



Food and Agriculture  
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United Nations

# Climate-smart livestock production

A practical guide for Asia and the Pacific region

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## Preface

Population growth, rapid urbanization and dietary changes have resulted in an accelerated, growing demand for food. The Food and Agriculture Organization of the United Nations (FAO) estimates that by 2050, some 50 percent more food will be needed, especially in developing countries and emerging economies. Climate change is one of the factors negatively affecting food production.

The effects of climate change will vary by region, country and location. Increasing temperatures, increased climate variability and more frequent and severe extreme weather events are all threatening food production and the livelihoods of smallholder farmers.

This guide addresses the relation between climate change and the livestock sector from a technical point of view. It looks at the importance of the livestock sector for food security, as well as how it can adapt to climate change and lower greenhouse gas (GHG) emissions attributed to the sector.

Livestock emit greenhouse gases that contribute to climate change. At the same time, there are opportunities to greatly reduce such emissions in developing countries through improved efficiency in livestock production practices. Such huge, yet largely unexploited opportunities will be described in this guide.

Policymakers, development practitioners, technical personnel, farmers, academics and extension agents would definitely benefit from this guide which focuses on long-term climate change mitigation and adaptation of livestock production systems in Asia and the Pacific region.

## Acknowledgements

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## Abbreviations and acronyms

CSL	Climate-smart livestock
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas
GLEAM	Global Livestock Environmental Assessment Model (FAO)
IPCC	Intergovernmental Panel on Climate Change
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change

### Chemical formulae

CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon dioxide
N <sub>2</sub> O	Nitrous oxide





## Executive summary

Population growth, rapid urbanization and dietary changes have resulted in growing global demand for livestock products, with a negative impact on climate change. Increasing temperatures, increased climate variability, and more frequent and severe extreme weather events are all threatening livestock production systems.

The livestock sector is a major contributor to climate change, generating significant emissions of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). It is estimated that the sector emits about 7.1 giga-tonnes of CO<sub>2</sub> equivalent (CO<sub>2</sub>eq.), about 18 percent of the total anthropogenic greenhouse gas (GHG) emissions (FAO, 2006). The main share of GHG emissions derive from enteric fermentation and manure management.

Climate-smart livestock (CSL) solutions can contribute to a reduction of GHG emissions through improved livestock productivity, efficient use of natural resources, carbon sequestration and integration of livestock into the circular bioeconomy. Other CSL solutions focus solely on climate change adaptation.

Livestock productivity can be improved either by increasing the output (e.g. increased milk production) or by decreasing inputs while maintaining the same output, for example by using higher quality feed rations. It is estimated that improving livestock productivity will reduce emissions per unit of livestock product by 20 to 30 percent. There are specific livestock feed products that can lower GHG emissions, but it is unlikely that these will be available and affordable for smallholders in Asia and the Pacific any time soon.

Examples of CSL solutions focusing on the efficient use of natural resources include higher yields per hectare, higher water productivity, efficient use of low carbon energy, and the reduction of waste along the value chain.

A better integration of livestock in the circular bioeconomy will contribute to reduced losses and lead to an overall decrease in GHG emissions. The use of crop residues for animal feed is an example in this category, as well as improved manure management.

The impact of CSL solutions can be measured by using tools like the Global Livestock Environmental Assessment Model (GLEAM).

It is important for countries to have a coherent set of policies and regulations that take climate-smart livestock solutions into account at all levels; a policy coherence analysis could be a helpful tool.



# 1. Introduction

## 1.1 Livestock, food security and the Sustainable Development Goals

This introduction will provide an overview to livestock production in relation to food security and the Sustainable Development Goals (SDGs) from a global perspective. Section 1.2 introduces livestock production in Asia and the Pacific region, specifically.

Livestock provide many goods and services to people, including meat, milk, eggs, hides, feathers, fibres, animal traction and manure. They provide income and employment to an estimated 1.3 billion people in the world. In addition, they serve many social, cultural and financial roles in different societies. Livestock provide insurance, a banking system, status and income, and are very important in risk management, including climate change-related risks.

Livestock may be raised primarily for subsistence or local sales, or on the other end of the scale to supply international markets with large quantities of produce. In extremely dry areas, which account for 33 percent of the global land surface, livestock is often the only viable agricultural production system.

### **Food security and nutrition**

The Food and Agriculture Organization of the United Nations (FAO) states that food security exists when “all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life” (FAO, 1996 World Summit). Livestock play a critical role in food security, contributing to global calorie and protein intake, supplying around 33 percent of the world’s protein consumed. Livestock products will continue to be consumed in increasing amounts. Meat, milk and eggs, in appropriate amounts, are valuable sources of complete and easily digestible protein and essential micronutrients. Even small amounts of animal sourced foods in children’s diets improve not only their physical development but also their cognitive and learning abilities.

Livestock production and marketing can help stabilize the food supplies and provide individuals and communities with a buffer against economic shocks and natural disasters. Ruminants can increase the world’s human protein balance by transforming inedible protein found in forage into edible products.

### **Increasing demand for livestock products**

Global production of meat, milk and eggs has grown rapidly in the last decades in response to an increasing demand for livestock products. This increase is particularly strong in developing countries and has largely been driven by expanding populations, increasing incomes and urbanization. Between 1960 and 2005, annual per capita consumption of meat more than tripled; consumption of milk almost doubled; and per capita consumption of eggs increased fivefold in the developing world (FAO, 2018a).

Per capita meat consumption in developing countries is expected to increase to 26 kg and 32 kg in 2030 and 2050, respectively. Driven by demand, global production of meat is projected to more than double, from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050. Milk production is expected to increase from 580 to 1 043 million tonnes (FAO, 2018a).

## Sustainable Development Goals

Livestock are central to achieving many of the United Nations SDGs. Figure 1 illustrates the 17 SDGs.

The relation between livestock production and the most relevant SDGs are presented below, highlighting the relevant livestock sector to the particular SDG, possible key actions that will further enhance livestock contribution to the SDG, and ways in which the livestock sector influences the SDG in an undesirable way (FAO, 2018c).

### SDG1: “No poverty”

- Livestock play a key role in preventing people from falling into poverty.
- Around 600 million of the world's poorest households keep livestock as an essential source of income.
- The growing demand for livestock products and other changes in developing countries will provide opportunities and benefits to many livestock smallholder farmers.

### SDG 2: “No hunger”

- Livestock are a critical source of food, beside income, employment and savings.

### SDG 3: “Good health”

- Animal source foods provide high quality protein and energy as well as essential micronutrients, thereby contributing to good health.
- The livestock sector contributes to good health as functioning livestock services contribute to a reduction of zoonotic diseases.
- Inappropriate use, overuse and abuse of antimicrobials in animal production contributes to an increase in antimicrobial resistance (AMR) of pathogens causing human infections and/or animal infections.

### SDG 5: “Gender equality”

- Women in developing countries are fully involved in livestock systems.
- Women often face greater economic, social and institutional barriers in livestock production systems.
- Policies and programmes should work to remove root causes of gender inequalities as well as the obstacles and constraints facing women.

Figure 1: Sustainable Development Goals



Source: SDGs, <https://www.un.org/sustainabledevelopment/>

#### **SDG 6: “Clean water and sanitation”**

- Livestock production withdraws approximately 20 percent of all available freshwater, and this is expected to increase.
- Improving water use efficiency and policy guidance is important in ensuring access to safe water sources and sanitation.

#### **SDG 7: “Affordable and clean energy”**

- There is great potential within the livestock value chain for the use of clean energy technologies.
- Manure could provide a major renewable, affordable, reliable and sustainable fuel source.

#### **SDG 8: “Good jobs and economic growth”**

- The value of livestock production accounts for 40 percent of total agricultural output worldwide.
- Livestock production employs at least 1.3 billion people worldwide.
- Policies should promote livestock system models that lead to higher labour productivity, facilitate value-addition, and are labour-intensive.
- Diversification of the livestock value chain offers great opportunities for developing countries to accelerate economic development.

#### **SDG 13: “Climate action”**

- Livestock are highly vulnerable to climate change impacts.
- Livestock make a significant contribution to climate change.
- Improving livestock production efficiency is key to reducing emissions and building resilience to climate change.
- A number of climate change mitigation and adaptation options are available for livestock production systems (the topic of this guide).

#### **SDG 17 “Partnerships for the Goals”**

- Multi-stakeholder partnerships within the livestock sector need to be promoted to work towards sustainable production systems.
- There is a need to develop synergies and address conflicts and gaps among policy areas to effectively address cross-cutting challenges.
- Public–private partnerships and stakeholder consultations are critical in livestock sector development.

## **1.2 Livestock production systems in Asia and the Pacific**

As explained in the previous section, livestock provide many goods and services in different production systems. The scale, purpose and nature of the livestock farming enterprise is known as the **livestock production system**. The different production systems are described below, as they are closely linked to the type of climate-smart livestock (CSL) strategies that can be implemented in each production system.

Ruminant livestock, such as **cattle, buffaloes, sheep and goats**, tend to be dependent directly on the land, as they are fed mainly on locally grown roughages. Some larger commercial scale production systems, however, are not land-dependent. Their production systems are therefore primarily determined by agro-ecology and land use. Production systems for monogastric species such as **pigs**

**and chickens** depend more on consumer demand and the level of capital investment. This guide defines the following production systems (FAO, 2007):

1. cattle: land-based (i), mixed farming (ii) and feedlot (iii)
2. other ruminants: land-based (iv), mixed farming (v)
3. pigs: backyard (vi), semi-commercial (vii), commercial (viii)
4. poultry: backyard (ix), layers (x) and broilers (xi)

Following, an explanation of the key features of these farming systems.

### 1.2.1 Land-based systems

In these livestock systems, more than 90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds, and less than 10 percent of the total value of production comes from non-livestock farming activities.

### 1.2.2 Mixed-farming systems

In these livestock systems, more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities.

### 1.2.3 Feedlot

This production system is defined by the use of ruminant species, principally beef cattle, where feed is mainly introduced from outside the farm system. The system is based on high-producing, specialized breeds and their crosses. The system is feed-intensive and labour-extensive, and key efficiency parameters are daily weight gains and feed conversion.

### 1.2.4 Backyard

The backyard system (or subsistence system) is defined by the use of monogastric species, mainly poultry and pigs. In the backyard system, animals are usually confined in simple structures, often within the homestead, and provided with some feed supplementation. In general, family labour suffices for all production activities.

### 1.2.5 Semi-commercial

This system is defined by the use of monogastric species, mainly chickens and pigs. Up to 50 percent of the value of produce is for home consumption.

### 1.2.6 Commercial

This system is defined by the use of monogastric species, mainly chickens and pigs. Over 50 percent of livestock produce is for sale.

