effective in reducing soil erosion, and livestock consuming grazed forages under appropriate management will result in more carbon sequestration than emissions. Regeneratively grazed pastures maintain dense, diverse stands of living plants, which in addition to preventing erosion, can improve soil fertility, and reduce nutrient runoff due to increased water infiltration. Perennial pasture under regenerative management also improves water quality, promotes healthy soils which can absorb heavy rains, thereby mitigating nutrient and sediment runoff, downstream flooding and drought, and increases soil water storage capacity through organic matter accrual. It is clear that the benefits of cattle to carbon sequestration by effective grazing management, is of a magnitude that can exceed GHG reductions by reducing cattle numbers as proposed by many authors, and should be the preferred policy because of all the benefits to the environment and society at large, as described above.

#### *5.1.5. Associations with crops*

As discussed in Section 5.2.1., one of the most significant solutions to the problem of global warming and climate change is to draw down, or sequester, atmospheric $CO_2$ back into soil and other biotic pools through photosynthesis. This is a critical intervention to increase SOC levels beyond a threshold level of about 1.2% in the surface layer and 1.1–1.5% in the root zone, which will improve soil health, increase agronomic productivity and protect the quality of water resources. Over-tilled or degraded soils generally contain much lower levels of SOC and cannot perform these essential ecosystem functions and services. Further indicators are an improvement of 1% carbon in the upper 30 cm of the soil which will coincide with addition of 25 kg atmospheric N, and for each 1% increase in soil organic matter (SOM) soil water holding capacity will be increased by 16–250 kℓ/ha/year – the variation depending on soil type and land area.

No-till practices, therefore, offer promising options towards adaptation and mitigation of climate change. The addition of innovative and diverse cropping systems through crop rotations, sequences, associations and cover crops in RA and CA practices can have further benefits, with the integration of livestock through the inclusion and grazing of cover crops as one of the most significant ones. It was reported that cover crop effects on GHG fluxes mitigated warming by ~100–150 g $CO_2e/m^2$/year, which is higher than mitigation from transitioning to no-till. The most important factors were soil carbon sequestration and reduced fertiliser use, with an additional advantage if legumes were used in cover crop systems. Maximum benefits will be obtained if the full range of RA tenets are included. The multiple benefits achieved through the integration of the different tenets of RA are supported by research and farmer experiences across the world. Some of the different tenets of RA systems are shown in Figure 4.

