Building farmers' capacity and knowledge for climate resilience in agribusiness: Eastern Province, Rwanda

A climate resilience handbook for farmers

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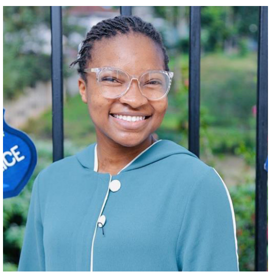

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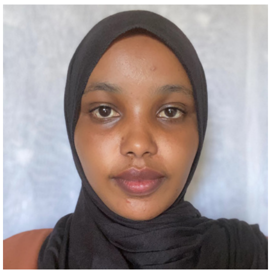

Dibo Duba is a researcher on resilience in dryland ecosystems at World Agroforestry (ICRAF). Her background in environmental conservation and climate change adaptation equips her with the knowledge and necessary skills to help develop mitigation measures and build resilience to climate change. She is part of a team currently implementing landscape and livelihood projects to combat climate change and is contributing to the TREPA project in Rwanda.

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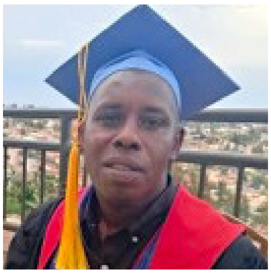


Executive summary

Climate change has had unprecedented effects on livelihoods and ecosystems, mostly in developing countries. Rwanda has experienced some years of below- and above-average precipitation, resulting in droughts and floods. Farmers have observed the delayed onset of rainfall, disrupting the agricultural calendar, while new pests and diseases threaten harvests and livelihoods. Among the four regions of Rwanda, the Eastern Province (EP) is categorized as the driest, and increased seasonal variability has exacerbated the vulnerability of EP constituents.

The aim of this handbook is to build farmers' knowledge and capacity for enhanced adaptive capacity through agricultural and tree-based value chains in the EP of Rwanda. The Green Climate Fund has provided financial resources to the Transforming Eastern Province through Adaptation (TREPA) project, whose aims include enhancing the climate resilience of agricultural value chains and commodities. Diversification and value addition are considered effective adaptation strategies to protect the most vulnerable population against climate shocks (Mulwa and Visser 2020). The most important climate shocks in the EP include droughts, floods, pests and diseases.

The project involved trainers of trainers (TOTs) as change agents. The ToTs were selected among farmers in the districts of Bugesera, Gatsibo, Kayonza, Kirehe, Ngoma, Nyagatare and Rwamagana. The training included both theoretical and field-based sessions and has been packaged into five (5) chapters in this handbook. The handbook commences with a brief introduction (Chapter 1) about increased seasonal variability and longer-term climate change, both of which are likely to worsen existing EP vulnerability to high levels of poverty and food insecurity (REMA 2015). Chapter 2 outlines climate change mitigation, adaptation and resilience measures as well as the role of nature-based solutions, such as agroforestry, in enhanced adaptive capacity. Chapter 3 discusses the building of resilience through beekeeping, which is a common livelihood practiced in the EP. The production system is mostly traditional, resulting in low productivity. Over 40% of the beekeepers have insufficient knowledge of beekeeping, thereby compromising their ability to contribute to livelihood diversification and increased resilience. The ToTs were taught about good beekeeping practices, value addition and tree-based forages, as well as the costs and benefits of traditional versus modern hives.

The co-learning aimed to enhance capacity and knowledge in the fodder value chain to promote fodder availability in the EP dairy sector. Farmers were trained on fodder production, harvesting, processing, storage and trading in times of scarcity, helping to diversify livelihoods. Chapters 4 and 5 outline the existing value chain's financial institutions as well as emerging opportunities, such as carbon trading and fodder enterprises.

The handbook provides some translated terms in Kinyarwanda – Rwanda's national language – to ease understanding among targeted users. It can be used to build the capacity of farmers to enhance climate resilience in agribusiness. The book therefore disseminates knowledge about existing agricultural and tree-based commodities, promoting sustainable agricultural production, beekeeping, fodder grass and trees as panaceas that support enhanced livelihoods, ecosystem restoration and carbon sequestration.

Chapter 1

Introduction

1.1 About the TREPA project

World Agroforestry (ICRAF) – in collaboration with the International Union for Conservation of Nature (IUCN), the Rwanda Ministry of Environment, the Rwanda Forestry Authority, the Belgian Development Agency (Enabel), World Vision and Cordaid International – is implementing the **Transforming Eastern Province through Adaptation** (TREPA) project in the Eastern Province of Rwanda[1] with the aim of shifting from degraded to resilient landscapes, and from fragile to sustainable livelihoods.

1 TREPA operates across all seven districts: Bugesera, Gatsibo, Kayonza, Kirehe, Ngoma, Nyagatare, Rwamagana.

Photo by Thomas Gakwavu/CIFOR-ICRAF

TREPA intends to increase the resilience of 75,000 smallholder farmers and restore 60,000 ha of degraded, drought-prone landscapes to promote climate-resilient ecosystems through agroforestry, soil-erosion control, reforestation, and the restoration of pastureland, including economic incentives to help develop the value chains of climate-resilient agricultural and tree products.

1.1.1 Why Eastern Province?

Rwanda's National Climate Change Vulnerability Index categorizes Eastern Province as the country's driest region, yet high levels of poverty and a low degree of development (REMA 2015) limit the capacity of poor households and communities to manage climate risk, thereby increasing their exposure to climate shocks. Greater seasonal variability and longer-term climate change are likely to worsen Eastern Province's existing vulnerability to high levels of poverty and food insecurity, while raising the likelihood of internal displacement and conflict along its borders (REMA 2015).

Food security and the agricultural sector's success are the primary concerns as most of Eastern Province's agriculture is rainfed and produced by smallholder farmers (Global Agriculture and Food Security Program, n.d.). The climate resilience training module was developed with the aim of building farmers' knowledge and capacity for climate resilience in agricultural and tree-based value chains in the EP of Rwanda.

1.1.2 Capacity-building approach

The project involved trainers of trainers (ToTs) as change agents in the dissemination of information to build climate resilience among farmers. Strengthening agribusiness value chains meant sharing knowledge on practices that can help farmers cope with climate change impacts – such as droughts and flooding – while boosting their capacity to implement practices that prevent such impacts from worsening.

We actively engaged the participants in discussions and created an open forum for feedback, questions and suggestions. This interactive approach was complemented by various training materials, farmer information briefs, peer-to-peer learning, experiential field-based visits and video presentations. The experiential and peer-to-peer learning focused on two value chains:

i. Beekeeping
ii. Fodder value chain

1.1.3 The seasonal patterns of Rwanda's regions

- Long rainy season: March–May; short rainy season: September–November
- Long dry season: June–August; short dry season: December to mid-February
- Rainfall variability will continue, with more intense rainfall events expected, leading to more flooding.
- Overall rainfall levels are expected to increase in western Rwanda and decrease in central and eastern Rwanda, with the semi-arid eastern region likely to suffer from more droughts.
- Climate adaptation must focus on coping with rainfall variability and the extreme events that result from more intense rainfall events (floods, landslips and landslides).

The annual rainfall and mean temperatures of each region are presented in Table 1.

