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Climate Smart Livestock Production: A Training Manual

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Climate Smart Livestock Production

Training Module

Author: Girma Tirfessa Diko*

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*Climate Smart Agriculture Specialist, Oromia Environmental Protection Authority. Email: tirfessa-girma@gmail.com

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Abbreviations and Acronyms

0C	Degree Celsius
CH_4	Methane
CO_2	Carbon dioxide
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
CSA	Climate Smart Agriculture
EBI	Ethiopian Biodiversity Institute
FAO	Food and Agriculture Organization
GHG	Greenhouse Gas
ILRI	International Livestock Research Institute
MoA	Ministry of Agriculture
NDC	Nationally Determined Contribution
NO_2	Nitrous Oxide
SDG	Sustainable Development Goals

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1 Introduction

In Ethiopia, livestock is a vital component of agriculture and holds significant cultural, social, and economic values. The country is believed to have the largest livestock population in Africa. According to the Ethiopian Central Statistics Agency's report, in 2022 the country had 66.2 million cattle, 38 million sheep, 45.7 million goats, 6.9 million camels, and 41.3 million chickens [Ethiopian Statistics Service, 2022]. The sub-sector contributes 45 percent to the agricultural GDP, 18.7 percent to the total national GDP, and 16-19 percent of foreign exchange earnings [Behnke and Metaferia, 2011] and provides diverse benefits, including food, clothing materials, fuel, fertilizer, draught power, income, and employment.

Despite the vast livestock resources in Ethiopia, the sector's economic contribution remains limited due to a combination of factors such as poor management, genetic limitations, limited infrastructure, insufficient market access, financial constraints and climate change impacts on animal physiology, feed availability, and the occurrence of several diseases [Li et al., 2025, Teku and Derbib, 2025, Abebe et al., 2022, Dadi, 2017].Livestock sector is not only a victim of climate change but also a significant contributor to it [Caro et al., 2014, Gerber et al., 2013].The current livestock management system, particularly free-grazing in fragile landscapes, contributes to land degradation and climate change through greenhouse gas emission. In Ethiopia, estimates indicate that, as of 2010, the livestock sector generates 65 million tonnes CO2 equivalent GHG, and is predicted to contribute 124 million tonnes in 2030 [FDRE, 2011].

The negative impacts of climate change on livestock production are already acutely being felt in Ethiopia posing a serious threat to food security, rural livelihoods and national economic growth [OCHA, 2022, FEWSN, 2022].Recurrent droughts, heat stress, declining availability of water, degraded grazing lands, and increased prevalence of livestock diseases are among the key manifestations of climate change affecting the sector[Tiruneh and Tegene, 2018, Bekele, 2017, Yilma et al., 2009]. While smallholder farmers and pastoral communities possess rich indigenous knowledge and centuries-old experience in adapting to environmental changes, the rapid pace,intensity and unpredictability of climate change are overwhelming their traditional coping mechanisms and capacities.

Given this reality, Ethiopia's livestock production system needs transition to climate-smart production system that can withstand and adapt to changing climatic conditions while continuing to meet growing demand of animal source foods and contribute to economic development. This transformation requires a multifaceted and integrated approach encompassing cutting-edge scientific research and innovations, comprehensive and continuous capacity building trainings for farmers and experts and strong political and institutional commitments. Adequate and sustained financial support is essential, alongside the establishment of enabling policies and governance mechanisms that promote sustainable land use and adoption of climate smart production practices.

This training module is part of a comprehensive climate-smart agriculture training manual developed specifically for development agents and technical experts. It serves as a technical reference in guiding farmers and pastoralists towards the adoption of sustainable, adaptive and productive livestock production practices. The module covers a wide range of interrelated topics including the relationship between livestock production and climate change, core concepts and principles of climate smart livestock production system, proven production practices that improve resilience and reduce emissions, supporting policies and indigenous knowledge. By providing a comprehensive understanding of climate-smart livestock production, the module aims to empower the practitioners with knowledge and tools needed to foster a more resilient, productive and environmentally sustainable livestock sector in Ethiopia. Ultimately it con-

tributes to national efforts toward climate adaptation, rural transformation, and sustainable development.

2 Livestock Production and Climate Change

Livestock are crucial for global food security, poverty reduction and economic development, but their production significantly contributes to climate change. Conversely, climate change negatively impacts livestock and the natural resources upon which they depend. This section explores the multifaceted relationship between livestock production and climate change, examining both the impacts of livestock on the environment and the effects of climate change on livestock production.

2.1 Climate change impacts on livestock production

Global climate change poses significant challenges to the farm animals and to the natural resources they depend on. The effects of climate change manifest in various forms, including increased ambient temperatures, erratic rainfall patterns, and a rise in life-threatening weather events such as heatwaves, floods, and droughts. These changes adversely affect the health, production, and reproductive performance of livestock. The impacts of climate change on livestock are broadly categorized into two main types: direct impacts and indirect impacts.

2.1.1 Direct impacts

Direct impacts refer to the immediate consequences of changing climate patterns on animals themselves that are directly attributed to changes in temperature, precipitation, and extreme weather events.

i. **Reduced metabolic efficiency**: Energy that could be used for growth or reproduction is diverted to maintain body temperature.

ii. **Reduced feed intake and production due to thermal stress**: Reduced feed intake is one response to high environmental temperatures. Ruminants experience reduced appetite under increased heat stress. The thermal comfort zone of dairy animals' ranges from 5 °C to 25 °C, within which they maintained a physiological body temperature of 38.4-39.1°C. However, air temperatures above 20-25°C in a temperate climate and 25-37°C in a tropical climate, enhance heat gain beyond that lost from the body and induces thermal stress and reduced feed intake[Das et al., 2016]. Goats are less susceptible to heat stress than other ruminants. However, their voluntary feed intake declines when the ambient temperature is more than 10 °C above their thermal comfort zone. Poultry animals also exhibit reduced feed intake when exposed to high temperatures. The reduction in feed intake causes decreases feed conversion efficiency, egg production and daily weight gain [Cheng et al., 2022]. More generally, across all the livestock types, heat-stress-related decreased feed intake leads to decreased milk, meat, and egg production, which in turn leads to further sectoral losses.

iii. **Reduced reproductive performance**: Heat stress affects reproduction for both sexes. For females, heat stress reduces estrous period and fertility while increasing the incidence of anestrous and embryonic death. For males, there are declines in semen quality, testicular volume, and quantity of fertile sperm[Das et al., 2016].

iv. **Compromised immune function**: The immune system of the animals is their major body defense that protects them from environmental stressors and other noxious insults. Heat stress can negatively affect immune functions via cell-mediated and humoral immune responses. As a result, periods of hot weather can cause livestock to be more vulnerable to diseases and raise the incidence of certain diseases (such as mastitis), leading to an increased potential of morbidity and death.

v. **Increased mortality**: Extreme climate events, such as heatwaves, droughts, floods, and storms, can have devastating impacts on livestock health and increase mortality rates. Heatwaves can lead to heat stress in animals, causing increased mortality rates. Livestock, such as cattle and poultry, are particularly vulnerable to high temperatures. Heat stress can lead to dehydration, reduced feed intake, and even death. Droughts cause water scarcity and reduce the availability of pasture and fodder, leading to malnutrition and starvation in livestock. As water sources dry up and vegetation diminishes, animals struggle to find adequate nutrition and hydration, which can lead to significant mortality rates. Storms and flooding can lead to direct mortality of livestock through drowning or injury.

2.1.2 Indirect effects

The indirect effects are linked to the modifications in ecosystems, changes in availability and quality of feedstuffs and drinking water, possible increases in animal diseases, higher energy prices and increased competition for resources.

i. **Reduced forage availability**: Changes in precipitation patterns and prolonged droughts leads to a decline in available forage, affecting livestock feed and health. The most serious impacts are in pastoralist area because of their high dependency on climate and limited adaptation opportunities. The consequences are most severe in arid and semi-arid grazing systems. For example, the 2015-2016 El Niño-induced drought in Ethiopia resulted in a severe shortage of pasture and water for livestock, leading to widespread livestock mortality. Climate change can also affect forage quality. Quality forage can be affected by climate through increased temperatures and dry conditions, which cause variations in concentrations of water-soluble carbohydrates and nitrogen. Quality may also decrease since rising temperatures can increase lignin within plant tissues and therefore reduce digestibility.

ii. **Water scarcity**: The livestock sector uses water for consumption by animals, growing feed crops, and product processing. Water scarcity, driven by reduced rainfall and increased evaporation, affects both livestock drinking water and water for irrigation, leading to conflicts among communities competing for limited water resources.

iii. **Diseases and parasite stress**: Changing climate patterns influence the distribution of disease vectors, leading to the emergence of new diseases and increased prevalence and distribution of existing diseases and pests. Increased temperature and altered precipitation can accelerate the incidence of pathogens and parasites. These may increase the potential for morbidity/mortality and associated economic loss. The following are some of the livestock diseases that are strongly associated with climate variability and change.

- **Rift Valley fever (RVF)**:- It is a viral disease that primarily affects cattle, sheep, and goats. It is transmitted by mosquitoes, whose populations can increase with warmer temperatures and increased rainfall, leading to outbreaks in new regions.

- **Trypanosomiasis**:- It is transmitted by tsetse flies, which thrive in humid environments. Climate change can expand the habitats of tsetse flies, increasing the risk of Trypanosomiasis in livestock.
- **Anthrax**: Anthrax is a serious disease usually caused by Bacillus anthracis bacteria. It's found naturally in soil around the world and commonly affects livestock and wild animals. Anthrax outbreaks mainly occur after heavy rains and floods followed by a dry period or with the onset of rains ending a period of drought. These climatic conditions favor the concentration of spores in the upper level of the soil, increasing the risk of spore ingestion by herbivores.
- **Foot-and-Mouth Disease**: This highly contagious disease is more likely to spread with increased animal movement, often driven by drought and scarcity of resources.
- **Bluetongue (BTV)**: It is a viral disease that affects ruminants, such as sheep, cattle, goats, deer, and camels. It is spread by the bite of infected midges and is not contagious between animals. Climate change is a major driver of the spread of the disease. Rising temperatures make it possible for midges to survive in regions where they previously couldn't.
- **Bovine Tuberculosis**: Bovine tuberculosis is a chronic bacterial disease that affects a wide range of animals, including livestock and wildlife. It's caused by the bacteria Mycobacterium bovis (M. bovis), which is closely related to the bacteria that cause human and avian tuberculosis. Prolonged droughts can increase the risk of occurrence of tuberculosis.

iv. **Resource prices increment**: Climate change can increase the price of resources like feed, water, and energy.

2.2 Livestock contribution to climate change

The livestock sector is a major contributor to climate change, generating significant emissions of carbon dioxide, methane and nitrous oxide. Globally, livestock production sector account for about 14.5 percent of all anthropogenic GHG and 70 percent of all emissions from agriculture, forestry, and other land use ([Caro et al., 2014]; [Gerber et al., 2013]). In Ethiopia, emissions from livestock sector accounted for 65Mt CO2 eq in 2010, with enteric fermentation accounting for the most (87 percent), followed by manure left on pasture (13 percent) [FDRE, 2011]. The livestock sector contribution to climate change is broadly categorized in to two as direct and indirect contribution.