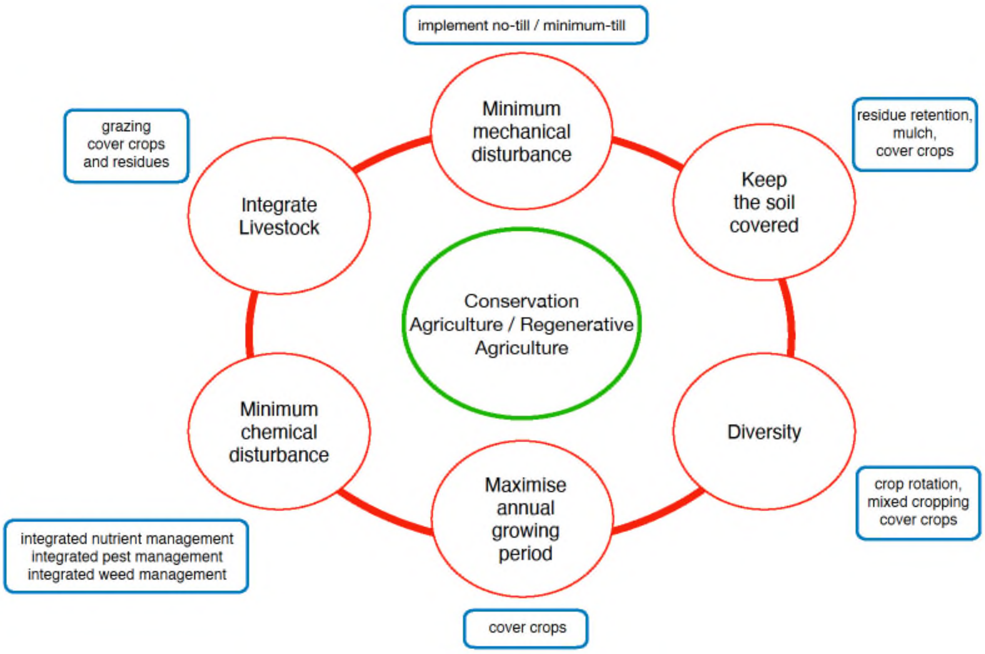



**Figure 4: Basic tenets of regenerative agriculture designed to draw carbon dioxide from the atmosphere**

As mentioned above and shown in Figure 4, livestock integration through crops (and trees where applicable) is a key component of RA systems. Grazing certain crops (e.g. cover crops) or crop residue with cattle (and other livestock) adds to the benefits of the described RA practices. In this regard, two reviews are of significance. The authors concluded: "Incorporating forages and ruminants into regeneratively managed agroecosystems can elevate soil organic C, improve soil ecological function by minimizing the damage of tillage and inorganic fertilizers and biocides, and enhance biodiversity and wildlife habitat, and to ensure long-term sustainability and ecological resilience of agroecosystems, agricultural production should be guided by policies and regenerative management protocols that include ruminant grazing". Other authors concurred by arguing that livestock re-integration holds notable potential to increase cropland SOC through controls on landscape net primary productivity, allocation of biomass below ground, efficient recycling of residual crop nutrients, an increase in photosynthetic capacity and soil biological activity related to a suite of soil ecosystem services. In integrated crop-cattle systems with crop residues and multi-species cover crops, more cattle numbers than normal can be used in comparatively high-density rotational management practices because of high plant biomass, to the benefit of photosynthesis, soil health, productivity and economic outcomes of the enterprise.

## 6. Observations and conclusions

The purpose of this investigation was to evaluate the risk to the global socio-economy and the environment if cattle production increases towards 2050, according to projected needs and demands of the global economy. The following observation and conclusions are pertinent:

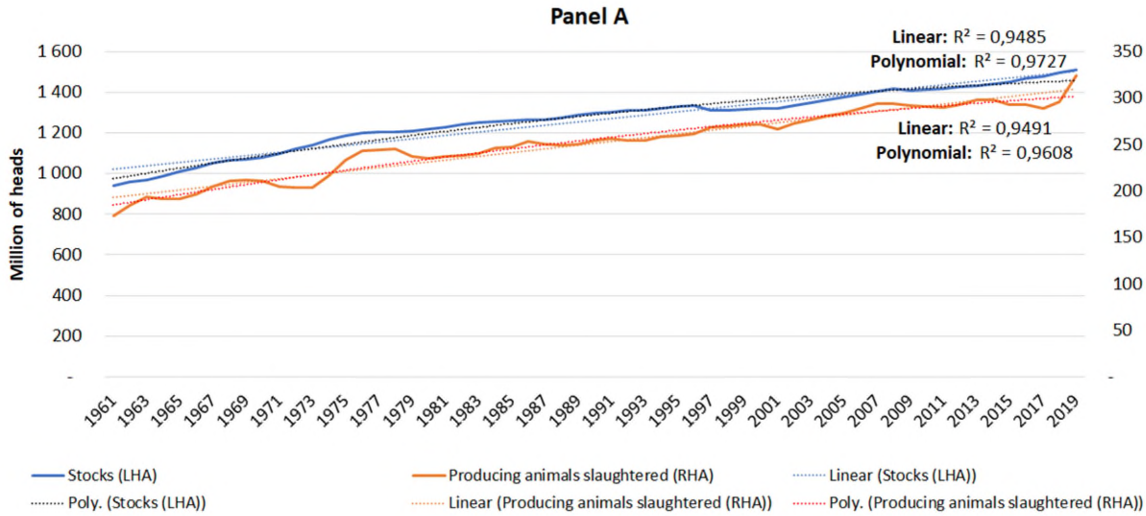
- Literature estimations of global and country cattle numbers vary considerably between literature sources. Also, expectations of numbers towards 2050 are unrealistic, which are of concern as projections of needs, future production and trade will not realise. Projections indicate stagnation and possibly a decrease in cattle foods, at least per capita.

