

THE STATE OF THE BIOECONOMY IN EASTERN AFRICA: 2024

SEI Stockholm Environment Institute

icipe

BioInnovate Africa

About The Report

In 2022, the East African Science and Technology Commission (EASTECO), the Stockholm Environment Institute (SEI) and the International Centre of Insect Physiology and Ecology (*Icipe*) through the BioInnovate Africa Programme developed the first Eastern Africa bioeconomy status report with the title *"State of the Bioeconomy in Eastern Africa: 2022"*[1] providing the baseline data on the state of the bioeconomy in all six East African Community (EAC) member countries and Ethiopia. This report gave an overview of the bioeconomy in Eastern Africa and the availability and use of bioresources in the region. Emerging opportunities for bioeconomy development and examples of new successful bioeconomy entrepreneurs were also presented.

This State of the Bioeconomy in Eastern Africa: 2024 report builds on the first status report developed in 2022. While the first status report was broad encompassing all the focus areas in the Regional Bioeconomy strategy this report has a focus on *Food security and sustainable agriculture.* There will be a series of three additional EAC bioeconomy status reports, one every second year, for the period of the current EAC Regional Bioeconomy Strategy, each with a focus on one of the strategic areas in the regional strategy. These status reports would form the basis for monitoring bioeconomy progress in the region, highlighting key pathways for bioeconomy development and suggesting actions mobilizing key actors to move forward developing a vibrant bioeconomy for the region contributing to the Sustainable Development Goals (SDGs) 2030, the EAC Vision 2050 and the Africa Union Agenda 2063. The partner institutions in the development of this status report are:

- **The Stockholm Environment Institute (SEI)** is an international non-profit research and policy organization that tackles environment and development challenges connecting science and decision-making to develop solutions for a sustainable future for all *(https://www.sei.org/).*
- **The East African Science and Technology Commission (EASTECO)** is mandated to promote and coordinate the development, management and application of science and technology in the Partner States for enhanced socioeconomic development and regional integration *(https://easteco.org/).*
- **The BioInnovate Africa Programme** is a regional science and innovation-driven initiative stimulating a bioeconomy in Eastern Africa. The initiative is supported by the Swedish International Development Cooperation Agency (Sida), and implemented by the International Centre of Insect Physiology and Ecology *(icipe) (https://bioinnovate-africa.org/).*

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Citation

Virgin, I., Lutta, A., Senyagwa, J., Osano, P., Tesfaye, K., Tafesse, F., Ochanga, P., Munganyinka, E., Masharabu, T., Ongol, M., Adhiambo, R., Muyambi,F., Kilelu, C., Haileselassie T, 2024. The State of Bioeconomy in Eastern Africa: 2024. Stockholm Environment Institute, The East African Science and Technology Commission and Bioinnovate Africa.

ISBN: 978-9914-772-58-6

Design/layout: Maina Wainaina

[1]https://bioinnovate-africa.org/the-state-of-the-bioeconomy-in-eastern-africa-2022/

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FOREWORD



The bioeconomy has emerged as a critical pillar for achieving sustainable development in the 21st century, offering innovative solutions to pressing global challenges such as climate change, food insecurity, and environmental degradation. For the East African Community (EAC), the bioeconomy presents a unique opportunity to leverage the region's abundant biological resources to drive inclusive economic growth, create jobs, and improve livelihoods.

This State of the Bioeconomy in Eastern Africa: 2024 report represents a significant step forward in our collective efforts to harness the potential of the bioeconomy in the region. Building on the foundation of the inaugural 2022 report, this edition focuses on food security and sustainable agriculture, which are central to the EAC's development agenda. The report provides valuable insights into the current state of bioeconomy activities across the region, highlighting both progress and opportunities for further development.

Eastern Africa is home to vast agricultural lands, rich biodiversity, and a youthful population—factors that position the region to become a leader in bioeconomy innovation. By capitalizing on these assets, we can transform traditional agricultural practices, increase the value of bio-based products, and develop new industries that are both sustainable and economically viable. The bioeconomy also holds the promise of improving food security, enhancing environmental sustainability, and creating resilient communities in the face of global challenges such as climate change.

The 2024 report outlines key areas where the bioeconomy can make a meaningful impact, including value addition to agricultural products, bioenergy, and novel food production. It also emphasizes the importance of building strong institutions, fostering innovation, and supporting the development of policies that create an enabling environment for bioeconomy growth.

As we look to the future, it is clear that the bioeconomy will play a central role in the EAC's development strategy. I call on governments, private sector players, development partners, and civil society organizations to collaborate in scaling up bioeconomy initiatives. Together, we can unlock the full potential of this dynamic sector and drive the transformation of our economies in a sustainable and inclusive manner.

I commend the efforts of the East African Science and Technology Commission (EASTECO), the Stockholm Environment Institute (SEI), the BioInnovate Africa Programme, and all other partners involved in the production of this report. Your commitment to advancing the bioeconomy in our region is an inspiration, and I look forward to seeing the positive impact of these efforts in the years to come.

H.E Veronica Mueni Nduva, CBS

Secretary General

The East African Community

EXECUTIVE SUMMARY

The Report

The State of the Bioeconomy in Eastern Africa: 2024 report is developed by the East African Science and Technology Commission (EASTECO), the Stockholm Environment Institute (SEI), and the International Centre of Insect Physiology and Ecology (*icipe*) through the BioInnovate Africa Programme. The report builds upon the foundational work presented in the inaugural 2022 report. While the initial report provided a broad overview of the bioeconomy across Eastern Africa, the 2024 edition focuses specifically on food security and sustainable agriculture. The report also gives an update on recent bioeconomy development in the region.

Rationale for development of Bioeconomy in Eastern Africa

The development of a bioeconomy in the region presents a transformative opportunity to improve rural livelihoods by improving sustainable economic growth, enhancing food security, and promoting environmental stewardship. The development of a bioeconomy presents a promising avenue for sustainable economic growth and development improving rural livelihoods across the region. The region's abundant natural resources, including agricultural products, forestry, and marine ecosystems, offer a rich foundation for bio-based industries.

However, the region has only to a limited degree, been able to apply technologies and know-how that could modernise agricultural production, bioprocessing and value addition. The low degree of bioprocessing and value addition to primary produce makes it difficult for the region to use its bioresources as an engine for economic growth. The development of a modern bioeconomy in Eastern Africa has significant potential to support several critical development goals and targets for the region, and will help deliver the following outcomes:

- **Sustainable industrialisation, job creation and green growth,** revitalising bioprocessing and biomass value chains in the region, and promoting circular economy production systems with reduced emissions, through productive and efficient use of biowaste.
- **Improved food and nutrition security** through enhanced value chains and processing, promoting a more secure and resilient food supply while contributing to *sustainable, healthy, affordable and nutritious food* for the growing population in the region.
- **Improved health,** using the biodiversity in the region to develop cost effective bio-based production systems for various biopharmaceutical products that address specific health challenges in the region (HIV, malaria and non-communicable diseases etc).
- **The creation of new bio-based products,** including biomaterials for construction, bio-inputs for agriculture, enzymes for industry, and bio-based feedstocks (e.g. biofertilizers, bio-packaging) to substitute products derived from petrochemicals or to satisfy growing demands from consumers (e.g. functional foods, special dietary needs, novel health and well-being products).
- **Linking farmers and bioentrepreneurs to market opportunities** and to local, national, regional and international markets. New bio-based value-added products attractive on a world market can assist the private sector in Eastern Africa to expand and improve their global competitiveness and stimulate sustainable economic growth.
- **Creating new forms of clean sustainable modern bioenergy,** such as biofuels, for transportation and electricity generation from biowaste and industrial by-products, mitigating climate change and reducing the massive use of fuelwood that leads to deforestation.
- **Protecting the environment** through converting waste, which today threatens ecosystems and freshwater resources, to useful products.

Bioeconomy development in Eastern Africa

There has been a significant growth in research and development in the academic sector in the region to address bioeconomy opportunities in the region. This includes research on crop value addition, value addition to biowaste, bioenergy production, biodiversity conservation, and sustainable agriculture practices. Efforts have been made to build human and institutional capacity in the bioeconomy through training programmes, workshops, and educational initiatives. The region has increasingly supported universities, research institutions and innovation capabilities, with a growing number of active and well-trained scientists. In addition, many countries in the region have embraced or are piloting different tools, agro-based clusters and platforms to promote agro-industrial development, which will serve as a base for expansion of bio-based business enterprises.

The most important action in a policy context and in terms of supporting the bioeconomy development in the region is the *East African Community Bioeconomy Strategy* which was developed and approved by the East African Community (EAC) in 2022. The Regional Bioeconomy Strategy provides a compelling framework for putting in place agreed goals and interventions which countries in Eastern Africa can use to develop a vibrant, inclusive and innovative bioeconomy contributing to sustainable development in the region. The overall mission of the strategy is to catalyse and support innovative and sustainable use of bioresources as the major driver of inclusive economic growth and job creation in Eastern Africa.

The Strategy has inspired and catalysed the development of national bioeconomy strategies and subsequent policy development and interventions for sustainable bio-based and inclusive economic growth in the region. Currently, several countries in the region are in different stages of developing bioeconomy strategies inspired by the Regional Bioeconomy Strategy. Ethiopia has drafted its national bioeconomy strategy which has been through extensive stakeholder meetings and has now been submitted to the Ethiopian Science and Technology Council for final approval and for further implementations steps. Uganda is in the process of developing its bioeconomy Strategy. Rwanda has developed the roadmap for development of its bioeconomy strategy and Burundi will, with support of EASTECO, soon start its strategy development process.

The EAC Regional Bioeconomy Strategy is focusing on how to add value to various type of bioresources and for different purposes and has four priority Strategic Thematic Areas:

1. **Food security and sustainable agriculture** with the specific objective to introduce new bio-based technologies and solutions to strengthen food and feed production, ensuring food security.
2. **Health and Wellbeing** with the specific objective to develop a bio-based healthcare sector contributing towards a healthy population with improved well-being, addressing regional priorities and building on indigenous knowledge and practices.
3. **Bio-based Industrial Development** with the specific objective to develop industries that stimulate sustainable economic growth and add value to under-utilised renewable resources in the region.
4. **Sustainable Energy** with the specific objective to increase the production and use of sustainable bioenergy and develop a range of bioenergy products for both household and industrial purposes.

Bioeconomy in support of Food security and sustainable agriculture

In this report we are focusing on the *Strategic Thematic Area 1: Food security and sustainable agriculture*. Here the future prospects but also examples of progress in the region are presented for the following key bioeconomy areas.

- ***Value addition*** to food crops, livestock, forestry, marine and aquatic resources and microbial products. Here value addition to cassava, avocado and waste side streams in the livestock processing sector are highlighted. The potential for adding value to fish processing waste, seaweeds and microalgae is also illustrated.
- ***Novel food and feed products*** focusing on insects for food and feed, and value addition to traditional and indigenous food resources such as leafy vegetables and sweet potato
- ***Bio-based agricultural inputs*** including (i) Biostimulants to enhance the growth and productivity of plants and (ii) Biopesticides for plant protection and (iii) Biofertilizers.

Bioeconomy Impact stories from the region

There is an increasing number of emerging bioeconomy initiatives and bio businesses in the region. A few of these are highlighted in the report, including:

- Development of palm oil value chains in Burundi
- Avocado oil in Ethiopia
- Valorisation of slaughterhouse waste in Kenya
- Bioenergy opportunities in Rwanda
- The Tatu Moja Vaccine for chicken production in Tanzania
- Sustainable Aviation Fuel in Ethiopia.
- Creating a building industry using locally sourced novel bio-based building material
- Biodegradable packaging materials made in East Africa
- Reviving and Developing the Sisal Bioeconomy in East Africa. The case of Tanzania

Monitoring bioeconomy development in Eastern Africa

Monitoring bioeconomy development in Eastern Africa is important for many reasons. It helps identify trends, challenges, and opportunities in the bioeconomy, enabling evidence-based decision-making and policy adjustments creating an enabling environment for bioeconomy development. It also helps to identify sectors with growth potential, with insights into market trends and demand dynamics informing and promoting entrepreneurship and innovation in the region. The question is however what to monitor? What type of data collection is most relevant to bioeconomy development in the region and what type of data collection is done today by government agencies and national statistics offices? Due to limited data collection and information gaps, a prioritization of what is most relevant to monitor needs to be done. In this report we are presenting a set of potential indicators that could be used for monitoring the bioeconomy in the region.

Gaps and Challenges in Bioeconomy Development in Eastern Africa

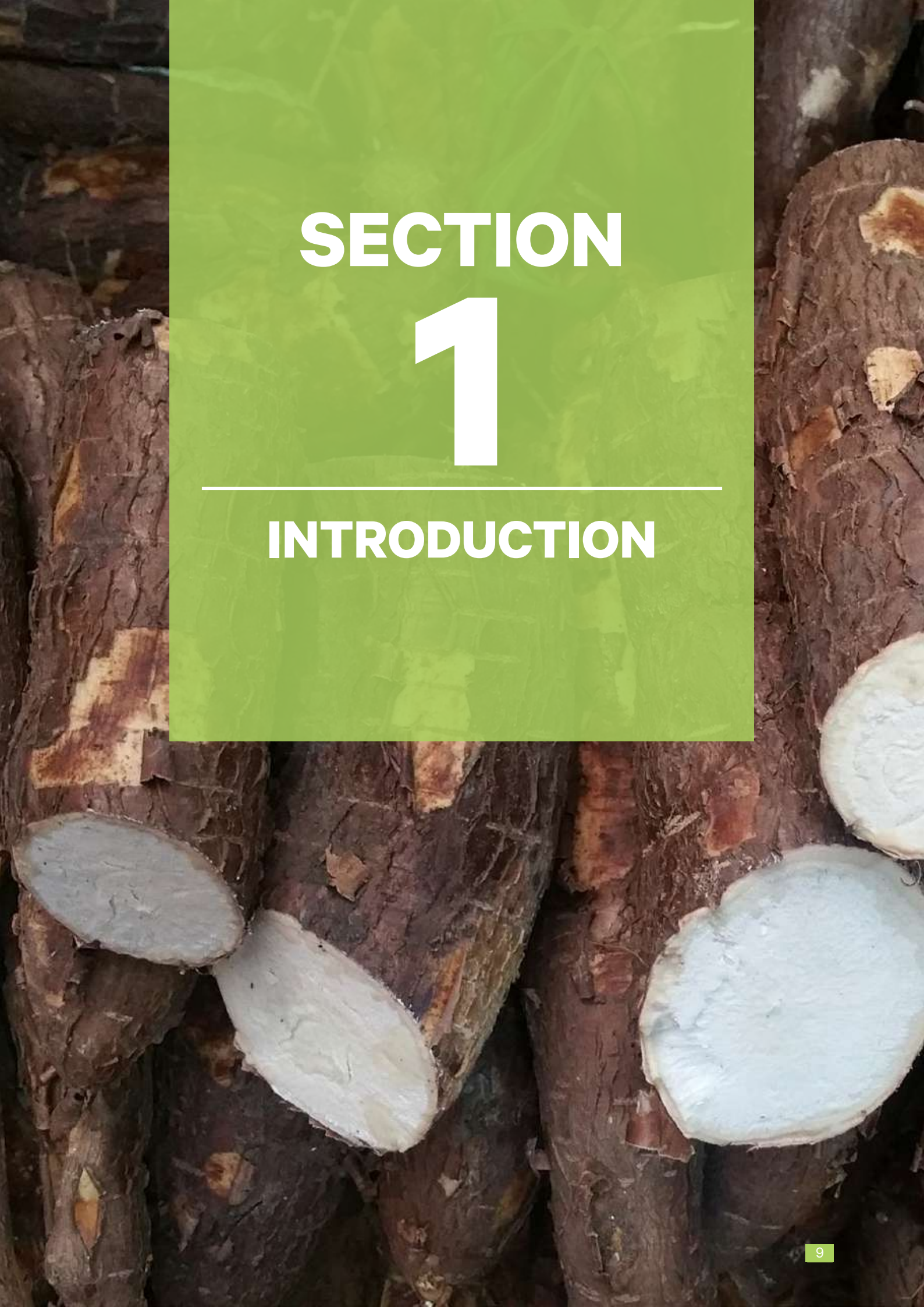
Despite the promising potential of the bioeconomy in Eastern Africa, several significant challenges impede its growth and development. Addressing these challenges is crucial to unlocking the region's bioeconomy potential and achieving sustainable economic and environmental outcomes. The key gaps and challenges include:

- Limitation in infrastructure, (transport, energy supply, storage facilities)
- Lack of technology and facilities for processing, and value addition
- Lack of skilled workforce
- Low agricultural productivity
- Inadequate and in many cases stifling policy and regulatory frameworks
- Lack of access to finance and venture capital
- Low level of private sector engagement,
- Inadequate Market awareness and weak demand/bioeconomy promotion

Way forward

The development of bioeconomy in the Eastern Africa countries has a large potential to support economic growth and sustainable development. However, it will only be achieved through strong leadership from governments, with the provision of appropriate policies, actions and incentives. Regional and international cooperation will also be important components in this endeavour. Below follows a list of ten recommended key actions that can be taken at national and regional level in support of bioeconomy development.

1. **Developing national bioeconomy strategies.**
2. **Monitoring and sharing information** including supporting a functional regional bioeconomy observatory
3. **Developing a regional expert Bioeconomy Committee.** Sharing information and providing advice to regional bodies and country governments and government institutions in the region on the implementation of bioeconomy strategies.
4. **Harmonisation of standards and regulations for bio-based products.** Regional integration through clear and coherent standards, common markets for bio-based products, (such as biofuel, novel foods/feeds, and biopesticides) needs to be developed to support biobased economic growth in the region.
5. **Improving biobusiness environment.** Policies are needed that provide motivation for innovators to translate innovations into businesses, support SME growth, business-to-business (B2B) collaboration and ease of doing business, incentivising the bio-businesses.
6. **Business incubation.** Professional business incubation services to assist innovation actors with business development and commercialising promising products and technologies is a key building block in modern bioeconomies.
7. **Capacity building** at multiple levels including highly trained academic staff at public R&D institutions, development of capacities in bioprocess engineering and valorisation of primary produce, entrepreneurship business planning and business management
8. **Investing in innovation infrastructure and centres of excellence** including development of biorefinery structures and agro-industrial development centres, and local and community-based bioprocessing structures.
9. **Attracting venture capital and investments.** Setting up investment agencies for novel technologies including bioeconomy development at regional and national levels with the task of attracting strategic investments in the region is one first step.
10. **Supporting networking and clustering.** Supporting collaborative platforms and clustering of bio-entrepreneurs and bio-based SMEs enabling them to share experiences and knowledge and providing them with business-to-business (B2B) opportunities.



SECTION 1

INTRODUCTION

1.1 RATIONALE FOR THE BIOECONOMY

Over the past 20 years, the value of the sustainable and circular bioeconomy in transforming the economy across all sectors has become more recognized globally. The bioeconomy can be defined as *"a knowledge-based production and utilization of biological resources, biological processes and principles to sustainably provide goods and services across all economic sectors* (International Advisory Council on Global Bioeconomy[2], 2023). It arises from different types of biological innovations and protects and regenerates renewable natural resources, providing local, regional, social and economic development opportunities. It provides essential building blocks for strategies to address value addition to bioresources including biowaste, climate change mitigation and adaptation and biodiversity loss, more broadly. This promotes job creation, safeguards livelihoods and secures future health and food supply. It is cross-sectoral, systemic and emergent in nature, and thus has a multi-faceted impact benefiting the economy, society and environment. The bioeconomy is therefore increasingly recognized as a key concept in making the transition to a sustainable and inclusive future.

The global bioeconomy is driven by various factors that reflect the growing recognition of the importance of biological resources in sustainable development and economic growth. Some of the key drivers include:

- **Resource Scarcity and Sustainability Concerns:** Depletion of finite resources and environmental degradation have led to a shift towards renewable and sustainable alternatives. Bioeconomy offers solutions that rely on biological resources, which can be replenished and managed more sustainably.
- **Rural Development, Economic Diversification and building value around local bioresources:** Transporting biomass long distances is usually costly and therefore, biomass should ideally be processed close to the site where it is harvested or acquired. The development of modern bioeconomies is therefore seen as a tool to revitalize rural communities, diversify agriculture, support job creation and increase the biomass production base and the opportunities for local value addition and bioprocessing. The bioeconomy has the potential to stimulate rural development by creating new markets for agricultural and forestry products, fostering rural entrepreneurship, and generating employment opportunities in rural areas. This can help diversify rural economies and reduce dependency on traditional sectors.
- **Climate Change Mitigation and Adaptation:** Bio-based products and processes often have lower carbon footprints compared with their fossil-based counterparts, making them attractive options for mitigating climate change. Bioeconomy initiatives contribute to reducing greenhouse gas emissions and promoting climate-resilient practices.
- **Demand for Renewable Energy:** As the world seeks to reduce dependence on fossil fuels, there is a growing demand for bioenergy sources such as biofuels, biogas, and biomass-based power generation, renewable resources that can replace petroleum, coal and gas. The bioeconomy can therefore play a fundamental role in the development of a low carbon economy by reducing greenhouse gas (GHG) emissions fulfilling the commitments in the Paris Agreement and decoupling GHG emissions from bio-based economic growth.
- **Circular Economy Principles:** Bioeconomy can contribute in several ways to the *circular economy,* including the utilization of organic side and waste streams from agriculture, forestry, fishery, food and feed and organic process waste. Biodegradable products can be returned to the organic and nutrient circle. Paper, other wood products, natural fibres, textiles and many more materials can be successfully recycled into value added products. Indeed, there is huge potential to convert biowaste from agro-and bioprocessing industries and human consumption, often causing environmental problems, into useful products such as energy, biofertilisers, feed, green chemicals, etc.
- **Technological Advancements:** Advances in biotechnology, including genetic engineering, synthetic biology, and bioprocessing, have significantly expanded the range of products and processes that can be derived from biological resources. This has unlocked new opportunities for innovation and commercialization within the bioeconomy.

[2]The International Advisory Council on Global Bioeconomy (IACGB) is an independent think tank composed about forty high-level bioeconomy leaders and experts from all hemispheres, representing different backgrounds and expertise, for more information see https://www.iacgb.net/home

- **Policy Support and Regulatory Frameworks:** Governments and international organizations are increasingly implementing policies and regulatory frameworks to support the development of the bioeconomy. This includes incentives for research and innovation, funding for bio-based projects, and standards for sustainable bio-based products.
- **Growing consumer awareness and preferences** for environmentally friendly products have created market opportunities for bio-based alternatives in sectors such as food, packaging, textiles, and cosmetics. Companies are responding to these trends by investing in bio-based innovations to meet consumer demand.