## 1.3 Animal genetic diversity

Climate change and animal genetic resources are interlinked: climate change severely threatens genetic resources, and conserving and using animal genetic diversity is essential for coping with climate change. Climate change puts stress on and poses many risks to animal genetic resources. In general, it is expected to change the distribution of species, population sizes, herd composition, the timing of biological events and the behaviour of many species.

Climate change threatens the animal genetic resources that might be used in the future to adapt production systems to climate change. On the one hand, extreme weather events can pose an immediate threat to the survival of specific breeds; on the other hand, as conditions change, varieties and breeds may be abandoned by farmers and livestock keepers. They may be lost forever if steps are not taken to ensure their conservation.

The conservation and sustainable use of a wide range of genetic diversity is fundamental in developing resilience to shocks, shortening production cycles and generating higher production. Animal genetic diversity is a precious and irreplaceable resource that humankind needs to continue valuing, conserving and using. Animal genetic resources safeguard livestock production and provide options for coping with climate change. Conservation and sustainable use of genetic resources will be critical for the development of climate-smart livestock strategies (FAO, 2017a).



## 2. Climate change

### 2.1 Introduction

In order to fully understand climate change, it is important to differentiate between the terms weather, climate, climate variability, climate change and global warming.

**Weather** is the state of atmospheric conditions at a particular place and time. The most common aspects of weather are felt by everyone during the day and include rain, humidity, wind, sunshine, cloudiness and temperature, but also extreme events such as tornadoes, droughts and tropical cyclones. Weather is dynamic and can change within a brief period of time, even within the same day.

**Climate** is the set of weather conditions prevailing in an area over a long time, typically three consecutive decades (IPCC, 2007). Several factors contribute to the definition of climate, including long-term average temperature and precipitation, but also the type, frequency, duration and intensity of weather events such as heatwaves, cold spells, storms, floods and droughts.

**Climate variability** is the natural fluctuation within the climate, including swings above and below the mean state. For example, if we consider rainfall in a given period in a particular region of the world, variability can be low, meaning that there is not much difference in quantity or timing of rains from one year to the other. In another region, there may be high variability, suggesting that rainfall quantity swings from far below average to far above average from year to year, and the timing is unpredictable. Climate variability affects weather conditions, including cyclone activity and temperature, as well as rainfall.

In some cases, patterns of weather conditions may vary in a natural cycle. These fluctuations or oscillations move between two central states and produce both local and distant repercussions. The El Niño-Southern Oscillation (ENSO) is an example of a periodic variation in which interactions between the atmosphere and the ocean in the tropical Pacific ultimately affect climate variability in many parts of the world.

The main difference between climate variability and **climate change** is that a trend over a longer period of time indicates a change in the climate. While fluctuations over shorter terms – days, seasons, years or several years – and in cycles are climate variability, a consistent linear trend will define climate change as patterns shift over decades. Climate change is detected when the climate – the long-term pattern of climate variability – and the mean exhibit significant measurable changes. For example, on average the climate gets warmer or cooler, or wetter or drier, over decades. The Earth's climate has always changed due to natural causes that include widespread volcanic activity and oscillations in the planet's rotational and orbital cycles.

Scientists have, however, been measuring fast increasing average global temperatures that cannot be attributed to natural causes. They conclude that this longer-term **global warming** is **anthropogenic**, meaning it is caused by human activities. For this reason, the United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as:

*“...a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”*

There are evident increases in high temperature extremes and heatwaves, and decreases in cold extremes all over the world. Looking at floods and heavy rain, we can see a climate change signal, since a warmer atmosphere has more moisture in it. This contributes to worldwide heavy rainfalls. At the same time, droughts are getting more intense, as a warmer climate means evaporation works faster, and soils dry out more quickly.

Studies show that concentrations of compounds that trap heat in the atmosphere, called greenhouse gases (GHGs), have increased substantially since the beginning of the industrial era. The two things that change surface temperature are the amount of sunlight reaching the ground, and the amount of greenhouse gas in the air. More greenhouse gas means a warmer climate.

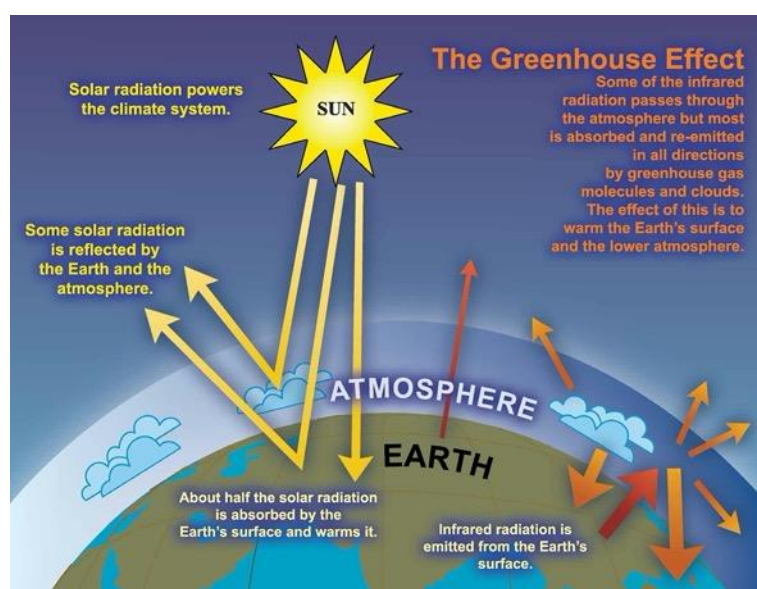
## 2.2 Greenhouse gases

Most of the sun's energy is radiated back into space; however, some of it is trapped in the ground, the ocean and the atmosphere. GHGs are atmospheric gases that can absorb infrared radiation, trapping heat in the atmosphere. This so-called greenhouse effect leads to global warming as illustrated in Figure 2.

Water vapour (H<sub>2</sub>O), **carbon dioxide (CO<sub>2</sub>)**, **nitrous oxide (N<sub>2</sub>O)**, **methane (CH<sub>4</sub>)** and ozone (O<sub>3</sub>) are the primary greenhouse gases. There are several entirely human-made GHGs in the atmosphere, but this guide will mainly focus on CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O as the key gases of concern for livestock production systems.

CO<sub>2</sub> is a naturally occurring gas and makes up 0.04 percent of the atmosphere. Even though this is a small percentage, an increase has a powerful effect, as it is excellent at absorbing heat radiated up by the Earth. CO<sub>2</sub> accounts for around three-fourths of total emissions, and its overall contribution continues to rise. CO<sub>2</sub> is also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass, and of land use changes and industrial processes.

Figure 2: The greenhouse effect



Source: IPCC, 2007.

It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured (called CO<sub>2</sub> equivalent, or **CO<sub>2</sub>eq**).

**CH<sub>4</sub>** (methane) is a significant greenhouse gas and is produced by livestock, as well as microbes in the soil and in water, such as in flooded rice fields. CH<sub>4</sub> absorbs heat at a much higher rate than CO<sub>2</sub>, but it stays in the air for much less time, only a decade or so (see Table 1).

**N<sub>2</sub>O** (nitrous oxide) is produced by farming, including organic (manure) and synthetic fertilizer applications, industrial processes, and burning fossil fuels.

The strength of the greenhouse effect of a GHG is partly determined by its **global warming potential (GWP)**, as well as its **atmospheric lifetime**. GWP is a measure of the radiative effect of each unit of gas over a specified period of time, expressed relative to the radiative effect of CO<sub>2</sub>. An amount of gas with high GWP will warm the Earth more than the same amount of CO<sub>2</sub>.

Atmospheric lifetime measures how long a gas stays in the atmosphere before being naturally removed. A gas with a long lifetime can exert more warming influence than a gas with a short lifetime (assuming the GWPs are equal). Table 1 presents values for these two characteristics for the critical greenhouse gases of concern - methane has a much higher warming potential than carbon dioxide (25 times more), but its lifetime is much shorter (12 years).

**Table 1: Greenhouse gas – warming potential and lifetime**

Greenhouse gas	GWP, 100-year time horizon	Atmospheric lifetime (years)
Carbon dioxide, CO <sub>2</sub>	1	100
Methane, CH <sub>4</sub>	25	12
Nitrous oxide, N <sub>2</sub> O	298	114

Source: *Fourth Assessment Report (IPCC, 2007)*.

## 2.3 Climate change in Asia and the Pacific

A general increase in average temperatures has been observed across most of the Asian region over the past century, including increasing temperature extremes. The impacts of climate change on food production and food security in Asia will vary by region, with many regions to experience a decline in productivity. Higher temperatures will lead to lower crop yields because of shorter growing periods.

Rapid urbanization, industrialization and economic development will be compounded by climate change in the region. That is expected to adversely affect the sustainable development capabilities of most Asian developing countries by aggravating pressures on natural resources and the environment.

Extreme climate events will have an increasing impact on human health, security, livelihoods and poverty. These events include more frequent and intense heat waves, heavy rain events, floods and droughts.

Some data of the GHG emissions in Asia and the Pacific region are (ADB, 2017):

- 40 percent of the current global CO<sub>2</sub> emissions derive from Asia and the Pacific region, expected to be 48 percent by 2030;
- 89 percent of these emissions originate from only three countries: China, India and Indonesia;
- Asia's share of global electricity demand will be 43 percent in 2030.

## 2.4 How climate change affects livestock

There are many ways climate change affects the livestock sector, both directly and indirectly. Direct effects include increased temperatures, changes in the amount of rainfall, shifts in precipitation patterns and increased frequency of extreme weather events. Increased heat stress and reduced water availability can also have a direct negative effect on livestock production (see Box 1; climate-smart livestock options in relation to heat stress are listed in section 3.6.1).

Indirect impacts will be experienced through modifications in ecosystems, changes in availability, production costs, quality and type of feed and fodder crops, possible increases in animal diseases, higher energy prices and increased competition for resources. Climate change could lead to the increased emergence of livestock diseases, as higher temperatures and changed rainfall patterns can alter the abundance, distribution and transmission of animal pathogens.

The most severe impacts are expected in arid and semi-arid grazing systems, where higher temperatures and lower rainfall are expected to reduce yields and increase land degradation. Table 2 provides an overview of the effects of climate change on livestock production systems.

### Box 1: Effects of heat stress on livestock

Climate-related heat stress has an impact on the normal behavioural, immunological and physiological functions of animals. In addition, as feeding patterns change, metabolic and digestive functions are often compromised. Heat stress also has a negative effect on animal welfare.

Livestock will normally maintain their body temperature within a fairly narrow range ( $\pm 0.5$  °C) over the course of a day. Exposure to high heat load will induce a heat stress response as the animal attempts to maintain its body temperature. The stress response is influenced by several factors including: species, breed, previous exposure, health status, level of performance, body condition, mental state, and age. Insufficient acclimatization or adaptation would determine what an animal experiences as stressful. Animal response to stress usually results in a loss of performance (e.g. growth or reproduction) before cellular and molecular stress responses are activated. Under extreme conditions, there may be an increase in mortality rates. All of these changes lead to economic loss. In many cases, heat stress is not recognized by farmers.