- Comparison between cattle and Late Pleistocene (LP) mega-herbivore numbers show little difference in $CH_4$ output. Lower herbivore estimates for the 1800s are coincidental because of massive extirpations across continents. The evidence, however, is limited. Similar comparisons on biodiversity revealed more resemblance between LP herbivores and modern-day livestock herbivores than with modern-day wild herbivores. These findings are positive for cattle.
- Livestock provide over half of the global agricultural output and current world trade is healthy. Cattle, in addition to being a source of food, provide several essential socio-economic services in the developing world which cannot be replaced.
- Consumption of animal-based foods is rapidly increasing in developing and transition countries, yet still way below consumption in developed countries. The low consumption in poor countries is a major reason for nutritive imbalances, stunting and low cognitive development as animal-based foods are nutrient dense, in contrast to plant-based foods, which alone can rarely meet nutrient requirements.
- Although the literature is contradictory, there are very little meta-analysed studies which show negative relationships between animal-based foods and cardiovascular diseases and cancer. It is rather a case of quantity resulting in obesity and insulin resistance.
- Methane emissions by cattle are much lower than previously accepted because the relationship with the biogenic carbon pathway has not been understood, and carbon as a sink as well as how it is affected by the physiological function of the animal has not been taken into account. In addition, the global warming potential of $CH_4$ has been over estimated.
- Nitrous oxide is a dangerous polluter in the atmosphere. In agriculture, it is primarily derived from chemical fertilisation during crop and pasture cultivation, which in addition is damaging to soil health. These practices should be limited and organic sources such as animal (cattle) manure and compost used.
- Grasslands constitute 46% of rangeland surface, have co-evolved with herbivores and is the largest source of photosynthesis and carbon sink into soil, even larger than forests. The implication is that this resource and its herbivore grazers (cattle being the prime example) need to be protected against degradation at all costs. Also because maximising carbon sequestration is more effective in limiting atmospheric carbon accumulation than emission reduction.
- Photosynthesis, carbon sequestration and soil health should be emphasised in rangeland management using quick rotation and comparatively high-density grazing practices with cattle where feasible, and in crop cultivation, by introducing multi-species cover crops and livestock grazing. This will allow more animals per area of land to the benefit of productivity and economic returns.
- Livestock forms an integral part of regenerative agriculture systems leading to multiple environmental, social and economic benefits, with soil health at the centre.
- Finally, there is very little evidence of socio-economic and environmental risk if cattle production is to be increased towards 2050, provided a number of influencing factors are addressed, such as resource degradation. For the developing world an increase in cattle foods will be mostly beneficial. However, cattle number and production trends

do not predict an increase, which points to further increases in pork and chicken to meet future demands for animal-based foods.

## Annexure 1: Growth in the cattle population, production and yield over time according to the FAO

According to the FAO, the number of cattle increased steadily from about 950 million animals to more than 1.4 billion from 1960 to 2020, as can be seen in Figure A1 (A). The polynomial relationship which we compiled has a higher $R^2$ (0.9727) than the linear relationship ($R^2$ = 0.9485), which suggests that the cattle numbers have been increasing at a declining rate. Likewise for the yield growth (Figure A1 (B)) that increased from approximately 160 kg/carcass to 220 kg/carcass with the polynomial function having the higher $R^2$ suggesting an increase at a decreasing rate. The combined impact of the yield increase and the increase in the herd has led to an increase in production (Figure A1 (B)) from approximately 28 million tonnes to 68 million tons, an average growth rate of 1.57% per year.



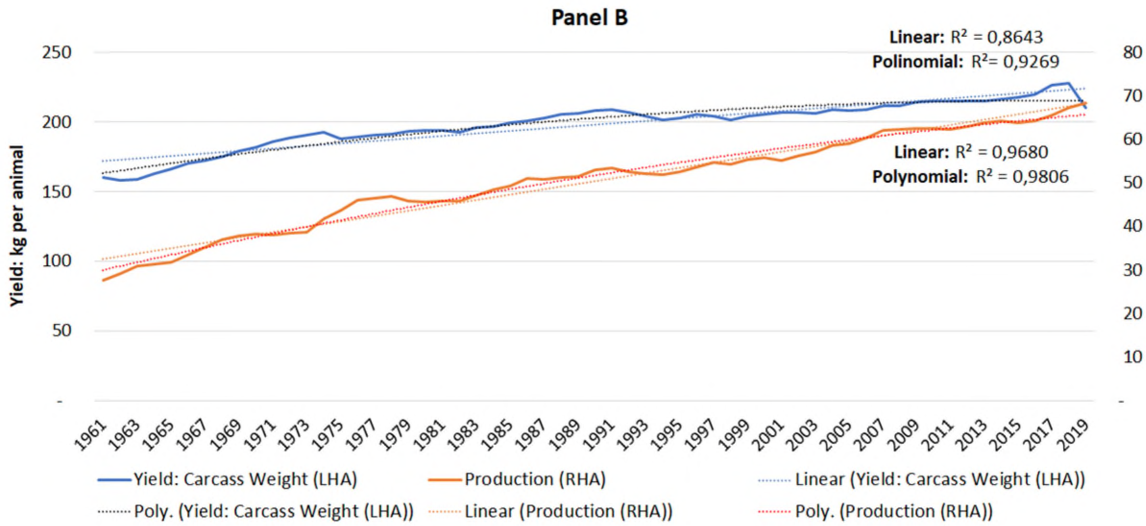



**Figure A1: Global cattle statistics: stocks and animals slaughtered (Panel A) and carcass yields and production (Panel B) between 1961 and 2019 and its linear and polynomial relationships**