These drivers collectively contribute to the growth and expansion of the global bioeconomy, driving innovation, sustainability, and economic development across various sectors and regions.

Bioeconomy growth offers an opportunity for countries in Eastern Africa to achieve many of the Sustainable Development Goals by 2030, making use of the region's abundant natural resources, including under-utilised agricultural waste materials, to produce value added products with applications in many sectors including food, health, energy and industrial goods, thereby creating jobs, generating wealth, and connecting smallholder farmers to new bio-based value chains. The development of a modern bioeconomy in Eastern Africa has significant potential to support several critical development goals and targets for the region, and will help deliver the following outcomes:



Sustainable industrialisation, job creation and green growth, revitalising bioprocessing and biomass value chains in the region, and promoting circular economy production systems with reduced emissions, through productive and efficient use of biowaste.



Improved food and nutrition security through enhanced value chains and processing, promoting a more secure and resilient food supply while contributing to *sustainable, healthy, affordable and nutritious food* for the growing population in the region.



Improved health, using the biodiversity in the region to develop cost effective bio-based production systems for various biopharmaceutical products that address specific health challenges in the region (HIV, malaria and non-communicable diseases etc).



The creation of new bio-based products, including biomaterials for construction, bio-inputs for agriculture, enzymes for industry, and bio-based feedstocks (e.g. biofertilizers, bio-packaging) to substitute products derived from petrochemicals or to satisfy growing demands from consumers (e.g. functional foods, special dietary needs, novel health and well-being products).



Linking farmers and bioentrepreneurs to market opportunities and to local, national, regional and international markets. New bio-based value-added products attractive on a world market can assist the private sector in Eastern Africa to expand and improve their global competitiveness and stimulate sustainable economic growth.



Creating new forms of clean sustainable modern bioenergy, such as biofuels, for transportation and electricity generation from biowaste and industrial by-products, mitigating climate change and reducing the massive use of fuelwood that leads to deforestation.



Protecting the environment through converting waste, which today threatens ecosystems and freshwater resources, to useful products.

1.2 A BRIEF OVERVIEW OF INTERNATIONAL BIOECONOMY DEVELOPMENT

The international bioeconomy is rapidly evolving, driven by advances in technology, policy initiatives, and the growing need to achieve sustainability. The bioeconomy is increasingly seen as a key enabler and solution provider to global sustainability challenges of various sectors and dimensions of society. Policymakers worldwide also increasingly recognize the potential of the bioeconomy, and more and more countries and regions around the globe are developing their strategic vision for the bioeconomy in their specific national contexts.

Overall, some of the key trends in international bioeconomy development today are a focus on:

- **Circularity** and the creation of a circular bioeconomy, where biological resources are reused, recycled, and repurposed to minimize waste and maximize resource efficiency
- **Bio-based Products** with an Increasing development and commercialization of bio-based products, such as bioplastics, biofuels, and green chemicals, which offer sustainable alternatives to their fossil-based counterparts.
- **Biotechnology and Genomics:** advances in biotechnology and genomics are driving innovation in the bioeconomy, enabling the development of new bio-based products and processes. CRISPR and other gene-editing technologies are particularly impactful.
- **Digitalization:** The integration of digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), and big data, is optimizing bioeconomy processes and improving efficiency across various sectors.
- **Sustainability within the bioeconomy,** addressing global environmental challenges, such as climate change, biodiversity loss, and resource depletion.

In North America, the United States and Canada are major actors in the global bioeconomy, focusing on bioenergy, biotechnology, biomanufacturing and sustainable agriculture. The United States has a national bioeconomy blueprint which is a strategic framework that outlines goals, priorities, and actions to advance the bioeconomy. The blueprint emphasizes innovation, public-private partnerships, regulatory frameworks, and workforce development to enhance the country's competitiveness in the global bioeconomy while addressing issues like sustainability, climate change, and resource efficiency. Canada emphasizes the development of bio-based products and sustainable forestry.

The EU is committed to foster bioeconomy development, with a comprehensive and recently updated EU bioeconomy strategy, aimed at fostering innovation, circularity, sustainability, competitiveness, mitigating and adapting to climate change. The EU invests heavily in research and innovation and promotes the integration of bio-based industries.

In the Asia-Pacific region, countries like China, Japan, and Australia are making substantial investments in bioeconomy sectors. China is focusing on biotechnology and bioenergy, while Japan emphasizes the development of bio-based chemicals and materials. Australia is leveraging its agricultural and forestry resources to drive bioeconomy growth.

In Latin America, Brazil and Argentina are key contributors to the bioeconomy, primarily through their strong agricultural sectors. Brazil's biofuel industry, based on sugarcane ethanol, is one of the world's most advanced. In Argentina the bioeconomy heavily relies on its robust agricultural sector, with its advancements in agricultural biotechnology.

Developing and emerging economy countries (such as Colombia, Ethiopia, Namibia, South Africa, and Thailand) are also increasingly engaged and, through new bioeconomy strategies, seeking to adapt existing technologies (e.g., biorefineries) to local conditions, aiming to address persistent social and economic challenges and promoting job creation and increased livelihood opportunities.

International and multilateral cooperation is seen in many bioeconomy strategies as a key building block. Consequently, multilateral organizations have intensified their engagement in and for bioeconomy. The G20 under India's lead in 2023 drew attention to bioeconomy, and Brazil in 2024 put bioeconomy even more prominently on the G20 agenda. The Food and Agriculture Organization of the UN (FAO) included bioeconomy in its new science strategy *Bioeconomy for sustainable food and agriculture* and is now one of 20 programme priority areas in the FAO Strategic Framework for 2022–2031.

As for trends in recent agendas, policies and strategies there is a focus on enhancing synergies and minimizing trade-offs among economic, environmental, and social objectives. The fundamental objectives to be achieved through bioeconomy expansion are major contributions to climate neutrality, food and nutrition security, improved health, economic growth and many other objectives aligned with the UN Sustainable Development Goals. Recent policies and strategies are increasingly emphasizing the pivotal role of the bioeconomy in strategically enhancing global supply chain resilience of food, feed, fibres and other crucial biomaterials.

In order to address the biomass availability gap[3] and facilitate sustainable development, bioeconomy strategies promote circularity models that emphasize bioresource optimization, recycling, use of waste side streams and sustainable consumption, as well as an increase in biomass productivity in agriculture and forestry. The latter is driven by precision agriculture, biotechnology and other innovative technologies.

There is also increasing global attention being paid to the blue bioeconomy and the use of aquatic resources in freshwater (lakes, rivers, ponds) and marine environments (oceans, seas) and the need for sustainable and more effective resource management. This includes improving processing technologies and streamlining the supply chain from harvest to market. Improved aquaculture is also a fundamental part of the blue bioeconomy with cultivation of different species from different trophic levels (fish, shrimp, algae, seaweed, etc), sustainable feed alternatives such as plant-based or insect-based feeds and increased use of waste products.

1.3 OVERVIEW OF BIOECONOMY IN THE REGIONAL CONTEXT OF EASTERN AFRICA

1.3.1 Bioeconomy Strategy development in Eastern Africa

In Eastern Africa, a number of policies and strategies that support the development of an Eastern African bioeconomy have been developed at the regional level. The most important action in a policy context and in terms of supporting the bioeconomy development in the region is the East African Community Bioeconomy Strategy which was developed and approved by the 17th Sectoral Council of Education, Science and Technology, Culture and Sports that was held on 19th -23rd April 2022 in Dar es Salaam, United Republic of Tanzania. This Regional Bioeconomy Strategy provides a compelling framework for putting in place agreed goals and interventions which countries in East Africa can use to develop *a vibrant, inclusive and innovative bioeconomy contributing to sustainable economic growth and development in East Africa*. Moreover, the strategy is aligned with expressed commitments to environmental sustainability, climate change adaptation and mitigation, reversing or changing unsustainable practices. *The overall mission of the strategy is to catalyse and support innovative and sustainable use of bioresources as the major driver of inclusive economic growth and job creation in East Africa*.

The East African Regional Bioeconomy Strategy was a developed through an open, transparent, and broadly consultative process with a view to including a variety of perspectives and to reflect different contextual realities in the countries in the region. The Strategy has inspired and catalysed the development of national bioeconomy strategies and subsequent policy development and interventions for sustainable bio-based and inclusive economic growth in the region. Currently, several countries in the region are in different stages of developing bioeconomy strategies inspired by the Regional Bioeconomy Strategy (see table 1).

Ethiopia has drafted its national bioeconomy strategy and validated the document through extensive stakeholder meetings and development partners in December 2023. The document has been submitted to the Ethiopian Science and Technology Council for final approval and for further implementations steps.

Uganda is in the process of developing their bioeconomy Strategy, Rwanda has developed the roadmap for development of their bioeconomy strategy and Burundi will, with support of EASTECO, soon start their strategy development process.

[3]Studies suggest that the gap between the potential demand for biomass and its sustainable supply can be as big as 40-70%

Table 1- Summary of bioeconomy strategy development for countries in Eastern Africa

Country	Has a dedicated Bioeconomy policy/ strategy	Advanced stage of Bioeconomy policy/ strategy development	Starting to develop a bioeconomy strategy
Burundi	No	No	Yes
Ethiopia	No	Final draft of a bioeconomy strategy developed	Yes
Kenya	No	No	No
Rwanda	No	No	Yes
Tanzania	No	No	Yes, COSTECH will start strategy development in 2025
Uganda	No	No	Yes, currently drafting a bioeconomy policy

1.3.2 Research, Innovation, Entrepreneurship and Knowledge Sharing

There has been a long and significant growth in research and development in the academic sector in the region to address local challenges and opportunities in the bioeconomy. This includes research on crop value addition, value addition to biowaste, bioenergy production, biodiversity conservation, and sustainable agriculture practices. Efforts have been made to build human and institutional capacity in the bioeconomy through training programmes, workshops, and educational initiatives. The region has increasingly supported stronger universities, research institutions and innovation capabilities, with a growing number of active and well-trained scientists. In addition, all the countries in the region have embraced or are piloting different tools, agro-based clusters and platforms to promote agro-industrial development, which will serve as a base for expansion of bio-based business enterprises.

The BioInnovateAfrica Programme is the largest bioscience and bioeconomy collaboration platform in Eastern Africa. (https://bioinnovate-africa.org/). The initiative is supported by the Swedish International Development Cooperation Agency (Sida) and based in and implemented by the International Centre of Insect Physiology and Ecology (*icipe*) in Nairobi, Kenya. The Programme acts as a capacity building platform and biobusiness incubator, supporting scientists and innovators in the region to link biologically based research ideas, inventions, and technologies to business and the market. Current BioInnovate Africa partner countries are Burundi, Ethiopia, Democratic Republic of Congo, Kenya, South Sudan, Rwanda, Tanzania and Uganda.

The purpose of BioInnovate Africa is to enhance the capacity of Eastern African universities, research organisations and firms to translate modern bioscience research outputs into innovations targeting smallholder farmers and agro-process enterprises in the region. The Programme is generating and developing bioinnovations (knowledge, products and services), bio-based business models, new small enterprises, spin-off companies, networks and partnerships and policy analysis. These outputs are expected to harness modern biology and bioscience innovations with the goal of improving productivity and sustainability of farmers, agribusinesses and agro-processors. The Programme is supporting the development of innovation multi-actor consortia, involving scientists, private sector and civil society actors and is implemented through three thematic areas:

- Value addition to agro-produce, converting waste to useful products
- Value addition to agro/biowaste, connecting farmers and agribusinesses to new markets and value chains
- Policy development for delivering bioscience innovations and supporting Bioeconomy development

The Biosciences eastern and central Africa-International Livestock Research Institute (BecA-ILRI) Hub also plays a pivotal role in fostering an bioeconomy ecosystem in the region. The Hub connects scientists from National Agricultural Research Systems, the CGIAR and advanced research institutes from the global north to tackle significant agricultural challenges in Africa. By offering access to cutting-edge bioscience technologies, comprehensive knowledge, mentorship and technology incubation and deployment, the hub aims to empower researchers to develop homegrown solutions that contribute significantly to food, nutrition security and bioeconomy development across the continent.

Entrepreneurship and Startups: There has been a growing interest in bio-based entrepreneurship and startups in East Africa, with initiatives focusing on value-added processing of food renewable energy, healthcare biotechnology, and valorization of biowaste. Incubators, accelerators, and funding opportunities have also slowly emerged, particularly in Kenya[4], to support bioeconomy startups.

International Collaboration: East African countries have been engaging in regional and international collaborations to exchange knowledge, expertise, and best practices in the bioeconomy. This includes partnerships with global organizations, research institutions, and donor agencies to leverage resources and expertise for bio-based development. Of particular importance in the development is the Global Bioeconomy Summit (GBS) 2024 held for the first-time outside Europe in Nairobi, Kenya on 23 – 24 October 2024. GBS2024 provides a platform to discuss global bioeconomy issues in an inclusive manner. GBS2024 profiles and recognizes the importance of bioeconomy in advancing sustainable development bringing together bioeconomy experts and high-ranking representatives from politics, science, civil society, and the business sector from all hemispheres. The summit will focus on sustainable bioeconomy as the key to decarbonization and sustainable transition to less fossil fuel dependent, rural and urban green economies; while building resilient and sustainable food systems, reversing biodiversity loss, meeting health challenges, and using innovation as a driver for new economic opportunities, especially jobs for the youth

Demonstration projects/value addition initiatives: Pilot projects and demonstration initiatives have been implemented to showcase the potential of the bioeconomy in Eastern Africa. These projects often focus on sustainable land management, renewable energy deployment, bioprocessing technologies, and community-based initiatives for rural development. Ethiopia now has four Integrated Agro Industrial Parks (IAIPs) strategically located across agriculturally rich regions. The value chains within IAIPs include fruits, vegetables, dairy, meat, poultry, coffee, cereals, and pulses, using locally sourced produce. Generally, IAIPs provide modern infrastructure for agro-processing and connect with farms and communities through rural transformation centres (RTCs) facilitating better market access for smallholder farmers. These IAIPs attract both local and global investors, leading to high-quality production and contributing to job creation, transforming the lives of farmers and unemployed citizens.

While there is significant potential for the bioeconomy in Eastern Africa, challenges such as limited infrastructure, inadequate financing, policy gaps, and regulatory barriers remain. Addressing these challenges requires coordinated efforts from governments, the private sector, civil society, and development partners to create enabling environments for bio-based innovation and investment.

[4]https://www.xyzlab.com/post/startup-accelerators-incubators-in-kenya#viewer-58c1h



SECTION 2

OPPORTUNITIES FOR BIOECONOMY DEVELOPMENT IN EASTERN AFRICA

2.1 A FOCUS ON FOOD SECURITY AND SUSTAINABLE AGRICULTURE

The economies of countries in the Eastern African region are mainly agri-based and according to World Bank data[5] over 30% of the region's GDP is currently directly attributed to agriculture and other bioeconomy related sectors. The bioeconomy holds significant potential to contribute to sustainable development and economic growth in Africa by leveraging the continent's abundant biological resources and addressing various socio-economic challenges. However, the region has only to a limited degree, been able to apply technologies and know-how that could modernise agricultural production, bioprocessing and value addition. The low degree of bioprocessing and value addition to primary produce makes it difficult for the region to use its bioresources as an engine for economic growth.

The EAC Regional Bioeconomy Strategy is to a large extent focusing on how to add value to the various types of bioresources for different purposes.

The Strategy has four priority Strategic Thematic Areas forming the core of Strategy, these are;

Strategic Thematic Area 1:



Food security and sustainable agriculture with the specific objective to introduce new bio-based technologies and solutions to strengthen food and feed production, ensuring food security.

Strategic Thematic Area 2:



Health and Wellbeing with the specific objective to develop a bio-based healthcare sector contributing towards a healthy population with improved well-being, addressing regional priorities and building on indigenous knowledge and practices.

Strategic Thematic Area 3:



Bio-based Industrial Development with the specific objective to develop industries that stimulate sustainable economic growth and add value to under-utilised renewable resources in the region.

Strategic Thematic Area 4:



Sustainable Energy with the specific objective to increase the production and use of sustainable bioenergy, and develop a range of bioenergy products for both household and industrial purposes.

In this report we will focus on the Strategic Thematic Area 1: Food security and sustainable agriculture.

[5]Africa Overview: Development news, research, data | World Bank

The bioeconomy presents several opportunities to improve agriculture in the region in various ways. Bioeconomy innovations can enhance food security in the region by increasing agricultural productivity and improving the nutritional value of crops. For example, biofortification techniques can enrich staple crops with essential nutrients, addressing malnutrition problems in the region. The bioeconomy also encourages diversification of agricultural products and value-added processing, enabling farmers to generate multiple income streams. By utilizing biomass and residues for novel food and feed products, biofuels, bio-based materials, and biopharmaceuticals etc, farmers can tap into new markets and increase their resilience to market fluctuations. The bioeconomy also has the potential to create employment opportunities in rural areas in the region, from biomass cultivation to bio-processing facilities, and various stages of the bioeconomy value chain can generate jobs, fostering economic development and reducing rural poverty.

Overall, leveraging the bioeconomy can play a significant role in transforming agricultural systems in the Global South, not least in Eastern Africa,, promoting sustainable development, poverty alleviation, and resilience in the face of environmental and socio-economic challenges.

In the Food security and Sustainable Agriculture Thematic Area in the EAC Regional Bioeconomy Strategy there are three key result areas;

- Value addition to food crops, livestock, forestry, marine and aquatic resources and microbial products,
- Novel food and feed products
- Bio-based agricultural inputs

The potential for bioeconomy development in these three key result areas will be described in more detail below.

2.2 VALUE ADDITION TO FOOD CROPS, LIVESTOCK, MARINE AND AQUATIC RESOURCES

Value addition allows farmers to sell processed or transformed products at higher prices compared with raw commodities. This can significantly increase their incomes and improve livelihoods, helping to alleviate poverty and reduce reliance on subsistence farming. Processed and value-added products often also have access to a broader range of markets, both domestically and internationally. By diversifying their products through value addition, Eastern African farmers can also reduce market risks associated with a reliance solely on raw commodity markets.

Value addition to primary agriculture produce often involves processing and packaging that meet higher quality and safety standards. Processed and value-added products have higher export potential compared with raw commodities. By adding value to their crops, Eastern African agro producers can tap into growing urban markets in the region and connect Eastern African farmers to consumers in the EU and other international markets. Investing in value addition can also promote the adoption of new technologies and innovative practices which can lead to improvements in productivity, efficiency, and sustainability across the agricultural value chain. Value addition activities such as processing, packaging, and marketing require additional labour, leading to job creation in rural areas where employment opportunities may be limited. This contributes to economic growth and reduces urban migration pressures.

Value addition to primary agriculture produce also encourages diversification of agricultural activities beyond traditional staple crops, such as maize. This can lead to more resilient agricultural systems, better adaptation to climate change, and reduced vulnerability to market fluctuations.



2.2.1 Food crop value chains

The majority of food produced in Eastern Africa is only minimally processed. Many crops are processed into flours, like maize, sorghum, millet, soybean, or cassava, while a portion of fruit produced, such as mangos, bananas and pineapples, may be dried. However, there are major opportunities to add additional value to food crops in the region. Here we will bring up a few crop examples and value addition opportunities including making use of side streams.



2.2.1.1 Adding value to Cassava

Cassava, which can grow well on marginal lands, is one of the most important staple foods in Eastern Africa. It is estimated that 60% of the production is destined for household consumption and 40% for marketing[6]. According to Munguti et al. (2023)[7], cassava, which is known as a "poor man's crop", is predominantly grown by subsistence farmers as a staple crop on plots averaging 1 to 3 acres. Cassava is identified as one of the emerging market-oriented commodities that could contribute to improving the livelihood of small holder farmers in the region.

Cassava production and its optimized food, nutritional, and industrial positioning as a climate smart crop in Eastern Africa faces major challenges. The production challenges are associated with the increased prevalence of pests and diseases, lack of quality pathogen-tested planting material, ill-defined and poorly functioning seed system structure, and lack of statutory regulations to guide the cassava seed value chain[8]. Cassava's usefulness is also limited by poor nutritional value and the presence of toxic cyanogenic glycosides in the leaves and roots[9] although breeding efforts are under way to develop improved varieties including through the use of modern biotechnology techniques[10]. High post-harvest losses due to the fast decomposition of harvested cassava is also a major problem necessitating rapid processing which involves a range of techniques such as drying, cooking and fermentation of cassava to improve its shelf life, reduce weight, and enhance its overall value[11]. Most of the processing is however done locally, using traditional technologies and limited access to modern processing techniques and value chains[12]. Thus, despite the recognition of the high value of cassava, Eastern African countries have so far only to a limited degree responded to the opportunities of using cassava cultivation, processing, and value addition as an engine for agricultural growth, job creation, and the development of a modern bioeconomy. While commercial enterprises using cassava as an industrial crop have been quite successful in countries like Brazil and Thailand[13], such attempts have failed in Africa, including Eastern Africa.

There are however significant opportunities to improve cassava productivity and processing through development of cassava based biorefineries producing several types of industrial graded starch, biofuel, and other bio-based products. Such new value chains would also connect cassava smallholders to emerging and growing markets in the region and internationally for products such as novel cassava food and feed products and starch-based bio packaging products. For this to happen, the creation of collaborative platforms for increased cassava productivity and value addition, sharing and learning from other regions will be important through integration of training and extension for farmers, shared expertise, infrastructure, and business incubation facilities. Private-public partnerships for technology and industrial development will also be key in realizing the potential of cassava cultivation and processing.