Source: Adapted from CSIRO, 2012.

**Table 2: Direct and indirect impacts of climate change on livestock production systems**

Direct impacts	Indirect impacts
<ul style="list-style-type: none"> <li>increased frequency of extreme weather events</li> <li>increased frequency and magnitude of droughts and floods</li> <li>productivity losses (physiological stress) due to temperature increase</li> <li>change in water availability</li> </ul>	Agro-ecological changes and ecosystem shifts leading to: <ul style="list-style-type: none"> <li>alteration in fodder and feed quality and quantity</li> <li>change in host-pathogen interaction resulting in an increased incidence of emerging diseases and disease epidemics</li> <li>increased resource prices (e.g. feed, water, energy and housing - e.g. cooling systems)</li> </ul>

Source: FAO, 2017a.

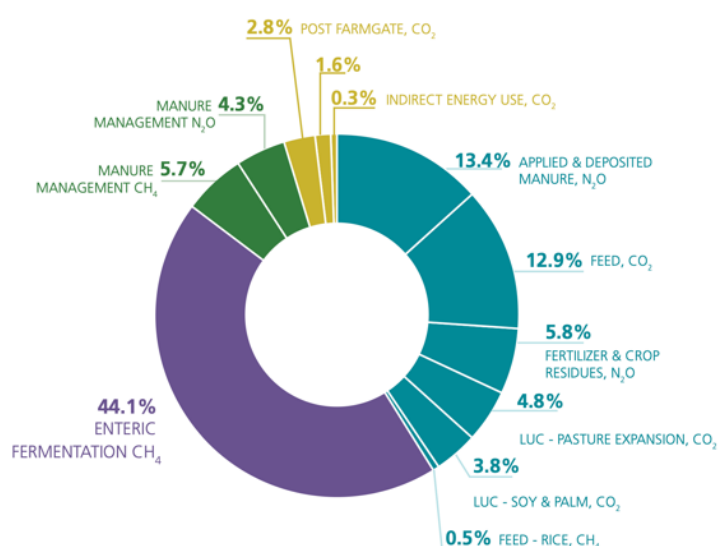
## 2.5 How livestock affects climate change

The livestock sector is a major contributor to GHGs, generating significant emissions of carbon dioxide, methane and nitrous oxide. Livestock contribute to climate change by emitting GHGs either directly (e.g. from enteric fermentation and manure management) or indirectly (e.g. from feed production activities). Based on a life cycle assessment (LCA), it is estimated that the sector emits about 7.1 giga-tonnes of CO<sub>2</sub> equivalent, about 18 percent of the total anthropogenic GHG emissions (FAO, 2006).

The major sources of livestock emissions are illustrated in Figure 3.

Figure 3 shows that methane from enteric fermentation is the highest contributor (44.1 percent) to GHG emissions for the livestock sector. N<sub>2</sub>O emissions from applied and deposited manure is the second largest contributor (13.4 percent), followed by CO<sub>2</sub> emissions related to feed production (12.9 percent).

**Figure 3: Main livestock emissions**



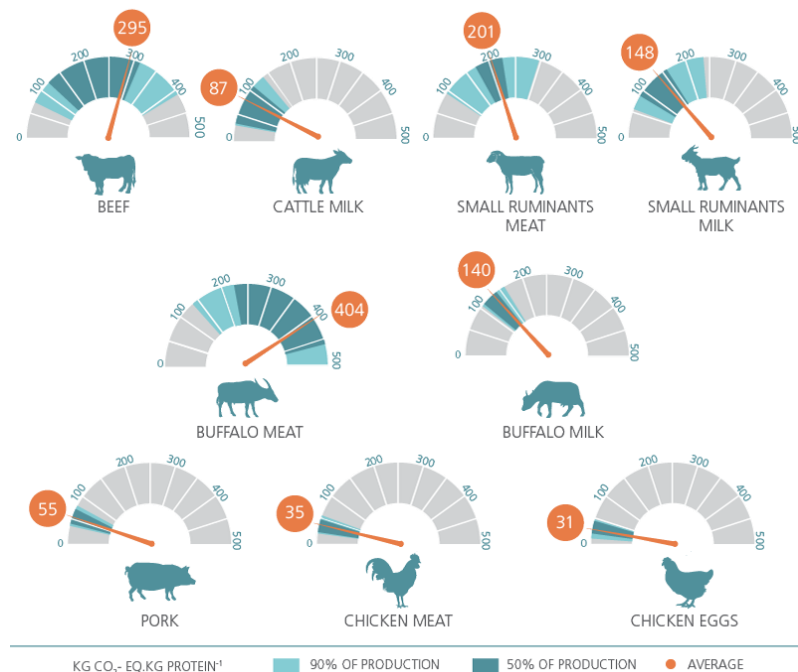
Legend: LUC – land use change (emissions related to deforestation, e.g. the transformation of forest to cropland (soy & palm) and of forest to pasture - Opio et al., 2013).

Source: FAO, 2017a.

GHG emissions per unit of livestock product for some livestock products are illustrated in Figure 4 (FAO, 2017b) – figures in Kg CO<sub>2</sub>eq per kg of protein.

Figure 4 clearly shows that products from ruminants, especially meat, contribute more to GHG emissions per kg of protein than monogastric livestock. Beef and meat from buffaloes are the livestock products with the highest CO<sub>2</sub> emissions (295 and 404 per kilogram of protein respectively), followed by meat from small ruminants (201/kg of protein). Chicken eggs contribute the least GHG emissions (31/kg of protein).

**Figure 4: Greenhouse gas emissions per livestock product**



Source: FAO, 2020.

## 3. Climate-smart livestock strategies

### 3.1 What is climate-smart livestock?

Recognizing the importance of climate change on the livestock sector and vice versa, FAO has developed its “**climate-smart livestock**” approach (see Box 2 for the definition).

#### Box 2: Definition of climate-smart livestock

The climate-smart livestock approach is a comprehensive approach that works towards sustainable livestock production systems that fully support, as much as possible:

- climate change adaptation and mitigation activities
- food security
- sustainable incomes
- animal welfare
- reduce the environmental impact

*Source: Adapted from FAO, 2017a.*

The climate-smart livestock solutions discussed in this guide will focus on practical solutions relevant for smallholder livestock production systems in Asia and the Pacific, in line with the overall mandate of the FAO Regional Office for Asia and the Pacific (RAP).

A climate-smart approach looks at strategies to prevent climate change (‘mitigation’), as well as adjust to climate change as it is already taking place (‘adaptation’). The Intergovernmental Panel on Climate Change (IPCC, 2001) defines climate change **adaptation** as the “adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities”.

Climate change **mitigation** as defined by IPCC is the “anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gasses”. Even though there are some differences between adaptation and mitigation, the two are interlinked and both are crucial in combating climate change. In the context of this guide, the two terms will not be used as separate measures, but linkages will be highlighted, demonstrating complementarities and synergies.

Following, some of the ways recognized by FAO to reduce emissions from livestock production and increase resilience to climate change (FAO, 2017b):

- livestock productivity
- natural resource use efficiency
- carbon sequestration
- better integration in the circular bioeconomy
- specific adaptation measures

These strategies are briefly highlighted below and further explained in detail in the next sections, which also include practical examples.

**Livestock productivity:** improving productivity per animal or group of animals will lead to both improved food security and reduced GHG emissions in livestock production systems. Production efficiency will lead to less emissions per unit of livestock product and can be achieved, for example, through better animal husbandry and livestock support services (see section 3.2).

**Natural resource use efficiency:** improving efficiency of natural resource use will lead to both improved food security and reduced GHG emissions. The efficient use of natural resources like land, water, energy and other inputs will lead to reduced waste along the value chains and reduced GHG emissions (see section 3.3).

**Carbon sequestration:** the potential for carbon sequestration in the context of livestock production systems mainly focuses on grasslands, legumes and fodder trees. Grasslands are estimated to contain globally 343 billion tonnes of carbon, nearly 50 percent more than is stored in forests worldwide. Degradation of grasslands also reduces farmers' capacity to adapt to climate change (see section 3.4).

**Integration in the circular bioeconomy:** a circular bioeconomy minimizes the leaks of energy and materials from the system by recirculating them in production. CSL solutions related to better livestock integration include the use of manure and animal traction for increasing crop productivity, as well as the share of livestock by-products in livestock feed, nutrient recycling or in energy generation (see section 3.5).

**Specific adaptation options:** this describes some specific CSL adaptation solutions that are not directly related to any of the other CSL options mentioned above. Examples of these solutions include (livestock) insurance, early warning systems, disease surveillance and climate control in animal housing systems (see section 3.6).

In general, a combination of existing CSL options will be required to reach the best result, both in climate change mitigation and adaptation interventions. Table 3 presents an overview of several CSL practices and technologies for smallholders, and their impact on food security, as well as the effectiveness of adaptation and mitigation strategies. These practices are described in detail in the sections below.



**Table 3: Overview of climate-smart livestock options**

	Food security	Adaptation	Mitigation	Main constraints
Supplementary feeding	+	+	++	Easy but costly
Grazing/pasture management	+/-	+	++	Lack of technical info and capacities
Animal breeding	+	++	++	Technical, economic, institutional
Animal and herd management	+	++	+	Technical, institutional
Animal health and disease prevention	++	++	+	Technical, institutional
Agroforestry practices	++	++	++	Technical and economic
Anaerobic digesters for biogas and fertilizer	+++	+++	+++	Investment costs
Manure management	++	+	++	
Energy use efficiency		+	+++	Subsidized energy costs
Improved feeding practices (e.g. precision feeding)	+++	+	+++	High operating costs
Warning systems	++	+		Technical, institutional
Weather-indexed insurance		+		Technical, economic, institutional
Temperature control systems	++	+++	-	High investment and operating costs
Disease surveillance and monitoring	++	+++	+	
Building resilience along supply chains	++	+++	-	Requires coordination

*Mitigation/adaptation potential: + = low; ++ = medium; and +++ = high*

*Source: Adapted from FAO, 2017a.*

## 3.2 Livestock productivity

Livestock productivity is measured as the ratio of outputs to inputs. Improving livestock productivity will lead to both improved food security and reduced GHG emissions. This guide defines the quantity of meat, milk, eggs or other products produced annually from a given inventory of livestock or per animal.

Productivity gains arise from an increased number of animals born and raised per breeding animal per year, increased growth rates and market weights of animals intended for slaughter, or increased amount of livestock products per animal per year. In addition to increasing outputs, livestock farmers can decrease the inputs, for example the quantity of feed required to produce a certain unit of product in order to increase productivity.