2.2.1 Direct Contributions

The direct contributions of the livestock sector to climate change primarily involve emissions of greenhouse gases from various biological and mechanical processes within livestock farming.

i. **Enteric methane emissions**: One of the most significant direct contributions comes from methane emissions. Ruminant animals, such as cattle, goat, sheep and camel, produce methane during the digestion process known as enteric fermentation. This process occurs when microbes in the stomach of these animals break down food, releasing methane as a byproduct. Methane is predominantly produced by methanogens in the process of anerobic degradation of plant biomass in rumen and it is eructated or exhaled mainly through the mouth and nostrils.

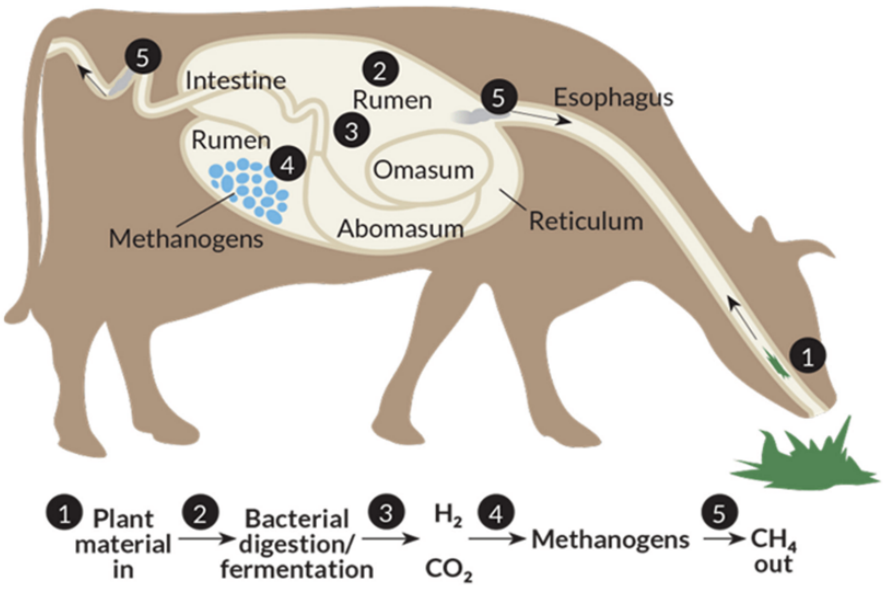


Figure 1: Enteric methane production process

ii. **Methane and Nitrous oxide emission from manure**: Another source of direct emissions is manure management. When livestock manure is stored or treated in systems that promote anaerobic conditions, such as lagoons or pits, it emits methane and nitrous oxide. Both gases are powerful contributors to global warming.

iii. **Carbon Dioxide Emissions**: Although less significant than methane and nitrous oxide, carbon dioxide emissions also arise directly from on-farm energy use. This includes the use of fossil fuels for machinery, heating, and transportation within the livestock production process.

2.2.2 Indirect Contributions

Indirect contributions involve emissions generated from activities associated with livestock production but not directly from the animals themselves.

i. **Deforestation and Land Use Change**:A major indirect contribution of livestock to climate change is deforestation and land use change. Though it is not common practice in Ethiopia, forests are often cleared to create pastures or grow feed crops, such as soybeans, for livestock. This deforestation not only releases stored carbon dioxide but also reduces the planet's capacity to absorb CO2.

ii. **Feed Production** The production of livestock feed is another significant source of greenhouse gas emissions. Fertilizer application, irrigation, and the use of machinery all contribute to carbon dioxide and nitrous oxide emissions. Additionally, the conversion of land for feed crops can lead to soil degradation, further exacerbating climate change.

iii. **Supply Chain Emissions**:The processing, packaging, and transportation of livestock products contribute indirectly to climate change. Each step in the supply chain involves energy consumption and emissions, adding to the sector's overall carbon footprint.

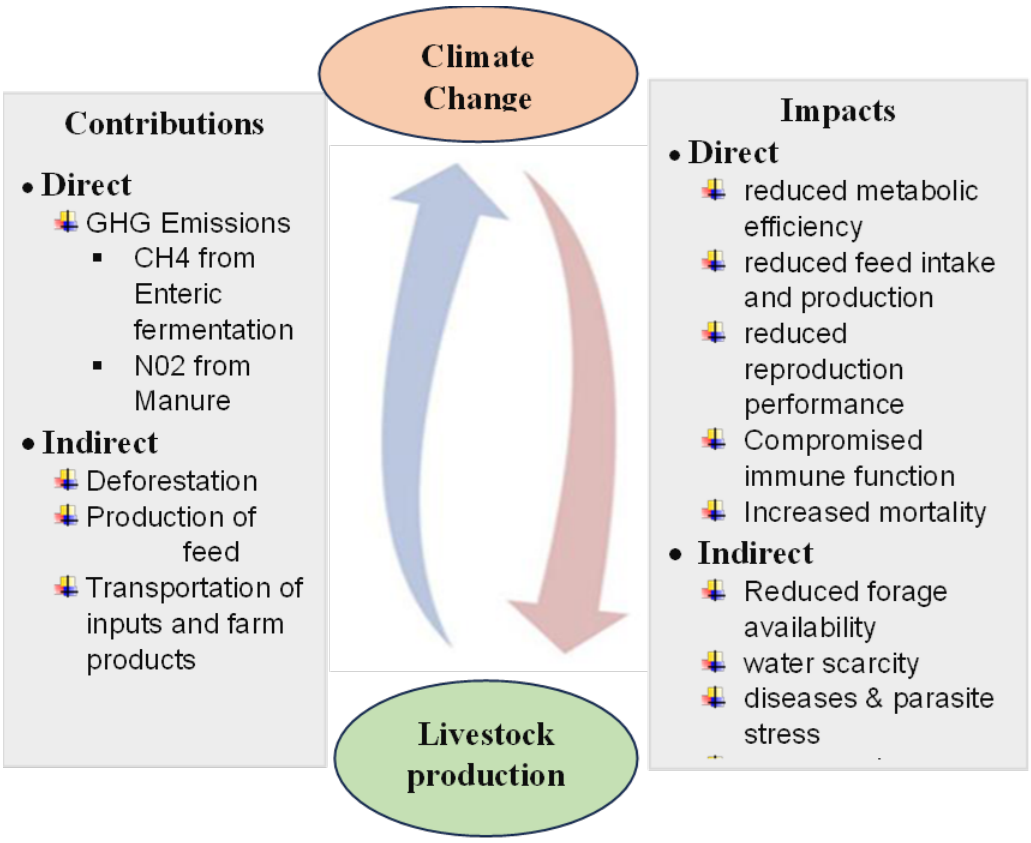


Figure 2: The relationship between Climate change and livestock production

3 Climate Smart Livestock Production, Principles and Importance

3.1 Climate smart livestock production

A climate-smart livestock approach is an all-encompassing strategy that aims to create sustainable livestock production systems that fully support food security; climate change adaptation and mitigation efforts; sustainable incomes, and animal welfare and environmental impact reduction. It is a set of practices that aim to reduce the environmental impact of livestock production while also increasing food security and the livelihoods of livestock producers. Thus, climate smart livestock production aims to:

- meet the challenges of food security through sustainable production approaches,
- reduce impacts of climate change on animals and their farmers through reducing exposure to short-term climatic variability, while also strengthening their resilience to climate-related shocks and longer-term impacts,
- contribute climate change mitigation by reducing/removing greenhouse gas emissions along livestock value chain.

3.2 Importance of climate-smart livestock production

Climate-smart livestock production is essential for achieving global food security and environmental sustainability in the face of a growing population and climate change. Its key importance

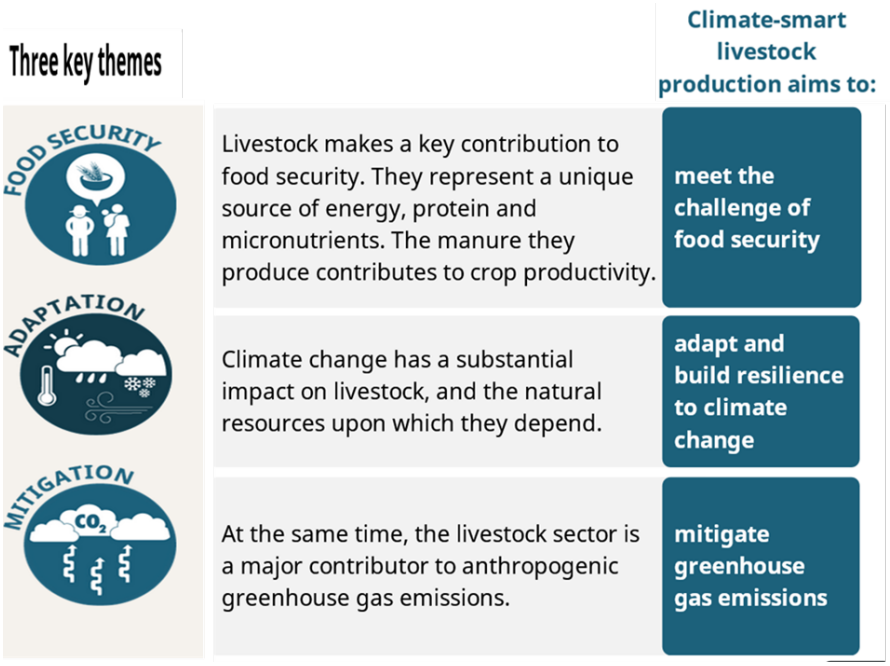


Figure 3: Themes and aims of climate smart livestock production

and benefits are:

- **Food Security**: As the global population continues to grow, climate-smart livestock production can help meet the increasing demand for animal protein while ensuring that production systems are sustainable.
- **Mitigation of Climate Change**: Livestock production is a significant source of greenhouse gas emissions (especially methane). Implementing climate-smart practices can reduce these emissions, contributing to global climate change mitigation efforts.
- **Economic Resilience**: By improving productivity and reducing costs associated with feed and health management, climate-smart practices can enhance the economic viability of livestock farming, particularly for smallholder farmers.
- **Ecosystem Services**: Sustainable livestock production can enhance ecosystem services such as soil health, biodiversity, and carbon sequestration, contributing to overall environmental sustainability.
- **Adaptation to Climate Variability**: Climate-smart practices help livestock producers adapt to the impacts of climate change, such as increased temperatures, droughts, and changing precipitation patterns, thereby enhancing their resilience.
- **Social Benefits**: Implementing climate-smart livestock production can lead to improved livelihoods for farming communities by providing stable income sources, enhancing food security, and empowering women and marginalized groups involved in livestock production.
- **Global Goals Alignment**: Climate-smart livestock production aligns with global initiatives such as the Sustainable Development Goals (SDGs), particularly those related to zero hunger (SDG 2), climate action (SDG 13), and responsible consumption and production (SDG 12).