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[6]Akongo, G. O., Otim, G. A., Turyagyenda, L. F., Bua, A., Komakech, A., & Obong, S. (2021). Effects of improved cassava varieties on farmers' income in northern agro-ecological zone, Uganda. *Sustainable Agriculture Research*, 10(2), 65-73.
[7]Munguti, F. M., Nyaboga, E. N., Kilalo, D. C., Yegon, H. K., Macharia, I., & Mwango'mbe, A. W. (2023). Survey of cassava brown streak disease and association of factors influencing its epidemics in smallholder cassava cropping systems of coastal Kenya. *Frontiers in Sustainable Food Systems*, 6, 1015315
[8]Githunguri, C. M., & Njiru, E. N. (2020). Role of cassava and sweetpotato in mitigating drought in semi-arid Makueni County in Kenya. In *African handbook of climate change adaptation* (pp. 1-19). Cham: Springer International Publishing.
[9]Kanaabi, M., Settumba, M. B., Nuwamanya, E., Muhumuza, N., Iragaba, P., Ozimati, A., ... & Kawuki, R. S. (2024). Genetic Variation and Heritability for Hydrogen Cyanide in Fresh Cassava Roots: Implications for Low-Cyanide Cassava Breeding. *Plants*, 13(9), 1186.
[10]Otun, S., Escrich, A., Achilonu, I., Rauwane, M., Lerma-Escalera, J. A., Morones-Ramírez, J. R., & Rios-Solis, L. (2023). The future of cassava in the era of biotechnology in Southern Africa. *Critical Reviews in Biotechnology*, 43(4), 594-612.
[11]Mwang'ombe, A., Onyango, S., Kilalo, D. C., & Wasswa, P. (2023). Empowerment and poverty reduction in rural coastal Kenya through the cassava value chain. In *University Engagement with Farming Communities in Africa* (pp. 141-156). Routledge.
[12]Fathima, A. A., Sanitha, M., Tripathi, L., & Muiruri, S. (2023). Cassava (Manihot esculenta) dual use for food and bioenergy: A review. *Food and Energy Security*, 12(1), e380.
[13]de Oliveira Gonçalves, L., São Julião, S. M., Zago, L., & Santana, I. (2024). Cassava, an illustrious (un) known: Consumption of recipes with the root and its derived products. *International Journal of Gastronomy and Food Science*, 35, 100812.

The cassava value chain in Eastern Africa offers a myriad of value-added opportunities, ranging from food processing to *renewable energy and sustainable packaging,* and with strategic investment and supportive policies, these opportunities can drive economic growth and sustainability in the region. Among the most promising avenues is the processing of cassava into *High-Quality Cassava Flour (HQCF),* which has emerged as a versatile ingredient with applications in bakery products, snacks, and confectionary[14]. Eastern African countries can capitalize on the growing demand for gluten-free and nutritious flour alternatives by utilizing advanced processing techniques and implementing stringent quality control measures. Cassava flour is already used in composite flour manufacture, especially for markets in the region where a blend of 60% cassava flour and 40% millet is a common staple food in the rural areas such as Western Kenya and Uganda[15].

The production of *industrial starch and glucose syrup* presents a lucrative opportunity for value addition, serving diverse industries such as food, pharmaceuticals, and textiles. Investment in processing facilities equipped with modern technologies can unlock the potential of cassava-derived starch and syrup, while research into modified starches and specialty sugars can further enhance market competitiveness[16].

Bioethanol production from cassava also offers a sustainable solution to energy needs, reducing dependence on fossil fuels and providing an additional revenue stream for farmers and processors[17]. Eastern African countries can tap into the renewable energy market and contribute to environmental sustainability by leveraging fermentation and distillation processes.

Cassava by-products such as peels and cake can be processed into *high-quality animal feed,* improving livestock nutrition and productivity. The energy level of dried cassava (3200-3400 kcal/kg of chips) makes cassava a preferred constituent of both poultry and fish feeds when combined with alternative sources of protein such as soya. Additionally, the utilization of cassava leaves, rich in protein and essential nutrients, holds promise to produce nutritious supplements, culinary products, and animal feed additives.

The development of *biodegradable packaging materials* derived from cassava starch also presents an opportunity to reduce environmental pollution and promote sustainability in the packaging industry[18]. Through investment in research and development, Eastern African countries can enhance the production of eco-friendly packaging solutions while enhancing the competitiveness of their cassava sectors.

[14]Abubakar, M., Wasswa, P., Masumba, E., Kulembeka, H., Mkamilo, G., Kanju, E., ... & Ongom, P. (2023). Pasting properties of high-quality cassava flour of some selected improved cassava varieties in Tanzania for baking
[15]Kesselly, S. R. (2023). *Modification of cassava and cowpeas flours and their use in flatbread (Chapati) making* (Doctoral dissertation, Makerere University).
[16]Nuwamanya, E., Kanaabi, M., Katungisa, A., Muhumuza, N., Lyatumi, I., Esuma, W., ... & Atwijukire, E. (2023). Evaluation of the industrial potential of cassava based on pasting properties of cassava flour from Ugandan elite varieties. *African Crop Science Journal,* 31(2), 201-214.
[17]Anwar, A. F., Sanitha, M., Tripathi, L., & Muiruri, S. (2023). Cassava (Manihot esculenta) dual use for food and bioenergy: A review. *Food and Energy Security,* 12(1).
[18]Joshi, P., Gupta, K., Uniyal, P., Jana, A., Banerjee, A., Kumar, N., ... & Khatri, O. P. (2023). Cassava starch-derived aerogels as biodegradable packaging materials. *Materials Chemistry and Physics,* 296, 127282.

Cassava Value addition country by country

Production	Value addition/processing initiatives
Production	**Value addition/processing initiatives**
Burundi	
The most widely grown tuber and root crop in Burundi is cassava, representing some 77% of the total production of tubers and roots in Burundi. Cassava occupies an important place because in terms of food, it remains the second most consumed tuber in the country behind the potato[19]. The cassava production is estimated at roughly 2 million tons of bitter cassava and and 350 000 tons of sweet cassava[20]	Some private and public initiatives for artisanal food processing exist. These include among others grinding and packaging of cassava products.
Ethiopia	
In Ethiopia, cassava accounts for 17.7% of the overall production of root crops[21]. It is among the most widely cultivated crops in southern parts of the country specially in Wolaita zone, with a productivity ranging from some 20 tonnes/ha, under optimal conditions, about 80 tonnes/ha[22].	Cassava is a food security crop and revenue-generating crop in Ethiopia and mostly consumed as a boiled tuber. It is now however increasingly being processed into flour, which is mixed with cereals such as teff, barley, and wheat for bread or injera preparation. The recently increasing price of Teff and other drought sensitive crops in Ethiopia may be an excellent opportunity to allow an increase in the production of the more drought tolerant cassava.
Kenya	
Cassava is predominantly grown in the Coastal, Central, and Western regions of Kenya, serving as a vital source of food, income, and livestock feed. Cassava production in Kenya is estimated to be 1 million tonnes annually. Farmers have access to high-yielding varieties of cassava that can mature in 6 to 12 months producing some 20 tonnes per acre. These varieties are suitable for direct consumption as well as for processing into starch, flour, and animal feed. Officials from the Ministry of Agriculture highlight that Kenya has the potential to produce over 3 million tonnes of cassava annually. Promoting cassava as a climate-friendly and pest-resistant crop can significantly boost production, especially in regions where farmers are grappling with the adverse effects of climate change[23].	While most of the cassava that is produced is consumed for food/feed with little to no value addition. Giraffe Bioenergy is a company in Kenya that focuses on producing ethanol cooking fuel from cassava. Their mission is to improve rural livelihoods by establishing local manufacturing of this clean fuel. The initiative aims to increase the incomes of smallholder farmers, mainly women, by leveraging under-utilized semi-arid lands for cassava farming. Their goals include producing 45 million litres of ethanol by 2028, boosting food security, and promoting environmental sustainability through climate-resilient farming practices[24].

[19]Nzigamasabo, A., & Zhou, H. M. 2006. Functional and chemical properties of ikivunde and inyange, two traditionally processed burundian cassava flours. *Journal of Food Biochemistry*, 30(4), 429–443.
[20]ISTEEBU 2018. Enquête Nationale Agricole du Burundi 2016-2017. 131 p.
[21]Tafesse A, Mena B, Belay A, Aynekulu E, Recha JW, Osano PM, Darr D, Demissie TD, Endalamaw TB and Solomon D (2021) Cassava Production Efficiency in Southern Ethiopia: The Parametric Model Analysis. Front. Sustain. Food Syst. 5:758951. doi: 10.3389/fsufs.2021.758951
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[24]https://www.giraffebioenergy.com/

CONT.D

Production	Value addition/processing initiatives
Tanzania	
Tanzania produces about 5.6 million tonnes of cassava per year, which is mainly used traditionally to make ugali and porridge. With improved technologies, innovation and global interaction, cassava flour has become a versatile ingredient used in various culinary applications, including baking, thickening, coating and snacks.	Mercibel Product Ltd is a Tanzanian medium sized enterprise that produces and commercializes cassava flour by employing modern processing technologies. This is done through a hydraulic presser or mechanical screw presser extracting starch liquid from the grated cassava, which is then separated from the solid product before solar drying. The dried cassava shreds are fed into a milling machine where they are pulverized into a fine powder for sale to the retail and wholesale traders. The company has capacity to produce about 15 tonnes of cassava flour per month. The reduced starch cassava flour has lower Glycemic Index (GI) which results in more stable blood sugar level after consumption, and improves digestibility for people with digestion issues or sensitivity to high starch foods, and increases shelf stability of cassava products.
Rwanda	
The yearly cassava production in Rwanda is some 520,000 metric tons, The national average yield was 13.3 tonnes per hectare in 2024. The cultivated area was estimated at rougly 251 000 ha hectares, an increase of 5 percent from season 2023.	• Kinazi Cassava Plant Limited (KCP) is a cassava processing company located in Ruhango District, Southern province of Rwanda with the following objectives: 1. Increase value addition to cassava crop in Rwanda 2. Improve farmers' incomes and living standards 3. Promote, market and distribute high quality cassava products • The plant processes fine cassava flour from fresh cassava tubers, grown in Rwanda through the wet milling process.
Uganda	
Uganda is one of the leading producers of cassava in Africa where it is a significant staple crop providing food security and income for millions of Ugandans. Uganda produces approximately 3-5 million metric tons of cassava annually, and where the average yield is about 10-15 metric tons per hectare.[25] However, yields can be significantly higher in regions with better soil fertility and where improved farming practices and disease-resistant varieties are used.	Value addition of cassava in Uganda is undertaken by a diverse group of stakeholders, including private companies, cooperatives, non-governmental organizations (NGOs), and research institutions. These entities engage in various activities to enhance the value of cassava, from processing into different products to marketing and distribution. A large part of the cassava in Uganda is processed to different products and roughly the distribution[26] looks[27] like the following: • High-Quality Cassava Flour (HQCF): 0,5.-1 million metric tons • Cassava Chips: 400-700,000 metric tons • Starch Extraction: 500-900,000 metric tons • Animal Feed Production: roughly 500,000 metric tons • Bioethanol Production: 100- 200,000 metric tons • Traditional Foods and Fermented Products: ~1-2 million metric tons A key private sector actors is Nile Agro Industries Ltd, a leading company in cassava processing, producing a range of cassava-based products including high quality cassava flour cassava starch animal feed and supporting smallholder farmers through outgrower schemes

[25]https://www.ubos.org/explore-statistics/2/

[26]https://naro.go.ug/e-library/information-sheets/

[27]https://unffe.org.ug/category/articles/

2.2.1.2 Adding value to Avocado

The production of avocados has experienced notable growth in Eastern Africa, specifically in countries such as Kenya, Ethiopia, Rwanda and recently in Burundi. These countries possess agro-climatic conditions that are favourable for avocado farming. The avocado fruit has emerged as a significant agricultural export and a means of sustenance for numerous small-scale producers in the region[28]. Countries in the region have demonstrated a keen interest in harnessing the potential of avocados, as seen by countries such as Kenya emerging as significant players in the worldwide avocado export market[29]. The production of avocados exhibits robust growth in the elevated regions and tropical lowlands of Eastern Africa. Due to an increasing recognition of their health advantages and adaptability in culinary applications, avocados have been transformed into oils, purees, and cosmetic products[30]. This value addition not only appeals to a wide range of markets but also effectively tackles the problem of possible wastage[31]. The European Union, with a particular emphasis on the United Kingdom, serves as a significant consumer of avocados originating from Eastern Africa[32].

Avocado production in Eastern Africa presents a wealth of opportunities for value addition across its value chain. From cultivation to distribution, various stages offer avenues for increasing the economic value of avocado fruit. One prominent avenue lies in processing avocados into oil. Avocado oil is renowned for its nutritional benefits and versatility in culinary and cosmetic applications. Eastern African countries can capitalize on this by establishing processing facilities to extract oil from ripe avocados. Cold-pressed or solvent extraction methods produce high-quality avocado oil suitable for cooking, salad dressings, skincare products, and hair treatments. This value addition opportunity not only enhances the shelf life of avocados but also creates a premium product with high market demand.

The production of avocado pulp and puree presents another significant opportunity, as these are valuable ingredients used in various food products such as dips, spreads, sauces, and smoothies[33]. Surplus or imperfect avocados can be converted into pulp and puree for both domestic consumption and export. Proper packaging and preservation techniques are used to extend the shelf life of avocado-based products, thereby reducing post-harvest losses and increasing market access. Moreover, there is potential for the development of avocado-based functional foods. Avocado is rich in essential nutrients, antioxidants, and healthy fats, making it an ideal ingredient for functional foods targeting health-conscious consumers.

Collaboration with food scientists and nutritionists can lead to the development of innovative avocado-based products, such as fortified beverages, energy bars, and dietary supplements[34]. These value-added products cater to niche markets and command premium prices. The manufacturing of avocado-derived cosmetics also presents an opportunity for value addition. Avocado oil and avocado butter are prized ingredients in the cosmetic industry for their moisturizing, nourishing, and anti-aging properties[35].

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[28]Legesse, T., Kebede, K., Ashebir, A., Ganewo, Z., Alemu, A., & Samuel, A. (2024). Can high-value markets ensure households food security? Evidence from avocado producers in Sidama Region of Ethiopia. *Cogent Social Sciences*, 10(1), 2297758.

[29]Shivachi, B., Okoth, M., & Gikonge, D. (2023). The Status of Avocado Production, Postharvest Handling and Utilization in Kenya. *East African Journal of Science, Technology and Innovation*, 4.

[30]Alghanam, A. (2023). Functional Foods produced from avocado fruits. *Journal of Sustainable Agricultural and Environmental Sciences*, 2(4), 73-80.

[31]Gebru et al. (2022) *CGIAR Online.*

[32]Kamonde (2021). *MBA Thesis, University of Nairobi.*

[33]Sarantakou, P., Andreou, V., Paraskevopoulou, E., Dermesonlouoglou, E. K., & Taoukis, P. (2023). Quality Determination of a High-Pressure Processed Avocado Puree-Based Smoothie Beverage. *Beverages,* 9(2), 38.

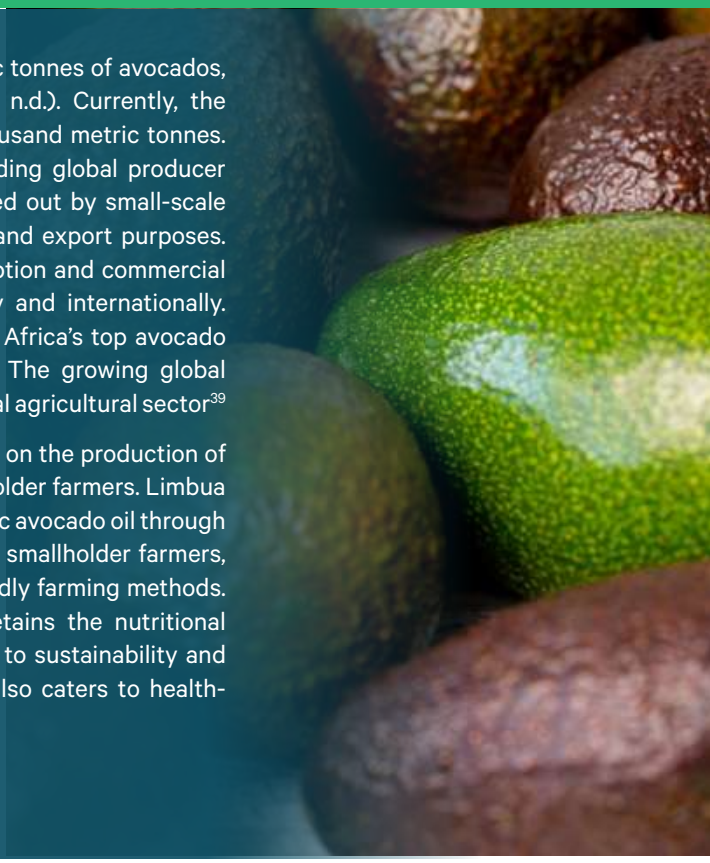
[34]Nyakang'i, C. O., Ebere, R., Marete, E., & Arimi, J. M. (2023). Avocado production in Kenya in relation to the world, Avocado by-products (seeds and peels) functionality and utilization in food products. *Applied Food Research*, 3(1), 100275.

[35]Flores, M., Saravia, C., Vergara, C. E., Avila, F., Valdés, H., & Ortiz-Viedma, J. (2019). Avocado oil: Characteristics, properties, and applications. *Molecules*, 24(11), 2172.

The utilization of avocado by-products offers additional avenues for value addition. Avocado processing generates by-products such as peels, seeds, and leaves, which are utilized for various purposes. Avocado seed extracts, rich in antioxidants and phytochemicals, are processed into dietary supplements, herbal teas, or natural dyes Avocado peels and leaves, known for their antimicrobial properties, are incorporated into organic fertilizers, animal feed additives, or herbal remedies.

The waste generated from avocados can be transformed into value added bioproducts through waste valorization[36]. The avocado wastewater, which accounts for 45% of the total waste produced from cold pressed avocado oil, can be transformed into avocado wastewater powder. This powder can be used as a bio-antioxidant[37]. The avocado peels and seeds, on the other hand which make up approximately 27% of the waste produced during avocado processing, contain valuable components that can be extracted and utilized as bioactive compounds like catechin and quercetin. Alternatively, they can be processed into other products such as bioethanol, which can serve as an environmentally friendly fuel source[38].

Box 1 Avocado production and value addition in Kenya



As of 2020, Kenya produced approximately 323 thousand metric tonnes of avocados, an increase from 264 thousand metric tons in 2019 (Kenya, n.d.). Currently, the production of avocado in the country stands at around 417 thousand metric tonnes. This significant growth underscores Kenya's position as a leading global producer of avocados. About 70 percent of avocado production is carried out by small-scale farmers who cultivate the fruit for subsistence, local markets, and export purposes. Avocado production in Kenya caters to both domestic consumption and commercial needs, with the fruit seeing increased popularity both locally and internationally. Avocados are Kenya's most exported fruit, making the country Africa's top avocado exporter and the world's third-largest producer of avocados. The growing global demand for avocados continues to drive the expansion of this vital agricultural sector[39]

Limbua Avocado Oil Factory is a Kenyan enterprise that focuses on the production of high-quality avocado oil. The avocados are sourced from smallholder farmers. Limbua Avocado Oil Factory specializes in producing high-quality, organic avocado oil through sustainable and fair-trade practices. By partnering directly with smallholder farmers, Limbua ensures fair pricing and promotes environmentally friendly farming methods. Utilizing advanced cold-pressing techniques, the company retains the nutritional benefits and rich flavour of the avocado oil. Their commitment to sustainability and community impact not only supports the local economy but also caters to health-conscious consumers both locally and internationally[40].

[36]Olupot, P. W., Mibulo, T., & Nayebare, J. G. (2023). Characterization of Uganda's Main Agri-Food Value Chain Wastes for Gasification. *Energies,* 17(1), 164.

[37]Permal, R., Chang, W. L., Chen, T., Seale, B., Hamid, N., & Kam, R. (2020). Optimising the spray drying of avocado wastewater and use of the powder as a food preservative for preventing lipid peroxidation. *Foods,* 9(9), 1187.

[38]Restrepo-Serna et al, (2022). *Waste and Biomass Valorization,* 13(9), 3973-3988.

[39]Nyakang'i, C. O., Ebere, R., Marete, E., & Arimi, J. M. (2023). Avocado production in Kenya in relation to the world, Avocado by-products (seeds and peels) functionality and utilization in food products. *Applied Food Research,* 3(1), 100275.

[40]https://www.limbua-group.com/en/quality/organic-avocado



2.2.2 Value addition to waste side streams in the livestock processing sector

Adding value to livestock products and waste streams from processing of meat, milk, and hides can substantially increase their market worth.

In the slaughterhouse sector, on average, the solid waste collected from bovines is 275 kg per tonne of live weight killed (TLWk), which is about 27.5% of the animal's live weight. This waste includes intestines, stomach contents, blood, dung,, urine, inedible offal, meat trimmings, bones, and condemned meat.[41]

The handling and disposal of slaughterhouse waste varies by country and region, influenced by local regulations, infrastructure, and practices. There is significant variation in the extent of untreated slaughterhouse waste across Eastern Africa, but many reports suggest that most of the slaughterhouse waste in the region remains untreated. As an example, a report by the National Environment Management Authority (NEMA) in Kenya suggests that a major portion of slaughterhouse waste in Kenya is improperly managed[42]. For instance, in Nairobi, up to 80% of slaughterhouses were found to dispose of their waste inappropriately, either through open dumping or direct discharge into water bodies. This in turn leads to contamination of drinking water, posing environmental and public health risks. Value addition to slaughterhouse waste is an attractive solution to this problem. The value addition to waste from slaughterhouses means converting the waste into commercially viable end products, such as high-quality organic fertilizer and biogas for various energy purposes. There are a number of successful initiatives in adding value to slaughterhouses waste in the region. One example of such an initiative is described in section 3.

The leather industry in Eastern Africa is also a significant part of livestock value addition in the region and contributes significantly to employment, with thousands of jobs in tanning, manufacturing, and associated services. The leather production chain involves various stakeholders, including livestock farmers, livestock traders, butcheries, slaughter facility owners, hides and skins traders, exporters, and tanners. The leather value chain also includes artisanal footwear and leather goods manufacturers, who play a crucial role in enhancing the quality and marketability of leather products, thereby promoting both domestic and foreign investments in the industry. Ethiopia is one of the largest leather producers in Africa, known for its high-quality hides and skins. Kenya, Tanzania and Uganda also have a growing leather industry with significant contributions to the economy.

The leather production industry in Eastern Africa does however face several environmental challenges, mainly due to the tanning process. The tanning process involves the use of various chemicals, including chromium salts, which can be highly toxic. Effluents from tanneries often contain these chemicals, leading to the contamination of local water bodies. Most tanneries in Eastern Africa lack proper wastewater treatment facilities, resulting in the discharge of untreated or partially treated effluents into rivers and lakes. This pollution seriously harms aquatic ecosystems and contaminates drinking water sources. However, there are initiatives in treating and adding value to tannery waste. One such example is the Mojo Tannery in Ethiopia where an integrated system has been developed in collaboration with Addis Ababa University to manage the tannery's wastewater and solid waste. This system includes an anaerobic-aerobic sequencing batch reactor (SBR) and constructed wetlands. The biogas generated from the anaerobic digestion of tannery waste is used for cooking and potentially for electricity generation. This innovative approach helps in reducing pollutants and generating renewable energy[43].