Improving livestock productivity is an important CSL strategy and will reduce emissions per unit of livestock product by 20 to 30 percent. This should be pursued by improving livestock management practices in all possible ways. These practices include improving the quality of feed, formulating appropriate feed rations, genetic selection and breeding, improving fertility parameters, housing, veterinary care and lifetime productive performance. Increasing livestock productivity is important in climate change adaptation and mitigation, and as a means to improve rural livelihoods and food security.

### 3.2.1 Animal nutrition

Animal nutrition plays a critical role in improving livestock productivity. Proper nutrition and nutrition management, both in terms of quantity and quality, are important for production, fertility, disease prevention and lifetime productive performance. Imbalanced feeding leads to an increase in GHG emissions, either as CH<sub>4</sub> from enteric fermentation in ruminants or as CH<sub>4</sub> and N<sub>2</sub>O produced from manure. Some examples of CSL options related to feed are:

- formulating balanced feed rations with high-quality feed ingredients;
- improving feed conversion rates and forage digestibility, through e.g. effective silage and hay preservation;
- better grassland management, e.g. by introducing legumes into grass pasture;
- selecting better feed resources, including alternative feed products and feed additives;
- supplementation with small amounts of concentrate feed and mineral/urea/molasses supplementation;
- low emission feed;
- feed additives.

#### **Balanced feed rations**

Correctly balanced feed rations need to be fed throughout the seasons; the nutrient content is targeted to the type of animal, that is, a dairy cow versus a young calf, or a layer versus a broiler. Consideration for balanced feed rations include selecting feeds with high protein, easy digestible forages for ruminants, providing mineral and vitamin supplements, supplying feed additives and optimizing proteins and amino acids in diets to improve feed conversion. It is important to provide a continuous and sufficient supply of quality animal feed throughout the seasons. For ruminants, fodder conservation techniques like making hay and silage are important CSL solutions to ensure a continuous supply of quality feed, especially in seasons where it is either too cold or too dry to grow fodder. Imbalanced feeding results in:

- low production, poor growth and reproduction
- animals are more prone to metabolic disorders such as acidosis, ketosis, etc.
- slow growth in young animals
- shorter productive life
- excessive amounts of pollutants released into the environment
- lower profit to farmers

In India, a programme by the National Dairy Development Board (NDDB) on the reduction of enteric methane emissions as a consequence of feeding balanced rations to dairy animals, was estimated at around 15 to 20 percent per kg of milk produced (see Box 3).

### Box 3: Case study: Balanced feed rations, India

In India, a programme by the National Dairy Development Board (NDDB) has developed user-friendly computer software for advising milk producers to balance dairy feed rations with available feed resources. With the help of trained 'Nutrition Masters', knowledgeable about feed ingredients across various agro-climatic regions, farmers were trained on the preparation of balanced rations, and they are responsible for training village level training of trainers (TOT) trainings. The activities included the development of software on hand-held devices, that enabled the 'Nutrition Masters' to collect data and formulate appropriate feed rations for smallholders, using local feed resources.



Data generated so far from approximately 11 500 animals in seven locations indicate that feeding a balanced ration can increase net daily income by 10–15 percent for smallholder farmers. Both milk production increased and the cost of feeding decreased. Milk production efficiency (milk yield/dry matter intake) for cows before and after ration balancing were 0.58 and 0.78 kg respectively, and for buffaloes the corresponding values were 0.53 and 0.66 kg respectively. Feeding a balanced ration to dairy animals for sixty days, also significantly reduced faecal egg counts of internal parasites. Levels of serum immunoglobulins: IgG, IgM and IgA increased, suggesting improved animal immunity.

Furthermore, feeding balanced rations was estimated to reduce enteric methane emissions by 15–20 percent per kg of milk produced. Furthermore, the rations had a positive effect on the nitrogen utilization in the feed, as less nitrogen was secreted.

Large scale implementation of such programmes can help improve the productivity of livestock in developing countries. Similar approaches can also be adopted for growing and beef animals, taking into consideration local feeding and management conditions.

Source: FAO, 2012.

#### Improved feed conversion

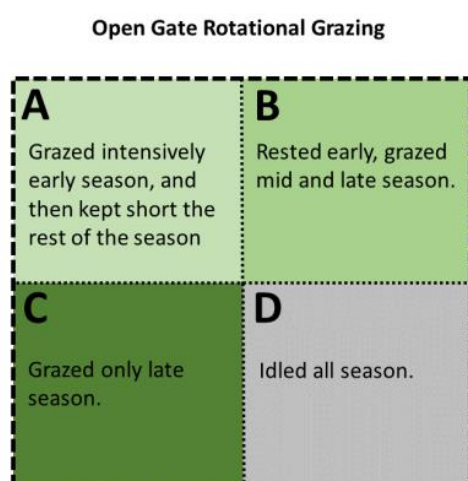
Carbon dioxide emissions associated with feed production, especially soybean, are significant. Improved feed conversion ratios have already greatly reduced the amount of feed required per unit of animal product. However, there is significant variation between production units and countries.

Further progress is expected to be made in this area through improvements in feed management and livestock breeding. Reducing the amount of feed required per unit of output (e.g. beef, milk) has the potential to reduce greenhouse gas emissions and increase farm profits. Feed efficiency can be increased by developing breeds that grow faster, are hardier, gain weight more quickly, or produce more milk. Feed efficiency can also be increased by improving herd health through better veterinary services, preventive health programmes and improved water quality (FAO, 2017a).

**Grassland and grazing management** are key CSL interventions; by optimizing the grazing pressure on land and by improving grasslands for animal feed, grassland will be more productive and provide feed with a better nutritional quality for livestock.

A key grazing management strategy is **rotational grazing**, which will enhance the quality and digestibility of the forage (see Figure 5). In order to implement successful rotational grazing strategies, some investment might be needed, for example on fencing and the provision of drinking water, as well as some additional labour requirements. Overgrazing can be prevented through controlled rotational grazing. This would stop land degradation and increase soil carbon sequestration. As animals will graze the forages in a relatively earlier growth stage, the quality and digestibility of the grass will be higher and will improve the quality of the diet (see above).

Figure 5: Example of rotational grazing



Source: prairieecologist, <https://prairieecologist.com/2017/11/21/open-gate-rotational-grazing/>

Other grazing management options include finding the right balance among the different land users and adapting grazing practices accordingly. Optimal grazing leads to improved grassland productivity and delivers adaptation and mitigation benefits. However, the net influence of optimal grazing is variable and highly dependent on baseline grazing practices, plant species, soils and climatic conditions (FAO, 2017a).

Furthermore, **increasing livestock mobility**, a traditional strategy of nomadic and transhumant herders for matching animal production needs with changing rangeland resources, can significantly enhance the resilience of these livestock systems to climate change (drought in particular). Other **land tenure reforms** will be needed to deal with the encroachment of cultivated lands, as well as other land uses that impede livestock mobility.

**Grassland management** involves the sowing of improved varieties of pasture, typically replacing native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes. The introduction of **legumes** in pastures increases forage production and diet digestibility, thereby improving productivity and decreasing methane emissions. The fertilization and nutrient management of pasturelands will improve the overall productivity of the land and the quality of animal feed.

### Agroforestry

Agroforestry is the collective term for land use systems and technologies in which woody perennials (e.g. trees, shrubs, palms or bamboos) and agricultural activities are implemented on the same piece of land. Agroforestry is important in the context of CSL, as trees can sequester carbon in the soil, provide shade and improve animal nutrition. It also improves the resilience of agricultural production to climate variability by using trees to intensify and diversify production and buffer farming systems against hazards. The advantages of trees in relation to climate change are (FAO, 2017a):

- trees support the growth of annual crops by recycling nutrients in the soil;
- trees provide livestock with protection from cold wind and snow in winter and from the hot sun and drying winds in summer;
- trees regulate soil temperature and moisture, improve water infiltration and provide a buffer against climate variability;

- trees provide shelter from the wind and protect soil from erosion, contributing to resilience;
- trees can sequester carbon.

**Table 4: Commonly used fodder trees in Asia and the Pacific**

<i>Gliricidia sepium</i>	<i>Calliandra calothyrsus</i>
<i>Gliricidia maculata</i>	<i>Erythrina variegata</i>
<i>Leucaena leucocephala</i>	<i>Prosopis cineraria</i>
<i>Sesbania sesban</i>	<i>Moringa oleifera</i>
<i>Sesbania grandiflora</i>	<i>Artocarpus integra</i>
<i>Acacia catechu</i>	<i>Tephrosia spp</i>
<i>Acacia nilotica</i>	<i>Flemingia spp</i>
<i>Acacia Siberians</i>	<i>Bauhinia Racemosa</i>

### Low-emission feed products

Feed resources that are minimizing environmental and carbon footprints are receiving growing attention worldwide and will contribute to overall resource use efficiency. The biggest potential gains to reduce emissions in this way would be in pig and poultry production systems.

Feeding by-products from agriculture and the agri-food industry or feed that has been produced by using conservation agriculture are examples of low emission feed resources (see section 3.5). Other low emission feed products include insect-based feeds, specific feed additives (see below) and others.

In recent years, there has been a growing demand for **insect-based feed products** as a source of protein in animal feed rations due to their efficiency in converting their feed into protein. The most promising species for industrial feed production are black soldier flies, common housefly maggots, silkworms, locusts/grasshoppers/crickets and yellow mealworms (Harinder *et al.*, 2014; Binder, 2019).

The crude protein contents of these alternative resources are high (42 to 63 percent), and so are the lipid contents (up to 36 percent oil) which could possibly be extracted and used for various applications, including biodiesel production. Unsaturated fatty acid concentrations are high in housefly maggot meal, mealworm and house cricket (60-70 percent), while their concentrations in black soldier fly larvae are lower (19-37 percent). Studies have confirmed that palatability of these alternate feeds to animals is good and they can replace 25 to 100 percent of soymeal or fishmeal depending on the animal species. Introducing these low-cost types of feeds might be beneficial, for example in poultry and pig production systems, where feed costs are relatively high (Harinder *et al.*, 2014).

### Feed additives

Feed additives, including probiotics, plant derived extracts as well as enzymes such as methanogen-specific enzymes can support the maintenance of the intestinal barrier in animals, reduce the variability of nutrient utilization, reduce methane emissions and improve the animal's ability to cope with and recover from immunological challenges (Binder, 2019).

There are feed additives that selectively inhibit microorganism in the rumen and lower the emission of methane from cattle. For example, some larger feed companies (e.g. DSM) are currently producing commercial additives for ruminants that **suppress methane production** (claims are by 20 to 30 percent). The enzyme is 3-nitrooxypropanol (3NOP). These additives will have to be fed to the

animals on a daily basis. It will take some time for these feed additives to be affordable and available to smallholder farmers in developing countries.