Table 1. Ranges in precipitation and air temperature

Region	Annual rainfall (mm)	Mean air temperatures (°C)
Eastern plains	700–1,100	20–22
Central plateau	1,100–1,300	18–20
Highlands, including Congo-Nile Divide and the volcanic mountain chains of Virunga	1,300–1,600	10–18

Source: Rwanda Environment Management Authority

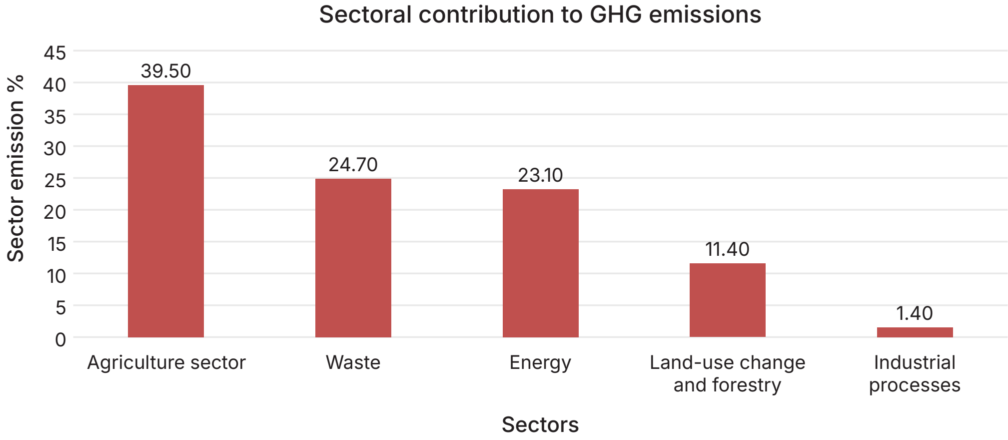


Figure 1. Rwandan sectoral contribution to GHG emissions (IMF 2022)

The training included an interactive session on the following topics:

1. Climate change indicators and effects in the Eastern Province
2. Climate change adaptation strategies for farmers in the Eastern Province
3. Knowledge and practice for building climate resilience in the beekeeping value chain
4. Knowledge and practice for building climate resilience in the fodder value chain
5. Agricultural and tree-based financing

1.2 Climate change

Climate change refers to any change in climate over time, whether due to natural variability or human forces (Minx et al. 2021)as agreed upon in the Paris Agreement, comprehensive and reliable information on anthropogenic sources of greenhouse gas emissions (GHG. Rwanda has experienced some years with below- and above-average precipitation, resulting in droughts and floods. Farmers have observed the delayed on-set of rainfall, disrupting the agricultural calendar, while new pests and diseases threaten harvests and livelihoods.

1.2.1 How do you know there is a change in climate?

- Climate is the average weather at a given point and time of year over a long period, typically 30 years (Minx et al. 2021)
- The weather (rainy, sunny, cloudy, windy) changes from day to day, but climate is more constant
- If the climate doesn't remain constant, we call it climate change (UN n.d.)
- Climate variability includes all variations in the climate that last longer than individual weather events (Minx et al. 2021)
- Climate change refers only to those variations that persist for a longer period, typically decades or more (Minx et al. 2021)

In Rwanda, climate change indicators are seen in **droughts, floods, landslides, windstorms and severe rainstorms.**[2]

Most Eastern Province farmers have experienced heavy agricultural losses due to prolonged droughts, more pests and diseases, and an increase in average precipitation, with shorter and more intense rainy seasons. Temperature increases have also been experienced across Rwanda (UNEP 2024).

1.2.2 Causes of climate change

Generally, climate drivers are both natural and anthropogenic (caused by humans). Figure 1 shows the sectoral contribution to greenhouse gas (GHG) emissions in Rwanda.

2 Read more here: https://gcos.wmo.int/en/global-climate-indicators


Land degradation caused by deforestation.
Source: CIFOR-ICRAF Flickr


Deforestation increases GHG emissions.
Source: Pixabay

Fossil-fuel-powered transportation.
Source: Pixabay


Conventional cookstove that utilizes more wood fuel than improved cookstoves.
Photo by Jane Mutune/CIFOR-ICRAF

Here are some of the climate change drivers that you may be familiar with:

a. Food production

Agriculture is the main livelihood activity in Eastern Province, pursued by 80% of its households. Food production causes emissions of carbon dioxide, methane and other greenhouse gases (Shabir et al. 2023) in various ways:

- Clearing of forests for agriculture
- Clearing of land for agriculture by tilling and ploughing
- Overgrazing
- Digestion by cows
- Production and use of inorganic fertilizers for growing crops
- Household use of woodfuel and kerosene
- Industrial fossil fuels used in milk processing and irrigation
- Industrial processes to package and distribute/transport agricultural products

b. Transportation

Most cars, trucks and motorcycles in Eastern Province run on fossil fuels. This makes transportation a major contributor of greenhouse gases, especially carbon dioxide emissions (Shabir et al., 2023). Road vehicles account for the largest part, due to the use of petroleum-based products, like gasoline, in internal combustion engines. The energy sector contributes 23% of total emissions in Rwanda, as seen in Figure 1.

c. Deforestation

GHG emissions are also caused by deforestation (the cutting down of trees in forests) to clear land for crops or pastures; illegal logging; and the overextraction of fuelwood. Trees store carbon in the soil and in their trunk. When trees are cut down, they release the stored carbon into the atmosphere. Deforestation and unsustainable farming practices are the major emission sources in the Eastern Province of Rwanda.

d. Manufacturing goods and industrial growth
In the Eastern Province, manufacturing and other industries produce GHG emissions mostly from burning fossil fuels (Shabir et al. 2023) to process agricultural products, such as milk and yoghurt; to prepare brick kilns and irrigation; and to transport inputs and outputs.

e. Cooking energy
The Eastern Province continues to use woodfuel, which causes emissions. The unsustainable extraction of woodfuel causes forest degradation, a common source of GHG emissions.

1.2.3 Natural consequences of climate change

Likely impacts of temperature changes in Eastern Province

- Banana production is likely to be unaffected as this crop grows well at higher temperatures.
- Bean yields will decline as the cooler temperatures required for optimal production are no longer consistent.
- Main cash crops, coffee are expected to be negatively affected by climate change as they require specific temperatures for efficient production.
- High temperatures foster plant diseases, such as coffee leaf rust and fruit blight, and accelerate fruit maturation, while low temperatures facilitate coffee berry diseases.
- Higher temperatures increase the risk of severe droughts.
- Temperature changes alter the occurrence and distribution of pests and diseases, such as the berry borer beetle and Rift Valley fever (REMA 2024).

Likely impacts of rainfall changes in Eastern Province

- Reductions in agricultural production
- Reduced agricultural productivity from lower water availability
- Food insecurity from stunted trees and crops, crop failures
- Increased incidence of pests and diseases
- Animal deaths from starvation
- Disruption of agricultural calendar
- Drier wetlands, reduced river base flows from drought
- Downstream irrigation projects affected by reduced base flows
- Damage to water supply infrastructure (from floods and drought)
- Increased post-harvest losses and aflatoxin incidence, particularly for cereals

Effects of climate change on biodiversity

- High rates of soil erosion in Eastern Province
- Plants and wildlife threatened by increased disruption of pollination and predator–prey relationships due to rising temperatures
- Less tourism, a key source of earnings and economic diversification, due to reduced biodiversity
- Greater aridity in dry areas due to rising temperatures
- Soil erosion likely as too much rain at one time exceeds soil absorption capacity

Social threats arising from climate change

- Little economic scope to rebuild and adapt to drought and extreme temperatures
- Health impacts (low-income communities at greater risk of disease, injury, malnutrition, conflicts, hunger)
- Impact of diseases from insects, rodents, contaminated water or food
- Respiratory infections from indoor air pollution
- Hunger and malnutrition from extreme weather events
- Threats to fisheries, crops and livestock
- Diminished water and grasslands for grazing due to heat stress, causing lower crop yields and affecting livestock.

Chapter 2

Climate change mitigation, adaptation and resilience

Adaptation refers to additional activities needed to cope with droughts, floods, pests and diseases (Minx et al. 2021)as agreed upon in the Paris Agreement, comprehensive and reliable information on anthropogenic sources of greenhouse gas emissions (GHG. The adaptation measures for Eastern Province include new crop varieties; drought-tolerant livestock and crops; altering sowing times; livelihood diversification; crop rotation; rainwater harvesting technologies and irrigation; improved post-harvest handling; and value addition on crop and livestock products.