The dairy sector can be a part of the bioeconomy by minimizing waste and making broad use of by-products. African Center for Technology Studies (ACTS) Africa and partners is investigating the value addition potential in the Kenyan dairy sector and the dairy bioeconomy through the project (VALORISE), described below in Box X.

[41]Kabeyi, M. & Olanrewaju, O. (2021). Optimum Biogas Production from Slaughterhouse for Increased Biogas and Electricity Generation.

[42]Government of Kenya (2021). Kenya State of Environment Report 2019 -2021, Nairobi, Kenya.(https://www.nema.go.ke/images/Docs/EIA_1920-1929/NEMA%20SoE%202019-2021.pdf)

[43]https://bioinnovate-africa.org/?s=mojo+tannery&submit=

Box 2. A Circular Bioeconomy for the Kenyan Dairy Sector (VALORISE)



Central to the development is circular bioeconomy (CBE) is to increase resource-use efficiency and create economic benefits along the value chain by promoting the recycling and reuse of processing side streams. The Kenyan dairy industry contributes approximately 14 per cent of the agricultural gross domestic product making it a national key economic sector. The Kenya Dairy Board notes that the current consumption of dairy products is 110 litres per capita/year but is projecting an increase to 220 liters/year by 2030. A doubling of dairy product consumption by 2030 – including processed products such as yoghurt, butter, ghee, and cheese – will significantly increase valuable side streams, especially sweet whey from cheese production and acid whey from processing of Greek yoghurt and cream cheeses. Simultaneously, climate change impacts threaten current dairy production models, increasing pressure to use scarce feed and land resources more efficiently. The valorization of dairy side streams such as whey into valuable food or feed products is extremely relevant in this context. Recent research from the VALORISE project[44] reveals opportunities for growth and innovation, but also challenges. The project investigates how adding value to side streams such as whey can be integrated in the Kenyan dairy industry to enhance business opportunities while lowering environmental footprint. Milk production in Kenya reached 6.03 billion litres in 2021 with 802 million litres going through formal processing, a 27% increase from 2020. The same year, the share of processed products such as butter and ghee increased by 7.1% while cheese increased by 11.6%[45]. Findings from the VALORISE project survey of 25 processors on their outlook on processing indicate a significant, continued growth in dairy product diversification. Among the many new products entering the Kenyan market, cheese is of interest to many processors because of the high demand and high profitability, especially due to its use as an ingredient in fast foods such as pizzas and burgers. This comes with increased whey production as a side stream. Currently, most dairy processors consider whey as a waste stream and give it for free to pig farmers for use as feed, or simply drain it into the sewer. The main reasons for this low-value utilization are the high cost of investment in processing technology and low economic viability – in part due to the low volumes of whey being generated. Additionally, lack of knowledge on opportunities for whey valorisation is also limiting. However, some dairy processors consider opportunities for whey utilization, first in production of animal feed and then as a food protein. To realize the opportunities of whey valorisation, processors are considering a shift toward product diversification in response to market dynamics. This is accompanied by an expanding capacity for advancement of technology and partnership in research, development, and innovation, underpinned by a supportive regulatory environment and access to finance for initial capital investment. There is currently one whey-based food product in the Kenyan market with several processors exploring new products and a few already using whey as a milk substitute. Additionally, the VALORISE project is using whey to develop a lysine-enhanced protein-biomass animal feed supplement and it is assessing prototypes of whey-based products for human consumption.

There are thus clear opportunities for integrating a circular based economy approach in the Kenyan dairy industry through increased processing of cheese, whey and acid whey. As processors respond to these opportunities they must have access to adequate volumes of high-quality milk. They will need to incentivize farmers to supply such milk through a price premium and they must enable them to do so through improved production and logistical support. These mechanisms are likely to increase farmer incomes. However, to harness these opportunities there is need to address market, technology, and financial gaps, coupled with enhanced policy readiness.

Catherine Kilelu,(ACTS) Simon Bolwig, Bockline Bebe

[44]The circular bioeconomy for the Kenyan dairy sector (VALORISE) is a research and innovation project implemented by the African Centre for Technology Studies (ACTS) in partnership with, Roskilde University, Egerton University, Technical University of Denmark, Arla Foods Ingredients, International Centre for Tropical Agriculture, and East and Southern Africa Dairy Association (ESADA). The project receives financial support from the Ministry of Foreign Affairs of Denmark. Source: https://valorise.acts-net.org/

[45]KNBS,2022).



2.2.3 VALUE ADDITION TO MARINE AND AQUATIC RESOURCES IN EASTERN AFRICA

In recent years, the concept of the blue economy has gained significant traction as nations worldwide explore sustainable ways to utilize their oceanic and freshwater resources. Eastern Africa is home to numerous lakes, rivers, and freshwater ecosystems that support significant inland fisheries. Lake Victoria and Lake Tanganyika are among the largest and most productive freshwater bodies in the world, providing vital fish stocks for local communities and commercial fisheries. Although Eastern Africa's coastline is relatively short compared with other regions, it has a rich diversity of marine resources, including fish, crustaceans, molluscs, and seaweeds. Both Kenya and Tanzania have active coastal fishing industries, harvesting a variety of fish and seafood species from nearshore waters. Value-added aquatic products provide a reliable and nutritious food source for communities in Eastern Africa. Processed fish and seafood offer extended shelf life, reducing post-harvest losses and ensuring a more stable food supply, especially in regions prone to food insecurity.

The Case of Lake Victoria

Historically, Lake Victoria has been one of the most productive freshwater fisheries in the world, The most harvested species from the Lake Victoria include Nile perch, Nile tilapia and various species of cichlids. Nile perch became a major commercial species exported to international markets. However, overfishing, environmental degradation, and the invasiveness of Nile perch leading to the extinction or severe reduction of several native fish species, have impacted the fisheries of Lake Victoria in recent years. As a result, fish catches have fluctuated, and efforts to sustainably manage the fisheries and restore the lake's ecosystem have become increasingly important.

In 2023, the total fish catch from Lake Victoria was reported to be approximately 1.2 million metric tonnes. This figure represents a slight increase compared with previous years, reflecting ongoing efforts to manage and sustain the lake's fishery resources. Around the lake fish processing industries generate approximately 150,000 tonnes of waste with nearly 80% dumped and not utilised. The residues of fish filleting can however be used to make low-cost products with a high concentration of essential nutrients. For instance, in Uganda by-products from Nile perch (*Lates niloticus*) are used in development of different micro-nutrient fish powders that could be used to enrich diets. Fish skin, which today is considered as waste, can be processed into leather. In Kisumu about 70 tonnes of fish skin waste are reported to be generated weekly to make leather products for export[46].

Thus, more sustainable and resource efficient use of the of the lake is a necessity, improving fish processing, value chains, and broadening the utilization of the lake's resources in a sustainable manner. This would involve promoting sustainable fishing practices, supporting aquaculture initiatives, and exploring value-added opportunities in fish processing and trade

The Case of Lake Tanganyika

As of 2023, the total fish catch from Lake Tanganyika is estimated to be approximately 200,000 metric tonnes[47]. This figure represents the combined catch from the lake's riparian countries: Burundi, the DRC, Tanzania, and Zambia. Lake Tanganyika, one of the African Great Lakes, is a significant source of freshwater fish and supports a diverse ecosystem with various commercial and artisanal fisheries. The lake is one of the richest ecosystems in the world. and home for more than 1,300 species of vertebrates and invertebrates, of which around 500 are endemic[48]. More than 60% of the fish found in Lake Tanganyika are endemic, including species that are highly sought after by aquarists around the world[49]. The lake provides a valuable basis for aquatic bioeconomy development. Value addition to the lake's resources is presently very limited. Investment in and by various value addition actors, including clusters of fishery industries processing various fish products in a sustainable manner, is thus a big development opportunity. It is a transboundary lake and the Lake Tanganyika Authority, established by the Governments of Burundi, Democratic Republic of Congo (DRC), Tanzania, and Zambia, has a mandate to promote regional cooperation required for socio-economic development and sustainable management of the Lake Tanganyika basin. The Authority has an important role in fostering the growth of blue economy in the basin.

[46]Gumisiriza R et al. 2009. Nile perch fish processing waste along Lake Victoria in East Africa: Auditing and characterization. African Journal of Environmental Science and Technology Vol. 3 (1), pp. 013-020, January 2009. Available online at http://www.academicjournals.org/AJEST

[47]https://www.fao.org/fishery/en/knowledgebase/72

[48]Evert M.J. 1980. Le lac Tanganyika, sa faune et la pêche au Burundi. Université du Burundi.

[49]https://www.agl-acare.org/lake-tanganyika

Value addition in the Marine sector - seaweed harvesting in Zanzibar

Seaweed harvesting in Zanzibar, has generated significant socio-economic benefits and promotes environmental sustainability and resilience to its coastal communities.

Seaweed is rich in essential nutrients, vitamins, and minerals, and processed seaweed products such as snacks, supplements, and condiments can provide nutritious food options for local consumption and export. Processing seaweed into higher-value products such as carrageenan (a food additive and thickening agent), cosmetics, pharmaceuticals, and fertilizers can significantly enhance the economic returns for seaweed farmers and processors.

Zanzibar is a significant producer of seaweed, producing around 11,000 tons per year (dry weight) particularly *Eucheuma* and *Kappaphycus* species, which are cultivated for various purposes, including food, cosmetics, pharmaceuticals, and industrial applications. Currently, only 2.7% of seaweed produced and harvested in Zanzibar is used by local small-scale processors for production of food, traditional medicine and cosmetics products. The remaining 97% is exported, dried but unprocessed to countries including France, United State of America and Denmark. Seaweed farming in Zanzibar is an important foreign exchange earner, generating up to US$8 million a year and employing around 30,000 people in Zanzibar and 6000 in the Tanzania mainland, the majority of whom are women. Seaweed production is labour intensive, and there are limited processing facilities for value addition. In addition, much of the seaweed production has been undertaken unsustainably. Thus, modern sustainable seaweed farming methods and a higher degree of processing and value addition would boost the local economies and livelihoods on Zanzibar.

There are about 280 species of seaweed species in Tanzania but only the two genera of *Kappaphycus* and *Eucheuma* are produced for commercial purposes, the rest have not been touched. Studies have shown potential in other species and recommended their use for commercial production[50]. For example, studies have shown that *Gracilaria* spp. are a good source of agar with good gelling properties hence recommended for commercial production[51]. The price of seaweed in Tanzania varies depending on the whether it is sold as seedlings, dried, bleached or unbleached products, where price can vary from 0,2-0,8 USD per kg, with the dried *Kappaphycus* spp. fetching the highest price. However, the production of seaweed in Tanzania is facing a number of challenges that have resulted in a drop in production especially *Kappaphycus* which has the highest market value. Challenges include the effects of climate change and a resulting increase of raising seawater surface temperature causing diseases, *Cyanobacterium* bloom killing some seaweed species, inadequate modern facilities for high yield seaweed production and lack of a seaweed policy. These challenges need immediate solutions for growth of the seaweed industry.

Seaweed production has nevertheless the opportunity to grow. Availability of production information from other locations and other species of seaweed can be used to improve the production and seaweed value addition processes. This includes experimental studies and extraction of gel products from species such as *Gracilaria, Ulva* and *Sargassum,* that can be scaled up and used to expand the seaweed industry in Zanzibar and Tanzania.



[50]Msuya, F. E. (2020). Seaweed resources of Tanzania: status, potential species, challenges and development potentials. *Botanica Marina*, 63(4), 371-380.

[51]Msuya, F. E., & Hurtado, A. Q. (2017). The role of women in seaweed aquaculture in the Western Indian Ocean and South-East Asia. *European journal of phycology*, 52(4), 482-494

Microalgae production in Eastern Africa

Production of microalgae in Eastern Africa, such as *Dunaliella, Spirulina* and *Chlorella,* holds promise for various applications ranging from food and feed supplements to biofuels, pharmaceuticals, cosmetics, and wastewater treatment. Eastern Africa's agricultural sector and growing municipalities generate significant organic waste, which can be used as a nutrient source for microalgae cultivation through processes like anaerobic digestion or composting. This could contribute to waste valorization and nutrient recycling. Microalgae have numerous potential applications in Eastern Africa. The use of microalgal biomass in biorefineries can produce different products, such as biofuel, food, feed, and bioactive compounds. In addition, the microalgae used in waste treatment can have their biomass exploited.

Spirulina, a type of microalgae rich in protein, vitamins, and minerals, could address malnutrition and food security issues in the region. Both *Spirulina* and *Chlorella* are used to produce a range of health foods. The additional environmental benefits of *Spirulina* include carbon dioxide sequestration and the removal of nitrogenous and phosphorous waste. *Dunaliella salina* is another species of microalgae that produces valuable carotenes.

Additionally, microalgae-derived biofuels could offer renewable energy solutions, while algal extracts may have applications in pharmaceuticals, cosmetics, and bioremediation. While the industry may not be as developed as in some other regions, there are growing initiatives and potential opportunities for microalgae cultivation and utilization in Eastern Africa. Increasing consumer awareness, rising disposable incomes in urban areas, and a growing health and wellness trend could drive demand for *Spirulina*-based products across the continent. Microalgae are traditionally cultivated in large-scale commercial facilities, although the culture systems used to produce these species are fairly unsophisticated and do not require huge investment. *Dunaliella* is generally cultured in large (up to approx. 250 ha) shallow open-air ponds with no artificial mixing. Similarly, *Chlorella* and *Spirulina* also are grown outdoors in either paddle-wheel mixed ponds or circular ponds with a rotating mixing arm of up to about 1 ha in area per pond.[52]

However, there is also a growing trend of small-scale and community-based *Spirulina* production in the region. This decentralized approach allows for local production, employment generation and empowerment of communities, especially in rural areas. Despite its potential, the market for *Spirulina* and other microalgae in Africa faces challenges such as limited awareness among consumers, lack of infrastructure for large-scale production, and regulatory barriers. Addressing these challenges requires coordinated efforts from governments, private sector stakeholders, and civil society to create enabling environments for *Spirulina* cultivation, processing, and marketing. While microalgae offer a range of various benefits, sustainability considerations must be prioritized to mitigate potential negative environmental impacts such as eutrophication, habitat disruption, and water pollution. Sustainable cultivation practices, resource recycling, and environmental monitoring are necessary to minimize these risks. Thus, establishing clear regulatory frameworks and standards for microalgae cultivation, processing, and product quality is essential for industry development. Governments in Eastern Africa therefore need to develop or refine regulations to ensure environmental sustainability, food safety, and consumer protection in the microalgae sector.

[52]Compton, Jazmine R. (2024) "The Cultivation of Ulva Lactuca in Jambiani, Zanzibar: A Case Study," Anthós: Vol. 13: Iss. 1, Article 7.https://doi.org/10.15760/anthos.2024.13.1.7

Box 3. Ongoing Spirulina Production in Ethiopia and Rwanda

In Ethiopia, *Spirulina* especially *Arthrospira fusiformis* grows abundantly almost as a unialgal population in an Ethiopian soda lake, Lake Chitu, throughout the year[53]. The national *Spirulina* laboratory has been established under the Bio and Emerging Technology Institute (BETin) with the financial support of Ministry of Innovation and Technology (MinT) in 2020. Since then, laboratory research was performed with the aim of pure seed production. Currently, pilot scale production is underway in the Rift Valley.

Picture shows the Pilot scale *Spirulina* production pond at BETin *Spirulina* pilot production site located at Adami Tullu Agri Research Center, photo on March 2024, with the project leader Dr. Habte Jebessa.

In Rwanda, The Healthy Food & Feed company has initiated the growth and industrialization of *Spirulina* products. Currently the company utilizes the *Spirulina* product for nutritional purposes. The company has developed and adopted a model which integrates the cultivation of *Spirulina* with the aquatic fern *Azolla* which are environmentally friendly plants. There is a great potential to exploit the opportunities of commercializing the potential of *Spirulina* and its products to improve bio-based sectors through development of an algal biomass value chain for sustainable development, acknowledging and addressing economic, social and environmental challenges. Once the Rwanda National Bioeconomy strategy is in place, in terms of implementation, there will be a need to promote bioeconomy initiatives and growth areas, where the potential of the algae biomass value chain can be given more emphasis.



[53]Assaye, H., Belay, A., Desse, G., & Gray, D. (2018). Seasonal variation in the nutrient profile of Arthrospira fusiformis biomass harvested from an Ethiopian soda lake, Lake Chitu. *Journal of Applied Phycology,* 30, 1597-1606.

2.3 NOVEL FOOD AND FEED IN EASTERN AFRICA

2.3.1 Why novel food and feed?

Novel food and feed products play a crucial role in the bioeconomy by leveraging innovative approaches to utilize biological resources sustainably, addressing emerging consumer trends, and meeting evolving market demands. These products often result from advancements in biotechnology, bioprocessing technologies, and ingredient formulation and include products such as plant-based meat alternatives, insect-based foods, precision-fermented ingredients and nutraceuticals and functional foods.

There are also innovations in upcycling and valorization of biowaste which are leading to the development of novel ingredients and products. By-products from food processing, agricultural residues, and surplus produce can be repurposed into nutritious ingredients, dietary fibre, antioxidants, and flavour enhancers for use in food and feed formulations.

The need for novel food and feed in Eastern Africa is driven by several key factors that are both socio-economic and environmental in nature, such as:

- Population growth: Eastern Africa is experiencing rapid population growth, leading to increased demand for food. Novel foods can help bridge the gap between supply and demand.
- Nutritional deficiencies: Many Eastern African countries face challenges related to malnutrition and micronutrient deficiencies. Novel foods can provide essential nutrients and diversify diets, improving overall health.
- Climate change/resilience and environmental sustainability: A large part of the crop and livestock farming is vulnerable to the impacts of climate change. Novel foods, such as drought-resistant crops and alternative protein sources, can enhance food security by being more resilient to changing climatic conditions.
- Sustainable food system: Novel food and feed options can promote sustainable agricultural practices and circularity. For example, insects as livestock feed require fewer resources and generate less greenhouse gas emissions compared with conventional livestock feed. Promoting circularity and regenerative approaches to food production, processing and consumption minimizes waste and makes the most of resources, where biowaste products from one process become inputs for another, creating a closed-loop system.

The use and incorporation of local innovative feed resources in livestock production can help in securing sustainable food security and a circular economy in Africa. Although they have not traditionally been utilized as livestock feed ingredients or supplements, plant residues, biowaste and animal byproducts might considerably improve livestock production and advance Africa's circular economy as presented.

2.3.2 A growing use of insects as novel food and feed.

With a rapidly growing human population, the demand for animal and plant protein has radically increased, creating pressure on the food value chain in the face of depleting land and water resources. Protein-rich edible insects are increasingly being viewed as viable and sustainable alternatives to animal and plant proteins for improved food and nutritional security, and they already supplement the diets of more than 2 billion people worldwide. They contain substantial amounts of high-quality protein, essential amino acids, fibre, mono- and polyunsaturated fats, as well as various vitamins and minerals, often at levels comparable to traditional animal protein sources like beef or chicken[54]

In Eastern Africa, the most consumed insects include crickets, grasshoppers, locusts, and termites, all of which are highly nutritious and easily accessible. Crickets are significantly rich in crude protein and fat, which, respectively, make up to more than 50 percent and some 35 percent of their dry body weight mass. The insect is also rich in essential amino acids, minerals and vitamins, with almost 90 percent of its nutrients being digestible by the human body.

[54]Aguil Aguilar-Toalá, J. E., Cruz-Monterrosa, R. G., & Liceaga, A. M. (2022). Beyond Human Nutrition of Edible Insects: Health Benefits and Safety Aspects. Insects, 13(11), Article 11. https://doi.org/10.3390/insects13111007

Current consumption relies on wild harvesting, meaning demand far outweighs supply, and handling is generally unhygienic. The few good quality packaged insect food products available on the market are costly due to the seasonality and unpredictability of wild harvest. An innovation consortium within the BioInnovateAfrica Programme has therefore fine-tuned rearing techniques for the longhorn grasshopper and house/field crickets and adapted these techniques to farmer field conditions. The team has also scaled up the technology to ensure year-round market supply for safe production and packaging of insect food products[55]. The consortium has developed cricket-enriched products, cookies and instant porridge flour in Uganda, which were market tested with high acceptability results. This is a relatively new economic activity and there are no current standards and guidelines for rearing and processing of insects for food and feed, but work is ongoing in the region to develop such standards and guidelines.

Cattle, fish and poultry provide good sources of animal protein and yet their production is constrained by high costs of feed. With the growing population, the need for efficient and nutritious feed for livestock is driving the adoption of insect-based alternatives. According to published reports[56], the global market for insect derived feed is expected to reach USD 1,5 Billion by 2025 and a portion of this demand will be in Eastern Africa. At the same time, countries in Eastern Africa are experiencing serious waste management problems where almost 50%of total waste is biowaste and out of this, 50% does not make it to the dumpsites. There is thus a need to recycle nutrients in the waste to minimize stress on infrastructure. Using insects such as black soldier flies, silkworm pupae, grasshopper meal and cricket meal can increase the nutritional value of livestock feeds while limiting the use and dependence on fishmeal and also lowering the environmental impact of feed production. This strategy also has the additive advantage of lessening Africa's reliance on imported convectional feed resources, particularly soybean, maize, and fishmeal, which would result in large savings in foreign currency used in the import of these feed ingredients.

Black Soldier Fly (BSF) larvae feeding on biowaste are rich in protein, essential amino acids, and other nutrients necessary for the growth and health of chickens and fish. The high feed conversion efficiency of BSF larvae means that less feed is needed to produce the same amount of animal protein, making it a more resource-efficient option. Another innovation consortium within the BioInnovate Africa programme has tested and operated a BSF rearing and waste processing facility in Tanzania where BSF larvae are bred and used to convert biowaste into animal fodder[57]. This innovation consortium and other actors are also exploring economic avenues in Ethiopia, Kenya and Tanzania to upscale efforts to utilise BSF as a source of protein thereby lowering feed costs, improve efficiencies and yield for smallholder farmers and feed producers across Eastern Africa:

One of the consortia actors, BioBuu Limited, an East African insect company, collects various types of biowaste and feeds soldier fly larvae producing insect protein and organic fertilizer. Six years of R&D has now enabled them to develop a scalable model where each factory location is capable of delivering 30 tonnes per month of defatted insect protein and 100 tonnes per month of organic fertilizer. After developing factories in Tanzania and Kenya the company is now looking to open factories all across the continent.