3.3 Climate smart livestock production principles

Sustainable livestock production is increasingly important in the context of environmental concerns and climate change. Climate smart livestock system is grounded in two major principles: resource use efficiency and building resilience[FAO, 2013]. By adhering to these principles, livestock production systems can become more sustainable, ensuring food security and environmental preservation for future generations.

3.3.1 Resource use efficiency

Resource use efficiency refers to producing more with less, and delivering greater value with less inputs while minimizing waste and environmental degradation. Adopting techniques for optimal resource use is a crucial strategy for achieving sustainable growth in the livestock sector while mitigating climate change and environmental impacts. This principle involves:

- **Optimizing feed conversion**: Improving the feed conversion ratio ensures that livestock convert feed into body mass more efficiently, reducing the amount of feed required and associated environmental impacts. Develop and utilize feed that maximizes nutrient absorption and minimizes waste. This can include the use of high-quality forage, supplements, and alternative feed sources (e.g., agro-industrial by-products).
- **Water conservation**: Implementing strategies to reduce water usage and enhance water recycling can significantly decrease the water footprint of livestock production.
- **Energy efficiency**: Utilizing renewable energy sources and improving energy efficiency in operations reduces greenhouse gas emissions and reliance on fossil fuels.
- **Land management**: Practicing sustainable grazing and rotational farming helps maintain soil health and productivity, preventing land degradation and promoting biodiversity.
- **Waste Management**: Implement strategies for managing manure and other waste products to reduce methane emissions and nutrient runoff. This can involve composting, biogas production, and nutrient recycling.
- **Sustainable Resource Management**: Optimize the use of natural resources such as land, water, and feed to minimize environmental impacts. This includes practices like rotational grazing, integrated crop-livestock systems, and efficient water use.

3.3.2 Building resilience

Building resilience involves enhancing the ability of livestock systems to withstand and adapt to environmental and economic changes. It is about equipping farmers to absorb and recover from shocks and stresses to their agricultural production and livelihoods. Some shocks are short-term, others long-term. Some come suddenly while others are predictable. And some are more severe while others slowly erode farmers' ability to farm. Some adaptation options may be appropriate for short-term but others for the long-term (or both). In the short-term, adaptation to climate change is often framed within the context of risk management. Longer-term approaches to adaptation are often described in terms of 'climate-proofing development'. Adoption of new technology or system modifications (such as switching from extensive to mixed systems or altering the set of commodities produced) may be part of these strategies. It could take long time period for a problem to be recognized and for suitable and easily accessible technology to be developed. Key strategies under this principle include:

- **Genetic diversity**: Breeding programs that focus on genetic diversity can produce livestock that are more resistant to diseases and better adapted to changing climatic conditions. Utilize breeds that are more resilient to climate stressors (e.g., heat, drought) and have higher productivity. Selective breeding can enhance disease resistance and improve feed conversion efficiency.
- **Diversified production systems**: Integrating livestock with crop farming or other agricultural practices can create more resilient systems that benefit from multiple sources of income and nutrients.
- **Risk management**: Developing comprehensive risk management plans, including insurance schemes and emergency response strategies, can help mitigate the impacts of extreme weather events and market fluctuations.
- **Market responses**: Various trade and investment instruments can improve the resilience and ability to adapt to climate change (especially for smallholder farmers)
- **Policy response**: Policies that remove harmful or introduce nature-positive subsidies, promote income diversification, set up livestock early-warning systems are just a few examples.
- **Science and research**: A better understanding of climate impact on livestock in different regions, developing of new breeds and genetic types, disease control, improved water, and soil management.
- **Capacity building**: Training in climate smart agriculture practices and increasing the awareness, knowledge, and skills of farmers and herders to cope with the impact of climate change.
- **Livestock management**: Depending on region and breed, may include increased shading, access to water, reduction of livestock number, changes in the livestock composition, changes in diets and/or herding practices, and many more.
- **Technological options**: Modern technology can reduce vulnerabilities, i.e. by improving warning systems, converting byproducts into energy, and improving animal health and well-being.

4 Climate Smart Livestock Production Practices

Climate smart livestock production practices are a set of innovative, integrated and adaptive strategies aimed at enhancing livestock productivity while minimizing the sector's environmental footprint and increasing resilience to climate change.These practices aim not only to increase animal production and improve the livelihoods of livestock keepers, especially smallholders and pastoralists, but also to reduce greenhouse gas emissions, protect natural resources, and strengthen the sector's resilience to the adverse impacts of climate change. They involve a combination of improved animal husbandry, better feeding and breeding practices, sustainable pasture management, disease prevention, and early warning systems, all tailored to specific local conditions. By aligning livestock development with climate adaptation and mitigation goals, climate-smart livestock practices support long-term environmental sustainability, food security, and rural development.

4.1 Climate services for livestock production

Agriculture in Ethiopia is heavily dependent on weather and climate conditions. These factors critically influence the growth and productivity of crops and livestock, as well as the availability of water, timing of land preparation, planting, grazing patterns, and other key farm-level decisions. The Ethiopian climate is known for its spatial and temporal variability, which is further exacerbated by global climate change. Adapting agriculture to both climate change and variability requires farm decisions that are based on climate information. Weather forecasting and early warning of bad weather are very crucial to allow the farmers to take necessary preventive measures to protect the animals from bad weather conditions like severe heatwaves, cold waves, heavy precipitation, cyclone, flood and disease outbreaks.

Climate Services refer to the generation, translation, dissemination, and use of climate information to support decision-making and risk management. These services are designed to help individuals and institutions prepare for, respond to, and adapt to weather variability, climate extremes, and long-term changes in climate. In the context of livestock production, climate services offer vital information that can help farmers and pastoralists:

- Minimize losses during droughts and extreme weather events,
- Manage livestock health more proactively,
- Enhance resilience against climate-related shocks.

4.1.1 Climate services relevant to livestock sector

I. Real-time weather alerts

Real-time weather alerts are immediate,short-term warnings about hazardous weather events that may occur within hours or days. These alerts are critical for early action in the livestock sector, particularly in Ethiopia, where pastoral and agro-pastoral communities rely heavily on open grazing, natural water sources, and mobile herding systems. Timely alerts can help prevent livestock losses, protect animal health, and ensure herder safety. Real-time weather alerts can cover a range of sudden or extreme meteorological events that pose risks to livestock health, productivity, and survival. Below are the key types of real-time alerts that should be monitored and acted upon in the livestock sector.

Table 1: Real-time alerts (Heatwave, Rain, Wind, and Flood)

Weather condition	**Key Impact on Livestock**	**Key advisories**
Heatwave	• Heat stress and exhaustion • Reduced feed intake and milk yield • Lower fertility • Increased water demand • Death of young, sick, or weak animals	• Advise herders to provide clean water (twice daily or more) • Keep animals in shaded or ventilated areas • Avoid midday movement or transport • Include electrolytes in ration • Monitor for panting, drooling, lethargy
Heavy Rainfall	• Flooded grazing and waterlogged soils • Contaminated drinking water • Hoof diseases, diarrhea, parasites • Spoilage of stored feed	• Relocate animals to elevated ground • Cover feed with tarps • Monitor water for contamination • Prepare for parasite outbreaks
Flash Flood	• Drowning, injury • Erosion of grazing lands • Disrupted routes	• Identify and pre-mark safe zones • Warn riverbank communities • Halt herding in vulnerable zones • Move weak animals first
Strong Winds	• Shelter damage • Injury from falling trees • Panic and scattering • Dust inhalation, eye irritation	• Reinforce shelters • Keep animals enclosed • Store feed securely • Avoid long-distance herding

Table 2: Real-time alerts (Cold, Storm, and Disease Outbreaks)

Weather condition	**Key Impact on Livestock**	**Key advisories**
Thunderstorm	• Lightning strikes • Abortions in pregnant animals • Fright and disorientation • Shelter/equipment damage	• Move animals away from trees, water, metal fences • Use enclosed shelters • Provide dry bedding • Disconnect electric equipment
Cold Spell or Frost	• Hypothermia in calves/lambs • Reduced feed efficiency • Respiratory infections	• Provide warm bedding and windbreaks • Move to covered shelters • Increase feed energy (more grains)
Vector-Borne Disease	• Trypanosomiasis, Rift Valley Fever, Tick-borne fevers	• Start insect/tick control • Conduct preventive vaccination • Avoid infested areas • Monitor for fever, swelling, behavior

II. Weather forecast

A weather forecast is a scientific prediction of future atmospheric conditions such as rainfall, temperature, humidity, wind speed, and extreme events over a specific area and time period (daily, weekly, or seasonal). These forecasts are generated by national meteorological services, such as Ethiopia's National Meteorology Agency (NMA), and regional climate centers like the IGAD Climate Prediction and Applications Centre (ICPAC). They rely on satellite data, ground-based weather observations, advanced numerical weather prediction models, and historical climate records to produce accurate and timely forecasts. Weather forecasts provide critical information that can help livestock producers manage risks, make informed decisions, and increase productivity. Different types of forecasts offer varying levels of detail and lead time. Each type can be linked to specific, actionable advisories for the livestock sector, especially when interpreted and communicated effectively by extension workers.

a) Short-Term Forecast (up to 3 Days Ahead)

Short-term forecasts (1–3 days) provide highly localized, near-real-time predictions of weather conditions. These forecasts are essential for day-to-day decision-making in the livestock sector, enabling timely action to protect animals, adjust farm operations, and prevent losses.

Table 3: Short term weather forecast and tailored Livestock Advisories

Weather condition	**Tailored Livestock Advisory**
Heatwaves	• Increase watering frequency. • Reduce herding time during peak heat hours to avoid heat stress.
Unseasonal rains	• Adjust grazing routes to avoid flooded or waterlogged areas. • Move animals to higher, drier ground.
Sudden temperature drops in highland regions	• Strengthen shelters, especially for newborn, young, or sick animals. • Use extra bedding to keep animals warm.

b) Medium-Term Forecasts (4–10 Days Ahead)

Medium-term forecasts provide weather predictions for 4 to 10 days into the future. These forecasts offer early warnings about developing weather conditions and enable short-term planning for livestock operations. While not as precise as short-term forecasts, they are highly valuable for resource planning (e.g. feed supply and storage), animal health preparedness (weather-sensitive diseases), grazing schedules and other weather sensitive activities.

Table 4: Medium-term weather forecast and tailored advisories

Weather Condition	**Tailored Livestock Advisory**
Dry Spells	• Prepare and stock alternative feed sources (e.g., hay, crop residues). • Reduce herd movement to conserve animal energy and water.
Wet Spells	• Prevent livestock from using muddy or flooded routes, especially when trekking to grazing areas and markets. • Improve drainage around shelters and feeding areas.
Strong Winds	• Reinforce animal shelters, especially roof structures. • Avoid moving livestock during high wind periods to prevent stress or injury.

c)Seasonal Forecasts (1–3 Months Ahead)

Seasonal forecasts provide probabilistic climate outlooks for the upcoming 1 to 3 months, indicating whether rainfall and temperature conditions are likely to be above normal, below normal, or near normal compared to the long-term average. These forecasts help guide strategic decisions in the livestock sector. They are typically delivered before the belg (Feb–May) and kiremt (Jun–Sep) rainy seasons and the bega dry season (Oct–Jan).