Mitigation refers to efforts to avoid or absorb greenhouse gas emissions, which contribute to climate change (Minx et al., 2021)as agreed upon in the Paris Agreement, comprehensive and reliable information on anthropogenic sources of greenhouse gas emissions (GHG. The mitigation measures for Eastern Province include growing trees; conserving forests; promoting trees on farms (agroforestry); using energy-saving stoves and solar power; and conserving soil and water.

Photo by Sarah Ooko/CIFOR-ICRAF

2.1 Climate-smart practices to build resilience

Located in East Africa, Rwanda has a hilly terrain and a temperate climate, making it suitable for various types of agriculture, particularly tree crops. The agricultural sector is vital to Rwanda's economy, contributing about 33% of its gross domestic product (GDP) and employing around 70% of the workforce. Therefore, by improving this sector's resilience to climate change, we can simultaneously secure livelihoods and promote sustainable economic growth.

Climate resilience encompasses activities that enhance the ability of households to deal with drought, floods, pests and diseases, enabling them to bounce back after an extreme event. This training module covered climate-resilient activities throughout the agricultural and tree-based value chain.

2.1.1 Climate-resilient agricultural production

Climate-smart practices that build resilience at production level of agricultural value chains include:

- Utilization of drought-tolerant crops and livestock (e.g. cassava, yams, millet, sweet potatoes, beekeeping)
- Post-harvest handling of crop produce (e.g. drying of grains)
- Soil and water conservation technologies (e.g. terrace construction, agroforestry, cover crops such as sweet potatoes)
- Investment in irrigation and rainwater harvesting
- Uptake of crop and livestock insurance
- Growing drought-tolerant forage grass and trees
- Investing in forage conservation technologies (silage and hay) and pasture management
- Early-maturing crop varieties
- Control of soil erosion; soil fertility improvements
- Use of organic pesticides
- Planting a diverse range of crops
- Crop rotation

2.1.2 Resilient varieties

Climate-resilient crop and livestock varieties are essential to withstanding drought, low rainfall and high temperatures. They provide stability and boost sustainability in agricultural production. Bananas, sweet potatoes, cassava, traditional vegetables, bush beans and sorghum are some drought-tolerant crops grown in the Eastern Province.

Farmers can choose crop and livestock varieties that are more tolerant to changing climatic conditions, such as drought-tolerant or heat-resistant crops and livestock (Global Agriculture and Food Security Program, n.d.).

2.2 Agroforestry: Integrating crop, livestock and tree systems

The more diverse an agricultural system, the greater its ability to adapt to climate change. Agroforestry is a collective name for land-use systems and technologies where woody perennials (e.g., trees, shrubs, coffee, bamboo, mangoes, avocadoes) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence3.

The agroforestry systems observed during a field visit included the mixing of fruit trees (mostly avocadoes and mangoes) with annual crops and the planting of trees along the farm boundaries. Large farms were more likely to integrate forestry, particularly of eucalyptus trees.

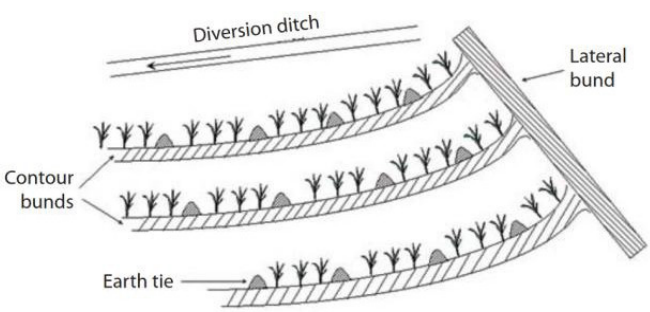
3 https://www.fao.org/sustainable-forest-management/toolbox/

Table 2. Trees suitable for agroforestry in Eastern Province

Agroforestry trees	
Trees	Local names
Markhamia lutea	Umusave
Maesopsis eminii	Umuhumuro
Terminalia superba	Teriminariya
Acacia sieberiana	Umunyinya
Acacia polyacantha	Umuharata
Acacia kirkii	Umukinga
Entada abyssinica	Umusange
Pterygota mildbraedii	Umuguruka

Importance of agroforestry

i. Trees on farms produce food/fruits, woodfuel and timber in the same area as crops.
ii. Trees on farms are a source of woodfuel, reducing pressure on tropical forests.
iii. Trees on farms serve as windbreakers, reducing the impact of extreme weather on crops and livestock.
iv. Trees reduce soil erosion and create a microclimate.
v. Agroforestry trees (e.g. *Calliandra* and *Sesbania sesban*) (Umunyeganyege) are a source of fodder for animals.
vi. Agroforestry trees (e.g. *Calliandra* and *Sesbania sesban*) (Umunyeganyege) fix nitrogen.
vii. Agroforestry trees (e.g. *Markhamia lutea*) (Umusave) are forages for bees, which improve household livelihoods.



Demonstration of contour bunds for field crops.

Source: Mati, 2005

2.3 Soil and water conservation measures

Practices like mulching, conservation tillage, cover cropping, and contour ploughing help improve soil health, enhance water retention, and prevent erosion. Healthy soils are better able to withstand extreme weather events and support crop growth.

What are the benefits of soil conservation?

- Increase in soil cover
- Increases infiltration
- Maintains soil fertility
- Stabilizes mechanical structures
- Productive use of land

2.4 Types of soil and water conservation measures

The commonly used soil and water conservation measures in the Eastern Province include contour bunds, bench terraces and agroforestry.

Contour bunds

Contour bunds are soil conservation structures that involve construction of an earthen bund by excavating a channel and creating a small ridge on the downhill side.

Bench terracing

Bench terraces are a series of level – or virtually level – strips running across the slope.

Bench terraces.

Source: CIFOR-ICRAF Flickr

2.5 Clean-energy technologies for climate resilience

TREPA has provided access to clean cooking technologies in the Eastern Province. These include more efficient cookstoves, such as pellet-based models, and technologies that replace charcoal with biomass briquettes and pellets.

Solar solutions are promoting agricultural resilience at every phase of the value chains. Farmers can explore renewable energy options, such as solar panels or wind turbines to reduce reliance on fossil fuels and non-renewable electricity.

What to consider before settling on solar-powered irrigation systems

- Assess water availability to supply the irrigation system.
- Asses solar resources to understand the intensity and duration of sunlight.
- Select the appropriate solar-powered pump (submersible or surface) that suits the water source and irrigation needs.
- Develop an efficient irrigation system that optimally utilizes the available water – this may include drip irrigation or other water-efficient methods to minimize water shortage and ensure even distribution of water across fields.
- Integrate water storage solutions into the system, such as tanks or reservoirs.
- Choose high-quality solar panels with sufficient capacity to meet the energy requirements of the water pump (i.e., solar panels with consistent energy production and reliable operation of the irrigation system).
- Implement water-saving technologies.
- Do some training on the installation, operation and maintenance of solar-powered irrigation systems.

2.6 On-farm constituted organic pesticide

Farmers use pesticides to increase crop productivity. Inorganic pesticides have been linked to air pollution. In general, most farmers rely on their own knowledge to mix these pesticides, with few precautionary measures taken. Organic pesticides are easy to constitute at farm level through the use of locally available materials that are safe to the human body and cause minimal air pollution.