[55]https://bioinnovate-africa.org/
[56]Insect Feed Market Report | Industry Analysis, Size & Growth Trends (mordorintelligence.com)
[57]https://bioinnovate-africa.org/

Box 4. Novel Insects as Human Food/Feed in Kenya

In Kenya, the acceptance and utilization of insects as food and feed are advancing through various strategic initiatives. The International Centre of Insect Physiology and Ecology (*icipe*) is at the forefront, pioneering technologies for the mass production of insects. Their efforts include developing optimal breeding techniques, efficient feed formulations, and controlled rearing systems. Moreover, *icipe* provides extensive training and ongoing support to local farmers and businesses, empowering them to engage in insect farming and fostering a network of skilled entrepreneurs in the field. Jaramogi Oginga Odinga University of Science and Technology (JOOUST) complements these efforts with focused academic research and practical applications. Their studies delve into the nutritional profiles and ecological impacts of edible insects, alongside the development of sustainable farming practices. Collaborating closely with communities and industry partners, JOOUST translates research findings into tangible outcomes, facilitating the commercialization of insect-based products and enhancing their integration into local agriculture.



Picture shows insect production in Kenya. Photo by Rael Adhiambo

Meanwhile, Ecovative Africa specializes in producing insect-based animal feeds, particularly utilizing black soldier fly larvae. This initiative addresses the pressing need for sustainable protein sources in livestock farming, aiming to substitute conventional feed ingredients like fishmeal and soybean meal. By converting organic waste into valuable biomass through large-scale larvae production, Ecovative Africa not only provides cost-effective feed solutions but also contributes significantly to environmental sustainability. Simultaneously, The Bug Picture, a social enterprise, focuses on promoting cricket farming among rural communities in Kenya. Through comprehensive training and market access facilitation, The Bug Picture empowers smallholder farmers to establish and manage cricket farms as reliable sources of income and nutrition. This initiative not only improves economic stability but also bolsters local food security by offering a nutritious alternative protein source.

InsectiPro, a Kenyan company specializing in insect farming, has developed efficient methods for producing crickets and Black Soldier Flies (BSF). They grow crickets in stackable crates, which optimize space utilization. Each female cricket can lay 300-400 eggs over two to three weeks. After hatching, the crickets are moved to feeding trays and are ready for harvesting in about five weeks. The crickets are then processed by freezing, thawing, and baking them for consumption. The company has grown to produce one tonne of product from its black soldier fly operations daily, as well as between 100-200kg of dried crickets a month. InsectiPro offers three cricket products which include Chirrup's, cricket powder sold for protein supplementation, and porridge used in feeding schemes[58]. For Black Soldier Fly products, they produce high-protein animal feed from defatted larvae, organic fertilizer from frass, and chitin for the pharmaceutical industry. InsectiPro aims to improve value addition by focusing on cricket powder, which can be easily incorporated into various dishes and drinks like smoothies and school meals, making it more palatable than whole crickets. The company faces challenges in exportation due to extensive administrative and paperwork requirements, as international standards for insect farming are not fully established. While InsectiPro has local certification, it is currently concentrating on regional markets due to these constraints.

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[58]Kenya: Insects as a food source for humans and livestock. (n.d.). Retrieved June 5, 2024, from https://www.howwemadeitinafrica.com/kenya-insects-as-a-food-source-for-humans-and-livestock/150613/

2.3.2 Traditional and indigenous food

Traditional and indigenous food resources constitute the bedrock of the diversity in food systems of communities in Eastern Africa. In many cases, these indigenous food resources are underutilized although many have a much higher nutrient content than crops commonly produced and consumed in the region, such as maize. With climate uncertainty, there is an urgent need to diversify the food base to a wider range of food crop species for greater system resilience. Although many traditional subsistence systems in Eastern Africa depend on one or more staples such as cassava, rice or maize, such diets are kept diverse and balanced through small but complementary amounts of animal source foods including birds, fish, insects and molluscs, as well as sauces and condiments obtained from forest plants. In recent years, there has been increasing recognition of the importance of indigenous crops in Eastern Africa for their nutritional value, resilience to local environmental conditions and contribution to food security and livelihoods. Indigenous crops also play a role in the region's agricultural heritage and have significant potential to address various challenges such as climate change adaptation, biodiversity conservation and rural development.

Increasing value addition to indigenous crops in Eastern Africa involves a multi-faceted approach that addresses various stages of the value chain, from production, post-harvest handling and processing to value-added products, marketing and informing consumers. New types of processing and value addition innovations can significantly enhance the attractiveness and marketability of indigenous and underutilized food in Africa by addressing various challenges and tapping into emerging consumer trends. Innovations can make a difference in several ways:

- ***Improved Shelf Life:*** Processing innovations such as dehydration, freeze-drying, and vacuum packing can extend the shelf life of perishable indigenous foods, reducing post-harvest losses and enabling distribution to distant markets. This enhances marketability by increasing accessibility and ensuring product freshness over longer periods.
- ***Improved Convenience:*** Innovations in processing techniques allow for the development of convenient and ready-to-eat products from indigenous foods. These include dried fruit slices, pre-cooked grains, snack bars, and instant mixes. Convenience products can cater to busy urban consumers and appeal to modern lifestyles, driving demand for traditional foods.
- ***Value-Added Nutritional Products:*** Processing innovations enable the development of value-added nutritional products from indigenous foods, such as fortified flours, protein-rich snacks, and health supplements. By enhancing the nutritional content and functional properties of these foods, they become more attractive to health-conscious consumers seeking natural and nutrient-dense options.
- ***Innovative Packaging Solutions:*** Creative packaging designs and materials can enhance the visual appeal, convenience, and preservation of indigenous foods. Packaging innovations may include resealable pouches, biodegradable materials, and eco-friendly packaging options. Attractive and sustainable packaging enhances product differentiation and consumer perception.
- ***Functional Ingredients and Extracts:*** Extraction and purification techniques can isolate bioactive compounds and functional ingredients from indigenous foods, such as antioxidants, vitamins, and phytonutrients. These ingredients can be used in the formulation of functional foods, beverages, and dietary supplements targeting specific health benefits, appealing to consumers looking for wellness products.
- ***Promotion and Storytelling:*** Leveraging storytelling and marketing campaigns that highlight the cultural heritage, biodiversity, and sustainability of indigenous foods can create emotional connections with consumers. Sharing stories of local farmers, traditional food artisans, and community traditions adds value and authenticity to the products, resonating with consumers' desire for authenticity and cultural experiences.

Traditional wild leafy vegetables are of agricultural and nutritional significance in Africa and have the potential to add diversity to traditional diets by providing unique flavours, textures and other sensory attributes. Some indigenous vegetables that have caught research attention in Eastern Africa in recent times include *Amaranthus hybridus* (amaranth), *Bidens pilosa* (blackjack), *Citrullus lanatus* (bitter melon), *Cleome gynandra* (spider plant) and *Vigna unguiculata* (cowpea). These underutilised and under-researched leafy vegetables lack to a large extent formalized value chains and processing opportunities. They also need to be promoted and popularised.

An example of such promotion efforts can be found in the AgriFoSe2030 project, *'Governance of food systems for improved food security in Nakuru and Kisumu Counties, Kenya*[59]. This project has produced a training manual on production, management, harvesting, preparation, and cooking of traditional leafy vegetables. The project also conducted various tests to assess the effects of different cooking methods on nutritional value of selected traditional leafy vegetables. Cooking demonstrations were also done aimed at building the capacity of actors (especially consumers and cooked food traders) on food handling, food safety, and the best preparation and cooking methods that would reduce loss of nutrients during preparation and cooking. Stakeholders were also given a chance to taste the different traditional leafy vegetables cooked using different cooking methods.



Photo 4: Stakeholders about to taste different traditional leafy vegetables cooked through different methods(Credit: Samuel Omondi)

Sorghum and millet are important climate smart and resilient food security crops in Eastern Africa. There has however been limited value addition to sorghum and millet in the region, due to inadequate processing infrastructure, weak market linkages and a lack of awareness and skills among value chain actors. Encouragingly enough, commercialization of novel sorghum and millet products is now more actively being pursued in Eastern Africa. This effort involves various initiatives aimed at enhancing the value chain, improving market access, and promoting the consumption of these crops. There are now efforts, albeit at low level, to develop a range of processed products such as fortified flours, breakfast cereals, snack bars, and beverages that are helping to increase the market appeal of sorghum and millet. Companies such as Prosoya[60] in Kenya are involved in processing sorghum and millet into various products like flour, snacks, and beverages. East African Breweries Limited (EABL)[61] through its subsidiary East African Malting Limited (EAML), has integrated sorghum into beer production. These initiatives have led to a more stable market for sorghum farmers in Kenya, Tanzania, and Uganda, leading to increased production and income for smallholder sorghum farmers in the region.

[59]https://www.slu.se/en/ew-news/2023/10/agrifose2030-handing-over-of-the-training-manual-and-cooking-demonstrations-for-traditional-leafy-vegetables-in-kisumu-county-kenya/

[60]http://prosoyakenya.co.ke/

[61]https://www.eabl.com/our-business#

Orange Flesh Sweet potatoes (OFSP) are an important traditional crop that also remain underutilized in Eastern Africa due to similar challenges faced by sorghum and millet. It is a highly nutritious crop with a higher concentration of beta-carotene than many vegetables, and it is also a source of potassium, fibre, and vitamins A and C among others. The crop can serve as a functional ingredient in formulated foods and nutraceuticals and is becoming increasingly popular as an alternative food raw material. OFSP roots can be processed into purees and subsequently incorporated in various products such as baby food, casseroles, puddings, bread, restructured fries, and beverages.

Several organizations and companies in Eastern Africa are now actively involved in adding value to sweet potatoes. One example is Organi Limited[62], based in Homabay County, Kisumu, Kenya, a value chain processor of OFSP into various food products such as sweet potato composite bakery, confectioneries, sweet potato puree and sweet potato flakes. Another example is the BioInnovateAfrica project "Orange-fleshed sweet potato (OFSP) puree for bakery applications in East Africa[63]. The aim of the project is to improve the technology of OFSP processing using thermal processing and hot fill without preservatives of OFSP puree. This technique has potential to increase shelf-life of the puree at ambient conditions to 6-12 months. The puree is being used by bakery industries in both institutional and informal settings in Kenya, Ethiopia (including injera bread making), Rwanda and Uganda.



[62]https://organilimited.com/about-us

[63]https://bioinnovate-africa.org/orange-fleshed-sweet-potato-ofsp-puree-for-bakery-applications-in-east-africa/



2.4 AGROBIOLOGICALS AND BIO-BASED AGRICULTURAL INPUTS.

2.4.1 What are Agrobiologicals?

Agrobiologicals are a diverse group of products derived from naturally occurring microorganisms, plant extracts, beneficial insects or other organic matter that can lead to among other things increased plant growth, control of plant diseases and improvement of soil health. They are typically broken down into categories according to their function in agriculture:

- **Biostimulants** are products to enhance the growth and productivity of plants.
- **Biopesticides** are products for plant protection (e.g. microbes, natural enemies, extracts from plants or animals).
- **Biofertilizers** is the term used for plant nutrition products.

2.4.2 The Push for Agrobiologicals –An International Perspective

The global use of agrobiologicals is experiencing significant growth responding to a pressing need to develop cheaper, more environmentally friendly alternatives to chemical pesticides. This growth is also driven by advancements in biosciences and rising consumer awareness about the health and environmental impacts of conventional chemical inputs. Due to the pressing need to produce more food more sustainably, the global growth of biopesticide sales is projected to outpace that of chemical pesticides in the years to come. The global agrobiological market[64] was valued at USD 13.4 billion in 2023 and is projected to grow to USD 44.7 billion by 2032, exhibiting an annual growth rate of 14.4 % during the forecast period. This expansion is fueled by technological advancements and increasing adoption of biological products across various regions. North America is the leading market due to strong investment in R&D and adoption of biological seed treatments and biopesticides. The U.S. Environmental Protection Agency's strongly supportive regulatory framework has also contributed to this growth. Europe is the second-largest market, driven by stringent regulations on chemical pesticides and high consumer awareness about organic farming. Both Asia-Pacific and South America are also anticipated to exhibit significant growth in the adoption of biological products due to increasing sustainability concerns and government initiatives promoting efficient pesticide production and adoption of biological products.

2.4.3 Why Produce and Use Agrobiologicals in Eastern Africa?

Smallholder farmers produce about 80% of the food consumed in Eastern Africa but their productivity remains low in comparison with farmers in other regions of the world. Thus, for smallholders in Eastern Africa to become more productive, profitable, and environmentally sustainable, they need a transformation agenda to support them. An important part of such an agenda is to increase smallholder access to affordable, sustainable, and improved technologies for crop pest control, livestock disease management and plant nutrition.

Reduced crop losses from insect pests and disease damage is one way to boost agricultural productivity in Eastern Africa in a sustainable manner. The most popular, but non-sustainable, method of pest control available to smallholder farmers is the use of chemical pesticides. The majority of smallholder farmers in the region cannot afford chemical pesticides, and their lack of access to protective gear predisposes them to dangerous exposure to pesticides that are subject to EU restrictions. Chemical pesticides also frequently cause pesticide resistance, unintentionally harm beneficial non-target species, and contaminate food and crop residues, putting people and livestock at risk. Agrobiological products are generally, but not always, less toxic to humans and other mammals and have generally less impact on wildlife and the environment compared with conventional chemical inputs. Agrobiological products also have the potential to produce high yields and profitable crops as an alternative to chemical pesticides.

[64] Agricultural Biologicals Market Size, Share and Growth [2030] (fortunebusinessinsights.com)

In terms of fertilizers, approaches to increase nutrient content in soils through biological nitrogen fixation (BNF) processes, also have a large potential in Eastern Africa. Organic by-products from agro-processing can also be used as fertilizers. Insect frass, the waste material from cultivation of insects such as black soldier flies, shows great potential for use as a fertilizer, and is produced in volumes up to 40 times greater than the insects themselves.[65]

Currently, agricultural inputs, such as pesticides and fertilizers are mostly imported to the region and represent a major cost for farmers and are thus out of reach for many smallholders. Agrobiologicals made from local renewable bioresources could be less costly and represent a major opportunity for countries in the region. Locally made bio-based solutions and agricultural inputs could promote agricultural productivity and livelihoods for smallholders, while also creating jobs in a growing local agrobiological products private sector.

The development and application of agrobiologicals also have the potential to allow smallholder farmers in the region to benefit from valuable niche markets, such as in the EU for agricultural produce free from pesticide residues. Eastern Africa is currently experiencing a surge in increased production of organic products. For the organic farmers in the region, finding alternatives to conventional pesticides and inorganic fertilizers is of particular importance.

In summary, production and use of agrobiologicals in the region thus have the potential to minimize reliance on synthetic chemicals and increase smallholder productivity, support sustainable food systems and contribute to the wider economy.

2.4.4 Current use of Agrobiologicals in Eastern Africa

The Eastern African region is well endowed with biodiversity resources and has a huge potential to produce and use agrobiologicals[66]. While there may be individuals who produce agrobiologicals from plant extracts for their own use or for an informal market, the production and use of agrobiologicals produced by the formal private sector is still minimal. There are instances where agrobiologicals are being produced by locally operating small firms in the region, however, the market and usage are insignificant compared to the need and the number of smallholder farmers.

There is however an increasing number of Eastern African companies and institutions engaged in local development of biocontrol and biofertiliser agents for the Eastern African market, worth roughly US$400 million annually. Some of the ongoing initiatives and actors in commercializing agrobiologicals in the region is shown in the table 1 below.

2.4.5 Challenges in the Production and Use of Agrobiologicals in the Region

While agrobiologicals have great potential in the region, efforts are needed to improve the efficacy and user-friendliness of bio-based agricultural inputs. There is a lack of synthesised data on their effectiveness and their uptake by smallholder farmers as well as certification and standards on agrobiological products. A lack of awareness and education on how to deploy their unique modes of action is also contributing to the low rate of adoption and use of agrobiologicals in Eastern Africa.

There is also a low production and access to agrobiologicals in the region. This underdeveloped agrobiologicals supply chains are partly due to the absence of policies and effective regulations. Thus, policies that will encourage uptake and use of locally produced agrobiologicals are key to supporting growth of the sector

[65]Poveda, J. (2021). Insect frass in the development of sustainable agriculture. *A review. Agronomy for Sustainable Development,* 41(1), 5.

[66]Moshi, A. P., & Matoju, I. (2017). The status of research on and application of biopesticides in Tanzania. Review. *Crop Protection,* 92, 16-28.

Mulugeta, T., Muhinyuza, J. B., Gouws-Meyer, R., Matsaunyane, L., Andreasson, E., & Alexandersson, E. (2020). Botanicals and plant strengtheners for potato and tomato cultivation in Africa. *Journal of Integrative Agriculture*, 19(2), 406-427.

Mueke, A., Alexandersson, E., Mulugeta, T., Kritzinger, Q., Matsaunyane, L., & Onyango, C. M. Knowledge, Attitude and Practice Analysis of Agricultural Biologicals in Kenya a Smallholder Farmers' Perspective. *Quenton and Matsaunyane, Lerato and Onyango, Cecilia M., Knowledge, Attitude and Practice Analysis of Agricultural Biologicals in Kenya a Smallholder Farmers' Perspective.*

Table 1. Listing of some of the active agrobiological companies in the region

Agrobiological companies and initiatives	Type of products	Countries
MIRCEN	Biofix (biofertilizer) Rhizobium bacteria increasing yield of pulses	Kenya and Tanzania
RealIPM Kenya (Part of Biobest Group)	A broad range of biopesticides, beneficial insects, natural enemies to plant pests and bio-fertilizers	Most of eastern Africa and parts of Southern Africa
Koppert Kenya (Part of Koppert International)	Crop protection products for diverse range of natural solutions for control pest and diseases and enhance crop health and resilience	Kenya, Tanzania, Rwanda, Uganda and Ethiopia
Dudutech, (Part of Bioline AgroSciences Ltd)	A broad range of biopesticides, beneficial insects, natural enemies to plant pests and bio-fertilizers	Active in Ethiopia and Kenya
Plant bio defenders	Production of bio pesticide known as Vuruga against fall armyworm in Tanzania	Tanzania
Guavay company limited	Production of Hakika organic fertilizers specialized for use in avocado, onion and rice production	Tanzania
Ng'wala Invention Limited	Ng'wala Inventions converts organic wastes to Low-cost two-in-one organic pesticides and fertilizers	Tanzania
Ya kwetu biotech company	Transforms organic wastes into valuable bio fertilizers	Tanzania
Agrichem Africa Tanzania Limited	Biofungicides, biopesticides, bioherbicides	Tanzania
Kenya Biologics	Biopesticides, biofungicides, biostimulants, deficiency correctors	Kenya
Farmtrack consulting	Biopesticides	Kenya
Osho Chemical Industries Ltd.	Biopesticides	Kenya
Insecta Limited	Biopesticides	Kenya
Bio Organic Ltd	Biopesticides	Kenya
Sineria Kenya Limited	Biopesticides	Kenya
Amiran (K) Ltd.	Biopesticides	Kenya
Juanco SPS Ltd	Biopesticides/botanicals	Kenya
Bayer East Africa LTD	Biofungicides	Kenya
Farmchem (K) Ltd	Biopesticides	Kenya
Organix Ltd	Botanical biopesticide	Kenya
KAPI Ltd.	Botanical biopesticide	Kenya
Agrichem & Tools Ltd	Botanical biopesticide	Kenya
Saroneem Biopesticides	Botanical biopesticide	Kenya
Lachlan Kenya Ltd	Semichemical based traps	Kenya
Green Ethiopia	Bio-fertilizers	Ethiopia
Eco-Green	Bio-fertilizers	Ethiopia
Mela-Organics	Bio-fertilizers	Ethiopia

Pathways to greater adoption and policy advocacy of agrobiological interventions in the region require interdisciplinary and multi-stakeholder engagements to address the wider indirect benefits of using agrobiologicals. Therefore, to ensure improved smallholder productivity, beneficial social-economic outcomes and lower adoption barriers by farmers, interventions need to be undertaken to create an enabling environment for the production and use of bio-based agricultural inputs. This includes strengthening industrial and commercial platforms in the region for their production and dissemination.

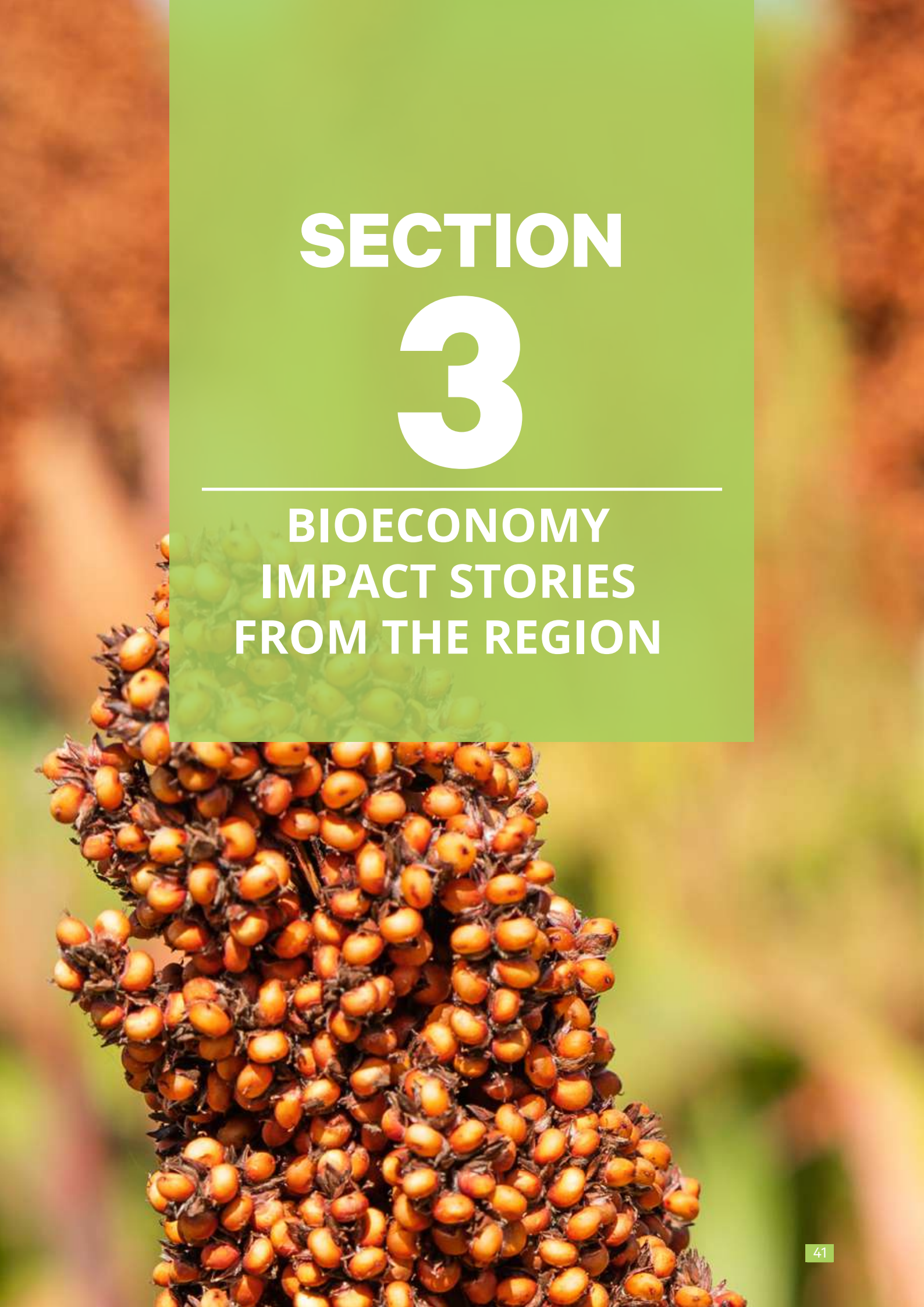
There is also a need for actor-driven production and user clusters with a forward-looking agenda on how to reduce barriers and strengthen the drivers for production and use of agrobiologicals in the region. So far, very limited work has been done in coordinating activities by the private sector, government, academia and the civil farming organisations on how to increase access to and use of bio-based agricultural inputs for smallholders in the region.