Table 5: Seasonal forecast and tailored advisories

Climatic Condition	**Tailored Livestock Advisory**
Droughts (Below-Normal Rainfall Forecast)	• Encourage early feed conservation (e.g., haymaking, silage). • Promote water harvesting techniques. • Advise controlled breeding to manage feed demand. • Support early destocking or enrollment in livestock insurance schemes.
Excess Rains (Above-Normal Rainfall Forecast)	• Promote proactive vaccination against common wet-season diseases (e.g., anthrax, pasteurellosis). • Improve shelter drainage to prevent foot rot and other health risks.
Shifting Onset/Cessation of Rains	• Adjust grazing and breeding calendars accordingly. • Guide on flexible feed planning and mobility routes. • Alert herders about possible prolonged dry or wet periods.

d) Agro-Meteorological (Integrated) Forecasts

Agro-meteorological forecasts are integrated forecasts that combine weather and climate information with agricultural and livestock data (such as pasture condition, soil moisture, vegetation indices, and livestock health indicators). These forecasts aim to provide location-specific, actionable guidance to farmers and herders to manage weather-related risks and optimize livestock production. They are not just about predicting weather, but about predicting how the weather will impact livestock systems and offering tailored management recommendations.

Table 6: Agro-meteorological forecast and tailored advisories

Forecast Condition	Tailored Livestock Advisory
A. Rainfall Forecast	
Normal to Above-Normal Rainfall	• Prepare for good pasture regeneration. • Consider pasture conservation or hay-making. • Maintain vaccination to prevent waterborne diseases (e.g., blackleg, anthrax).
Erratic or Below-Normal Rainfall	• Begin supplementary feeding planning early. • Delay herd movement until rains are confirmed. • Watch for early signs of water scarcity.
Heavy Rain / Flood Risk	• Move animals to higher ground. • Protect feed and shelters. • Avoid grazing in flood-prone riverbanks.
B. Temperature Forecasts	
High Temperature (Heatwaves)	• Increase watering frequency. • Reduce herding time during hottest hours. • Provide shade (trees, shelters, plastic roofing).
Low Temperature / Cold Spells (Highlands)	• Insulate animal houses with bedding materials. • Increase energy-rich feed (e.g., grain, molasses). • Group young animals for warmth.
C. Wind, Hail, and Storm Warnings	
High Wind Alerts	• Strengthen shelters and fencing. • Avoid transporting animals or herding in open plains. • Tie roof covers and shade cloths.
Storm Risk	• Keep young stock indoors. • Secure feed stores and equipment. • Avoid open field grazing.
D. Pasture and Rangeland Condition Forecasts	
Greening / High NDVI	• Use rotational grazing to prevent overuse. • Store excess forage for dry months. • Improve feed banks or community feed reserves.
Poor Vegetation / Low NDVI	• Prioritize weak animals for supplementary feeding. • Delay long movements where forage is scarce. • Consider partial destocking if no improvement is forecast.
E. Livestock Disease Risk Forecasts (Climate-sensitive)	
High humidity and warmth (e.g., post-rain season)	• Watch for foot rot, PPR, ticks, and helminths. • Start deworming and vaccination schedules.
Cool and Wet Highland Conditions	• Watch for pneumonia in small ruminants. • Avoid overcrowding and wet housing areas.

4.1.2 Accessing and disseminating Climate Information

I. Sources of weather and climate information

In Ethiopia, weather forecasts are generated and disseminated through a combination of national, regional, and international institutions. These sources provide critical information for planning and managing climate-sensitive sectors such as livestock production. Understanding where to access reliable and timely forecasts helps extension workers advise livestock keepers more effectively.

- **Ethiopian Meteorological Institute (EMI)**:The Ethiopian Meteorological Institute (EMI) is the primary and official source of weather and climate forecasts in Ethiopia. It collects and analyzes meteorological data using a network of ground-based weather stations, satellite observations, and forecast models. EMI provides:
  - Daily, weekly, and monthly weather forecasts
  - Seasonal climate outlooks
  - Early warning bulletins for extreme weather events (e.g., floods, droughts, heatwaves)
  - Agro-meteorological bulletins tailored to farmers and pastoralists

  The Ethiopian Meteorological Institute (EMI) disseminates forecasts through:
  - oNational TV and radio (EBC and regional stations)
  - Its website: https://www.meteo.gov.et
  - SMS alerts (in collaboration with Ethio Telecom and NGOs)
  - Telegram channels, Facebook, and printed bulletins
- **Regional Meteorological Offices (RBOs)**: These are regional branches of EMI that adapt national forecasts to the local context. They provide region-specific forecasts and collaborate with:
  - Regional agricultural bureaus
  - Livestock and pastoral development offices
  - Local media outlets: They are vital in translating forecasts into local languages and ensuring timely outreach to remote rural areas.
- **ICPAC – IGAD Climate Prediction and Applications Centre**: ICPAC provides regional seasonal climate forecasts and early warning updates for East Africa, including Ethiopia. It hosts:
  - GHACOF (Greater Horn of Africa Climate Outlook Forum) every quarter
  - Climate risk maps and advisory tools for livestock and agriculture ICPAC forecasts are used by EMI to refine national seasonal outlooks and guide contingency planning. Website: https://www.icpac.net
- **Mobile and Digital Platforms**: Several mobile and digital platforms are available for weather forecasting in Ethiopia, offering access to both general weather information and tailored agricultural advisories. Key platforms include:
  - the Ethiopian Meteorological Institute's Numerical Weather Prediction product
  - various mobile apps like "Ethiopia Weather" and "Ethio Weather", and the Ethiopian Digital AgroClimate Advisory Platform (EDACaP).

  These platforms leverage both satellite and ground-based weather data to provide forecasts and information relevant to various sectors, including agriculture, disaster preparedness, and daily planning.
- **Community Observations and Indigenous Knowledge**: While not formal forecasts, traditional observations remain relevant. Livestock keepers in pastoral regions monitor signs such as:
  - Wind direction and cloud movement
  - Insect behavior and flowering of trees
  - Animal migration patterns

  Extension workers should respect and integrate such knowledge when communicating scientific forecasts, enhancing trust and local relevance.

II. Guidelines for extension workers on disseminating weather forecasts to local communities

Timely and effective communication of weather forecasts can greatly enhance the ability of livestock keepers to prepare for and manage weather-related risks such as drought, floods, extreme heat, and disease outbreaks. Extension workers serve as crucial intermediaries between meteorological agencies and livestock communities. Below are recommended strategies for effective dissemination of weather forecasts.

a) Use Locally Understood Language and Terms

- Translate forecast information into local languages.
- Use simple, non-technical terms (e.g., say "heavy rains expected in two days" instead of "high precipitation is forecast").
- Relate forecasts to visible indicators (e.g., pasture greening, water scarcity) that farmers can relate to.

b) Leverage Community Structures and Gatherings

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- Share forecasts during weekly market days, cooperative meetings, religious gatherings, or village assemblies ("Iddir", "Gadaa" meetings).
- Work with community leaders, elders, and pastoral associations to relay messages through trusted channels.

c)Utilize Local Radio and Community Loudspeakers

- Collaborate with local FM stations and community radios to broadcast forecasts and advisories daily or weekly.
- In areas without radio, use megaphones or loudspeakers mounted on vehicles or at mosques/churches.

g) Combine Forecasts with Indigenous Knowledge

- Respect and validate local forecasting methods (e.g., observing animal behavior, plant flowering).
- Discuss forecasts in community meetings alongside elders to build trust and ensure alignment with local perceptions.
- Use both traditional signs and scientific forecasts to reach consensus.

h) Ensure Timeliness and Frequency

- Share daily or weekly updates during critical seasons (e.g., March–May and June–September rainy seasons).
- If possible, pre-alerts (48–72 hours ahead) for extreme events should be prioritized.
- Use 10-day, seasonal, and real-time alerts depending on availability from EMI or ICPAC.

i) Coordinate with Local Institutions and Partners

Collaborate and Work with:

- Woreda Disaster Risk Management Office
- Water and Irrigation Bureaus
- Animal Health Workers
- NGOs and cooperatives
- Ensure consistent messaging and avoid misinformation.

j) Document and Provide Feedback

- Keep a log of forecasts shared, methods used, and livestock keepers' responses.
- Collect feedback from communities to improve message clarity and relevance.
- Report needs or gaps back to EMI or agricultural bureaus to improve forecast tailoring.

4.2 Feed and nutrition management

Feed shortage is among the main constraints to Ethiopian livestock production. Forage availability in grasslands depends on rain fall pattern. In mixed farming areas grazing lands are steadily shrinking by being converted to arable lands and are restricted to areas that have little value for farming potential. This resulted in animals increasingly being fed on crop residues and other conventional and non-conventional feeds. However, crop residues are not capable of enhancing productivity of animals when fed solely because of their deficiency in essential nutrients, low digestibility and low voluntary intake by animals. As these feeds have high content of lingo-cellulosic components, their digestibility in the rumen is very low resulting in low nutrient release and also high enteric methane production. Therefore, improving the quality and quantity of feed is essential to improve livestock productivity and production while lowering their carbon footprint. Using and practically applying research-based strategies and improved execution to enhance livestock feed supply both in quality and quantity can improves production and productivity of the sector and reduces the cost required for the purchase of feed. Production of different improved forages in different forage production strategies increases the feed supply

4.2.1 Climate smart forage development

Forage production and conservation is important to ensure the availability of feed and better animal performance throughout production period. There are several strategies of forage development that fit to land holding and farming system of small holder farmers in Ethiopia.

i. Backyard forage production

Backyard forage production is a strategy for growing forage crops in small plots and hedges around a farmer's house or compound. This is the most important initial strategy since it is developed in the farmer's household, and is very convenient for intensive feeding of dairy cattle, fattening and small ruminants and do not compete with crop land. The higher fertility levels typically found in and around house compounds also help with the successful establishment of backyard forage. This strategy aids to acquire larger biomass yield from small plots of land in good management (which has positive impact in enhancing livestock). Backyard forage can be cut and carried to tethered or housed animals, or cut and conserved for dry season use in mixes with crop residues and natural pasture hay or roughages. It should be one of the first strategies to be promoted by extension agents since it is easily established and managed, and provides the means to reduce grazing pressure on common grazing areas. There are several forage species suitable for backyard production. Woody leguminous browse species are particularly suited to this strategy because of their multipurpose benefits and rapid growth rates. Tall growing tropical grasses are also suited to backyard forage development[Mengistu, 2002].