A solar powered irrigation system.
Photo by Sarah Ooko/CIFOR-ICRAF

Organic pesticides help farmers increase crop productivity safely and sustainably, without polluting their environment or harming their health.
Source: Pixabay

Ingredients include:
- Chili peppers
- Tobacco leaves
- *Tithonia diversifolia* (Icyicamahirwe)
- Aloe vera leaves
- White soap (Tembo)
- Mortar/pestle (Isekuru)
- Water
- Strainer
- Cooking pan
- Bucket

Instructions for making organic pesticide:
- Wash all materials thoroughly with clean water, including all leaves.
- Combine all ingredients, including all leaves.
- Place all ingredients in a mortar and grind them to a fine consistency.
- Do not mix with tobacco leaves; instead, soak the tobacco leaves in clean water, using 7–10 leaves per litre of water.
- Measure out 1 kg of the finely ground mixture.
- Place the 1 kg of ground mixture in a cooking pan and boil.
- Use a strainer to separate and retain the coloured water.
- Dissolve 10 grams of white soap in 1 litre of clean water, then mix it with 4 litres of the boiled mixture (strained).
- Transfer the mixture to a sprayer and add 1 litre of the soaked tobacco leaf water. Mix thoroughly.
- Use the pesticide immediately after preparation, as its effectiveness diminishes after two days.

2.7 Post-harvest handling and processing

Value addition is the process of changing or transforming a product from its original state to a more valuable state.

2.6.1 Value addition for quality grains and nuts

Avoid and sort out rotten, diseased and discoloured grains.

i. Clean grain to remove foreign matter and chaff. Use a wire mesh sieve to filter good grains from foreign matter. Large foreign matter, like stones, can be removed by hand.
ii. Dry the grain. Wet grain promotes the growth of fungi (Aspergillus flavus), which
iii. Causes aflatoxins to thrive. Dry the grain to 13.5% moisture content before storing. Use a tarpaulin and allow the grain to dry in the sun. Pouring grain on the ground increases the rate of contamination with aflatoxins and other organisms.
iv. Storage: Use sisal bags to store grains. Avoid using polypropylene bags. Sisal bags allow air to pass through, unlike polypropylene bags, which cause moisture accumulation and mould. High moisture levels cause aflatoxins to develop.
v. Parasite infestation: Do not store grain with live weevils. Manage weevil infestation before storing at home or delivering to a warehouse.

Chapter 3

Building climate resilience through beekeeping

Many smallholder farmers in the Eastern Province of Rwanda – both at farm level and in cooperatives – undertake beekeeping as an alternative livelihood. Beekeeping requires little space and is less affected by extreme weather than crops and large livestock. Besides, the presence of bees is an indicator of a healthy ecosystem. Bee products include processed and unprocessed honey and wax. Good practices result in quality bee products as well as enhanced household incomes and ecosystems.

3.1 Good practices for quality beekeeping

Quality beekeeping involves a combination of good practices aimed at promoting the health and productivity of honeybee colonies while ensuring

Image Source: Pexels

the sustainability of beekeeping operations. Here is a list of good practices for quality beekeeping:

1. **Education and training:** Farmers need to continuously educate themselves about beekeeping practices, as well as pest and disease management, through books, courses, workshops and peer-to-peer learning in beekeeping cooperatives.
2. **Hive maintenance:** Farmers need to regularly inspect and maintain beehives to ensure a sound structure – free from damage – and provide a suitable environment for bee colonies to thrive.
3. **Hive hygiene:** Maintain cleanliness within the hive by regularly removing debris, dead bees and excess propolis. Clean and sanitize hive equipment between uses to prevent the spread of diseases and pests.
4. **Pest and disease management:** Control pests – such as Varroa mites and hive beetles – as well as diseases (including foulbrood) by using a combination of cultural, biological and chemical control methods.
5. **Queen management:** Monitor the performance of queen bees and replace ageing or failing queens, as needed, to maintain colony vigour and productivity. Consider requeening the hive with queens from reputable breeders to introduce desirable traits, such as disease resistance and honey production.
6. **Swarm prevention:** Implement swarm prevention techniques – such as providing adequate space, making splits, and managing colony population dynamics – to minimize the risk of colonies swarming and to ensure the retention of productive worker bees.
7. **Forage management:** Promote biodiversity and sustainable forage availability by planting bee-friendly plants, maintaining natural habitats and avoiding the use of pesticides and herbicides that are harmful to bees and other pollinators.
8. **Nutrition supplementation:** Provide supplemental feeding – such as sugar syrup or pollen substitute – during times of nectar dearth or when colonies are low on food reserves in order to support colony growth and survival.
9. **Record keeping:** Keep detailed records of hive inspections, management activities, colony performance and environmental conditions to track trends over time, identify potential problems and make informed management decisions.
10. **Equipment maintenance:** Regularly clean and maintain beekeeping equipment – including hive components, tools and protective gear – to ensure their effectiveness and longevity.

3.2 Quality of honey products

The quality of honey products can be influenced by various factors throughout the production process. The key elements that contribute to the quality of honey products include:

- **Floral source:** The type of flowers from which bees collect nectar greatly influences the flavour, aroma and colour of honey. Different floral sources produce unique honey varieties with distinct characteristics.
- **Purity:** High-quality honey should be free from adulterants, such as added sugars or syrups, and should be pure.
- **Processing:** The method of honey extraction and processing can impact its quality. Gentle processing techniques, such as cold extraction or minimal filtration, help retain the natural enzymes, nutrients and flavour of honey.
- **Harvesting practices:** Proper harvesting practices, including appropriate timing and methods, ensure that honey is collected at optimal ripeness, preserving its quality and nutritional value.
- **Storage conditions:** Honey should be stored in clean, airtight containers away from light and moisture to maintain its freshness and prevent spoilage.
- **Climate and environmental factors:** Environmental conditions, such as temperature, humidity and rainfall,

can influence the composition and characteristics of honey.

- **Beekeeping practices:** Ethical and sustainable beekeeping practices, including hive management, pest control and bee health management, contribute to the overall quality of honey products.
- **Geographical origin:** Honey produced in specific geographical regions, known as "monofloral" or "varietal" honey, often fetches higher prices due to its unique flavour profile and perceived quality associated with the region's flora and environmental conditions.
- **Certifications and standards:** Compliance with industry standards and certifications, such as organic certification or quality assurance programmes, can assure consumers of the honey's quality, purity and authenticity.
- **Packaging and labelling:** Proper packaging and labelling, including accurate information about the honey's origin, processing methods and nutritional content, help consumers make informed choices.

3.3 Steps and hygiene in honey processing

Processing honey involves several steps to extract it from the hive and ensure its cleanliness and quality. Here are the steps involved in honey processing, along with hygiene practices to maintain throughout the process:

- **Harvesting:** When harvesting honey, ensure that you wear clean protective clothing, including a beekeeper's suit, gloves and veil, to minimize contamination and protect yourself from bee stings. Use a smoker to calm the bees before opening the hive. Select frames with capped honey cells, indicating that the honey is ripe and ready for extraction.
- **Transportation:** Transport the honey frames carefully to the extraction facility in clean containers or bee boxes to prevent damage and contamination. Avoid exposing the frames to excessive heat or direct sunlight during transportation.
- **Uncapping:** Before extracting honey, the wax caps covering the honey cells need to be removed. Use a clean uncapping knife or fork to carefully slice off the wax caps, ensuring that the knife is cleaned and sanitized between frames to prevent cross-contamination.
- **Extraction:** Place the uncapped frames in a honey extractor, which uses centrifugal force to spin the honey out of the cells. Ensure that the extractor is clean and sanitized before use. Extract the honey gently to avoid overheating or damaging the honey.
- **Filtering:** After extraction, the honey may contain small particles of wax, propolis, or other debris. Filter the honey through a fine mesh or cheesecloth to remove these impurities. Ensure that the filtering equipment is clean and free from contaminants.
- **Settling and skimming:** Allow the filtered honey to settle in clean, food-grade containers for several hours or days to allow air bubbles and any remaining impurities to rise to the surface. Skim off any foam or debris that accumulates on the surface of the honey.
- **Bottling:** Once the honey has settled and been skimmed, transfer it into clean, sterilized jars or bottles for storage and distribution. Use clean equipment and avoid touching the inside of the containers to prevent contamination.
- **Labelling and sealing:** Label the honey jars with important information such as the harvest date, floral source (if known), and any relevant certifications or quality standards. Ensure that the lids or caps are tightly sealed to prevent moisture or contaminants from entering the jars.
- **Storage:** Store the bottled honey in a cool, dry place away from direct sunlight to preserve its quality and prevent crystallization. Ensure that the storage area is clean and free from pests or other contaminants.