Pathways to **greater adoption and policy advocacy** of agrobiological interventions in the region require **interdisciplinary and multi-stakeholder engagements** to address the wider indirect benefits of using agrobiologicals.

SECTION 3

BIOECONOMY IMPACT STORIES FROM THE REGION





3.1 DEVELOPMENT OF PALM OIL VALUE CHAINS IN BURUNDI.

In addition to traditional cash crops, mainly coffee, tea and cotton, Burundi is in the of promoting new emerging cash crops. These include the Hass avocado, also known as “Ruhere” avocado in Kirundi, essential oil plants (such as patchouli, catnip) and palm oil. The main palm growing region in Burundi is Rumonge and Nyanza-Lac, providing for more than 85% of Burundian palm oil production. Palm oil cultivation in Burundi was encouraged in the 1980s to fill the edible oil deficit which was estimated at 98%. Palm oil is part of many food and cosmetic products in the country and is a highly used cooking oil.

Since 2007, the Palm Oil Office (OHP), whose main mission is to promote, supervise and coordinate the activities of the palm oil sector in Burundi, has been carrying out a restructuring of the old palm groves from 1983. In this process the old “Dura” palm trees commonly called “Ibirundi”, which have become less productive, are being replaced with a new more productive variety, “Tenera”, imported from Côte d’Ivoire, Benin or Costa Rica. The Tenera variety has been tested since early 2000 and it has been shown that it can produce 40 bunches of palm while the old “Dura” variety produces half or even less. While industrial Palm oil production only existed in Rumonge, OHP undertook the extension of the palm groves at the same time as the restructuring of the old palm groves. Climatic and agronomic studies have shown that oil palm could grow well also in other places in Burundi, such as Makamba, Rutana, Ruyigi, Cankuzo, Muyinga, Kirundo, Bujumbura, Bubanza and Cibitoke provinces. Efforts by OHP are therefore made to expand palm oil production also to these provinces.



Photo. Young palm oil plantations in Burundi

Three methods of processing palm oil are practiced in Burundi. This involves artisanal, semi-industrial and industrial processing. The artisanal processing produces between 80% and 90% of the country’s palm oil. The low mechanization in this production provides job opportunities, but production suffers from low quality and productivity. There is also a growing momentum in improving the productivity and quality of palm oil production in the country. A large quantity of palm oil produced in Burundi is purchased by two large companies, namely: Savonor and Lite. These companies refine and process this oil and transform it into other products such as soap, beauty products or and into well-refined oil called “COOKI” sold in different food stores in the capital Bujumbura and to different provinces.

A growing oil palm production is a real economic engine on a large scale for Burundi and a driving force for development not only for households, but also for the country. It is increasingly becoming an industrial crop creating employment from importation of palm oil seeds, nurseries, planting, crop management, harvesting and processing. The oil palm sector is also attracting large investors, creating new jobs, and brings added value to the local economy. According to the National Agricultural Investment Program (PNIA), the palm oil sector in Burundi earns nearly USD 25 million, contributing around 2.7% to the Gross Domestic Product (GDP). Currently grown in ten low-altitude provinces out of the country's 19, palm oil production and value addition to palm oil can become an increasingly important source of foreign currency and livelihood improvement. A sustainable and productive palm oil sector in Burundi can thus be an important part of the bio-based economy in Burundi. Extension of palm oil groves could however raise land use, biodiversity and environmental concerns, which indeed is a major concern worldwide for palm oil production. Thus, expansion of palm oil production in Burundi needs to be carefully planned and monitored ensuring environmental, social and economic sustainability.



3.2 AVOCADO OIL IN ETHIOPIA

Avocado is a highly favoured fruit in Ethiopia, ranking second in fruit cropland area after bananas. In 2021, the country produces some 245 000 metric tons of avocados across roughly 30 600 hectares of land, with an average yield of 8,020 kg per hectare[67][68]. Smallholder farmers are the main producers of avocados in Ethiopia, facing challenges such as diseases, pests, post-harvest losses, limited market access, and low value addition. Many small-scale farmers struggle to access export markets due to a lack of global Good Agricultural Practice certification, leading to selling their produce at low prices in local markets or even leaving fruits to waste.

Ethiopia has established four Integrated Agro-Industrial Parks (IAIPs) under its Growth and Transformation Plan II (GTP II) to drive industrialization and structural transformation in the country[69]. The IAIPs consist of Agro-Industrial Parks and Rural or Agriculture Transformation Centers (RTCs), providing shared infrastructure and state-of-the-art facilities for firms. Since 2019, several avocado oil processing companies have been established in Ethiopia, making avocado oil processing a lucrative investment in the country's avocado value chain. This has led to a significant increase in the production of avocado fruits and value-added products, particularly unprocessed oil, with a growing number of processing companies enabling access to international markets[70].

Ethiopia has benefited from the avocado value chain, with earnings from avocado oil exports reaching approximately $1.7 million in 2020 from a single exporter alone. The demand for Ethiopian avocado oil is rising in markets like Europe, the Middle East, and the U.S., with products such as organic extra virgin avocado oil, body lotion, lipstick, and blended products like butter, lemon, or garlic gaining popularity. Ethiopia has seen an 11% increase in income from avocado oil exports since 2021, indicating a positive trend in revenue generation from the avocado value chain[71].

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[67]CSA. *The Federal Democratic Republic Of Ethiopia Report On Area And Production Of Major Crops.* vol. I (2021)

[68]Abdela, K. & Mamta, B. Review On Current Status Of Avocado Production In Ethiopia. *EPRA Int. J. Multidiscip. Res. (IJMR)-Peer Rev.* J. 9, 446–451 (2023).

[69]UNIDO. *Integrated Agro-Industrial Parks* (IAIPS) In Ethiopia. (2016).

[70]Green Sustainable Ethiopia Network. Yirgalem Integrated Agro Industry Park; YIAIP: An engine for the Region's Avocado Production & Development. 2024 (2024)

[71]Freshela. Avocado Market Price in Ethiopia – 2024 Prices and Charts. h?ps://www.freshelaexporters.com/avocado/prices/ethiopia (2024).

SUNVADO PLC, the pioneering avocado oil processing factory in Ethiopia, was established in 2019 within the Yirgalem Integrated Agro-Industrial Park (YIAIP)[62]. The company commenced avocado oil processing operations for the first time in the Eastern African nation following the establishment of market connections with 88,000 farmers in the vicinity of YIAIP[72]. SUNVADO PLC collaborated with 59,455 smallholder farmers to attain organic certification and facilitated the establishment of three female-operated seedling nurseries, training over 60 women in the process.

Subsequently, WBM PLC, the second avocado oil processing facility, initiated the production of organic crude and extra virgin avocado oil within the same park, boasting a capacity of five tonnes per hour. This company sourced organic avocados from over 40,000 smallholder farmers and generated employment opportunities for more than 200 individuals. Currently it is exporting its organic avocado oil to the Netherlands market[73]. In addition to the IAIPs, various private avocado processing facilities are operating in different regions of the country. For instance, Akshay Jay Oil, situated at Jimma Industrial Park, has a processing capacity of 7,000 kg per hour, specializing in organic crude, extra virgin, and refined avocado oil products[63]. YIAIP reports indicate that approximately 80 tonnes of waste are produced by a single processor, posing a challenge for the park. Consequently, two companies obtained licences to convert this waste into biofertilizer. Similarly, Akshay Jay Oil has commenced construction activities to transform the generated waste into biofertilizer as well[74]. Some of the factors that boost the avocado market in Ethiopia are the following:

- Favorable climatic conditions,
- The presence of IAIPs located in the areas where avocado production is surplus,
- Capacity building given for smallholder farmers to grow in compliance with the requirements of the export market through RTCs.
- The presence of a reliable logistics link railway line and the sea freight connection to markets in Europe and the Middle East.



Yirgalem Integrated Agro Industry Park[62] .

[72]EM. Ethiopia's Second Avocado Oil Processing Facility Starts Production. *Ethiopian Monitor https://ethiopianmonitor.com/* (2021).

[73]EM. Ethiopia's Second Avocado Oil Processing Facility Starts Production. *Ethiopian Monitor* https://ethiopianmonitor.com/2021/12/31/ethiopias-second-avocado-oil- processing-facility-starts-produc?on/ (2021).

[74]EH. Indian Company expanding investment for compost production from industrial waste products. *ETHIOPIAN HERALD* http://press.et/herald/?p=76870. (2023).



3.3 VALORISATION OF SLAUGHTERHOUSE WASTE IN KENYA

Nyongara Biogas Plant in Kenya is a renewable energy facility that converts organic waste into biogas, providing a sustainable energy source for the local community[75]. The plant processes agricultural and animal waste through anaerobic digestion, producing biogas for cooking, heating, and electricity generation. This not only reduces reliance on fossil fuels but also mitigates environmental pollution by managing waste effectively. Additionally, the by-products of the process serve as high-quality organic fertilizers, enhancing soil fertility for local farmers.

The Nyongara Biogas Plant in Kenya forms an innovative and sustainable partnership with the Dagoretti Slaughterhouse in Nairobi, Kenya by creating a model of integrated waste management and renewable energy production. The plant utilizes anaerobic digestion to convert organic waste, primarily sourced from the slaughterhouse, into biogas and digestate. This process involves breaking down animal manure and other organic materials in the absence of oxygen, producing biogas used for cooking, heating, and electricity generation. By capturing methane emissions and reducing reliance on fossil fuels, the biogas plant significantly mitigates greenhouse gas emissions and environmental pollution. The continuous supply of organic waste from the Dagoretti Slaughterhouse ensures a steady feedstock for the Nyongara Biogas Plant, addressing the slaughterhouse's waste disposal challenges and reducing its environmental footprint. The plant not only provides a sustainable waste management solution but also generates employment opportunities and cost savings for the local community. The by-product, digestate, serves as a high-quality organic fertilizer, enhancing soil fertility and boosting agricultural productivity for local farmers[76].

This integrated system exemplifies a circular economy where waste is repurposed into valuable resources, promoting sustainability and environmental conservation. The collaboration provides reliable and affordable energy access to the local community and supports agricultural development, contributing to food security and economic growth. The success of this partnership serves as a scalable model for other regions, demonstrating the potential for widespread adoption of sustainable waste management and renewable energy solutions[77].

[75]Odero, J., Rao, K. C., & Karanja, N. (n.d.). Power from slaughterhouse waste (Nyongara Slaughter House, Dagorretti, Kenya).

[76]Currently the biogas plant is no longer operational due to technical challenges in maintaining it, however the slaughterhouse is exploring investment opportunities to repair and possibly expand the waste treatment facility

[77]Biogas | Energy. (n.d.). Retrieved June 19, 2024, from https://www.energy.go.ke/biogas

Learning & Research Institutions Critical in Leather Industry Growth—The Technical University of Kenya. (n.d.). Retrieved June 20, 2024, from https://tukenya.ac.ke/136-learning-research-institutions-critical-in-leather-industry-growth



3.4 RWANDA BIOENERGY OPPORTUNITIES

Rwanda has abundant bioresources, limited access to fossil fuel resources and minimal levels of industrial development. A shift from natural economies to bioeconomies could avoid the pitfalls associated with heavy dependence on fossil fuels, while increasing productivity and value addition in their bio-based supply chains. Rwanda has significant biomass resources that could be utilized for energy production including agricultural residues, forest residues, and municipal soil waste. Estimates suggest Rwanda's biomass potential could provide up to 80% of the country's total energy needs. The key biomass resources include crop residues (from coffee, tea, maize, beans), animal waste and wood from forests and plantations. According to Rwanda Energy Group report (2024), the current national energy balance statistics for Rwanda show that biomass (mostly wood fuel) accounts for about 83% of the total energy consumption, followed by petroleum at 9.7%, electricity at 1.3% and others at about less than 0,5%. In rural areas, the reliance on biomass is over 90%. Most Rwandans live in rural areas where traditional biomass, mainly wood fuel has remained the leading source of energy for cooking.

Wood fuels (firewood and charcoal) account for over 80% of Rwanda's total primary energy consumption making them a key source of bioenergy in Rwanda. However, the reliance on forests for bioenergy has led to concerns such as deforestation, unsustainable harvesting practices and environmental degradation. Thus, prompting efforts to improve biomass use efficiency, promote sustainable forest management, and explore alternative energy sources could help country meet its energy and environmental goals.

A report by Stockholm Environment Institute on the alternative bioeconomy pathways for Rwanda shows that the current total biomass energy demand for Rwanda is expected to increase by 48% to 4.8 million tonnes of wood equivalent in all sectors in 2030 and 10.2 million tonnes in 2050. This growth is mainly attributed to population increase and urbanization. In addition, the projected demand for biomass-dependent industries such as tea processing, brickmaking, construction and timber is expected to increase rapidly, contributing 9% of total consumption by 2030 and 14% in 2050. However, with the sustainable and resource efficient use of bioenergy the amount of wood required to meet demand would reduce by about 2 million tonnes by 2030 and about 5 million tonnes by 2050.

To meet increased bioenergy demands and safeguard forest ecosystem services, enhanced biomass use efficiency is thus critically needed in Rwanda, shifting from traditional bioenergy use such as firewood or charcoal to more modern forms of bioenergy, processed biofuels such as biomass pellets or ethanol would increase efficiency, reduce pressure on forests and woodlands while also adding value to local supply chains. Apart from a sustainable forestry, the agricultural sector in Rwanda can also provide bioenergy feedstock, increased agricultural productivity and higher value added in agro-processing lead to greater economic output while also increasing the availability of agricultural waste and residues for animal feed, composting or energy feedstocks. This facilitates strategies for forest conservation or land restoration, which would contribute to ecological health and greenhouse gas mitigation Rwanda.

Bioethanol has significant potential as an energy source in Rwanda. Bioethanol production can be achieved from different cardohydrate rich by-products such as sugarcane, corn and wheat, sugar beet and cassava among others. Estimates suggest Rwanda could produce up to 150 million liters of bioethanol per year from agricultural feedstocks.

The potential biogas market in Rwanda is estimated at 150,000 households, among predominantly rural customers. Government of Rwanda through the National Domestic Biogas Programme (NDBP) has put in place an elaborate program for disseminating bio digesters in households, schools and prisons to reduce demand for wood and charcoal and improve people's health. The NDBP's initial focus was on capacity development, training technicians and entrepreneurs, and social marketing.

The Rwandan government announced a policy to introduce biogas digesters in all schools (estimated at around 600), large health centers and institutions with canteens. Through this institutional biogas program, institutional biogas digesters were constructed in secondary schools and prisons. Since the beginning of the program, over 10200 domestic biogas digesters have been installed in households. The prospects for bioenergy in Rwanda are therefore promising, given the country's abundant bioresources and the potential for transitioning to cleaner and more sustainable energy sources. In addition, policies to support the development of bioenergy technologies like biomas briquettes/pellets and biomass gasification were developed. The effort to promote improved cookstoves, biogas, digesters for households, and commercial bioenergy project are underway.

The key challenges encountered in this sector include limited awareness, access to finance, technical capacity, and infrastructure for bioenergy development. Opportunities exist to improve energy access, reduce deforestation, create jobs and support rural economic development through expanded bioenergy utilization. Thus, increased investment and public-private partnerships are needed to scale up bioenergy technologies and bionergy value chains in Rwanda.



3.5 TATU MOJA VACCINE FOR CHICKEN PRODUCTION IN TANZANIA

Currently, it is estimated that Tanzania has 38.2 million native chickens and 36.6 million exotic chickens including broilers. Out of 35% of subsistence households in Tanzania, 53% are involved in poultry production. This makes poultry farming an important farm sector in Tanzania in bridging the gap between protein related food requirements and food consumption, improving food security, promoting nutrition and health, empowering women and marginalized groups and addressing social inequalities.

However, the poultry farming faces notable challenges that hinder optimal production; including good quality breeds, extension services and diseases, especially Newcastle disease, fowl pox and infectious coryza diseases. The imported livestock vaccine accounts for 70% of the country's demand, posing burdens on foreign exchange. Tanzania could benefit from a commercial domestic production of vaccines that are tailored to parasites present in the country and a capacity building of local experts for effective extension services. Most of the vaccine imported requires cold chain throughout which cannot be afforded by farmers in remote areas with no electricity.



Tatu moja (Three in one) is a vaccine that has been researched and developed by scientists from Sokoine University of Agriculture (SUA). The vaccine contains a unique combination of vaccines that prevent three infectious diseases in chickens, Newcastle disease, fowl pox and infectious coryza that together contribute to 90% of chicken deaths per year. The vaccine has been thoroughly researched and approved by relevant regulatory bodies. Currently, Tatu moja is produced by Novel Vaccine Biological Company Limited (NOVABI), a Tanzanian local company based in Morogoro and and distributed by Farmers Centre Limited to various agro-dealers throughout Tanzania. Tatu moja is a thermostable vaccine that can be used under room temperature (not affected by temperature changes) and can easily be stored and administered. Presently, NOVABI has capacity to produce 12 batches of vaccine/month. Each batch containing 20,000 vials, and each vial contains 200 doses of vaccine which can be used to vaccinate 200 chickens, equivalent to 4 million chickens per month. The Tatu moja vaccine has been accepted by farmers due to its benefits, including

- The vaccine provides triple protection as it has a unique combination of three vaccines for Newcastle, fowl pox and infectious coryza chicken disease which are deadly killing diseases
- It's a thermostable vaccine that does not need refrigeration or cold chain during storage and transportation, making easier to use in rural and remote areas with limited electricity
- It simplifies veterinary care because it requires just a single dose of vaccine dropped in the eye of a chicken once for every four months; this has reduced challenging techniques, logistics and costs associated with multiple vaccinations.
- The vaccine has been given special colour that change when the vaccine is damaged or mixed with anything, providing quality assurance.

Production of Tatu moja vaccine has however been facing challenges that hindered expansion of the business to a large scale. These challenges include; (i) limited supply of fertilized eggs which are free from diseases required for production of vaccine, (ii) inadequate supply of vials used for packaging of the vaccine and (iii) inadequate awareness among the poultry farmers on the use of the vaccine as some of the farmers think Tatu moja is an alternative for all chicken diseases. For the effective use of the vaccine farmers need to be capacitated with the proper knowledge and skills about poultry rearing and management. The efficacy of Tatu moja also depends on proper chicken feeding, especially vitamins.



3.6 SUSTAINABLE AVIATION FUEL IN ETHIOPIA.

Ethiopia is actively exploring the development of Sustainable Aviation Fuel (SAF) to reduce its reliance on imported aviation fuel and support its agricultural sector. The Roundtable on Sustainable Biomaterials (RSB) has developed a 10-year roadmap in 2021 to advance Ethiopia's capacity to produce biofuels for SAF[78]. The main purpose of this roadmap is to identify the ideal feedstock and technology mix that adheres to the robust social and environmental sustainability requirements of the RSB, to inform policymakers of the necessary policy actions needed to incentivise SAF, and to support the development of more proposals and plans aimed at unlocking further funding and investment into SAF research, development, and pilot production.

The roadmap was developed in close collaboration with a national SAF Steering Committee representing local government, experts and the national airline. The methodology includes examining documentation reflecting the country's internal and external environment, SWOT and GAP analyses, and research of feedstock availability and SAF conversion pathways. Global SAF developments and trends have also been taken into consideration.

Key points from the roadmap include:

- Feedstock and Technology: The roadmap identifies castor and Ethiopian mustard as promising feedstocks for SAF production using hydro processed esters and fatty acids (HEFA) technology.
- Policy and Infrastructure: The Ethiopian Ministry of Transport aims for a 10% SAF mix by 2028/2029, which would require significant policy support and infrastructure development.
- Current Capabilities: By August 2024, Ethiopian airlines, Africa's largest airline has signed MoU with Satarem America Inc., a leading provider of sustainable energy solutions. The MoU will enable Ethiopian Airlines Group to incorporate SAF into its operations, thereby significantly reducing carbon emissions and supporting global efforts to combat climate change. SAF is a cleaner alternative to traditional jet fuel, produced from sustainable feedstocks that can lower greenhouse gas emissions

This initiative is part of Ethiopia's broader strategy to leverage its agricultural resources and reduce carbon emissions in the aviation sector. The roadmap proposes a three-phase approach comprising:

-Phase 1 (2021-2023): Establish a supportive policy framework.

-Phase 2 (2024-2028): Demonstrate SAF's viability and promote an open market.

-Phase 3 (2029-2030): Develop a long-term plan for a sustainable SAF industry

Source : (RSB, 2021)

[78]Roundtable on Sustainable Biomaterials (RSB) (2021). Development of Sustainable Aviation Fuel in Ethiopia: A Roadmap; A publication published under the 'Fuelling the Sustainable Bioeconomy' project supported through a grant from The Boeing Company.