Table 7: Key species suitable for backyard forage production

Altitude	**Browse legume**	**Herbaceous legume**	**Grasses**
Less than 2000m	Leucaena	Silver leaf desmodium	Panicum grass
	Sesbania	Green leaf desmodium	Rhodes grass
	Pigeon pea	Alfalfa	Elephant grass
2000–2400m	Tree lucerne	Lucerne	Alfalfa, Phalaris
	Sesbania	Verano stylo	Elephant grass
	Pigeon pea	Vetch	
Above 2400m	Tree lucerne	Alfalfa	Phalaris
		Vetch	Oat

Source: Alemayehu M., 2002



Figure 4: farmers at Endamehoni (Tigray)feeding their sheep with tree lucerne from their backyard.
Source:Feed and Forage Development Training Manual (Africa RISING) (Melkamu et al., 2021)

ii. Under sowing/inter-cropping

Under sowing and inter planting is the establishment of forage species in an annual crop or perennial plantation. This is a strategy of sowing forages under the main crops in a manner that cannot reduce the productivity of the main crops and is particularly suited to the production of tall growing cereals such as maize, sorghum or millet but also works with other cropping systems[Mengistu, 2002]. This strategy has various advantages:

- Improving the fertility of the soil
- Protecting soil erosion
- Producing additional good quality forage

Under-sowing with legumes produces large quantities of high-quality forage for utilization by either post-harvest grazing or cut and carry systems. The under-sown forage protects the soil from erosive rains, can contribute nitrogen for the food crop, and balances the forage value of crop residues. The strategy works well with sprawling and climbing legumes but is also effective with other forage legumes and dual-purpose legumes such as cow pea. The most common forage legumes suitable for under-sowing are cow pea, lablab, pigeon pea, vetch, Greenleaf Desmodium, white clovers and native clovers under varying agro-ecological zones (AEZs). Tree crops can also be under sown or inter planted with leguminous forages. The establishment of annual or perennial legumes under tree crops is a reliable strategy, which is well accepted by farmers. It is particularly appropriate to the more intensive horticultural and forestry systems where the under sown legume is intensively managed with cut and carried systems for livestock feed. The strategy primarily involves lower altitude systems where fruit, coffee, coconuts, enset or chat are grown[Mengistu, 2002].



Figure 5: Intercropping: (Left) Maize with Lablab; (Right) Maize with Vetch

Source: Sidama region, Malga woreda(left) and Getnet et al., 2022(right)

iii. Contour forage strips

Contour forage strips are strategically planted bands of mixed herbaceous and tree legumes and grasses, following the contour lines of a slope[Mengistu, 2002]. They serve multiple purposes, including:

- **Forage Production**: The diverse mix of species provides valuable fodder for livestock, contributing to agricultural productivity.
- **Soil Conservation**: Contour strips act as natural barriers, slowing down water runoff and promoting infiltration. This reduces soil erosion and enhances soil moisture retention.
- **Shelter and Fuelwood**: The inclusion of tree legumes offers shade and shelter for animals, as well as a source of fuelwood for local communities.



Figure 6: Desho grass developed on contour in Doyogena woeda (left) and Tree lucerne alley cropped with Tef(right)

Source:ILRI/Zerihun Sewunet-(left) and Fekede et al.2018(right)

Contour forage strips are particularly successful when perennial, thick rooted grasses are mixed with woody leguminous species. Fast-growing, resilient species like pigeon pea, Phalaris, and green leaf desmodium are recommended as understory plants, especially when combined with taller species like Leucaena or tree lucerne. Stoloniferous species such as Rhodes grass are not suited to contour forage strips because of their weed potential in crop areas[Mengistu, 2002].

Table 8: Forage species suitable for on contour production

Altitude	**Browse legume**	**Herbaceous legume**	**Grasses**
<2000m	Leucaena	Siratro	Panicum
	Sesbania	Axillaris	Setaria
	Pigeon pea	Silver leaf desmodium	Vetveria
		Green leaf desmodium	
		Vetch	
		Verano staylo	
2000–2400m	Tree lucerne	Green leaf desmodium	Phalaris
	Sesbania	Axillaris	Setaria
	Pigeon pea	White clover	
		Vetch	
		Alfalfa	
>2400m	Tree lucerne	White clover	Phalaris
		Vetch	
		Maku lotus	
		Alfalfa	

Source:[Mengistu, 2002]

iv. Over sowing common grazing areas

Over-sowing involves introducing improved forage species into existing grazing lands without any cultivation or other inputs. This makes it a low-cost strategy suitable for resource-limited settings.Over-sowing is particularly effective with legume species characterized by rapid growth and prolific seeding, enabling them to establish quickly and spread naturally. Examples include Vetch, Stylosanthes guianesis, and Desmodium silver leaf. From grass species Rhodes grass is the most promising species for this strategy. Because of the low input nature of this strategy, incremental forage yields are not large but pioneer species with good grazing tolerance and natural seeding ability gradually colonize common areas and improve the overall species composition available for grazing[Mengistu, 2002].

v. Stock exclusion areas or forage banks

Stock exclusion areas are an important means of protecting degraded areas, key watersheds and common land. They also provide an opportunity to develop forage banks for use during droughts or periods of seasonal forage shortage. The introduction of browse species, productive legumes and improved grasses can rapidly increase the productivity of exclusion areas. Key species for stock exclusion areas in different agro-ecologies of Ethiopia are summarized in the following table. Forage banks should be established at the beginning of the wet season. Stylosanthes hamata and S. guianesis are particularly suitable for forage banks[Mengistu, 2002].

Table 9: key forage species suitable for stock exclusion areas

Altitude	**Browse legume**	**Herbaceous legume**	**Grasses**
<2000m	Leucaena	Siratro	Plicatulum
	Sesbania	Axillaris	Setaria
		Silver leaf desmodium	Buffel Grass
		Green leaf desmodium	
		Cook stylo	
		Wynn cassia	
		Seca stylo	
		Verano stylo	
2000–2400m	Tree lucerne	Green leaf desmodium	Phalaris
	Sesbania	Axillaris	Setaria
	Leucaena	White clover	
		Seca stylo	
		Verano stylo	
		Siratro	
>2400m	Tree lucerne	White clover	Phalaris
		Vetch	
		Maku lotus	

Source: Alemayehu M., 2002

vi. Agroforestry

Agroforestry is the deliberate combination of trees with crop plantation or pastures, or both in an integrated and sustainable farming system to optimize the use of accessible resources. This aspect is predominantly important for farmers with limited land. Many of the forage production strategies can be developed as agroforestry systems. In particular contour forage banks and under sowing of tree crops or forest plantations can be designed as agroforestry systems where leguminous browse species provide an upper storey in a forage system or under sown legumes and grasses provide an under storey in a forestry or horticultural system. Because many agroforestry strategies include leguminous species, they are also attractive to farmers facing problems of declining soil productivity. To get comprehensive benefit and to keep the ecological balance and natural resources/soil, water, livestock, native forests and their products[Mengistu, 2002].

vii. Forage development on marginal lands

Forage can be developed on marginal lands that are not suitable for crop cultivation. Mostly both extremes of topography — steep slopes and bottomland are not suited for normal crop production and can be considered for forage production. Forage can be produced on sloping land features like gullies, escarpments and peak lands by employing strategies potentially applicable in these areas.

4.2.2 Forage conservation

The supply of feed fluctuates in most parts of the tropics including in Ethiopia. Preserving surplus feed in the wet season for use in the dry season is one method of making the supply of feed to livestock more evenly distributed throughout the year. Any surplus forage should be conserved for use during the dry season when feed supply is scarce and feed quality is poor. Hay-and silage-making are two main methods of preserving forages.

i. Hay making

Hay making turns green, perishable, forage into a product that can be safely stored and easily transported without danger of spoilage, while keeping losses of dry matter and nutrients to a minimum. This involves reducing its moisture content from 70 - 90 percent to 20 - 25 percent or less. Drying should be done as quickly as possible to minimize losses. At mowing, the herbage will contain between 70 and 90 percent of moisture, and this will have to be reduced to between 12 and 20 percent before the hay can be stored safely. All activities in haymaking must be done on time, from mowing, through turning, to windrowing and baling or stacking, otherwise the crop will spoil. Crops with thin stems and more leaves are better suited for haymaking as they dry faster than those with thick, pity stem and small leaves. These may include, among others: grass, Oats, Desmodium, Alfalfa Napier grass.

ii. Silage making

Silage making is an effective method of forage preservation. Silage could be prepared from maize, sorghum, napier grass etc. Crops are harvested around at 50 percent flowering stage, chopped, wilted to reduce the moisture content to 65-70 percent and put in a silo pit maintaining anaerobic condition for around 2 months. Silage can be fed at 5kg per animal at beginning for adjustment and then can be fed like green fodder later. This means that silage could be used as substituent of green grass in the lean period but it is better to feed green grasses during period of availability.

Materials and steps to make silage

Materials needed

- Forage crops: Maize, sorghum, or Napier grass.
- Tools: Machetes, choppers, or manual chaff cutters.
- Silo types: Pit silo, plastic bags.
- Cover materials: Plastic sheets
- Additives like molasses for fermentation(optional)

Technical Steps Step 1: Choose the Right Forage Crop

- Ideal crops: Maize, sorghum, Napier grass.
- Harvest at the at 50 percent flowering stage or when grains are in the milky stage.
- For Ethiopian conditions, maize and sorghum are common due to high yield and adaptability

Step 2: Harvest and Chop

- Harvest the forage at the correct stage for maximum nutrition (at 50
- Chop into small pieces (2–3 cm) to ensure compactness and proper fermentation

Step 3: Fill and Compact

- Dig a pit silo or use a trench silo lined with plastic sheets
- Above-ground silos can also be used, especially in areas with poor drainage
- For smallholders, large plastic bags are an effective alternative
- Spread the chopped forage in layers (10–15 cm thick).
- Compact each layer using feet or heavy objects to remove air pockets
- Add molasses or water if the crop is too dry

Calculate Silo Volume: To find the silo volume, use the formula:

$$Volume(m3) = \frac{Totalsilage(kg)}{Density(kg/m3)}$$

Example: If we want to store 45,000kg silage with 600 kg/m3

$$Volume(m3) = \frac{45,000}{600} = 75m3$$

Table 10: The density of different Silage crops

Forage crop	Silage density (kg/m^3)	Key factors
Maize Silage	650–750	High density due to high moisture and starch content
Sorghum Silage	600–700	Slightly lower density than maize; ideal for areas with dry climates
Napier Grass Silage	500–650	Lower density due to higher fiber content; requires better chopping and compaction

Step 4: Seal and Cover

- Cover the forage with a plastic sheet
- Seal the edges with soil, stones, or weights to ensure airtight conditions.
- Ensure no air enters the silo to allow proper fermentation.