3.4 Safety gear during honey harvesting

Safety gear is essential during honey harvesting to protect beekeepers from bee stings and other potential hazards. Here's a list of safety gear commonly used during honey harvesting:

- **Beekeeper's suit:** A full-body beekeeper's suit provides comprehensive protection against bee stings. It typically includes a jacket with attached hood and veil, pants and gloves. The suit should be made of thick, sting-resistant material, such as cotton or canvas.
- **Veil:** A veil attached to the beekeeper's suit protects the face and neck from bee stings. The veil should be securely attached to the suit and provide ample visibility without obstructing vision.
- **Gloves:** Beekeeping gloves cover the hands and wrists to prevent bee stings while handling frames and extracting honey. Choose gloves made of thick, puncture-resistant material that allows for dexterity and grip.
- **Boots:** Wear sturdy, closed-toe boots or shoes to protect the feet from bee stings and other potential hazards. Tuck the pant legs into the boots to prevent bees from crawling inside.
- **Beekeeping smoker:** A bee smoker is a device used to produce cool smoke that calms the bees during hive inspections and honey harvesting. It helps reduce the likelihood of defensive behaviour and stinging.
- **Hive tool:** A hive tool is a multipurpose tool used for prying apart hive components, scraping propolis, and manipulating frames. It helps beekeepers work efficiently while minimizing disturbance to the bees.
- **Communication device:** Carry a communication device, such as a mobile phone or two-way radio, to call for help in case of emergencies.
- **Weather-appropriate clothing:** Dress appropriately for the weather conditions, wearing layers to stay comfortable and protected from heat, cold or rain.

Honey packaged by Akagera Buffer Zone.
Photo by Jane Mutune/CIFOR-ICRAF

3.5 Value addition on honey products

Value addition to honey products involves transforming raw honey into various processed products with added value in terms of quality, convenience and market appeal.

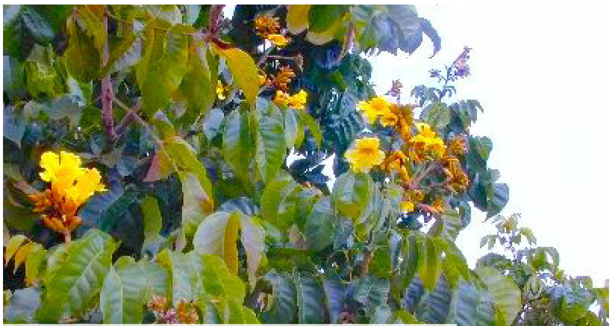
3.6 Tree-based bee forages

Tree-based forage offers numerous advantages for beekeepers, including year-round availability, diverse nutritional content, high nectar production and environmental benefits. By promoting tree planting and conservation efforts, beekeepers can enhance bee health, honey production and ecosystem resilience.

Table 3. Tree forages ecologically suitable to Eastern Province

No	Name	Local name
1	*Markhamia lutea*	Umusave
2	*Leucaena diversifolia*	Lesena
3	*Calliandra calothyrsus*	Caliyandara
4	*Vernonia amygdalina*	Umubilizi
5	*Senna siamea*	Gasiha
6	*Senna spectabilis*	Gasiha
7	*Acacia angustissima*	Akasiya
8	*Vachellia sieberiana*	Umunyinya
9	*Mangifera indica*	Umwembe
10	*Persea americana*	Avoka
11	*Tephrosia vogelii*	Umuruku
12	*Sesbania sesban*	Umunyeganyege

3.7 Tree-based bee forages suitable to Eastern Province



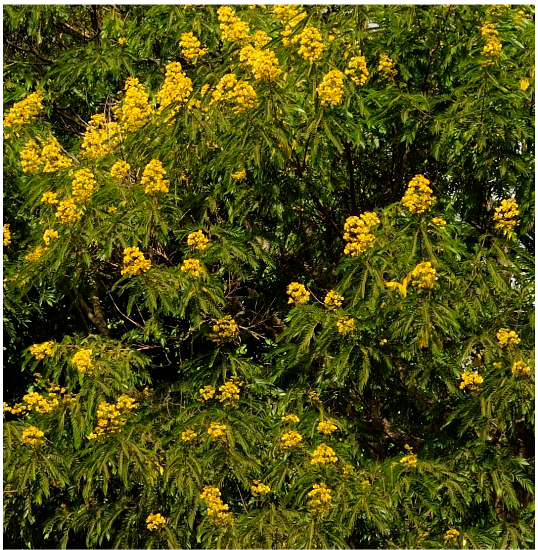
Umusave (*Markhamia lutea*).
Photo by AFT team/ Agroforestree Database

Lesena (*Leucaena trichandra*).
Photo by Sarah Ooko/CIFOR-ICRAF

Caliyandara (*Calliandra calothyrsus*).
Photo by Sarah Ooko/ CIFOR-ICRAF

Umubilizi (*Vernonia amygdalina*).
Photo source: CIFOR-ICRAF Flickr

Gasiha (*Senna spectabilis*).
Photo by Philipp Weigell/Wikipedia



Gasiha (*Senna siamea*).
Photo by Forest & Kim Starr/Agroforestree Database

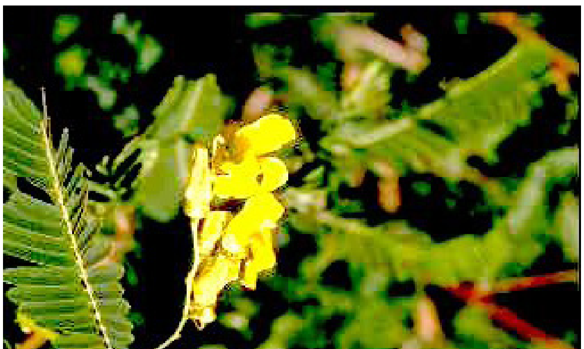
Akasiya (*Acacia polycantha*).
Photo source: Pixabay

Umunyinya (*Acacia sieberiana*).
Photo by Chris Fagg/Agroforestree Database

Umwembe (*Mangifera indica*).
Photo source: Pixabay

Avoka (*Persea americana*).
Photo by Kelvin Muchiri/CIFOR-ICRAF

Umuruku (*Tephrosia vogelii*).
Photo by Colin E. Hughes/ Agroforestree Database



Umunyeganyege (*Sesbania sesban*).
Photo by Anthony Simons/Agroforestree Database

3.8 Benefits and costs of traditional and modern hives

Table 1. Benefits analysis of 10 traditional hives

Item	Production/year	10 tradit. hives/kg	Price (in RWF)		Benefits/year in RWF
			Unit cost	Total cost	
Annual production per hive/honey	6 kg	60	4,000	90,000	240,000
Beeswax sheets per kg	50 g	1.4	8,000	11,200	11,200
Total sales					251,200
Total annual benefits					47,300