3.7 CREATING A BUILDING INDUSTRY USING LOCALLY SOURCED NOVEL BIO-BASED BUILDING MATERIAL

Embracing biobased building materials can transform Eastern Africa's construction sector, offering a sustainable path to urbanization that aligns with economic and environmental goals. Biobased building materials offer a sustainable alternative to traditional construction materials, aligning with global and regional efforts to reduce carbon footprints and promote environmental sustainability. With the region's population growing and urbanization accelerating, sustainable construction is crucial. The conventional building methods using cement and steel could make Eastern African urbanization a major contributor of greenhouse gas emissions and global warming. However, alternative methods like mass timber construction can position Eastern African at the forefront of global decarbonization efforts, driving economic and social benefits across the value chain.

New timber products such as cross-laminated timber (CLT) often called mass timber are thick, compressed layers of wood, creating strong, structural load-bearing elements and are considered the building material of the future. One cubic metre of wood binds half a ton of carbon dioxide, whereas conventional concrete construction is responsible for 25% of CO^2 emissions. The construction industry, responsible for nearly 40% of global carbon emissions, can drastically reduce its footprint by adopting mass timber for a substantial portion of new buildings[79].



Construction using mass timber in Fumba Town: Photo by CPS

In Eastern Africa, CPS Zanzibar's projects, Fumba Town and The Burj Zanzibar, exemplify the potential of mass timber. A 4,000 cubic metre building in Burj Zanzibar with 28 floors can bind 3,200 tons of carbon dioxide, stored in the wood forever. Though the region has traditionally used timber for small-scale and domestic purposes, such as firewood, charcoal production, and local building construction it has recognized the potential of timber as a sustainable building material going by the Fumba Town Development by CPS Zanzibar Ltd that will arguably lead up to the tallest CLT constructed tower in Africa.

[79]Ahn, N., Dodoo, A., Riggio, M., Muszynski, L., Schimleck, L., & Puettmann, M. (2022). Circular economy in mass timber construction: State-of-the-art, gaps and pressing research needs. Journal of Building Engineering, 53, 104562.

Mass timber is often proposed as the prime example of a sustainable alternative to steel and concrete in construction. Mass timber, an engineered wood product made from compressed wood panels, offers several advantages. It is 15 times stronger than steel, lighter, more flexible, and thermally efficient. Every cubic meter of mass timber used instead of concrete prevents two tonnes of CO2 emissions[80]. Prefabricated panels reduce construction time, costs, and emissions, while offering enhanced safety and resilience, being more fire-resistant and earthquake-resistant compared to concrete. Particularly, prefabricated mass timber panels, such as cross-laminated timber (CLT) and mass plywood panels (MPP), enable a new integrated building technology, revolutionizing the use of timber in construction. Mass timber panels are used as structural building components such as load bearing floors and walls.

Domestic production of mass timber in Eastern Africa can leverage a variety of resources. Forests offer a traditional source of timber, while rapidly growing bamboo presents an alternative. These materials can be sustainably harvested and processed into engineered wood products like CLT. Exploring the region's specific forest composition and bamboo species will be crucial in optimizing material selection and production processes. A strategic approach to resource utilization, encompassing both forest timber and non-timber fibre like bamboo, is essential for establishing a robust and resilient domestic supply chain for mass timber production.

A coordinated full value chain approach from forest to building will be required to create an enabling environment for wood buildings. Governments in the region should incentivize the use of biobased materials through supportive policies and regulations. Investment in research and development should focus on improving the performance and cost-efficiency of biobased materials. Training programs for builders, architects, and engineers on the benefits and use of biobased materials are essential. Public awareness campaigns should educate stakeholders about the advantages of biobased building materials.



Governments in the region should **incentivize the use of biobased materials** through supportive policies and regulations.

[80]Abed, J., Rayburg, S., Rodwell, J., & Neave, M. (2022). A Review of the Performance and Benefits of Mass Timber as an Alternative to Concrete and Steel for Improving the Sustainability of Structures. Sustainability, 14(9), 5570.



3.8 BIODEGRADABLE PACKAGING MATERIALS MADE IN EASTERN AFRICA

The unique potential of a global, United Nations-led plastic treaty is to hold all countries to a high common standard on plastic consumption and create a clear path toward a future free from plastic pollution. This will create a level playing field that incentivizes and supports national actions. The impending Global Plastic Treaty underscores the urgent need to address plastic pollution on a global scale. As Eastern Africa grapples with burgeoning waste management challenges, the transition to biodegradable packaging materials becomes imperative. The region can mitigate plastic waste, protect ecosystems, and foster sustainable economic growth by adopting eco-friendly alternatives.

Biodegradable packaging offers a promising solution to reduce plastic pollution, safeguarding the environment and human health while stimulating innovation and job creation in the green economy. Eco-friendly packaging from biowastes offers a sustainable solution to environmental and economic challenges in East Africa. Utilizing bio-waste to create packaging products not only addresses waste management issues but also contributes to the circular economy, reducing reliance on non-renewable resources and mitigating the environmental impact of traditional packaging materials. Biowaste, including agricultural residues, food waste, and other organic materials, is abundant in East Africa. Converting these materials into packaging products presents an innovative solution to several challenges. It reduces the volume of waste sent to landfills, provides a renewable source of raw materials for packaging, and creates new markets and job opportunities in waste collection, processing, and packaging production. Key biowaste sources include crop residues such as maize stalks, banana leaves, and sugarcane bagasse; food waste like peels, shells, and other by-products from food processing; and forest residues such as wood chips and sawdust from timber processing. These eco-friendly packaging solutions offer significant advantages. They reduce greenhouse gas emissions and pollution, decompose naturally, lowering litter and soil contamination, and reduce dependency on fossil fuels, conserving natural resources.

Biodegradable packaging is still relatively expensive if compared with plastics from oil, but its use in the market for packaging is growing because of the positive effects of the renewable natural source and its biodegradability, compostability and use as a bioenergy source.

In Uganda, small enterprises produce biodegradable bags from banana fibers. Banana stem fiber is utilized to create eco-friendly bags with various beneficial properties. The fiber extracted from banana stems is biodegradable, lightweight, and possesses excellent tensile strength, making it an ideal material for sustainable packaging[81]. Made up of thick-walled cell tissue and bonded by natural gums, banana fibre mainly composed of cellulose, hemicelluloses and lignin is similar to natural bamboo fibre but its fineness and spin ability are better than bamboo and ramie fibres. Banana stem hitherto considered a complete waste, is now being made into banana-fibre cloth which comes in differing weights and thicknesses based on what part of the banana stem the fibre was taken from. The innermost sheaths are where the softest fibres are obtained, and the thicker and sturdier fibres come from the outer sheaths.

[81]Bordón, P., Paz, R., Peñalva, C., Vega, G., Monzón, M., & García, L. (2021). Biodegradable polymer compounds reinforced with banana fiber for the production of protective bags for banana fruits in the context of circular economy. Agronomy, 11(2), 242.



Biodegradable bags from Banana waste Source: Fibertext green paper LTD in Kenya

In Kenya, the company Fibertext green paper Ltd buys banana waste from farmers, including stems and extracts fibres from which they make paper and biodegradable packaging material that is cut, folded and branded according to customer demand. In Kenya, banana stems are an underutilized source of fibre and are often left to rot after the banana fruits are harvested. Kenya has approximately 80,000 hectares of banana cultivation with 1200 banana plants per hectare, which translates to about 96 million banana plants[82]. In the post harvesting process, these stems have been used for making manure, livestock feed, and craft items such as mats, The use of banana waste fibres for bio packaging is therefore a new and growing areas of value addition to banana waste.

BioinnovateAfrica is also implementing a biobased packaging project in Uganda, Rwanda and Tanzania that aims to produce packaging materials from cassava biowaste to provide more eco-friendly alternative products. The production of bio-degradable packaging materials could boost local cassava production capacity and create more jobs in the region. The project develops grocery bags, food packaging, and grain storage biobased packaging materials. The technology relies on conventional polymer processing, where starch from cassava waste is converted into bioplastic extrusion, injection and compression molding, and solution casting. This involves establishment of blending and proportion integration of the various waste materials with the final product constituting at least 70% of the cassava biowaste as a base material. The products can biodegrade between 3 to 6 months, hence providing the best alternative to polythene-based plastics.

[82]Musombi, S. K., Wanduara, M., & Kisato, J. (2024). Fabrication of a Sustainable Biodegradable Packaging Alternative for the Fashion Industry from Banana Waste. East African Journal of Business and Economics, 7(1), 23-33.



3.9 REVIVING AND DEVELOPING THE SISAL BIOECONOMY IN EASTERN AFRICA. THE CASE OF TANZANIA

Sisal is a natural fibre obtained from the leaves of the Agave sisalana plant. The fibre is used to make twine, rope, cord, and mats due to its strength, durability, and ability to stretch. Sisal grows well in hot climates and arid regions and thus is an important crop in the Tanzanian economy. Sisal is one of the historical cash crops in Tanzania that has stood the test of time. Sisal growing in the country was started in the German colonial era and over time became one of the key cash crops in Tanzania. The country was once the world producer of sisal before the decline of the world demand in natural fibres after introduction of synthetic ones. Sisal is produced in estates and small holder farms that are organized within estates. There are over 30 sisal estates and businesses, many of these estates have processing units utilized by the estates (56% of farms), medium scale farmers (forming 24% of farms) and small holder farmers (21% of farms)[83]. Between 2018 and 2022 sisal has experienced a 22.1% increase in production, registering as the fastest growth in cash crops between those years[84]. The value of exports in 2022 was 24.3 million dollars (ibid). As the world is experiencing a boom in the demand for natural fibres, increased production of sisal is expected, hence sisal bole waste will also increase.

Traditional sisal use in the country has been solely for production of fibres that are semi processed and exported, mainly to Europe and recently to China which has become the leading market for sisal products[85]. In Tanzania each tonne of sisal fibre produces about 24 tonnes of solid waste material that is left to compost in an uncontrolled manner and decomposes in anaerobic and aerobic conditions[86]. Waste produced at the processing/decortication sites where for every tonne of sisal fibre produced 100m^3 of wastewater and 25 tonnes of solid waste.[87] The sisal pulp waste is estimated to have the potential to produce 18.6 MW through biogas electricity (ibid). Waste from sisal leaves is processed to produce biopesticide, a product that is being developed by the TARI Milangano institute.

The current processing of sisal fibres from the plant uses only 2% of the whole plant, leaving 98% as farm waste[88] with very limited use. The sisal bole forms the largest component of farm waste, which is currently crushed in the farm and left to rot before being burned during farm preparations. The bole forms 2 million tonnes of on farm waste a year[89] , yet it presents great potential in development of a myriad of high value products, some of them tested at laboratory scale and others being developed towards commercialization e.g. production of biobased chemicals such as citric acid[90], inulin[91] and lactic acid[92] at laboratory scale. Another sugar available for processing from the sisal bole is xylose that is available in significant quantities and can be used for dietary needs. The short fibres from sisal can be used in dietary supplements, tea bags and the paper industry. These products can help create new markets for sisal farmers and sisal processing actors, providing additional incomes.

[83]https://pdf.usaid.gov/pdf_docs/PA00WJTZ.pdf

[84]URT, 2022. Economic Survey

[85]ibid

[86]Colley, T.A.; Valerian, J.; Hauschild, M.Z.; Olsen, S.I.; Birkved, M. Addressing Nutrient Depletion in Tanzanian Sisal Fiber Production Using Life Cycle Assessment and Circular Economy Principles, with Bioenergy Co-Production. Sustainability 2021, 13, 8881. https:// doi.org/10.3390/su13168881

[87]Yhedego,M. and Mng'agi,A. (2017). Sisal waste utilization for generation of electricity in Tanga region, Tanzania DOI:10.13140/RG.2.2.14454.19521

[88]https://pdf.usaid.gov/pdf_docs/PA00WJTZ.pdf

[89]Elisante, E and Msemwa,V. (2010). Dry Method for Preparation on Inulin Biomass as a Feedstock for Ethanol Fermentation. African Crop Science Journal, Vol.18, No 4, pp215-222

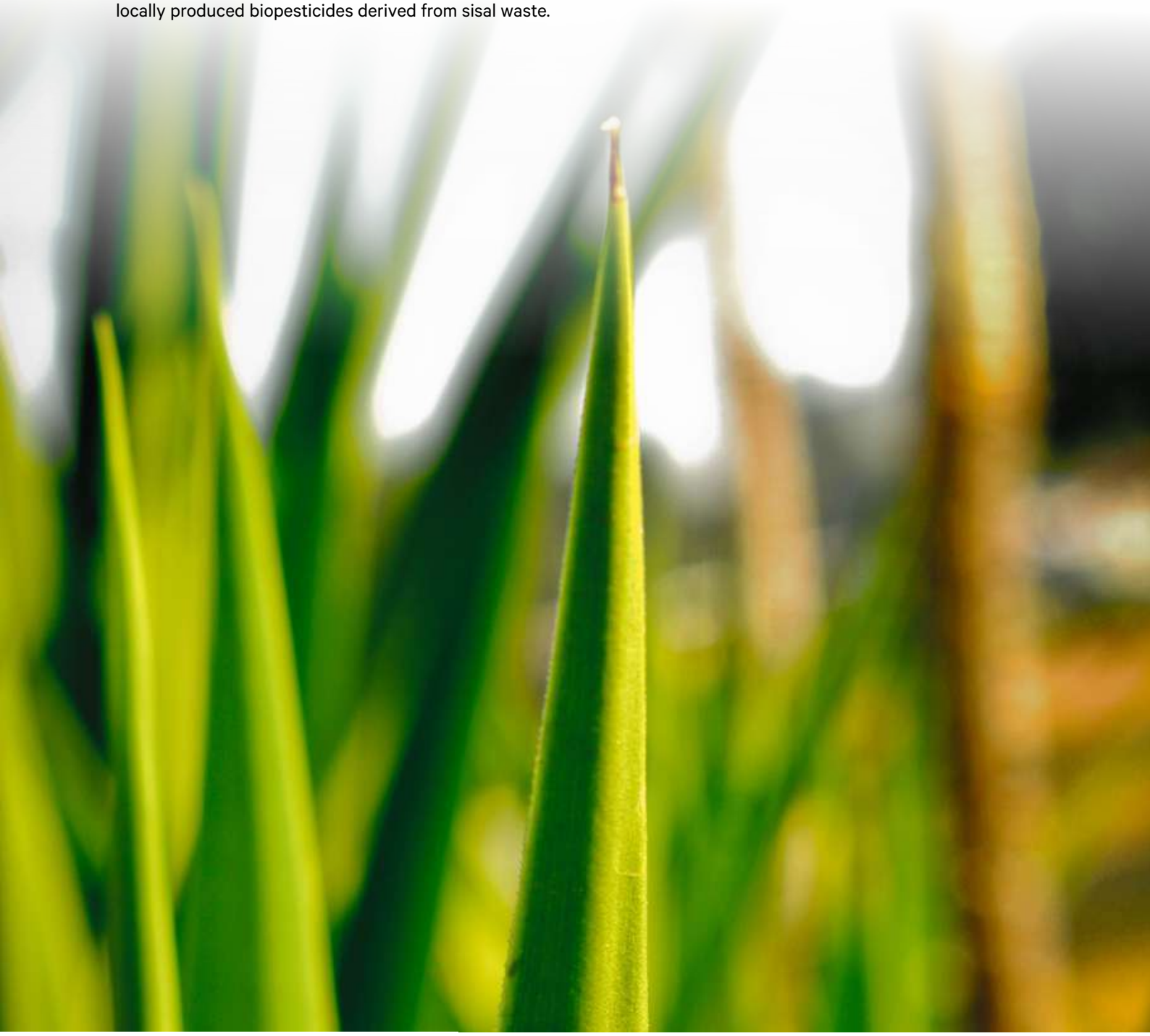
[90]https://www.suaire.sua.ac.tz/items/03ed8b28-0c2d-4ff6-9760-e7a82c2d4df1

[91]ibid

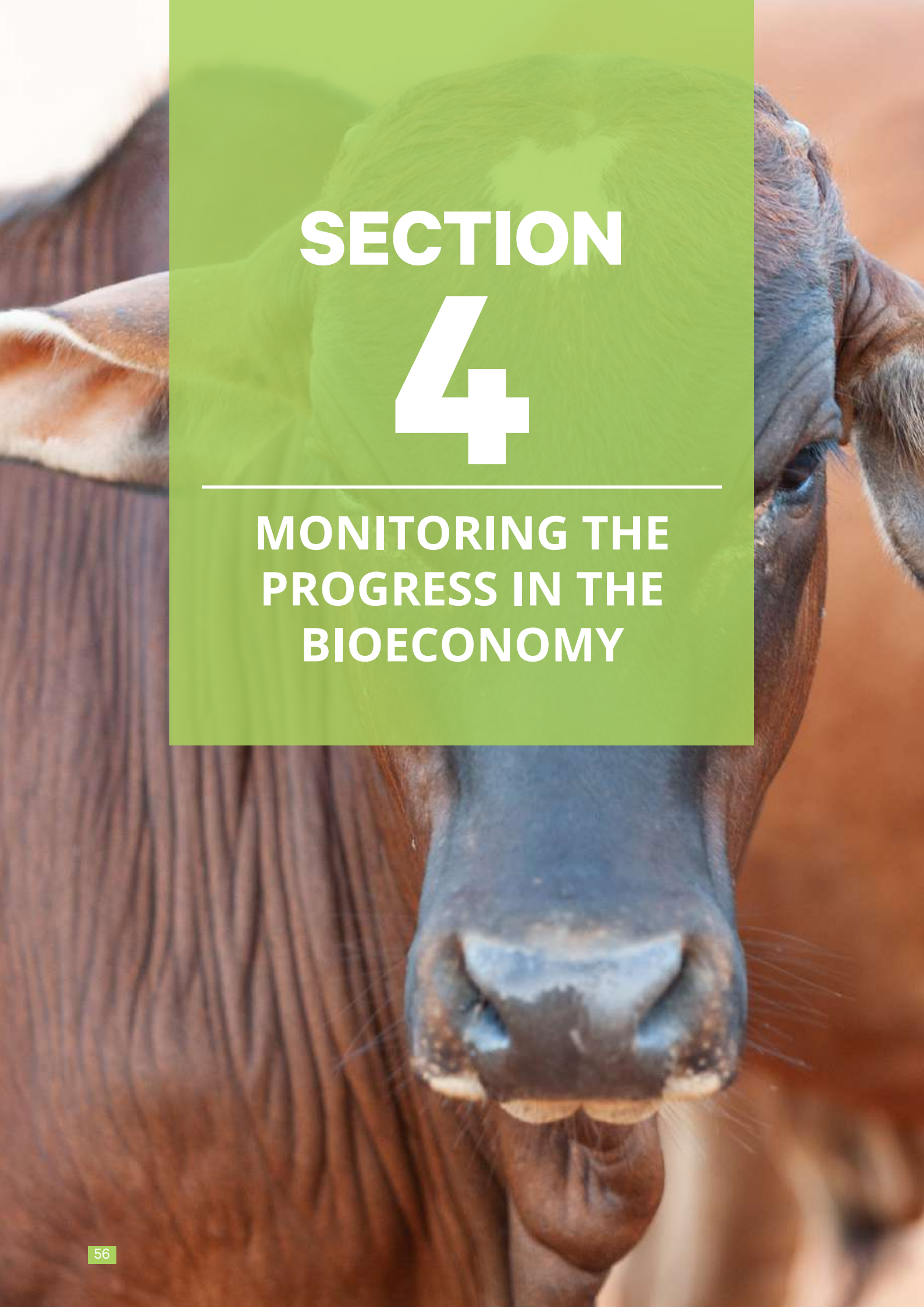
[92]Msuya, N., Temu, A., & Minja, R. (2022). Effect of Temperature, Catalyst Concentration and Time, on Polylactic Acid Production from Sisal Boles Juice by Ring Open Polymerization. *Tanzania Journal of Engineering and Technology*, 41(2), 70-81. https://doi.org/10.52339/tjet.v41i2.780

Tanzania may position itself as a regional champion in the circular economy by developing and optimizing sisal value chains making use of the different types of sisal waste, not used today. Sisal juice can be processed into high value products such as industrial sugars, biopesticides, and agave syrup (which alone has a market potential expected to be at 700M USD)[93], ethanol, bioplastics, fertilizer and growth substrate. Liquor similar to tequila is another product that can be produced from sisal bole juice, with a market potential of 133M USD[94]. With processing of sisal waste farmers stand to earn more income from further development of sisal waste value chains that catalyse local sisal product manufacturing processes.

Tapping into this sleeping giant of opportunities will have positive effects on the local economy of small holder farmers and rural economies, contributing to the badly needed jobs and towards building resilient economies through local production of clean energy and other higher value products. Value addition to sisal and improving sisal farming profitability will also support climate smart farming and production of healthy food crops through increased use of locally produced biopesticides derived from sisal waste.



[93]https://pdf.usaid.gov/pdf_docs/PA00WJTZ.pdf
[94]ibid



SECTION 4

MONITORING THE PROGRESS IN THE BIOECONOMY

4.1 PERFORMANCE INDICATORS TO MONITOR BIOECONOMY DEVELOPMENT

Monitoring bioeconomy development is becoming increasingly important as bioeconomy strategies are developed, while the demand for bio-based materials from agriculture, forestry, fisheries, and organic waste is increasing and new bioresource circular flows are being explored. There is consequently a growing interest among governments in setting up bioeconomy monitoring systems that can measure bioeconomy progress, from biomass extraction to consumption and recycling, and their implications for sustainability and development.

However, monitoring bioeconomies and their economic, environmental, and social impacts is not straightforward since the bioeconomy spans across many sectors. Moreover, official economic statistics and distinctions are rarely made between bio-based and non-bio-based products. Work on developing generally agreed performance indicators and metrics on monitoring progress of the bioeconomy is therefore ongoing. A first set of indicators to monitor and evaluate the sustainability of bioeconomy were published by the FAO in 2019[95]. Some common bioeconomy indicators are listed in the box below.

As the bioeconomy has continued to emerge in policy agendas, there are also different approaches and ideas on how to measure progress and the effect of the bioeconomy[96]. A first and quite traditional approach is to approximate the bioeconomy as a share of the GDP, where bioeconomy is seen as a sector that can be identified by the flow of products and services. Related to this is the estimation of employment shares of the bioeconomy. A second approach is to measure the share of renewable bio-based content embedded in the economy's products and services. A third approach is to consider the bioeconomy as being more of a process transforming the economy and thus more oriented towards a change process, with a set of specific outcomes. This may include things like reduced carbon emissions, treatment of wastewater increasing sustainability, biodiversity improvements, and increased employment in the value-added sector. Each of these is measured in technical and economic ways. Well-being outcomes could also be included, such as health improvements as a result of increased access to various bio-based health products.