Step 5: Fermentation Process and using

- Allow the silage to ferment for 2–3 weeks.
- In cooler Ethiopian highlands, fermentation may take longer (4–6 weeks).
- Open the silo only when needed.
- Remove just enough silage for daily feeding.
- Reseal the silo immediately to prevent spoilage

4.2.3 Contribution of Forage production and conservation to CSA pillars

i. Productivity:

- improves livestock productivity through increased forage availability and quality

ii. Adaptation

- Forage production and conservation ensures the availability of forage thought the year and this adds to resilience of livestock to drought.
- Forage legumes can improve soil fertility when integrated with food crops

iii. Mitigation

- Forage crops traps atmospheric carbon through photosynthesis
- Legume forages can reduce NO2 by reducing nitrogen fertilizer application crop field and CO2 in manufacturing process of fertilizer
- Tanning containing forage legumes can reduce enteric methane emission

4.3 Feed quality improvement

Feed quality has an important impact on methane production, as it can alter the rumen fermentation pattern. In mixed farming areas crop residues can constitute large portion of the ration of ruminants. While these feed resources provide cheap feed source, they are usually of low digestibility and deficient in crude protein, minerals and vitamins. This low digestibility substantially limits productivity and increases CH4 emissions. Increasing the digestibility of feed rations by improving the quality of crop residues, or supplementing diets with concentrates will reduce CH4 emissions. Improving the quality of feed is an effective way to get better animal performance and reduced rumen methane production.

Crop Residue Treatment using Urea

- Urea treatment is a cost-effective method to enhance the nutritional value of crop residues.
- Low-quality residues such as teff straw, maize stover, barley, wheat straw are commonly treated with urea to improve digestibility and protein content.
- Increased Protein Content: Urea boosts the nitrogen content of residues.
- Improved Digestibility: Urea breaks down lignin and cellulose, improving feed quality.
- Enhanced Palatability: Animals find treated residues more palatable.
- Cost-Effective: A simple, affordable method for improving livestock feed.

Step-by-Step Process

- Prepare the Urea Solution: Dissolve 4 kg of urea in 100 liters of water. We can add 3-5kg of molasses if available
- Spread Crop Residue: Layer 10–15 cm of crop residue. Chopp the residue if needed
- Apply the Solution: Evenly distribute the urea-water mixture.
- Compact the Layers in the silo: Press down to remove air.

  Bag Silo: Plastic bags used for small-scale treatments Plastic bag with 1.5m and 1.5m height can accommodate 50-200kg crop residue

  Volume of silo= 2m* 1m*1m (can hold 150-250 kg straw)
- Seal and Ferment: Cover with plastic and seal airtight for 2-3 weeks.Keep the silo airtight to preserve nutrients and prevent spoilage.

Practical Tips for Successful Treatment

- Do not use urea above the recommended level.
- Ensure proper compaction for anaerobic conditions.
- Seal the silo tightly to maintain fermentation quality.
- Avoid over-wetting to prevent mold.
- Gradually introduce treated residue into livestock's diet.
- Urea treated straw is not recommended for monogastric, young and pregnant animals

Contribution of quality improved feed to CSA pillars

i. **Productivity**: Productivity of the animas can be unquestionably increase when fed with better quality feed

ii. **Adaptation benefits**: Better feeding can enable the animals to resist diseases and harsh environment

iii. **Mitigation benefits**: Grinding and pelleting of roughages can decrease methane production by improving passage rate supplementation of roughage feed with concentrate can reduce enteric methane production by improving digestibility, fevoring propionic acid production.

4.4 Feeding management

i. Adopting cut-and-carry feeding system:

The cut and carry system of livestock feeding is a sustainable and climate-smart practice that can significantly enhance the efficiency and productivity of livestock farming. This method involves cutting forage or fodder and carrying it to animals, rather than allowing them to graze freely. By adopting this system, farmers can address several environmental and agricultural challenges while ensuring better nutrition for their livestock. One of the primary advantages of the cut and carry system is its potential to prevent overgrazing. By controlling the amount of fodder given to livestock, farmers can protect pastures from being depleted, which helps maintain soil health and prevent erosion. By optimizing the diet of livestock, the cut and carry system can reduce methane emissions, a potent greenhouse gas, from ruminants. Better nutrition improves digestion and reduces enteric fermentation, thus lowering the environmental impact of livestock farming.

ii. Precision feeding

Depending upon the production cycle of animals, nutrient requirement differs. Precision feeding refers to matching the dietary requirement with the dietary supply of the nutrients. Accurate estimation of the nutrient requirement of an animal and supply of the same amount through accurate feed analysis not only helps maximize production but also to minimize feed wastage and GHGs emission per unit of product and per head of animal. The nutrient requirement of a lactating animal at the stage of peak production is different from that of the dry period. Thus, providing the right amount of nutrient to the right animal at right time helps maintain a healthy rumen and maximize microbial protein synthesis which indirectly maximizes feed efficiency and decreases methane emission.

Nutrient requirement of dairy cows

1. **Maintenance requirements**: Adult cow, which is not producing still, needs nutrients to survive (Required for respiration, blood circulation, maintaining the body temperature, etc. and also for movement.)

Table 11: Maintenance nutrient requirements of Dairy Cows

BODY WEIGHT	PROTEIN G CP	TDN (G)	ME MJ
200	233	1900	34.5
250	256	2200	38.7
300	276	2500	42.9
350	299	2800	47.2
400	321	3100	51.4
450	344	3400	55.7

2. **Production requirements**:

- When a cow is producing (giving milk), extra nutrients are needed above the maintenance level.
- Feed requirements of lactating dairy cattle vary according to their production stages

Table 12: Production nutrient requirements of Dairy Cows

% FAT IN THE MILK	PROTEIN (G CP)	TDN (G)	ME MJ
2.5	72	255	4.19
3.0	78	280	4.53
3.5	84	305	4.87
4.0	90	320	5.21
4.5	96	340	5.55
5.0	102	365	5.89

Table 13: Concentrate feeding guide for lactating Dairy Cows

Milk Yield (L/day)	With green pasture	With first grade hay	With second grade hay	With crop residue
5	1.4 kg	1.5kg	2 kg	2.5 kg
7	2 kg	2.3 kg	2.8 kg	3.5 kg
10	2.8 kg	3.3 kg	3.5 kg	5 kg
12	3.4 kg	4 kg	4.5 kg	6 kg
15	4.3 kg	5 kg	5.4 kg	7.5 kg
17	5.1 kg	6 kg	7.7 kg	9 kg
20	5.7 kg	6.7 kg	9.7 kg	10 kg

iii. Grazing Management

Grazing management plays a critical role in promoting environmental resilience and climate change mitigation. Sustainable grazing management practices like rotational grazing, adjusting stocking densities to feed yield can reduce grazing pressure, enhance carbon sequestration and helps to rehabilitate poor land and stops degradation.

Participatory Grazing Land Management

Participatory Grazing Land Management (PGLM) is community-driven approach to manage grazing lands sustainably. It balances ecological health and livelihoods. It is vital for pastoral and agro-pastoral communities to sustainably utilize the grazing land.

Steps to Implement Participatory grazing management

Step 1: Situation Assessment

- Conduct baseline studies: rangeland conditions, livestock populations.
- Map stakeholders: pastoralists, farmers, local authorities, NGOs.

- Identify existing traditional grazing systems and challenges.

Step 2:Community Awareness and Mobilization

- Build trust and promote dialogue.
- Organize meetings to discuss sustainable grazing benefits.
- Share knowledge on overgrazing and climate impacts.

Step 3:Participatory Resource Mapping

- Collaborate to map Grazing lands,Water points, Migration routes etc
- Determine the carrying capacity of the grazing land
- Use local knowledge and GIS tools.

Step 4:Developing Grazing Management Plans

- Create community-driven plans on
  - Rotational grazing systems
  - Species-specific grazing zones
  - Grazing schedules
  - Over-sowing
  - Bush clearing
  - Fire protection etc
- Ensure community approval.

Step 5: Establishing Rules and Agreements

- Develop bylaws on grazing limits and penalties
- Formalize agreements for cross-boundary grazing.
- Establish community-based resolution committees.
- Align customary laws with national policies.

Step 6: Capacity Building

- Train on livestock management, sustainable grazing techniques and ecosystem monitoring
- Promote alternative livelihoods (fodder production, market-oriented livestock production)

Step 7:Implementing Grazing Systems

- Enforce and assist the community to:
  - adjust the stocking rate based on the carrying capacity of the grazing land
  - use rotational grazing system and decide on resting period of each paddocks.
  - to implement other planned management activities.
  - Use dialogue and mediation to address disputes.
- Combine customary and formal resolution systems

Monitoring and Evaluation

- Conduct regular assessments of Vegetation health, Water availability and Livestock productivity
- Adapt plans based on findings.
- Involve the community in tracking progress

Key Considerations

- Climate Variability/change: Use drought-tolerant forage species.
- Land Tenure: Clarify communal land ownership.
- Inclusion: Ensure participation of women and youth

Contribution of feeding management to CSA pillars

i. Productivity

- Grazing management can increase livestock performance by improving grassland productivity
- Cut and carry feeding system can improve productivity the animals ,since the animal movement is limited and energy is saved. The forage is utilized at right maturity stage and this contribute for better productivity of the animals
- Precision feeding maximize production but also to minimize feed wastage and GHGs emission per unit of product and per head of animal

ii. Adaptation benefit

- Cut and carry feeding and grazing management can contribute to enhancement of environmental resilience by avoiding land degradation (soil erosion, biodiversity loss)

iii. Mitigation benefit

- Enteric emission intensities can be lowered, because with less grazing pressure and animals have a wider choice of forage, and tend to select more nutritious forage
- Soil carbon sequestration that results when grazing pressure is reduced as a means of stopping land degradation or rehabilitating degraded lands.
- Precision feeding maximize production but also to minimize feed wastage and GHGs emission per unit of product and per head of animal
- In cut and carry feeding ,the excreta can be managed properly and utilized for compost making or biogas production which can reduce CH4 and NO2 emission.

4.5 Destocking and switching to low emitting animal species

Destocking refers to the practice of reducing the number of livestock. This approach aims to alleviate the pressure on natural resources, such as water and grazing land, while also decreasing greenhouse gas emissions associated with livestock farming. In addition to destocking, transitioning to animal species that produce fewer emissions is another effective climate-smart practice. Certain species emit less methane and require fewer resources, making them more sustainable options for farmers. In particular, small ruminants like sheep and goats are better adapted to hotter environments when compared to cattle, and have a better ability to survive, produce, and reproduce in harsh climatic regions, particularly those experiencing climate change. Low-emitting animals (poultry, sheep, goat and fishery) are high feed converters and low GHG emitters as compared to large ruminants (including cattle and camels). These animals are high protein suppliers as well as high sources of income for the rural population.

- compared to cattle, small ruminants have smaller impact on soil erosion because of their lighter weight
- the pressure on grazing area is less with small ruminants than with cattle
- small ruminants can graze/browse in areas where cattle can't even reach
- CH4 emissions can be reduced due to reduction in population of large ruminants
- NO2 emission from manure left is reduced as the small ruminants leave less manure on the grazed area than cattle

4.6 Climate smart livestock breeds and breeding

In response of climate change challenges to livestock sector, the adoption of climate-smart livestock breeds and breeding practices has become a priority to ensure sustainable livestock production and enhance resilience to climate variability. Animal breeding to select more productive animals is strategy to enhance productivity and thereby lower CH4 emission intensities. 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, become more common with climate change. Feed efficiency can be increased by developing breeds that grow faster, are hardier, gain weight more quickly, or produce more milk. Breeding indices should include traits associated with thermal tolerance, low quality feed and disease resistance, and give more consideration of genotype-by-environment interactions to identify animals most adapted to specific conditions.