Note: RWF = Rwandan francs; kg= Kilograms

Table 2. Cost analysis of 10 traditional hives

	Item	Unit (10 traditional hives)	Number	Unit price (RWF)	Total price (RWF)
1	Traditional hives	Number	10	5,000	50,000
2	Gloves	Pair	1	10,000	10,000
3	Double stainer	Number	1	30,000	30,000
4	Smoker	Number	1	25,000	25,000
5	Pail	Number	1	20,000	20,000
6	Beekeeping brush	Number	1	3,500	3,500
7	Bee colony for transfer	Colonies in traditional hive	10	8,000	80,000
8	Beekeeping suits and boots	Number	1	55,000	55,000
9	Transportation cost		1	25,000	25,000
	Total costs				298,500

Note: RWF = Rwandan francs

Table 3. Benefits of 10 Langstroth hives

Item	Production/ year	10 Langstroth hives/kg	Price (in RWF)		Benefits/year in RWF
			Unit cost	Total cost	
Annual production per hive/Honey	32 kg	320	6,000	1,920,000	1,920,000
Beeswax sheets per kg	90 g	18	8,000	144,000	144,000
	Total sales				2,064,000
	Total annual benefits				717,500

Note: RWF = Rwandan francs

Table 4. Cost analysis of 10 Langstroth hives

	Item	Unit	Number	Unit price (in RWF)	Total price (in RWF)
1	Langstroth with two boxes	Kits	10	50,000	500,000
2	Protective gloves	Number	1	10,000	10,000
3	Honey extractor (three frames)	Number	1	320,000	320,000
4	Double stainer	Number	1	30,000	30,000
5	Spur embedder and hive tool	Number	1	13,000	13,000
6	Smokers	Number	1	25,000	25,000
7	Queen excluder	Number	10	6,000	60,000
8	Wax foundation sheet	kg	10	8,000	80,000
9	Pail	Number	1	20,000	20,000
10	Beekeeping brush	Number	1	3,500	3,500
11	Bee colony purchase	Colonies in traditional hive	10	8,000	80,000
12	Beekeeping suits and boots	Number	1	55,000	55,000
13	Transportation cost	-	1	50,000	50,000
	Total				1,346,500

Note: RWF = Rwandan francs

Chapter 4

Building climate resilience through fodder production

Primary livestock production in the Eastern Province is hampered by an inadequate supply of appropriate animal feed and fodder. Common livestock feed found in the Eastern province includes fodder grasses, such as Chloris gayana, Brachiaria, Kakamega and Desmodium, and fodder trees like Gliricidia, Calliandra and Leucaena.

4.1 Fodder grass and tree benefits

- Nutritional supplements, such as proteins, vitamins and minerals, necessary for livestock health and productivity
- Forage security by providing a reliable source of feed, especially during dry seasons when natural grazing is limited

Photo by Sarah Ooko/CIFOR-ICRAF

- High-quality fodder contributes to improved livestock health, reducing the risk of malnutrition and diseases.
- High nutritional content increases milk production.
- Soil conservation, reduced soil erosion, enriched soil organic matter and fertility
- Environmental benefits: protection of biodiversity, carbon sequestration, reduced need for inorganic fertilizers
- Diversification of farmers' income streams through the sale of surplus forage
- Reduced reliance on natural grazing, promoting grazing land restoration

4.2 Production of fodder grasses

4.2.1 *Chloris gayana*

Chloris gayana is a drought-tolerant grass species suitable for tropical and subtropical regions, thriving at elevations of up to 2,000 metres. It endures dry and semi-arid conditions, with optimal growth in areas with temperatures ranging from 16ºC to 37ºC and annual rainfall from 700 mm to 1,500 mm. The grass adapts to various soil types, including sandy, loamy and clay soils, with pH levels between 5.5 and 7.5. Notably, it exhibits high drought tolerance, with a root system capable of extracting water from depths exceeding 4 metres, allowing survival in regions with prolonged dry seasons. *Chloris* withstands seasonal waterlogging and brief flooding periods of up to 15 days.

4.2.2 *Brachiaria*

Brachiaria grass is a crucial tropical forage known for its abundant and nutritious biomass, resilience to various stresses, and soil fertility enhancement. Since 2007, numerous improved Brachiaria cultivars have been introduced and evaluated in Rwanda for their adaptability, biomass yield and livestock benefits. Evaluations across different agroecological zones demonstrated superior adaptation and higher yields of *Brachiaria* compared with Buffelgrass. *Brachiaria* has high protein and energy content, thus increasing animal production and milk yield. Brachiaria grass is strongly preferred by farmers due to its productivity and adaptability to low rainfall and acidic soils. Harvesting is done at the optimal stage of growth – typically when plants reach 60–90 cm in height and before flowering – using appropriate equipment to minimize damage. Processing involves chopping or shredding the forage into smaller pieces to enhance palatability and digestibility for livestock consumption. It is best to store processed *Brachiaria* forage in well-ventilated, dry storage facilities, such as hay barns or silos, to preserve its quality and nutritional value. By following these steps diligently, farmers can produce high-quality Brachiaria forage to meet their livestock's nutritional needs and enhance their overall health and productivity.

4.3 Production of fodder trees

4.3.1 *Gliricidia sepium* (Gilirisidiya)

The production of *Gliricidia* involves several steps to ensure optimal yield and quality for livestock consumption. These steps include selecting suitable varieties; preparing the land; planting seedlings; and applying good agricultural practices. *Gliricidia* can be harvested for fodder once it reaches a certain height, usually around 3-4 metres, or when the branches are sufficiently leafy. Harvested branches are typically chopped or shredded before being fed to livestock. Proper management practices help maximize fodder production and nutritional value, benefitting livestock health and productivity.

4.3.2 *Calliandra*

High-quality *Calliandra* involves choosing appropriate varieties suited to the local environment, and preparing the land properly with regular weeding. *Calliandra* can be harvested when it reaches a certain height, typically 1–2 metres, or when branches become leafy enough. Chop or shred the branches before feeding. Implementing effective management techniques is crucial for optimizing fodder production and nutritional content, thus enhancing livestock productivity.

Table 8. Fodder trees

Fodder trees	Local names
Gliricidia sepium	Gilirisidiya
Calliandra calothyrsus	Kariyandara
Leucaena diversifolia	Lesena
Leucaena trichandra	Lesena
Leucaena pallida	Lesena parida
Grasses	**Local names**
Chloris gayana	Kororisi
Brachiaria brizantha cv. Piatá	Brakiariya
Brachiaria brizantha cv. Basilisk	Brakiariya
Desmodium distortum	Desimodiumu
Pennisetum purpureum	Kakamega grass

4.3.3 *Leucaena diversifolia* (Lesena)

Proper management practices play a crucial role in optimal fodder production and nutritional content, thus enhancing livestock health and productivity. High-quality *Leucaena* practices involve:

- Selecting appropriate varieties suited to local conditions
- Proper land preparation, with consistent watering and weeding
- Harvesting Leucaena when its height is about 2–3 metres, or when the branches are sufficiently leafy
- Chopping or shredding before feeding

Peer-to-peer learning on fodder production during a field visit, Nyagatare District.
Photo by Jane Mutune/CIFOR-ICRAF

4.4 Harvesting, processing and fodder storage

To ensure optimal quality, the following steps should be taken:

- Harvest grass and trees at an appropriate stage of maturity by cutting at a specific height to promote regrowth and to maximize nutritional value.
- Partially dry the forage to reduce moisture content, to facilitate easier handling and storage, and to prevent spoilage.
- Chop or shred to create smaller, more manageable pieces, enhancing its palatability and digestibility for livestock.
- Store in suitable facilities, like silos or hay barns, to maintain quality and protect against moisture and pests.
- Depending on the nutritional needs of the livestock, supplementary feeds – such as concentrates or minerals – may be added to ensure a balanced diet.
- Feed livestock according to their dietary requirements and feeding schedules, whether fresh or as silage, hay or dried fodder.
- Proper harvesting and processing practices are crucial to maximizing the nutritional value of fodder and supporting the overall health and productivity of the livestock.