The common Australian red **seaweed** (*Asparagopsis taxiformis* and *Asparagopsis armata*) can virtually eliminate methane emissions when fed to cattle and sheep, when it's fed as a dietary additive of up to 1 percent of the dry ration (CSIRO, 2019). Metabolites in the seaweed disrupt the enzymes that are responsible for the methane production in the rumen. The seaweed will have to be fed on a daily basis to be effective. A study showed that both the **legume species** *Leucaena* (*Leucaena leucocephala*) and *Desmanthus* (*Desmanthus virgatus*) have compounds that act on the microbes in the rumen that can reduce methane emissions up to 20 percent (CSIRO, 2019).

### 3.2.2 Genetic selection and breeding management

Breeding management and genetic selection have potential as a CSL strategy in climate change mitigation and adaptation. Breeding management is a key strategy to increase livestock productivity by improving traits such as live weight gain and milk yield or fertility. Well-designed selection and culling strategies, cross-breeding programmes and artificial insemination programmes can all contribute to increasing productivity, and thereby reducing methane emissions.

Cross-breeding programmes can potentially be designed, such that they address adaptation, food security and mitigation at the same time. For example, there are composite cattle breeds in Australia that have high tolerance for heat, disease resistance and better reproductive traits compared to other breeds (FAO, 2017a).

**Overall livestock system productivity** can be increased by reducing the number of non-productive or underperforming animals. This can increase efficiency and reduce emissions at the herd level. For example with cattle, reducing the age at first calving from four to three years on average means that farmers would need to keep fewer non-productive heifers to maintain the stock.

In the long-term, the **conservation of animal genetic diversity** can ensure that farmers have access to the best animals for each environment. In general, cross-breeding strategies that make use of locally adapted breeds, which are not only tolerant to heat and poor nutrition, but also to parasites and diseases (Hoffman *et al.*, 2008), may become more common with climate change.

Adaptation to climate change can also be fostered by switching livestock species. For example, camels were adopted as part of a livelihood strategy of a tribe that traditionally does not keep camels. This switch allowed them to overcome a decline in their cattle economy, which had been affected by drought, cattle raiding and animal disease.

#### Box 4: Case study: Dairy, Bangladesh

Extreme weather events are on the increase in Bangladesh, including heavy and erratic rainfall, flooding, sea level rise, increased salinity and increasing temperatures. Climate change is expected to severely challenge Bangladesh's ability to achieve its desired rates of economic growth and its food security goals. The dairy sector contributes for about 12 percent of agricultural GDP and to the livelihoods of an estimated 7 million smallholders.

The dairy cattle sector in Bangladesh is responsible for about 52.2 million tonnes CO<sub>2</sub>eq. The GHG profile is dominated by CH<sub>4</sub>, 79 percent of the overall emissions. Milk production from buffalo adds another 1.3 million tonnes CO<sub>2</sub>eq. The emission intensity of milk produced from dairy cattle and buffalo in Bangladesh is 11.1 and 3.2 kg CO<sub>2</sub>eq/kg fat and protein corrected milk (FPCM), respectively.

A collaboration between the Ministry of Fisheries and Livestock, the Bangladesh Livestock Research Institute, Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC), the New Zealand Government and FAO identified and prioritized interventions to reduce enteric methane emission intensity. The project team selected CSL solutions based on potential for improving productivity and reducing enteric CH<sub>4</sub> per unit of output. The following CSL solutions were identified:

- improving the quality and availability of feed resources;
- strategic feeding and supplementation to address the feed seasonality constraints;
- improved herd management and animal health interventions.

Based on the results, the project prioritized the CSL to identify those with high reduction potential, increased production and high economic return. The ranking can be found below:

1. feeding a balanced feed ration;
2. supplementation of diet with urea and molasses;
3. fodder cultivation (for commercial systems only);
4. udder health management.

### 3.2.3 Animal health services

Improving animal health services, including disease prevention and management, has a strong impact on the efficiency of livestock systems, food security and adaptation to climate change. Establishing strong animal health institutions, formulating dedicated policies and initiating research programmes focused on changing conditions are essential to improve livestock efficiency and increase the preparedness against new risks, including those resulting from climate change.

Proper animal health services will also lead to an increased lifetime productive performance (see section 3.2.4). Animal disease surveillance, early warning and rapid response is a key climate change **adaptation** option (see section 3.6.3).

### 3.2.4 Lifetime productive performance

Improving lifetime productive performance (or longevity) per animal or per group of animals will reduce GHG emissions as less animals will be required for the same amount of produce. At the same time, the number of young animals kept as replacement stock can also decrease for the same amount of produce.

Increasing lifetime performance is carried out by focusing on all the above-mentioned management improvements. It can be achieved by improving animal health services, housing, feeding, extension and training services, and in general animal husbandry improvements. At the same time, as a result of the animal husbandry improvements, the animal welfare status will improve as well.

CowSignals, a training company from the Netherlands, estimates that a 30 percent methane reduction can be achieved by better husbandry, when the productive life of a dairy cow is extended by two additional lactations (CowSignals, 2018).

### 3.3 Natural resource use efficiency

Natural resource use efficiency is measured by the ratio between the input of natural resources in the production process and the product output (e.g. litres of water used for one litre of milk). Examples of opportunities that fall within resource use efficiency are higher yields per hectare, higher water productivity, efficient use of low carbon energy, and the reduction of waste along the value chain. The use of indicators as the amount of energy per unit of product or the amount of water used per unit of product are helpful to measure the resource use efficiency and waste along the value chain.

#### 3.3.1 Energy

Energy demand is expected to increase by 30 percent between 2010 and 2035 (FAO, 2017a), partly due to climate change as energy demand will increase (e.g. for climate control and irrigation). Energy prices are likely to increase as well. An increasing development of the livestock value chains in developing countries will also lead to an increase in energy demand, for example as more products are processed, mechanization increases and transport requirements grow. The amount of energy used in processed animal feed and fertilizer is particularly concerning.

The efficient use of energy, including the use of renewable energy, is an important CSL strategy to minimize the use of fossil fuels. Following, a list of CSL options related to energy.

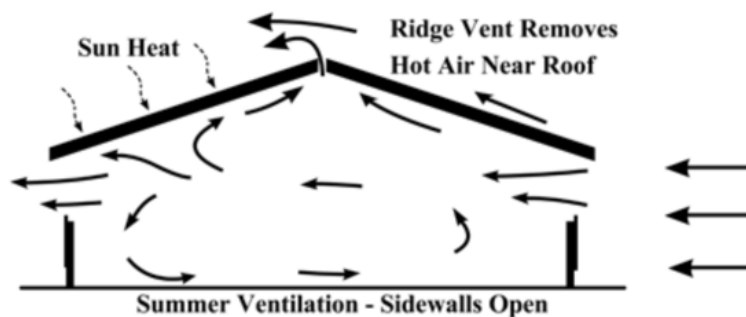
#### **Energy efficiency**

Increasing energy efficiency and conservation can be achieved by using machinery and equipment with a higher energy efficiency on the farm and elsewhere in the livestock value chain. This equipment uses less energy per unit of product. Some examples include:

- using natural ventilation in barns and sheds instead of cooling systems with high energy consumption (see Figure 6);
- efficient systems for cooling milk at dairy farms, for example heat exchangers cooled by well water, variable speed drives on the milk pump, and refrigeration heat recovery units;
- efficient systems for heating water;
- replacing incandescent lighting with high efficiency lights like LED;
- efficient livestock watering systems;
- efficient heating systems for piglets;
- using animal manure instead of fertilizer;
- equipment for feed manufacturing;
- reduction of transport along the value chain, e.g. sourcing supplies locally;
- using conservation agriculture techniques instead of pesticides.



Figure 6: Example of natural ventilation in a barn



Source: Dairyland Initiative, <https://thedairylandinitiative.vetmed.wisc.edu>

### Renewable energy

Solar energy, photovoltaic (PV) cells and solar thermal collectors, wind power, hydropower and other renewable energy sources can be used to minimize the need for non-renewable energy sources along the livestock value chains.

The cost of renewable energy equipment and materials have been coming down considerably in the last few years, especially solar PV systems which are becoming more affordable for smallholder farmers as well. Energy storage is still relatively expensive but recently large advances have been made in terms of efficiency and cost reduction.

Figures 7 and 8 present two examples of solar energy using a solar thermal collector and a solar PV system. Figure 7 shows an efficient solar thermal collector that uses evacuated tubes for solar water heating; this collector can for example be used at milk collection points, to properly clean milk cans with hot water. Figure 8 shows a water drinker using a solar PV system to drive the water pump, providing the cattle with full-time access to water.

Box 5 presents an interesting case study on the use of renewable energy in a milk cooling system in Tunisia. Examples of other renewable energy sources include the use of animal manure for biogas (see section 3.5) or efficient biomass stoves.

Figure 7: Solar thermal collector



Source:FAO,2017

[http://www.fao.org/fileadmin/user\\_upload/aqwa/docs/bari2017/Session5/SolarE\\_introduction\\_1.pdf](http://www.fao.org/fileadmin/user_upload/aqwa/docs/bari2017/Session5/SolarE_introduction_1.pdf)

©FAO

Figure 8: Solar water drinker



Source: TopSun, 2020

<http://www.topsunpump.com/>

©TopSun

### Box 5: Case study: Solar milk cooling, Tunisia

In Tunisia, an innovative technology to cool milk on the farm is entirely based on renewable energy. The system is composed of conventional 40 litre milk cans with an ice compartment and removable insulation. The ice is produced by a solar powered freezer that can harness solar radiation with help of an adaptive control unit. The system is composed of photovoltaic panels, small batteries, an adaptive control unit, a charge controller and a commercially available direct current refrigerator with an integrated fan and 25 two-litre plastic cans for the ice blocks. The system can cool down 30 litres of milk by using ice as cooling medium.



©FAO/Jurjen Draaijer

The introduction of the solar milk cooling system has shown considerable results in improving milk quality during transport and overnight storage. With the solar milk cooling system, it is possible to collect the evening milk with the next day's morning milk and be assured that the milk will be acceptable. If a farm has a minimum of 15 litres of uncollected evening milk, as was the case for one farm in this study, the farmer can earn an extra income of minimum EUR 3.75 per day, which comes to EUR 112 per month and around EUR 1 350 per year.

The total price of the system is around EUR 2 700 and the price of a litre of milk in Tunisia is EUR 0.25. The payback period of the innovation would vary depending on the volume of milk cooled and sold per day. It should take around two years, if the farmer successfully sells 14.5 litres per day. However, the solar cooler could be shared by a cluster of farmers, as the system is designed for a maximum capacity of 60 litres per day. Each farmer could have his or her own milk cans. In this way, the costs of the system will be divided among the different farmers and the payback time will be shorter.