4.6.1 Breeding strategies

To develop and promote climate-smart livestock, Ethiopia employs various breeding strategies:

- **Selective breeding**: This involves selecting animals with desirable traits and breeding them to enhance these qualities in future generations. Indigenous breeds are often more resilient to climate stressors compared to exotic breeds. They are better adapted to high temperatures, high solar radiation, and dry conditions than exotic breeds due to their physical and morphological characteristics, which allow them to successfully regulate their body temperature. The focus is on identifying and promoting these indigenous breeds based on their adaptive traits.
- **Cross breeding**: Crossbreeding combines the strengths of indigenous breeds with the productivity traits of exotic breeds. This approach aims to produce animals that not only have enhanced productivity but also retain the resilience traits of local breeds. Careful selection and management are essential to ensure that the beneficial traits are maintained.
- **Community-based breeding programs**: These programs involve local communities in the breeding process, ensuring that the breeds developed are suited to the specific needs and conditions of the area. Engaging communities increases the adoption rates and ensures the sustainability of breeding efforts. Farmers are trained to improve selection methods (for instance by retaining fast-growing ram lambs for breeding, rather than selling them), community flocks are pooled to enlarge the gene pool from which breeding sires can be selected, and a recording system monitors the performance of individual animals, leading to continuous genetic improvement.

4.6.2 Ethiopian Livestock breeds

Ethiopia, with its diverse climates and varied ecosystems, is home to numerous livestock breeds adapted to specific environmental conditions.

iv. Cattle breeds

Although the country's cattle genetic resources have not been fully characterized, 28 indigenous cattle breeds have been identified in Ethiopia [Hunde and Tadese, 2020]. Ninety-eight percent of cattle breeds in the country are indigenous breed. The following are some of the notable cattle breeds found in the country having various economically and environmentally important traits.

- **Boran cattle**: The Boran cattle, native to Ethiopia, are well-known for their ability to withstand harsh climates and poor forage conditions. They are popular cattle breed, predominantly utilized for milk and meat and widely distributed across various countries of Africa. They are best feed converter, have long distance walking ability, drought and disease resistance, reasonable conception, excellent mothering ability, well developed herd instinct, more docile and heat tolerance, longevity.
- **Fogera breed**: This breed has superior quality traits, including greater milk production, drought tolerance, and a better growth rate. Adaptive to seasonal flooding and the swampy conditions of the area. Tolerate tick and flies bitts relatively better than other breed in surrounding.
- **Horro breed**: It is distributed in Horro Gudru, Western Shewa, and adjoining areas. The breed is kept for draught power, Meat and milk purpose. It is adaptive in to humid and wetter agricultural area.
- **Sheko breed**: Sheko cattle breed represents the last remnants of Africa's original Bos taurus (humpless shorthorn) cattle which were probably the first to be domesticated in eastern Africa. The breed is found in southwest of the Ethiopia and it is kept for milk, meat, draught power and known by its trypanotolerance. Sheko cattle have better feed conversion efficiency, longevity, and fertility good mothering ability compared to other cattle breeds in adjacent areas.
- **Holstein Friesian**: Holstein Friesian cows produce the highest amount of milk. They can adapt to a wide range of climates.
- **Crossbred cattle**: Crossbred cows with 50 to 75 percent Friesian blood produce more milk than local breeds. However, reproductive performance decreases as the level of exotic blood exceeds 50percent.

v. Sheep and Goat breeds

From small ruminant livestock category, nine sheep and eight goat breeds have been identified in the country. Indigenous breeds of sheep and goats have been selected over the years based on their hardiness and ability to survive in harsh conditions. These animals are considered to be well adapted to the climate and environment of Ethiopia and their meat is of high quality. The following are some of the indigenous sheep and goat breeds naturally possessing some climate-smart traits. These include:

- **Afar sheep**: Afar sheep is a small sized breed (30–35 kg) found in Middle Awash Valley of eastern Ethiopia, extending as far as Dire Dawa in the east and the town of Bati in the north. They are hardy and tolerate periods of drought relatively well as the breed evolved under harsh environmental conditions.
- **Blackhead Somali sheep**: The Blackhead Somali is indigenous to the Ogaden area of the Somali Region. The breed is also known by various names in eastern Africa. The Blackhead Somali is distinguished by the black color of the head. They are hardy and well adapted to the dry, drought-prone environments.
- **Horro sheep**: The natural habitats of Horro sheep are the western and southwestern parts of the country. They are widely distributed in areas covering western Shoa to East and West Wollega, Illubabor and Jimma zones of Oromia Region. Horro sheep are larger than most other indigenous sheep and more more prolific. .
- **Bonga sheep**: The Bonga sheep is a distinctive and valuable breed indigenous to Ethiopia, particularly prevalent in the south-western region of the country. They are a large, well-known breed of sheep in Ethiopia that are known for their long, fat tails and high-quality meat. One of the most notable traits of Bonga sheep is their adaptability to diverse environmental conditions. This breed can thrive in both highland and midland areas, demonstrating resistance to common diseases and parasites. Their ability to graze on a variety of forages makes them an ideal choice for sustainable sheep farming in Ethiopia. The breed is known for its quality and flavor meat.

- **Afar Goats**: The Afar goat is found in Afar Region and eastern and western Hararghe zones of the Oromia Region. Its distribution extends to the Afar area of Eritrea and northern Djibouti. Afar goats are well adapted to arid environments where they are watered every three or four days. These goats are hardy and used to long distance trekking in search of feed and water.
- **Somali goats**: The Somali goats are widely distributed in northern, lowlands of Bale and Borana zones of Oromia and in some parts of Sidama Region. They are reared for meat, milk, various social affairs and skin production. This goat breed is known for its drought resistance and ability to travel long distances in search of food and water.
- **Western Lowland goats**: The Western Lowland goat is a distinct breed found predominantly in the lowland regions of western Ethiopia (Metekel, Assosa and Gambela). These goats are well-suited to the hot and often arid climates typical of the region, showcasing remarkable resilience and adaptability. Their ability to withstand high temperatures and their efficient browsing habits make them ideal for the lowland areas. They are primarily raised for meat, milk and skin.
- **Arsi-Bale goats**: The Arsi-Bale goats are widely distributed covering the whole of Arsi, Bale and western Hararghe zones of the Oromia Region, and the high-altitude areas of Sidama Region. Arsi-Bale goats are also found in most areas of the Rift Valley from Lake Abaya to south Shoa Zone. They are mostly kept in small flocks in mixed farming areas. The Arsi-Bale goat breed has developed unique characteristics that enable it to survive and thrive in the semi-arid and mountainous regions of Ethiopia. These goats are known for their heat tolerance, drought resistance and disease resistance.

4.7 Climate smart livestock Health management

Climate change poses significant challenges to livestock health, impacting their productivity and welfare. Livestock health management is a key strategy to build up their adaptive capacity to climate change impacts and boost their productivity. Feed efficiency can be increased by improving herd health through better veterinary services, preventive health programmes(vaccines) and improved water quality. Reducing the prevalence of common diseases and parasites would generally reduce emissions intensity as healthier animals are more productive, and thus produce lower emissions per unit of output. Better nutrition, improved animal husbandry, the regular maintenance of animal health and the responsible use of antibiotics can improve reproduction rates, reduce mortality and reduce the slaughter age. All of these measures will therefore increase the amount of output produced for a given level of emissions. To combat the impact of climate change on livestock diseases and vectors, several strategies can be implemented:

- **Vaccination Programs**: Expanding vaccination coverage can protect livestock from prevalent diseases, mitigating the impact of outbreaks.
- **Improved Surveillance and Monitoring**: Establishing robust systems for tracking disease outbreaks and vector populations can help in early detection and response.
- **Nutritional management**: Effective nutritional management is crucial for maintaining the health and productivity of livestock. Good nutritional management can help prevent diseases and improve the immune response of livestock. A well-balanced diet strengthens the immune system, making animals less susceptible to infections and illnesses.
- **Adaptive Breeding**: Breeding programs that focus on developing heat-tolerant and disease-resistant livestock breeds are crucial in a changing climate. These breeds are better equipped to thrive in varying environmental conditions
- **Improved Animal Housing**: providing adequate shelter can protect livestock from extreme weather conditions. Well-designed housing can shield animals from heat and cold stress, thereby maintaining their health and productivity.
- **Research and Education**: Investing in research to understand the link between climate change and livestock diseases, and educating farmers on adaptive practices can enhance resilience.

4.8 Climate smart livestock housing and stock management

Climate-smart housing with the provision of proper drinking and feeding facilities is required for intensive livestock farming to cope with very hot and cold climatic conditions. Good housing with proper design, height,

and orientation and with good open space for ventilation and comfortable space per animal can provide a cooler microenvironment inside the house. In Ethiopia, extreme heat is a major characteristic of some zones while others experience cold temperatures. Each situation has its own requirements for the design and construction of optimum animal housing. The general requirements of good livestock housing are:

- good animal housing is that it should alter or modify the environment for the benefit of animals and buffer the animal from climate extremes to reduce stress allowing optimal animal performance in terms of growth, health and reproduction.
- The main climatic factors from which protection is needed are high and low ambient temperatures, environmental humidity, solar radiation, wind and rain.
- Houses are important in protecting feed and equipment from damage, in saving labor, and in helping to manage effectively, including breeding.
- The housing should meet animal requirements and serve a producer's needs at the lowest possible cost
- The houses need to be strong enough to last a long time; be large enough for the number of animals to be accommodated comfortably, allow freedom of movement for all animals; be well-drained or have well-maintained dry bedding and easy to clean.
- Should be designed in way that allow sun shines evenly. Here, the orientation of the shed can be important depending on the climate. One can prevent the sun from heating up the stall too much by placing the longitudinal axis of the stall east - west. If, on the other hand, one wants the sun to shine on the floor so that the floor dries up and parasites die, it is better to build the shed along a north – south axis (This is preferred in humid areas)
- Be well lighted and ventilated for air circulation and removals of dust gases. It is necessary to make the shed sufficiently high and make sure there are openings for ventilation in the roof or walls. It is essential to note that ventilation is good, but draughts are bad! The ventilation openings must, therefore, be placed high enough so that air does not blow directly past the animals (draught).
- Have suitable isolation pens for sick or injured animals as far away from the main house as much as possible
- It should be built only on well-drained area

4.9 Improving market efficiency and off-take rates at early ages

Strengthening livestock marketing is one of climate smart practices under livestock production with positive mitigation in supporting faster turnover of marketable animals. Improved marketing can increase the productivity of the households' livestock-keeping activities. Promoting the sale of animals when they are young reduces environmental degradation and the amount of GHG emitted by unnecessary stay of the animals on farm.