4.4.1 Farm-made hand hay baler

Livestock keepers can construct a homemade hand baler using a box measuring 0.75 metre in length, 0.5 metre in width and 0.3 metre in height. This makeshift baler can produce hay bales weighing 12 kg each, which is sufficient to feed one cow per day.

Building your box baler: Constructing a box baler is as simple as building and securing a crate upon a wheeled platform. Whether you build the baler from new or used parts, you will need larger tyres on the rear to be able to manoeuvre over logs and brush. The front wheels are optional, and most balers use fixed feet that provide a stable base to compress the straw into a tight bale.

Table 11. The pros and cons of a hand hay baler

Benefits	Drawbacks
Low cost	Cumbersome
Simple to operate	Labour-intensive
Access to brushy and remote areas	Inefficient
Ideal for small-scale/start-up capability	Limited production
Protective of rare plants and ground vegetation	

Source: Anis Trend

4.5 Feeding livestock

Farmers cultivate various types of fodder grass, such as *Chloris gayana* and *Brachiaria*, and fodder trees like *Calliandra*, *Leucaena*, and *Gliricidia*. These fodder sources are rich in essential nutrients, such as proteins, vitamins and minerals, which are crucial for the growth and productivity of livestock. The feeding process typically involves harvesting the fodder grass and trees, chopping or shredding into consumable pieces, and then feeding it to the animals.

Livestock – including cattle, goats and sheep – consume fodder to meet their dietary requirements and to maintain good health. Farmers may supplement the fodder with concentrates or minerals to ensure a balanced diet for their animals. Feeding livestock with fodder grass and trees plays a significant role in improving animal productivity, including milk production in dairy cows and weight gain in meat-producing animals. The integration of fodder grass and trees to livestock feeding practices contributes to enhanced animal husbandry and household livelihoods.

Table 9. Cost-benefit analysis of fodder production

	Items	Quantity (ha)	Unit Price(ha) in RWF	Total (Rwf/ha)
1	Seed purchase	8	7,000	56,000
2	Ploughing	35	2,000	70,000
3	Levelling/discing	20	2,000	40,000
4	Manure	2	15,000	30,000
5	Planting	25	2,000	50,000
6	Weeding	15	1,500	22,500
7	Harvesting labour	30	2,000	60,000
8	Belling	1	6,000	6,000
9	Rope	12	6,500	78,000
10	Total expense (C)	148	44,000	412,500
11	Yield (hay/ha) (D)	2,100	3,500	7,350,000
	Net income (RWF/ha) (=D-C)			**6,937,500**

Note: RWF = Rwandan francs

Chapter 5

Building climate resilience through tree-crop value chains in Rwanda

In Chapter 1, we discussed sustainable land-management practices. Our goal in this chapter is to explore how sustainable practices in agriculture can help build resilience against climate change, while boosting local economies.

5.1 The importance of tree crops

Tree crops – such as coffee, tea and fruits – play a pivotal role in Rwanda's agriculture. These crops are less vulnerable to weather extremes than annual crops due to their deep root systems and perennial nature. Let's briefly overview some key tree crops:

- Coffee: As one of Rwanda's critical exports, coffee cultivation provides an income source for thousands of Rwandan farmers. The *Coffea arabica* variety thrives in Rwanda's climate.

Photo by Jane Mutune/CIFOR-ICRAF

- Tea: Another major export product, tea is cultivated on significant portions of Rwanda's agricultural land, benefitting from the country's rich volcanic soils.
- Fruit trees: Fruits – such as avocadoes, bananas and mangoes – are increasingly vital for both domestic consumption and export.

5.2 Current challenges in tree-crop agriculture

Despite their potential, tree-crop value chains in Rwanda face several challenges exacerbated by climate change. Understanding these issues is essential to developing effective solutions:

- *Climate variability*: Unpredictable weather patterns impact crop yields, making traditional farming methods less reliable.
- *Pest and disease outbreaks*: Warmer temperatures and increased humidity can lead to the proliferation of pests and diseases.
- *Soil degradation*: Over-farming and poor land management have led to soil erosion and loss of fertility.
- *Market access*: Limited access to markets and fluctuating prices affect profitability for farmers.

5.3 Building resilience:

To help mitigate these challenges, various strategies can be implemented to build resilience within tree-crop value chains. Let's look at some of these strategies:

5.3.1 Utilization of sustainable agricultural practices is crucial for long-term resilience:

- *Agroforestry*: Is the practice of integrating trees with crops and livestock enhances biodiversity and soil health. The interactions between trees and/or with crops and livestock results in the following benefits[4]:
- Provide; fodder for livestock, woodfuel, food, shelter, income from products including timber and fruits. Trees restore landscapes and enhance provision of ecosystem services e.g. reduced soils erosion, carbon sinks, higher soil moisture and shed.
- *Conservation tillage*: Conservation tillage means any tillage which minimises soil disturbance and helps maintain soil structure and moisture levels (Conservation Tillage - ScienceDirect, 2005.). For example, crop residues such as maize stalks cover the soil surface and reduce soil erosion and enhance soil fertility. No-till farming, in which the soil is left undisturbed by tillage and the residue is left on the soil surface, is the most effective soil conservation system.
- Conservation tillage practices will eventually create a soil, water, and biological system that more closely resembles native soils. Farmers need to be encouraged to join or

4 https://www.worldagroforestry.org/about/agroforestry#:~:text=Agroforestry%20is%20the%20interaction%20of,coffee%2C%20rubber%20and%20oil%20palm

form cooperatives to establish contacts with extension services, and organizations promoting conservation agriculture practices and enhance uptake of these technologies(Mutune et al. 2011.).
- *Integrated pest management*: Using biological control and organic farming techniques reduces reliance on chemical pesticides.

5.3.2 Water management techniques

Efficient water use is fundamental, especially during periods of drought:
- *Rainwater harvesting*: Capturing and storing rainwater ensures supply during dry spells.
- *Irrigation systems*: Introducing drip or sprinkle irrigation systems optimizes water distribution.
- *Terracing*: Contour farming helps conserve water and reduce soil erosion on slopes.

5.3.3 Use of technology and innovation

Technology plays a crucial role in enhancing productivity and resilience:
- *Geographic information systems and remote sensing*: Used for climate monitoring and early-warning systems.
- *Mobile apps*: Provide farmers with weather forecasts, climate and market information.

5.4 Community involvement and supportive policies

Sustainable change requires meaningful community involvement and policy support:
- *Cooperative models*: Farmers forming cooperatives enables resource sharing and collective bargaining.
- *Capacity building*: Training programmes equip farmers with necessary skills and knowledge.
- *Policy frameworks*: Government policies should facilitate sustainable practices and offer financial incentives.

5.5 Case study: Success stories in Rwanda

Let's examine a few success stories highlighting the impact of these strategies:

Coffee cooperatives
Several coffee cooperatives in Rwanda have successfully enhanced resilience by adopting sustainable farming practices and establishing direct trade links with international buyers. This not only improves income stability for farmers but also promotes environmental conservation.

Agroforestry projects
Projects introducing agroforestry practices have led to improved soil health and increased biodiversity, providing a buffer against climate impacts. Moreover, value addition on various tree-crop products is essential. The purpose is to increase the shelf-life of the tree-crop products. This includes cleaning, drying, packaging and branding.