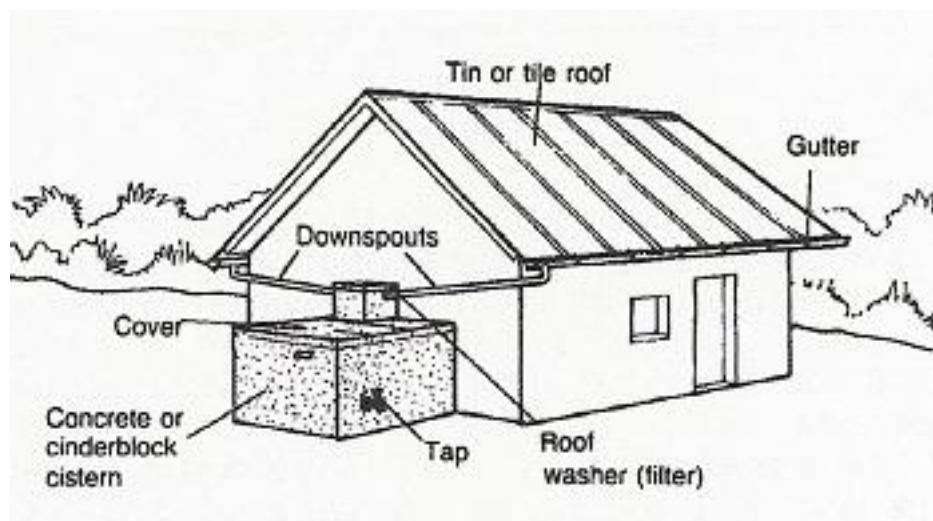
Source: FAO 2017a.

### 3.3.2 Water

Many of the impacts of climate change are resulting from the impact of limited **water availability**. Reduced rainfall, increased variability of rainfall, increased evaporation rates and extreme weather events will affect feed production and drinking water shortages, which will affect the livestock value chains in general. At the same time, increased temperatures will lead to an overall increase in water requirements, degradation of water quality and increasing competition over water resources. CSL options specifically related to the efficient use of water are mainly focused on climate change adaptation and include:

- efficient water harvesting techniques (e.g. roof water harvesting, see Figure 9);
- weather forecasting, crop insurance;
- use of drought-tolerant feed crops;
- water management;
- reduction of water waste;
- increased water storage;
- efficient and low-energy irrigation methods;
- financing for water-smart investments;
- development of policy and regulations related to efficient water use.

Figure 9: Simple roof water harvesting system



Source: *A Layman's Guide to Clean Water*, <http://www.clean-water-for-laymen.com/collecting-rain-water.html>

### 3.3.3 Waste reduction

**Reducing waste** along the value chain is a CSL strategy that will overall lead to a more efficient use of natural resources. A large volume of livestock products is wasted even before reaching the consumer. Previous study suggests that about one-third of food produced is wasted (FAO, 2017a). The losses and waste also mean that the GHG emitted during their production have served no useful purpose. Waste reduction can substantially contribute to improving resource use efficiency such as land, water, energy, as well as other inputs such as nutrients. The energy embedded in global annual food losses is thought to be around 38 percent of the total final energy consumed by the whole food chain (FAO, 2017a). The use of other natural resources like water will also be reduced substantially when the amount of waste is reduced. CSL options related to the reduction of losses and waste include:

- ensuring proper sanitation at all stages of the value chain;
- higher payments for good quality products, e.g. quality base milk payment systems;
- appropriate processing, labelling and packaging, distribution, transport and storage of livestock products to extend shelf life;
- recycling of waste, e.g. using crop by-products as animal feed;
- increased integration in the circular bioeconomy (see section 3.5);
- ensure efficient manure management;
- behavioural changes at retail and consumer level.

## 3.4 Carbon sequestration

One of the most clear-cut mitigation benefits in grassland management arise from soil carbon sequestration that results when grazing pressure is reduced as a means of stopping land degradation or rehabilitating degraded lands. In these cases, enteric emission intensities can also be lowered, because with less grazing pressure animals have a wider choice of forage and tend to select more nutritious forage, which is associated with more rapid rates of live weight gain (Rolfe, 2010). By

restoring degraded grassland, these measures can also enhance soil health and water retention, which increases the resilience of the grazing system to climate variability. However, if grazing pressure is reduced by simply reducing the number of animals, the total output (e.g. milk, meat) per hectare may be lower, except in areas where baseline stocking rates are excessively high (Rolfe, 2010).

Agroforestry is important in the context of CSL, as trees can sequester carbon in the soil, provide shade and improve animal nutrition.

### 3.5 Circular bioeconomy

A circular bioeconomy minimizes the leaks of energy and materials from the system by re-circulating them in production, while a linear economy uses external inputs to produce outputs and waste. Better livestock integration in the circular bioeconomy will contribute to reduced losses and lead to an overall decrease in GHG emissions.

The annual feed intake of livestock is about 6 billion tonnes of dry matter, or 20 percent of the global human harvest of biomass. Crop residues and agro-industrial by-products such as bran, molasses or oilseed cakes represent nearly 30 percent of the total livestock feed intake. These will be produced in larger amounts as the human population grows and consumes more processed food, and could become an environmental burden. Livestock play a critical role in adding value to these products. CSL solutions related to a better livestock integration are:

- increased feed and food crop productivity through manure and animal traction
- increased feed crop productivity
- reduced food and feed waste
- improved manure management

**Increase feed and food crop productivity through manure and animal traction:** the total nutrients from livestock manure exceed nutrients from synthetic fertilizers. However, globally, livestock manure supplies up to 12 percent of gross nitrogen input for cropping and up to 23 percent in mixed crop-livestock systems in developing countries.

**Increased feed crop productivity:** amount, timing and application mode of nitrogen fertilizer are keys to reducing N<sub>2</sub>O emission from fields. Reduced or no till, winter crop and perennial crops increase soil organic matter content and reduce field CO<sub>2</sub> losses. Variation in on-farm GHG emissions, which averaged 1.1 kg of CO<sub>2</sub>eq per kilogram of milk, was associated more with specific management practices than with farm size or dairy system (Wattiaux *et al.*, 2019).

**Increasing the share of by-products in livestock feed** or waste that humans cannot eat by recycling and recovering nutrients and energy from animal waste (e.g. biogas): approximately one-third of all food produced for humans is either lost (not suitable for consumption) or wasted. Prevention and reduction of these losses, combined with alternate uses of food waste, including food recycling, can help reduce these negative impacts. Feeding food losses to animals is a sustainable solution and brings more co-benefits by reducing waste streams, greenhouse gas emissions and supporting circular bioeconomy. It comes with some threats such as risks of introduction, dissemination and persistence of animal disease agents, chemical residues and zoonotic pathogens in the food chain. To ensure the safe use of food waste and loss and their traceability, it is essential to develop innovative technology, retailer standards and policies to frame their collection, treatment and usage.

These innovations can be supported by incentives and investment to develop infrastructure for food waste and loss treatment and educating consumers and retailers to separate food waste and loss from other waste. For instance, some national authorities have put in place laws to regulate food waste and loss recycling and have developed incentives for farmers and retailers such as a premium market for “eco-feed” animal products produced using food waste and loss.

### **Manure management**

Animal manure contains most of the essential micro- and macro-elements required for plant growth and represents a valid alternative to other fertilizers that release GHG emissions. Manure management refers to manure accumulation and collection in buildings, storage, processing and application to crops (Hristov *et al.*, 2013). Most methane emissions from manure derive from swine and beef cattle feedlots and dairy cattle, where production is carried out on a large scale and manure is stored under anaerobic conditions.

Manure is linked to both CH<sub>4</sub> and N<sub>2</sub>O emissions. Due to the nature of some opposed processes, practices that result in the reduction of CH<sub>4</sub> production can increase N<sub>2</sub>O emissions. For example, diet manipulation through reduced carbon phosphide (CP) in the animal diet, reduce ammonia (NH<sub>3</sub>) emissions from land applied manure. However, decreasing dietary protein concentration will likely increase CH<sub>4</sub> production and might affect animal productivity.

Most of the manure-related CH<sub>4</sub> emissions are produced under anaerobic conditions during storage and very little following land application; manure from grazing ruminants does not produce significant quantities of CH<sub>4</sub> because it remains largely aerobic. CSL solutions related to reducing CH<sub>4</sub> emissions are focused on preventing anaerobic conditions during storage or capturing and transforming the CH<sub>4</sub> that is produced if anaerobic conditions are present.

### **Box 6: Case study: Pig production, Thailand**

In Thailand, the temperature increase per decade is equal to 0.174 degree, higher than the rest of the world (0.126). The total GHG emissions from livestock production is estimated at 11.43 Mt CO<sub>2</sub>eq. In relation to pig production, manure management is the largest source of emission with the value of 1.552 Mt CO<sub>2</sub>eq per year in 2017, corresponding to 70 percent of all emissions from pig production.

The Department of Livestock Development launched the Green City Project in 2015, which is subsidizing the construction cost of biogas digesters and the promotion of wastewater treatment systems. The main goal was for the projects to reduce GHG emissions, as well as air and water pollution by the pig production systems. Pig farmers were able to reduce their energy costs by 64 percent on average after installation of a biogas system. Payback time was estimated at six years. Based on the results, the suggested CSL options for pig production are:

- encourage mixed farming systems for smallholders to utilize natural resources effectively;
- improve animal health services to cope with changing disease agents;
- design buildings to use natural ventilation, increase insulation, use of creep boxes for piglets;
- select crop varieties that can cope with changes in the climate;
- invest in water storage facilities;
- use less intensive rearing techniques, e.g. outdoor production systems;
- more research and development in relation to GHGs is required.

The production of N<sub>2</sub>O emissions from soil or manure storages is highly variable, difficult to measure and even more difficult to predict. For direct N<sub>2</sub>O emissions to occur, the manure must first be handled aerobically where ammonia or organic nitrogen (N) is converted to nitrates and nitrites

(nitrification), and then handled anaerobically where the nitrates and nitrites are reduced to  $N_2$ , with intermediate production of  $N_2O$  and nitric oxide (denitrification).

Manure management CSL solutions relevant for smallholder livestock farmers in Asia and the Pacific include feeding protein, manure storage, composting and biogas systems.