4.10 Manure management

Livestock manure is one of the main sources to GHG emissions in agriculture. Gas emission and leaching of nutrients, organic matter and odor from manure have undesirable effects on the environment. Efficient treatment of manure through biogas technology can reduce its methane emissions. The biogas technology, in one hand generates energy from manure, and on the other hand mitigates GHGs emission via substituting the firewood, kerosene and different chemical fertilizers. Anaerobic digestion of manure stored as a liquid or slurry can lower methane emissions and produce useful energy (e.g. biogas), while composting solid manures can lower emissions and produce useful organic amendments for soils. The captured CH4 can be flared or used as a source of energy for electric generators, heating or lighting. Energy generated in this way can offset CO2 emissions from burning fossil fuels.

4.10.1 Contribution of manure management to CSA pillars

i. **Productivity**: Contribute to improve crop productivity though improving soil fertility if used for compost making

ii. **Adaptation**: soil fertility improved and maintained

iii. **Mitigation benefit**: Biogas can reduce methane emissions. It also reduces NO2 and CO2 by reducing amount

5 Supporting Policies in Climate Smart Livestock Production

To make agricultural systems climate-smart requires actions at different levels of policies, institutions, investments and practices. Ethiopia has a number of policies and programs to support climate-smart agriculture. The followings are some of the supportive policies related to livestock production.

i. **National Determined Contribution (NDC)**[FDRE, 2021]: Ethiopia's NDC includes a commitment to reduce livestock greenhouse gas emissions by 7.6 percent by 2030. It also includes adaptation measures and gender considerations.

ii. **CRGE Strategy**[FDRE, 2011]: The Climate Resilient Green Economy (CRGE) Strategy is Ethiopia's ambitious plan to build a climate-resilient and green economy by 2025. This strategy builds on Ethiopia's NDC commitments by promoting sustainable grazing practices, improved animal husbandry, and efficient feed management.

iii. **Climate-smart agriculture investment plan**[Tesfaye et al., 2024]: This plan includes investments such as:

- Improving animal breeding and health management
- Improving forage production, management, and utilization
- Promoting dairy and poultry value chain efficiency

iv. **Growth and Transformation Plan (GTP II)**[ENPC, 2015]: The Growth and Transformation Plan (GTP) serves as a roadmap for Ethiopia's economic development, with a strong focus on agricultural transformation. In terms of livestock production, the GTP emphasizes on:

- Increasing the productivity of livestock through improved breeds, better veterinary services, and efficient feeding practices.
- Enhancing market access for livestock products, thereby improving the livelihoods of smallholder farmers.
- Investing in infrastructure to support livestock production, such as water supply systems and transportation networks.

v. **National policy and strategy on disaster risk management**[FDRE, 2013]: This framework for disaster risk management includes early warning and risk assessment, information management, capacity building, and disaster risk reduction integration into development plans. It is primarily concerned with droughts.

vi. **Agriculture Sector Programme of Plan on Adaptation to Climate Change**: It is the Agriculture Sector Climate Change Adaptation Plan[FDRE, 2011].

vii. **National Adaptation Plan (NAP)**[FDRE, 2017]: Ethiopia's National Adaptation Plan (NAP) is a critical policy framework that outlines strategies for adapting to climate change across various sectors, including livestock. For livestock sub sector, this policy frame work aims to:

- improve the resilience of livestock systems to climate change impacts, such as droughts and extreme weather events.
- sustainable grazing practices and better management of pasture lands to reduce overgrazing and land degradation.
- encouraging research on climate-resilient livestock breeds and feed resources

6 Climate Smart Indigenous Knowledge in Livestock Production

Local values, institutions and knowledge have enabled people to understand the happenings and changes in their environment. Local perceptions and knowledge provide a crucial foundation for community-based climate change adaptation measures and natural resource conservation. Indigenous knowledge systems of livestock care and health care is the only asset in the hands of the small holder farmers to mitigate the impact of climate change on livestock production. There are Some livestock production related existing indigenous knowledge [Amare and Gacheno, 2021];[Mekonnen et al., 2021] in Ethiopia:

- **Weather forecasting**: Indigenous people are good observers of changes in weather and climate. They have been using observations of tree phenology, animal behavior, astronomy, and moon movements to predict the climate, including the onset of rains and season quality.
- **Maintaining landscapes**: Traditional knowledge and institutions have maintained landscapes in Ethiopia for thousands of years, contributing to the diversity of crops and livestock breeds that help communities adapt to climate change
- **Ethnoveterinary medicine**: Ethnoveterinary methods are still used because they are affordable and readily available. Climate change has increased the number of livestock diseases, making ethnoveterinary medicine more relevant than ever.
- **keeping different species and breeds** of livestock which are selected and preferred for their production and adaptive traits.
- **Livestock breeding**: Pastoralists and agro-pastoralists have their own indigenous methods and knowledge of breeding systems of these breeds. Most of the smallholder farmers are accustomed to use pure breeding management by natural mating of selected bull within their own herd and/or with the neighborhood's herd.
- **Cut and carry feeding**: In mixed farming areas farmers have indigenous technical knowledge of harvesting of green feeds and stall feeding for fattening and preserving fodder for their livestock during time of feed shortage. These indigenous knowledges are importantly helped farmers to cope and adapt the impacts of climate change and variability
- **Improved grazing**: Even though, it's not well practiced improved grazing is one of traditional practice or techniques, which indigenous farmers' and pastoralists are used to feed their livestock and manage their environments.

The followings are the major barriers to integrate indigenous knowledge into development and technology transferring activities.

- Failure to recognize indigenous agricultural knowledge
- Improper documentation and communication of indigenous agricultural knowledge
- Modern technological advancements

Agricultural extension should be based on indigenous knowledge of local communities because it can lead to more effective and sustainable development. Local perceptions and knowledge provide a crucial foundation for community-based climate change adaptation measures and natural resource conservation. Integrating indigenous knowledge into development activities can lead to mutual learning and adaptation, which can strengthen local communities. Here are some general principles for using indigenous knowledge in agricultural extension:

- Collaborate: Work with indigenous knowledge holders and communities
- Get consent: Seek consent before considering Indigenous knowledge.
- Value local knowledge: Increase the value of local knowledge, especially among national governments and extension agencies.
- Use a flexible approach: Have a realistic and flexible view of local knowledge.
- Combine local and research knowledge: Use a combination of local and research knowledge in a participatory process.

- Start where people are: Base extension on the level of understanding, knowledge, interest, and readiness of the people.
- Relate new ideas to what people already know: Make sure new ideas relate to what the people already know and are familiar with.

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Annex

1. **Glossary of key Terms**

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects (IPCC)

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC).

Anaerobic digestion: The breakdown of organic matter by microorganisms in an oxygen-free environment. Animal Husbandry: The science and practice of breeding, raising, and caring for livestock.

Biogas technology: The process of using anaerobic digestion to break down organic matter, such as manure, in the absence of oxygen, producing biogas (a mixture of methane and carbon dioxide) and digestate (a nutrient-rich fertilizer).

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.

Climate Services: Information and tools that help farmers adapt to climate change and variability. Climate: Climate is the average weather conditions for a particular location over a long period of time, ranging from months to thousands or millions of years.

Climate-Smart Agriculture: Agricultural practices that sustainably increase productivity, enhance resilience (adaptation), reduce greenhouse gas emissions (mitigation), and enhance achievement of national food security and development goals.

Composting: A controlled process of decomposing organic matter, such as manure, using microorganisms in the presence of oxygen, resulting in a stable, nutrient-rich material.

Contour Forage Strips: Strategically planted bands of grasses and legumes that follow contour lines to reduce erosion and provide fodder or expected climatic stimuli and their effects or impacts.

Destocking: Reducing the number of livestock to alleviate pressure on resources and lower emissions.

Digestibility: The extent to which a feed can be broken down and absorbed by an animal's digestive system. Diversified production systems: Agricultural systems that incorporate a variety of crops or livestock, reducing risk and enhancing sustainability.

Drought: A prolonged period of abnormally low rainfall, leading to a shortage of water.

Economic resilience: The ability of an economic system to withstand and recover from shocks and stresses. Ecosystem services: The benefits humans receive from ecosystems, such as clean air and water, pollination, and climate regulation.

Enteric methane: A greenhouse gas produced by the digestive processes of livestock, primarily in the rumen.

Ethnoveterinary: Traditional animal healthcare practices based on local knowledge and resources, often using plants, minerals, and cultural techniques.

Extreme climate event: Extreme events are occurrences of unusually severe weather or climate conditions that can cause devastating impacts on communities and agricultural and natural ecosystems. Weather-related extreme events are often short-lived and include heat waves, freezes, heavy downpours, tornadoes, tropical cyclones and floods.

Food security: The state where all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and preferences for an active and healthy life.

Forage Banks: Protected areas used for growing and stockpiling fodder, particularly for dry seasons. Forage: Forages are plants or parts of plants eaten by livestock (cows, horses, sheep, goats) and wildlife

Genetic diversity: The variety of genes within a species or population, which is essential for adaptation and resilience.

Greenhouse gas (GHG): Gases in the atmosphere that trap heat and contribute to global warming. The primary GHGs are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases.

Hay: Hay is grass, legumes, or other herbaceous plants that have been harvested, dried and stored to be utilized

for ruminant animal feeding

Indigenous knowledge: Refers to understandings, skills, and philosophies developed by local communities with long histories and experiences of interaction with their natural surroundings

Intensive livestock farming: A high-input, high-output farming system that aims to maximize production per unit of land and labor, often involving confined housing and controlled feeding.

Manure management: Practices for handling, storing, treating, and utilizing animal manure to minimize environmental impacts and maximize its potential benefits. Marginal Lands: Lands unsuitable for conventional crop production.

Market efficiency: The degree to which market prices reflect all available information and resources are allocated efficiently.

Mitigation: Actions taken to reduce or prevent the negative impacts of climate change, such as reducing greenhouse gas emissions.

National Determined Contribution (NDC): A commitment made by each country under the Paris Agreement, outlining their actions to reduce greenhouse gas emissions and adapt to the impacts of climate change

Nutrient release: The process of making nutrients available to the animal through digestion and absorption. Off-take rate: The proportion of livestock sold or removed from a herd or flock over a specific period.

Overgrazing: Excessive grazing that damages vegetation and soil health.

Precision Feeding: Tailoring livestock diets to meet their specific nutritional requirements.

Resilience: The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

Resilience: The capacity of a system to absorb disturbances, reorganize, and retain its essential functions, identity, and structure.

Resource use efficiency: The ability to produce more goods and services with less input of resources, minimizing waste and environmental impact.

Risk management: The process of identifying, assessing, and mitigating potential threats to an organization or system.

Silage: Silage is a fermented feed resulting from the storage of high moisture crops under anaerobic conditions in a structure called as silo.

Sustainable Grazing Practices: Methods of livestock grazing that maintain or improve the health of the grasslands, prevent overgrazing, and contribute to carbon sequestration.

Thermoregulation: is the ability of the body to maintain its constant temperature.

Voluntary intake: The amount of feed an animal consume freely