5.6 Potential for future growth

The potential for further growth in Rwanda's tree-crop sector lies in continued investment in sustainable practices, strengthened farmer cooperatives, technology and infrastructure. The government and private sectors can play a significant role in facilitating this growth through:
- *Research and development*: Exploring new crop varieties and innovative farming techniques
- *Infrastructure development*: Improving transportation and storage facilities to minimize post-harvest losses
- *International partnerships*: Collaborating with global organizations to share knowledge and resources

Thus, tree-crop value chains involve a multifaceted approach that includes sustainable farming practices, efficient water management, the use of technology, and active community participation. Rwanda's unique geographical and climatic conditions offer a tremendous opportunity for enhancing the sustainability and profitability of tree crops, such as coffee, tea and fruits. By adopting these strategies, Rwanda can secure its agricultural future and improve the livelihoods of its people. Remember, every small action contributes to a more resilient planet!

5.7 Value chain finance

Cooperatives and farmer groups with viable and bankable business plans can access finance through:

- Agricultural loans from:
  - The Development Bank of Rwanda (BRD).
  - The Equity Bank Rwanda: A package for agriculture and environment
  - The International Fund for Agricultural Development (IFAD) funds investment costs of operational agriculture businesses.
  - Microfinance institutions
  - Savings and Credit Cooperative Societies (SACCOs) e.g. Umurenge SACCOs

Chapter 6

Emerging opportunities

- Fodder enterprises: Harvesting, aggregating, drying and baling raw fodder grass and trees, and selling them in times of scarcity.
- Innovations, such as solar/wind power and digital technologies, to communicate climate (through METEO) and market information (through the Esoko platform)
- Carbon markets and trading
- Clean technology enterprises
- Increased government and non-government interventions for climate change mitigation and adaptation

Photo by Sarah Ooko/CIFOR-ICRAF

Chapter 7

Conclusion

Farmers in the Eastern Province are acutely aware of extreme climate events, such as unreliable rainfall, which have exacerbated food insecurity. To counteract these challenges, they have implemented various climate actions aimed at transforming the situation. Climate-smart practices like soil and water conservation, agroforestry, conservation tillage, proper post-harvest handling, and aggregated marketing help build the resilience of agribusiness value chains.

In this context, farmers are considering investments in water harvesting, agroforestry and hillside irrigation to enhance resilience to climate change, as well as water and food security. Additionally, drying cereals and nuts before storage reduces post-harvest losses, lowers the risk of aflatoxin infestation, and extends shelf life. Beekeeping, tree crops, and fodder value chains are nature based solutions which provide livelihood diversification and contribute to ecosystem restoration.

Crop and livestock farmers in Rwanda can access agricultural loans through banks, SACCOs, and microfinance institutions. Climate information services are predominantly disseminated by METEO through short text messages and radio broadcasts.

Photo by Sarah Ooko/CIFOR-ICRAF

References

Anis Trend. n.d. The pros and cons of baling machines. Retrieved 4 November 2024. https://www.anis-trend.com/the-pros-and-cons-of-baling-machines/

Berry M. 2020. Coping with climate change through agroforestry: The experience of the Ykalingas in the Philippines. Nairobi: World Agroforestry (ICRAF). https://www.worldagroforestry.org/blog/2020/06/08/coping-climate-change-through-agroforestry-experience-ykalingas-philippines

Athanase, C., Muthuri, C., Kuyah, S., Mukuralinda, A., Mbaraka, S., & Sileshi, G. (2023). Pruning and green manure from Alnus acuminata improve soil health, and potato and wheat productivity in Rwanda. Agroforestry Systems, 98, 1–14. https://doi.org/10.1007/s10457-023-00904-5

CONSERVATION TILLAGE - ScienceDirect. (2005). Retrieved December 3, 2024, from https://www.sciencedirect.com/science/article/abs/pii/B0123485304002708

Coping with climate change through agroforestry: The experience of the Ykalingas in the Philippines. (n.d.). World Agroforestry | Transforming Lives and Landscapes with Trees. Retrieved November 7, 2024, from https://www.worldagroforestry.org/blog/2020/06/08/coping-climate-change-through-agroforestry-experience-ykalingas-philippines

Deforestation in Rwanda, ICRAF - Google Search. (n.d.). Retrieved November 7, 2024.

Dept, I. M. F. A. (2022). Rwanda: Request for a New 36-Month Policy Coordination Instrument and Request for an Arrangement Under the Resilience and Sustainability Facility—World Bank Assessment Letter for the Resilience and Sustainability Facility. IMF Staff Country Reports, 2022(381). https://doi.org/10.5089/9798400227875.002.A003

Mati, B. (2005). Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa.

Minx, J. C., Lamb, W. F., Andrew, R. M., Canadell, J. G., Crippa, M., Döbbeling, N., Forster, P. M., Guizzardi, D., Olivier, J., Peters, G. P., Pongratz, J., Reisinger, A., Rigby, M., Saunois, M., Smith, S. J., Solazzo, E., & Tian, H. (2021). A comprehensive dataset for global, regional and national greenhouse gas emissions by sector 1970–2019. Antroposphere – Energy and Emissions. https://doi.org/10.5194/essd-2021-228

Mulwa, C. K., & Visser, M. (2020). Farm diversification as an adaptation strategy to climatic shocks and implications for food security in northern Namibia. World Development, 129, 104906. https://doi.org/10.1016/j.worlddev.2020.104906

Mutune, J., Nyikal, R., & Kironchi, G. (2011). Determinants of adoption of conservation tillage practices in maize-cowpea cropping systems: The case of Makueni District, Kenya.

Nations, U. (n.d.). What Is Climate Change? United Nations; United Nations. Retrieved November 4, 2024, from https://www.un.org/en/climatechange/what-is-climate-change

Shabir, I., Dash, K. K., Dar, A. H., Pandey, V. K., Fayaz, U., Srivastava, S., & R, N. (2023). Carbon footprints evaluation for sustainable food processing system development: A comprehensive review. Future Foods, 7, 100215. https://doi.org/10.1016/j.fufo.2023.100215

Sustainable Agricultural Intensification for Improved Livelihoods, Food Security and Nutrition Project (SAIP) | Global Agriculture and Food Security Program. (n.d.). Retrieved November 4, 2024, from https://www.gafspfund.org/projects/sustainable-agricultural-intensification-improved-livelihoods-food-security-and-nutrition

The Pros and Cons of Baling Machines—Anis Trend. (n.d.). Retrieved November 4, 2024, from https://www.anis-trend.com/the-pros-and-cons-of-baling-machines/

REMA (Rwanda Environment Management Authority). n.d. Rwanda green growth climate resilience strategy. Kigali, Rwanda: REMA. Accessed 8 March 2024. https://www.rema.gov.rw

REMA (Rwanda Environment Management Authority). 2015. Baseline Climate Change Vulnerability Index for Rwanda. Kigali, Rwanda: REMA.

Schnetzer J and Pluschke L. Climate-smart agriculture. Solar-powered irrigation systems: A clean-energy, low-emission option for irrigation development and modernization. Practice Brief. Rome: FAO. https://openknowledge.fao.org/server/api/core/bitstreams/52160f7e-6106-41d1-b170-fb230a4e7071/content

Shabir I, Dash KK, Dar AH, Pandey VK, Fayaz U, Srivastava S, R N. 2023. Carbon footprints evaluation for sustainable food processing system development: A comprehensive review. Future Foods 7:100215. https://doi.org/10.1016/j.fufo.2023.100215

United Nations. n.d. What is climate change? Accessed 4 November 2024. https://www.un.org/en/climatechange/what-is-climate-change

UNEP (United Nations Environment Programme). n.d. Interactive country fiches (Rwanda). Retrieved November 4, 2024, from https://dicf.unepgrid.ch/rwanda/climate-change

UNFCCC (United Nations Framework Convention on Climate Change). 2020. Republic of Rwanda; Updated Nationally Determined Contribution. Accessed 9 March 2024. https://unfccc.int/sites/default/files/NDC/2022-06/Rwanda_Updated_NDC_May_2020.pdf

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