*Regression equations:*
*Panel A:*
*Linear: Stocks (million)(Y) = 8.327 (years post 1960)(X) +1014; Polynomial: -0.087$X^2$ +13 57X + 961*
*Linear: Animals slaughtered (million)(Y) = 0.616 (years post 1960) (X) + 31.98; Polynomial: -0.004$X^2$ +0.893X +29.16*
*Panel B:*
*Linear: Production (million tons) (Y) = 2.019 (years post 1960) (X) + 191; Polynomial: -0.015$X^2$ +2.902X +182*
*Linear: Carcass weight (kg) (Y) = 0.903 (years post 1960) (X) + 171; Polynomial: Y = -0.016$X^2$ + 1.859X + 162*

## Annexure 2: Cattle population of Brazil, India, China and Russia from various sources

The cattle population according to various sources for Brazil, India, China and Russia is depicted in Table A1.

**Table A1: Cattle population (million) of selected countries and global totals as compiled from various sources**

| Country | Reference | 2009 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brazil | WDA | | 203 | 208 | 213 | 219 | 226 | 232 | 238 | 244 | 253 |
| | FAOSTATS | 205 | | 187 | | | 218 | | 214 | | |
| | Statista | | | | | | 218 | | 214 | 215 | |
| | WCP | | | | 212 | | | 215 | | | |
| India | FAOSTATS | 196 | | 195 | | | 186 | | 185 | | |
| | Vikaspedia | | 191 | | | | | | | 193 | |
| | WCP | | | | 189 | | | 185 | | | |
| China | WDA | | 91.4 | 89.9 | 90.1 | 90.6 | 88.3 | 90.4 | 89.2 | 91.4 | 95.6 |
| | FAOSTATS | 82.6 | | 103 | | | 84.5 | | 63.4 | | |
| | WCP | | | | 114 | | | 83.2 | | | |
| Russia | WDA | | 19.7 | 19.3 | 18.9 | 18.5 | 18.2 | 18.2 | 18.1 | 18 | 17.9 |
| | FAOSTATS | 21 | | 28.7 | | | 19 | | 18.3 | | |
| | WCP | | | | 19.9 | | | 18.8 | | | |

**Table A2: Other countries with comparatively large cattle populations (>20 million head); averages between different sources**

| Country | 2009 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| United States | 94.7 | 90.1 | 92.6 | 89.3 | 91.9 | 92.8 | 94.0 | 94.6 | 94.3 | 94.0 |
| EU* | | 77.8 | 78.6 | 80.1 | 80.9 | 80.9 | 79.0 | 77.8 | 77.2 | 76.5 |
| Ethiopia | 50.9 | | 55.0 | 54.0 | | 59.5 | 60.9 | 62.6 | 61.5 | |
| Argentina | 54.5 | 52.2 | 52.5 | 51.7 | 53.1 | 53.4 | 54.1 | 54.5 | 54.5 | 53.8 |
| Sudan | | | | 41.9 | | | 30.7 | | | |
| Pakistan | 33.0 | | 36.0 | 38.3 | | 42.8 | 44.4 | 46.1 | | |
| Mexico | 32.3 | | 31.2 | 32.4 | | 33.9 | 31.8 | 34.8 | | |
| Australia | 27.9 | 28.4 | 28.3 | 29.2 | 27.4 | 25.0 | 26.2 | 26.1 | 23.7 | 23.2 |
| Tanzania | | | | 24.5 | | | 26.4 | | | |
| Bangladesh | 23.0 | | 22.8 | 24.0 | | 23.8 | 23.9 | 24.1 | | |
| Colombia | | 21.6 | 19.9 | 20.8 | | | 22.5 | | | |
| Nigeria | | | | 20.0 | | | 20.8 | | | |
| Total | | | | 506.2 | | | 514.7 | | | |
| World-A | | 1 002.0 | 1 005.0 | 1 009.0 | 969.0 | 979.0 | 985.0 | 996.0 | 989.0 | 988.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| World-B | | 1 427.0 | 1 432.0 | 1 439.0 | 1 452.0 | 1 470.0 | 1 478.0 | 1 494.0 | 1 511.0 | |

*EU excluding the UK