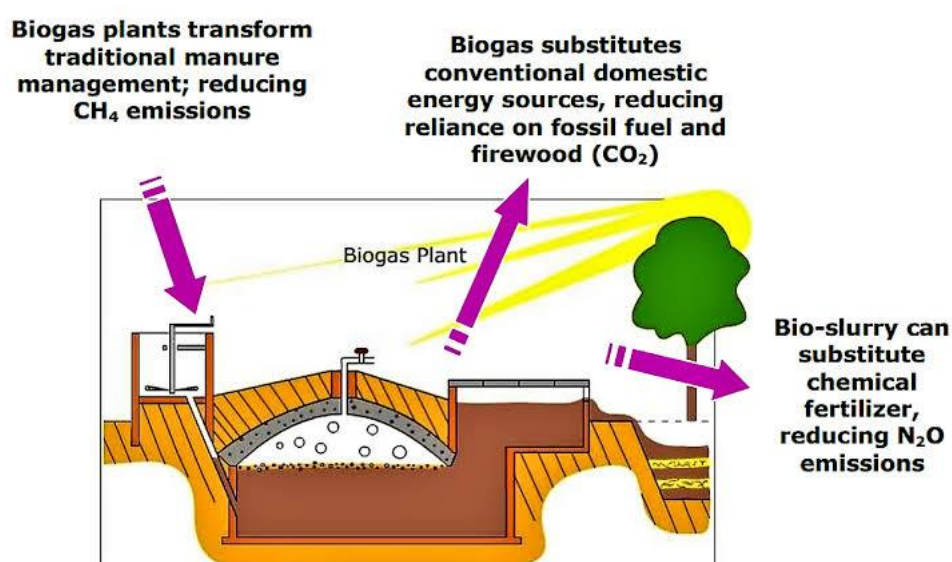
Feeding protein close to animal requirements, including varying dietary protein concentration with stage of lactation or growth, is recommended as an effective manure ammonia and  $N_2O$  emission mitigation practice.

Most mitigation options for GHG emissions from stored manure, such as reducing the time of manure storage, aeration and stacking, are generally aimed at decreasing the time allowed for microbial fermentation processes to occur before land application. These mitigation practices are effective, but their economic feasibility can be uncertain.

**Composting** can effectively reduce  $CH_4$  but can have a variable effect on  $N_2O$  emissions and increases  $NH_3$  and total nitrogen losses.

Anaerobic digesters (e.g. biogas systems) can increase farm profits by 10 to 20 percent and help reduce the environmental impact of livestock production. They are recommended as a mitigation strategy for  $CH_4$  to generate renewable energy, but their effect on  $N_2O$  emissions is unclear. Anaerobic digestion systems are not recommended for geographic locations with average temperatures below  $15\text{ }^\circ\text{C}$  without supplemental heat and temperature control. The captured  $CH_4$  can be flared or used as a source of energy for electric generators, heating or lighting.

Figure 10: Illustration of a small-scale biodigester



Source: SSWM, <https://sswm.info/>

### 3.6 Specific adaptation solutions

Livestock producers will have to adapt to changing climatic conditions and climate variability, as well as expanding populations, urbanization, economic growth, an increased demand for livestock

products and greater commercialization. It may not be enough anymore to resort to traditional coping mechanisms, and in order to cope with climate change, a wide array of specific adaptation options is available. Longer-term approaches to climate change adaptation are often described as 'climate-proofing'.

This section describes some CSL adaptation-specific solutions that have not been described elsewhere in this guide. These solutions include:

- minimizing heat stress
- insurance and early warning systems
- animal health surveillance, early warning and rapid response

### 3.6.1 Minimizing heat stress

As previously discussed, climate-related temperature changes have an impact on normal behavioural, immunological and physiological functions of animals. In addition, as feeding patterns change, metabolic and digestive functions are often compromised.

Effects of high heat load can be minimized through:

- adjusting the environment
- nutritional and watering strategies
- selection for thermal tolerance
- change of livestock species, e.g. goats rather than cattle

#### **Environment**

The two main strategies to improve heat exchange between an animal and its environment are:

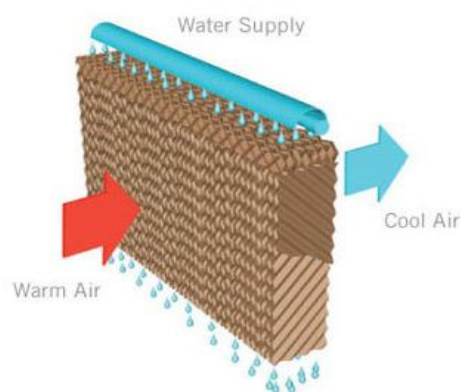
- design and construction of livestock facilities
- provision of shade
- increase of ventilation
- water misters, foggers, or pad cooling
- using sprinklers to wet animals

## Livestock facilities

The design and construction of livestock facilities can be adjusted to minimize heat stress. Ventilation can be improved. Other important considerations are shade, the orientation of the building in relation to the sun, and thermal characteristics of construction materials. **Figure 11: Evaporative pads**

**Shade** can for example be provided by roofs and trees. Design considerations for shade structures include insulation, orientation, pitch, height and material.

Air temperature can be further reduced by using **evaporative pads** (see Figure 11). As outside air enters an evaporative pad, energy is removed from both the wet pad and the air as the water evaporates, thereby decreasing air temperature. Hence, the air temperature entering the facility is lower (since heat was removed for evaporation) and the relative humidity as well as the water vapor content is greater.

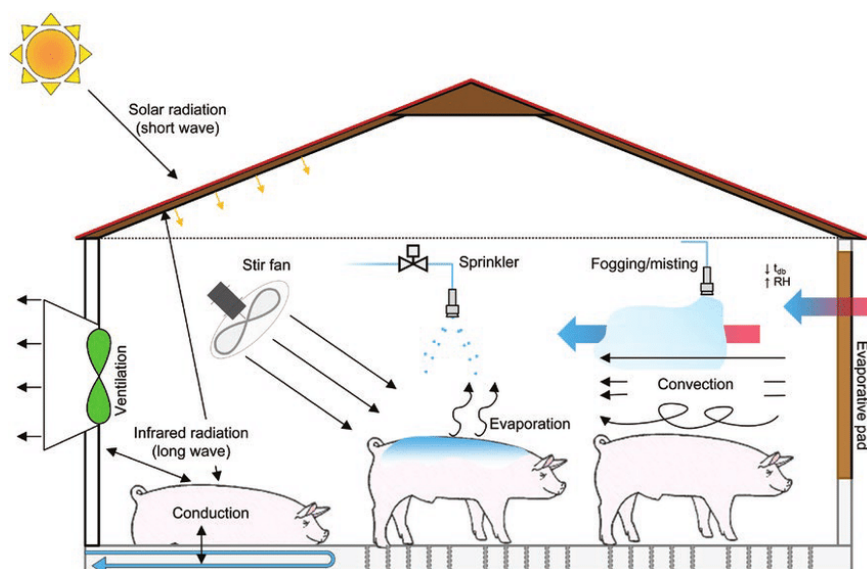


**Fogging and misting** systems can reduce air temperature via water evaporation. Fogging systems create very fine droplets usually achieved by high pressure. Conversely, misting systems generate larger droplets (low pressure) that do not fully evaporate while airborne can wet surrounding surfaces and animals.

**Air movement** over the animal affects both convective and evaporative heat loss. Another methodology is **skin wetting**, circulating cool water through the floor the animals lie on; this, however, is generally an expensive solution.

Figure 12 summarizes the environmental characteristics that can be modified to reduce heat stress (e.g. in pig production systems), such as surrounding surface temperatures through conduction and radiation, convection and evaporation.

**Figure 12: Illustration of cooling systems in a pig pen**



Source: Mayorga et al., 2019.



### **Nutritional and watering strategies**

Access to cool clean drinking water to meet potential peak demands is paramount. Water restriction will further increase the negative aspects of high heat load by decreasing evaporative heat loss, leading to further reductions in feed intake, so water intake may increase markedly during periods of high heat load.

Nutritional strategies include changes to feeding frequency and time of feeding, (e.g. feeding at night) and changes in ingredients (e.g. addition of dietary fat to increase energy density, or additional roughage added to cattle diets to reduce heat increment).

### **Genetic opportunities**

Genetic selection for thermal tolerance is one potential strategy to mitigate the effects of heat stress, but this is a long-term solution. Breeding goals may have to be adjusted to account for higher temperatures, lower quality diets and greater disease parasite challenge. Genetic variability for heat tolerance in a species occurs within and between breeds.

### **Cold stress**

On the other end of the scale, winter shelters for ruminants, for example in Mongolia, assist with colder climates, helping changing breeds or even livestock species that can better cope with the changing conditions in areas with increasing cold stress.

## **3.6.2 Insurance and early warning systems**

The use of weather information to assist in risk management for rainfall variability is a potentially effective option for climate change adaptation when preventive measures fail (FAO, 2017a), although climate forecasts will need to be improved to be truly effective.

Livestock insurance schemes that are weather indexed can be run by the private sector, although risks associated with this can be extremely high. Public-private partnership approaches to index-based livestock insurance, in which the public sector underwrites a share of these risks, could play an important role, for example based on satellite imagery. In situations where risks are unacceptably high for the private sector, public-private partnership approaches to index-based livestock insurance, in which the public sector underwrites a share of these risks, could play an important role.

In order to reduce the risk for insurance companies to insure livestock production systems, an insurance scheme could be set-up whereby the livestock producer pays a lower premium when preventive CSL options are implemented at the farm. The insurer would then need to verify the CSL solutions are being implemented.

## **3.6.3 Animal health surveillance, early warning and rapid response**

Climate change could lead to additional indirect impacts from the increased emergence of livestock diseases, as higher temperatures and changed rainfall patterns can alter the abundance, distribution and transmission of animal pathogens (FAO, 2017a). In addition to enhanced animal health management to maintain and improve animal performance, managing disease risks may also become increasingly important, as there may be an increase, for example in the emergence of gastro-intestinal parasites due to climate change.

Increasing temperature may also increase exposure and susceptibility of animals to parasites and diseases, especially vector-borne diseases (CSIRO, 2012). Many important animal diseases are affected directly or indirectly by weather and climate. Understanding the complex interactions between pathogens, vectors, host and climate is challenging; and the ability to predict the effect of climate change on diseases is crucial to disease outbreak preparedness and response.

There is a need for more investment in research to better understand the direct and indirect effects of climate change on animal production systems and to develop strategies for longer-term adaptation. Ongoing animal disease surveillance, early warning and rapid response will be key for animal health authorities and policymakers to develop and prepare response policies and preventive measures to assist livestock farmers to adapt to changing veterinary issues due to climate change.

### 3.7 Enabling environment

In order for any country to transition to a climate-smart enabling environment for the livestock sector, a coherent range of policies and regulations is required, as well as promoting research programmes to support the implementation of the climate-smart livestock solutions.

One of the key policy documents related to climate change for each country is the **Intended Nationally Determined Contributions** (INDC) document. The INDC contains (intended) reductions in greenhouse gas emissions under the UNFCCC. All countries that signed the UNFCCC were asked to publish their INDCs at the 2013 United Nations Climate Change Conference held in Warsaw, Poland. Under the Paris Agreement, adopted in December 2015, the INDC will become the first nationally determined contribution (NDC) when a country ratifies the agreement unless it decides to submit a new NDC at the same time.

The INDC and other policy documents, including livestock sector policies, will need to be coherent in their climate change approach in order to effectively implement CSL solutions. **Policy coherence** can be defined as “systematic support towards the achievement of common objectives within and across individual policies”.

An assessment of current policies related to livestock and/or climate issues is the first step into gaining a better understanding of the policy coherence. The purpose of the assessment is to comprehend how the policies integrate climate change adaptation and mitigation measures for the livestock sector and whether these policies are coherent in their proposed actions.

The Policy Coherence for Sustainable Development (PCSD) framework (OECD, 2016) provides guidance and a screening tool for analysing coherence issues. It also demonstrates how policy actions might support or hinder the achievement of SDG goals and targets. SDG target 17.14 is to “enhance policy coherence for sustainable development”. This SDG emphasizes the need to develop synergies and address conflicts and gaps among different policy areas to effectively address cross-cutting challenges.

The policy coherence review can focus on the presence and detail of livestock sector-related climate change adaptation and mitigation strategies, approaches and activities, and their alignment with the SDGs. The following three elements can be focus points:

1. food security and sustainable income
2. climate change adaptation and resilience

### 3. climate change mitigation

A scoring system can be developed to assist with the assessment. An example of a scoring system is found in in Table 5.

**Table 5: Scoring for policy strength and coherence for climate-smart livestock**

Level of strength and coherence	Description	Score
High	The policy strongly aligns with CSL, with specific attention to detailed activities, approaches and measures.	3
Partial	The policy supports CSL but with relatively little details on activities, measures and approaches.	2
Limited	The policy supports CSL, but lacks specific activities, measures and approaches.	1
None	There is no evidence that the policy supports CSL	0

*Source: Adapted from Ashley, 2019.*

## 4. Measuring climate-smart livestock impacts

### 4.1 The Intergovernmental Panel on Climate Change tiers

The IPCC has classified the methodological approaches for climate change measurements in three different tiers (GFOI, 2013), according to the quantity of information required and the degree of analytical complexity.

**Tier 1** employs the gain-loss method described in the IPCC Guidelines and the default emission factors and other parameters provided by the IPCC. There may be simplifying assumptions about some carbon pools. Tier 1 methodologies may be combined with spatially explicit activity data derived from remote sensing. The stock change method is not applicable at Tier 1 because of data requirements.

**Tier 2** generally uses the same methodological approach as Tier 1 but applies emission factors and other parameters which are specific to the country. Country-specific emission factors and parameters are those more appropriate to the forests, climatic regions and land use systems in that country. More highly stratified activity data may be needed in **Tier 2 to correspond with country-specific emission factors** and parameters for specific regions and specialized land use categories. Tiers 2 and 3 can also apply stock change methodologies that use plot data provided by national forest inventories (NFIs).

At **Tier 3**, higher-order methods include models and can utilize plot data provided by national forest inventories tailored to address national circumstances. Properly implemented, these methods can provide estimates of greater certainty than lower tiers and can have a closer link between biomass and soil carbon dynamics. Such systems may be Geographic Information System (GIS)-based combinations of forest age, class/production systems with connections to soil modules, integrating several types of monitoring and data. Areas where a land use change occurs are tracked over time. These systems may include a climate dependency and provide estimates with inter-annual variability.

Progressing from Tier 1 to Tier 3 generally represents a reduction in the uncertainty of GHG estimates, though at a cost of an increase in the complexity of measurement processes and analyses. Lower Tier methods may be combined with higher Tiers for pools which are less significant. There is no need to progress through each Tier to reach Tier 3. In many circumstances it may be simpler and more cost-effective to transition from Tier 1 to 3 directly than produce a Tier 2 system that will then need to be replaced. Data collected for developing a Tier 3 system may be used to develop interim Tier 2 estimates.

### 4.2 Global Livestock Environmental Assessment Model

FAO has developed its Global Livestock Environmental Assessment Model (GLEAM) (FAO, 2020), a GIS framework that simulates the biophysical processes and activities along livestock supply chains under a life cycle assessment approach. GLEAM aims to quantify production and use of natural resources in the livestock sector, and to identify environmental impacts of livestock to contribute to the assessment of adaptation and mitigation scenarios to move towards a more sustainable livestock sector.

GLEAM is a modelling framework that simulates the interaction of activities and processes involved in livestock production and the environment. The model can operate at (sub) national, regional and global scale. GLEAM differentiates key stages along livestock supply chains such as feed production, processing and transport; herd dynamics, animal feeding and manure management; and animal products processing and transport. The model captures the specific impacts of each stage, offering a comprehensive and disaggregated picture of livestock production and its use of natural resources.

## Features

Main features of the current GLEAM version:

- systematic, global coverage of six livestock species and their edible products: meat and milk from cattle, buffalo, sheep and goats; meat from pigs, and meat and eggs from chicken;
- spatially explicit modelling of livestock distribution, climatic data, feed yields and biophysical processes that allow the capture of local production drivers and constraints, environmental impacts and identification of intervention measures;
- estimation of greenhouse gas emissions from each stage of production. The model covers methane, carbon dioxide and nitrous oxide emissions, using an IPCC Tier 2 methodology, providing more accurate information on how animal feeding, herd and manure management options can help in mitigation;
- can be used to run scenarios of interventions in the livestock sector and can be coupled with other models (e.g. grassland models for sequestration, economic data for the cost of mitigation, etc.).

### Box 7: Case study: Climate-smart livestock project using GLEAM, Mongolia

Temperatures in Mongolia increased by 2.24 °C between 1940 and 2015. This temperature change is around three times the world average temperature increase. Annual precipitation during the last 76 years decreased by 7 percent on average. Mongolia recently experienced a high occurrence of heavy rains, permafrost decline, drought in summer, drying up of water sources and heavy snow in winter since the 1990s. According to a 2016 assessment (Densambuu *et al.*, 2018), 57.6 percent of pastureland in Mongolia has been degraded to a certain degree.

Since December 2018, FAO Mongolia is implementing the project “Piloting the Climate-Smart approach in the livestock production systems”. The project adopts CSL approaches in three different livestock production systems. The expected results of the project include the demonstration of low-carbon emission fodder irrigation techniques using solar photovoltaic cells, reduced N<sub>2</sub>O emissions through improved manure management and reduced CH<sub>4</sub> emissions from enteric fermentation. Better animal husbandry techniques, improved feeding strategies, better dry season feeding, and improved pasture management with reduced and more productive herds will contribute to these reductions ( changes estimated using FAO’s GLEAM model).

Preliminary results from the GLEAM analysis show a potential significant drop in GHG emissions, on average -21 percent for CH<sub>4</sub>, -21 percent for CO<sub>2</sub>, and -15 percent for overall GHG emissions after project completion in 2021.

## Outputs

A complete simulation of GLEAM produces multiple outputs which can be either final indicators or intermediate calculations for subsequent operations. In its current version, GLEAM 2.0 outputs include:

- livestock animal numbers, production systems and their spatial distribution;

- production of manure and its management;
- feed intake and animal feed rations composition and quality;
- land use associated with feed intake;
- production of livestock commodities;
- GHG emissions arising from each stage of production;
- nitrogen used at each stage of production;
- spatial resolution.

To capture this variability, GLEAM uses regional or (sub) national information on production practices and animal parameters. Additional data on livestock numbers, pasture and feed availability are incorporated with a resolution not coarser than 5 arc minutes (circa 10 x 10 km at the equator). This is the same spatial resolution at which GLEAM produces the outputs.

### **Livestock production systems**

The model uses a classification of farming systems based on feed use and agro-ecological conditions. GLEAM distinguishes three farming systems for cattle (grazing, mixed and feedlot), two for other ruminant species (grazing and mixed), three for pigs (backyard, intermediate and industrial) and three for chicken (backyard, layers and broilers). Three agro-ecological zones are considered: temperate, which includes temperate regions and tropical highlands; arid, including arid and semi-arid tropics and subtropics; and humid, comprising humid and sub-humid tropics.

### **Life cycle assessment**

Life cycle assessment is an environmental impact analysis which provides a holistic picture of production processes and identifies critical stages where impacts are highest. LCA can also evaluate intervention options and avoid possible trade-offs or shifts of impact from one phase to another, thus providing valuable information for stakeholders and decision-making processes.

### **Sources of greenhouse gas and global warming potential**

GLEAM identifies three main groups of emissions along production chains. Upstream emissions include those related to feed production, processing and transportation. Animal production emissions comprise emissions from enteric fermentation, manure management and on-farm energy use. Downstream emissions are caused by the processing and post-farm transport of livestock commodities. GLEAM considers the following three gases: carbon dioxide, methane and nitrous oxide.

### **Model description: structure and modules**

The structure of GLEAM consists of three main modules: the herd, manure, and feed module.

The **herd module** describes the herd structure and the characteristics of the animals. To allow an accurate accounting of production, natural resource use and GHG emissions (including the use of IPCC (2006) Tier 2 methodology), GLEAM differentiates based on animal type, weight, phases of production and feeding situation. The national herd is disaggregated into six cohorts: adult females and males, replacement females and males, and male and female fattening animals (or surplus animals). Critical data for herd modelling is mortality, fertility, growth and replacement rates. Other parameters used to define the herd structure are the age or weight at which animals transfer between cohorts, the duration of critical periods such as gestation, lactation and the proportion of adult males to adult females.

The **manure module** describes how manure is managed and simulates the rate at which excreted nutrients are applied to feed crops. Calculation is based on the total amount of excreted nutrients in

each cell (using Tier 2 excretion rates), the proportion of nutrients lost during manure management and the area of arable/grassland in the cell to determine the rate of application per hectare.

The **feed module** calculates the composition of the ration for each species, production system and location, the nutritional values of the ration and the impact associated with it such as land use and GHG emissions. The determination of the ration is done separately for ruminants and monogastric animals. In all ruminant production systems, the composition of the feed ration depends on the availability of pasture, fodder, crops and their respective yields. The fraction of concentrates varies widely, based on the need to complement locally available feed, the purchasing power of farmers and access to markets. The primary feed ingredients for ruminants include:

- Grass: comprises natural pasture, improved and cultivated grasslands, rangelands and marginal areas such as roadsides.
- Feed crops: crops used to feed livestock such as maize silage or grains.
- Tree leaves: browsed in rangelands or forests, or collected and fed to livestock.
- Crop residues: plant material not harvested, such as straw or stover.
- Agro-industrial by-products: by-products from processing non-food crops such as oilseeds cakes, molasses or cereals brans.
- Concentrates: high energy or protein mixtures of by-products and grains are processed at specialized feed mills into a compound feed.

The proportion of each feed component is determined differently for industrialized and developing countries. In industrialized countries, the composition and proportion of feed ration materials are taken from national inventory reports, literature and targeted surveys. For developing countries, a feed allocation scheme was developed, based on literature and expert knowledge. This scheme relies on a close relationship between land use, feed availability and the feed ration, and was also cross-referenced with a survey at the national level.

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Regional Office for Asia and the Pacific  
FAO-RAP@fao.org  
**Food and Agriculture Organization of the United Nations**  
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