The first approach, though a necessary step, is seen as unsatisfying because it simplifies the bioeconomy into a sector and neglects its externalities and contains all of the shortcomings of GDP accounting, and thus underestimates the bioeconomy's value to society. The second approach can only serve intermediate purposes, because a higher bio-based content in the economy's products and assets does not say much about sustainability, for example, about the resources' origins and how their production and utilization relate to sustainability. The third approach is more comprehensive and more connected to visions on how bioeconomy development can promote sustainable development. However, this is probably the most demanding approach, requiring specific data collection, and advanced monitoring efforts.

[95]Bracco, S., Tani, A., Çalıcıoğlu, Ö., Gomez San Juan, M. & Bogdanski, A. 2019. *Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward. Rome,*

[96]Wesseler, J. and von Braun, J. (2017). Measuring the bioeconomy: Economics and policies. *Annual Review of Resource Economics*. 9. 275–298

Box 5 - A list of common bioeconomy indicators.

- ***Biomass Production:*** Total biomass production measures the amount of biological resources (e.g., crops, forestry products, organic waste) available for bio-based activities.
- ***Employment in Bio-based Industries:*** Number of jobs directly and indirectly created by bio-based industries such as agriculture, forestry, fisheries, and bio-manufacturing.
- ***Value Added by Bio-based Industries:*** Contribution of bio-based sectors to the gross domestic product (GDP) or value added in the economy.
- ***Investment in Research and Development (R&D):*** Funding and expenditure on R&D activities related to bio-based technologies, products, and processes.
- ***Bio-based Product Sales:*** Revenue generated from the sale of bio-based products, including biofuels, bio-based chemicals, biomaterials, and bioenergy.
- ***Resource Efficiency:*** resource use in bio-based sectors including water, land, energy, nutrients.
- ***Carbon Footprint Reduction:*** Reduction in greenhouse gas emissions achieved through the adoption of bio-based processes and products compared to fossil-based alternatives. In addition, afforestation, sustainable land management and carbon footprints.
- ***Renewable Energy Production:*** Amount of energy generated from renewable bioenergy sources such as biofuels, biogas, biomass, and bioelectricity.
- ***Bioeconomy Policy Support:*** Existence and effectiveness of policies, regulations, incentives, and initiatives supporting the development and growth of the bioeconomy.
- ***Circularity and Waste Reduction:*** Degree of circularity achieved in bio-based value chains, including waste reduction, reuse, recycling, and biodegradability.
- ***Sustainable Land Use:*** Adoption of sustainable land management practices within bio-based sectors to prevent deforestation, promote agroforestry, and conserve biodiversity.
- ***Consumer Awareness and Perception:*** Public awareness, acceptance, and perception of bio-based products and their environmental and social benefits

4.2 MONITORING BIOECONOMY DEVELOPMENT IN EASTERN AFRICA

Monitoring bioeconomy development in Eastern Africa is important for many reasons. It helps identify trends, challenges, and opportunities in the bioeconomy, enabling evidence-based decision-making and policy adjustments creating an enabling environment for bioeconomy development. Monitoring the bioeconomy also enables governments in the region to assess its contribution to economic growth, rural development, job creation, and poverty reduction etc. It helps to identify sectors with growth potential, informing and promoting entrepreneurship and innovation in the region.

Monitoring also provides bio-based businesses with insights into market trends, demand dynamics, and competitive landscapes within the bioeconomy. It helps those businesses to identify market opportunities, develop competitive strategies, and innovate products and services to meet changing consumer preferences and market demands. The question is however what to monitor? What type of data collection is most relevant to bioeconomy development in the region and what type of data collection is done today by government agencies and national statistics offices? Due to limited data collection and information gaps, a prioritization of what is most relevant to monitor needs to be done. Such assessment also needs to be connected to an assessment of what is realistic to monitor.

The monitoring of bioeconomy development in Eastern Africa is therefore closely linked to the key priority Strategic Thematic Areas, and the key result areas in the East African Community Bioeconomy Strategy in 2022. The indicators in the table below are based on outcomes from the strategy considered feasible and realistic to monitor on the basis of how easily data can be harvested and analysed.

Table 2: Bioeconomy monitoring indicators for Eastern Africa

Category 1: Generic Indicators	
Indicator Category	**Proposed Indicators**
Biomass Production	• Total biomass production measured by the amount of biological resources (e.g., crops, forestry products, organic waste) available for bio-based activities.
Biomass Value addition	• Amount of biomass production that goes through agro-processing
Investment in Research and Development (R&D)	• Funding level and expenditure on R&D activities related to bio-based technologies, products, and processes.
Circularity and Waste Reduction	• Degree of circularity achieved in bio-based value chains, including waste reduction, reuse, recycling, and biodegradability.
Carbon Footprint Reduction	• Reduction in greenhouse gas emissions achieved through the adoption of bio-based processes and products compared to fossil-based alternatives.
Bioeconomy Policy Support	• Existence of bioeconomy strategy and policy • Existence and effectiveness of policies, regulations, incentives, and initiatives supporting the development and growth of the bioeconomy. (including biofuel blending mandates, renewable energy targets, and land tenure reforms promoting sustainable biomass production)
Infrastructure Development	• Evaluate the availability and accessibility of infrastructure supporting the bioeconomy, including transportation networks, storage facilities, processing plants, and distribution channels for bio-based products.
Public awareness and Perception	• Public awareness, acceptance, and perception of bio-based products and their environmental and social benefits
Education, Technology Transfer and Capacity Building	• Promote technology transfer, knowledge exchange, and capacity building initiatives to enhance the adoption of bio-based technologies, improve agricultural practices, and build local expertise in bioeconomy sectors.
Access to Finance	• Evaluate the availability of financing mechanisms and investment opportunities for bio-based projects, including access to credit, venture capital, and grants for smallholder farmers and rural entrepreneurs.
International Collaboration and Trade	• Foster regional cooperation, trade agreements, and partnerships for bio-based industries, including intra-regional trade of bio-based products, technology transfers, and collaborative research projects.
CATEGORY 2: THEMATIC INDICATORS	
Food Security and Agriculture	
Sustainable Land Management	• Adoption of sustainable land management practices within bio-based sectors to prevent deforestation, promote agroforestry, and conserve biodiversity.
	• Changes in land use practices to ensure the sustainability of biomass production, including measures to prevent deforestation, promote agroforestry, and protect biodiversity and ecosystem services. (measured using land use land cover change analysis)
Agricultural Productivity	• The productivity of key crops and biomass feedstocks used in bio-based industries, including yields per hectare, adoption of improved agricultural practices, and crop diversification efforts.

Novel food and feed products	• Number of products registered and approved in the market • Existence of standards and regulations for novel products
Bio-based agricultural inputs	• Number of products registered and approved in the market • Existence of standards and regulations for novel products
Health and Well Being	
Bio-based pharmaceuticals	• Number of pharmaceuticals and vaccines approved by the relevant agencies and their uptake
	• Existence of standards and regulations for pharmaceuticals and vaccines
Bio-based traditional medicines	• Number of approved traditional medicines and their uptake
	• Existence of standards and regulations for traditional medicines
	• Volume of exports of traditional medicines and bio-based cosmetic products
Bio-based cosmetics and well-being products	• Number of approved bio-based cosmetic products and their uptake
	• Existence of standards and regulations for bio-based cosmetic products
	• Volume of exports of bio-based cosmetic products
Bio-based Industrial development	
Employment in Bio-based Industries	• Number of jobs directly and indirectly created by bio-based industries such as agriculture, forestry, fisheries, and bio-manufacturing.
Value Added by Bio-based Industries	• Contribution of bio-based sectors to inclusive wealth index/GDP per year per country
Value-Added Processing	• Number and value of new investments in bio-based industrial development per year
	• Number of new value-added processing industries, such as bio-based chemicals, pharmaceuticals, and biomaterials, as well as investments in research and development for product innovation.
	• Revenue generated from the sale of bio-based products, including biofuels, bio-based chemicals, biomaterials, and bioenergy.
Bio-based Products	• Production volumes of bio-based products (e.g. construction materials, textile fibres and bio-based oils)
Sustainable energy	
Renewable Energy Production:	• Amount of energy generated from renewable bioenergy sources such as biofuels, biogas, biomass, and bioelectricity.
	• Biomass volumes that are converted into modern bioenergy in each country per year
Bioenergy Production	• The production and consumption of biofuels (such as ethanol and biodiesel) and biogas for electricity generation and cooking, as well as investments in bioenergy infrastructure and technology.
	• Number of new initiatives producing biofuels per year per country



SECTION 5

GAPS AND WAY FORWARD

5.1 GAPS AND CHALLENGES

In order to facilitate a progressive bioeconomy development in the Eastern Africa region, it is important to address the existing gaps, challenges, and needs for action. Some of the most serious challenges include:

- Limitation in infrastructure, (transport, energy supply, storage facilities[97])
- Lack of technology and facilities for processing, and value addition
- Lack of skilled workforce
- Low agricultural productivity
- Inadequate and in many cases stifling policy and regulatory frameworks
- Lack of access to finance and venture capital
- Low level of private sector engagement,
- Inadequate Market awareness and weak demand/bioeconomy promotion

These urgent challenges need to be addressed by actions such as:

- Continued Infrastructure development
- Capacity building in all central areas of the bioeconomy
- Creating an enabling policy and business environment
- Creating funding mechanisms and establishing funding priorities
- Promotion of Research and Innovation
- Promoting technology and business incubations

In terms of who should do what, a multi-stakeholder approach involving the government, private sector, research institutions, civil society organizations, and development partners is essential. The government should take the lead in policy development, infrastructure investment, and capacity building initiatives. Private sector actors can drive innovation, investment, and market development. Research institutions play a key role in knowledge generation and technology transfer. Development partners can provide technical assistance, funding support, and capacity building programs.

By addressing these challenges and taking urgent actions to promote bioeconomy development in Eastern Africa, the region could unlock its potential for sustainable economic growth, job creation, environmental conservation, and social inclusion. Collaboration among stakeholders and a coordinated effort towards a shared vision of a vibrant bioeconomy will then be key to success.

[97]Currently, small scale farmers in the region lose up to 40% of their produce due to post harvest losses caused by inadequate storage

5.2 WAY FORWARD

The development of bioeconomies in the countries in the region has a large potential to support economic growth and sustainable development. However, it will only be achieved through strong leadership from governments, with the provision of appropriate policies,actions and incentives. Regional and international cooperation will also be important components in this endeavour. Below follows a list of ten recommended key actions that can be taken at national and regional level in support of bioeconomy development. These key actions that were identified already in 2022 Eastern Africa bioeconomy status report[98], but where all considered to be key actions highly valid for the next coming years as well-.

1. **Developing national bioeconomy strategies.** The newly adopted regional Bioeconomy Strategy needs to be followed by the development of national bioeconomy strategies, anchored and linked to existing bioeconomy related national strategies and policies with detailed action plans, policy agendas and roadmaps relevant and appropriate for bioeconomy development for each country in the region. In concert with this, the EAC Regional Policy for Science, Technology and Innovation (STI) should include mechanisms for the sustainable financing of STI initiatives in partner countries, including bioeconomy initiatives. This should include mechanisms, such as an EAC Research and innovation fund, and calling for EAC Partner States to make annual contributions towards STI initiatives and bioeconomy development

2. **Monitoring and sharing information.** Monitoring and information sharing on bioeconomy development at national and regional level will enable benchmarking and allow actors across the region to identify progress, challenges, and gaps and weaknesses with regard to bioeconomy development and provide a basis for potential interventions. A functional regional **bioeconomy observatory** (https://bioeconomy.easteco.org/) has been established sharing data and information on the bioeconomy progress in the region, guiding and supporting bioeconomy development at national level. The data and information needs to be continuously updated in order for the observatory to be useful for the region. Initiatives to establish projects and programmes evaluating and systematically mapping strategic bioresources providing the basis for future bioeconomy investments and capacity building initiatives would also be important in this regard.

3. **Developing a regional expert Bioeconomy Committee**/(a think tank) sharing information and providing advice to regional bodies and country governments and government institutions in the region on the implementation of bioeconomy strategies.

4. **Harmonisation of standards and regulations for bio-based products.** Regional integration, through the creation of common markets for bio-based products, needs to be developed to support bio-based economic growth in the region. Today common standards for bio-based trade in regional markets (e.g. standards for fuel blending, biofuel, biopackaging, biopesticides etc) are largely lacking in the region. The region also lacks clear and coherent standards for novel food products which hampers innovation on novel foods. Thus, regional harmonisation of food safety and food content regulations and common policies, regulations and standards, including intellectual property regimes, supporting (not stifling) development and deployment of bio-based products ensuring product efficacy and safety are required. Consideration also needs to be given to ensure that import tariffs, such as for bioprocessing equipment, are not punitive. Depending on needs, aspirations and willingness to promote innovation in this area policy makers need to consider how to ensure that regulations, including GM legislation can keep pace with the rapid technology development.

5. **Improving bio business environment.** Currently the policy environment in the region stifles innovation and entrepreneurship. Policies are needed that provide motivation for innovators to translate innovations into businesses, support SME growth, business (B2B) collaboration and ease of doing business, incentivising the bio-businesses. Supporting private sector actors to meet their business development needs is also required. Public procurement regimes catalysing and supporting the development of bio-based value chains and sustainable

[98]https://bioinnovate-africa.org/the-state-of-the-bioeconomy-in-eastern-africa-2022/

production need to be developed.

6. **Business incubation** Professional business incubation services to assist innovation actors with business development and commercialising promising products and technologies is a key building block in modern bioeconomies. There are few business incubation actors in the region, and increased Investment by country governments and other donors would catalyse the bioeconomy development in the region. Organisation of technology fairs to provide an opportunity for entrepreneurs and potential investors to link up could be part of such incubation. Support to community driven value addition processes is also needed to ensure an inclusive bioeconomy development. These could be in the form of co-operatives, or formation of smallholder-based companies specialising in value addition to a specific bio-resource or a range of bioresources.

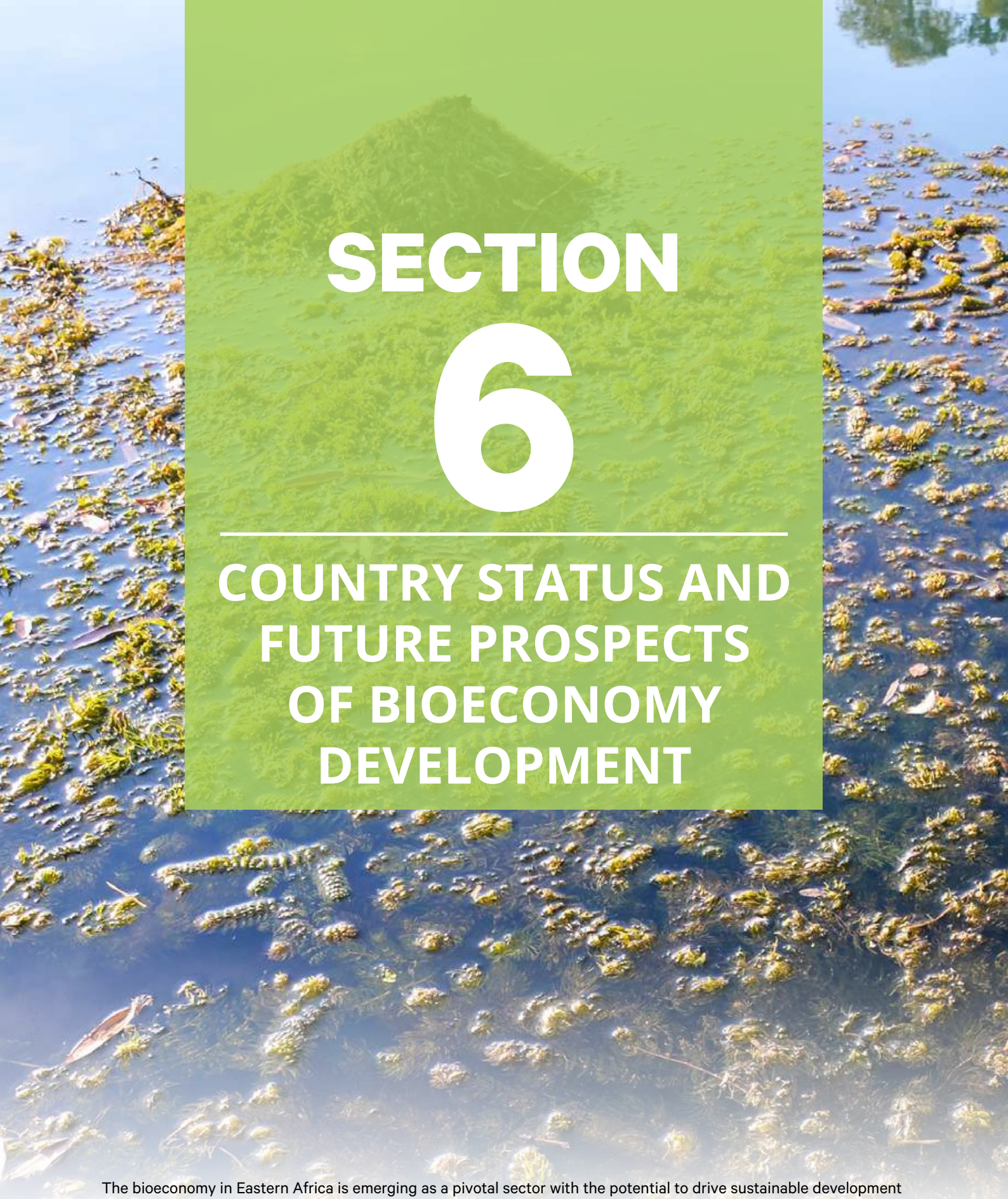
7. **Capacity building** at multitude levels is needed, including

    - Coordinating current R&D institutional arrangements in terms of their mandates, functions and activities in respect of bioeconomy-related issues.
    - Maintaining highly trained academic staff at public R&D institutions offering competitive remuneration and career opportunities
    - Enhancing capacity and developing up to date curricula in modern biosciences and related technologies, including synthetic biology, nanotechnology and bioinformatics, digitalisation and block chain technologies. For the health sector, building expertise in drug development, clinical trials and regulatory aspects is key.
    - Strengthening capacity in bioprocess engineering and valorisation of primary produce, including the construction and engineering of highly efficient and sustainable bioprocessing facilities at different scales, including modern biorefineries.
    - Building know-how in entrepreneurship at public sector institutions, including business planning and business management. This needs to go hand in hand with policies and incentives for staff to develop spin-off businesses.
    - Establishing and/or strengthening technology transfer offices in universities and research institutes to provide support for techno-economic analysis, IP management, and linkage with the private sector.
    - Strengthening key institutions and encouraging collaboration both regionally and nationally, where countries in the region can share specialized competence centers (e.g. universities, research institutions) distributed within the region through student exchange programmes etc.

8. **Investing in Innovation Infrastructure and centres of excellence** Countries in the region need to establish centres of excellence and collaborative regional bioeconomy STI programmes to access new and relevant technologies and bioeconomy know-how and adapting these to local needs and opportunities for value addition to primary produce and biowaste. This includes development of biorefinery structures and agro-industrial development centres, including the development of local and community-based bioprocessing structures.

9. **Attracting venture capital and investments.** Financing innovation and deployment of novel technologies is a key challenge for the region. Finding functional and innovative funding models will be crucial for development of bioeconomies in Eastern Africa. This will not be easy. Setting up investment agencies for novel technologies including bioeconomy development at regional and national basis with the task of attracting strategic investments in the region is one first step. Government funding, possibly leveraging donor funds, and providing support for start-up businesses with potential to develop innovative bioproducts or services for sale on emerging national, regional but also international markets would be strategic. Such support would also include entrepreneurs ready to launch market-changing companies – i.e., early investment in selected companies with well-defined plans for a technology-based product or services.

10. **Supporting networking and clustering.** Policy makers in the region need to find ways to support collaborative platforms and clustering of bio-entrepreneurs and bio-based SMEs enabling them to share experiences and knowledge and providing them with B2B opportunities. This may involve forming Bioentrepreneurs Associations at local, national and also regional levels providing stronger voices for bio entrepreneurs and bio-based SMEs and their role in propelling bioeconomy development in the region.



SECTION 6

COUNTRY STATUS AND FUTURE PROSPECTS OF BIOECONOMY DEVELOPMENT

The bioeconomy in Eastern Africa is emerging as a pivotal sector with the potential to drive sustainable development and economic growth across the region. This section provides a comprehensive overview of the current state of the bioeconomy in Eastern African countries, examining the diverse policies and strategies each nation has implemented to harness the benefits of biological resources. The section also explores the opportunities that arise from these efforts, including advancements in biotechnology, sustainable agriculture, and renewable energy as well as the challenges faced, which could impact the region's ability to fully realize its bioeconomy potential.



6.1 BURUNDI

Existing bioeconomy policies, strategies, roadmaps in Burundi

Burundi currently lacks a comprehensive legal framework for scientific research, despite constitutional provisions for the same. The nation's previous policy on scientific research and technological innovation expired in 2018 and has yet to be aligned with the East African Community's regional policy on science, technology and innovation. This absence of a robust legal and institutional framework has hindered research and development (R&D) institutions, making it challenging to secure funding. In response, the National Commission for Science, Technology, and Innovation (CNSTI) has drafted a *Bill on Research Organization (2023)* and a *Legal Framework for the National STI Fund* (2024). These initiatives aim to address the legal gaps, as outlined in the Constitution and the Ministry of Higher Education and Scientific Research's Sectoral Plan.

Burundi's Vision 2040 and 2060 emphasizes improving living conditions, reducing inequalities, and fostering sustainable development. To achieve these goals, the vision outlines five key pillars: state commitment, economic efficiency, social equity, sustainable ecology, heritage, and partnerships. Notably, half of the 22 strategic objectives within this roadmap directly relate to the bioeconomy sector.

While Burundi does not have a dedicated bioeconomy policy, its *Revised National Development Plan* (2018-2027) and *Priority Action Program* (2023-2027) share the same foundational pillars as the vision document. This alignment suggests de facto bioeconomy strategy focused on state involvement, economic growth, social welfare, environmental sustainability, and collaborative efforts. Essentially, although not explicitly termed a bioeconomy strategy, Burundi's development plans incorporate many of the core elements of such a framework. The five pillars on which the macro-economic policy instrument is based on, have all the features of a bioeconomy strategy. These are as follows: (i) State commitment, (ii) economic efficiency, (iii) social equity, (iv) ecology and sustainable heritage and (v) fruitful partnership.

Existing, emerging bioeconomy actors or new initiatives in the country

Burundi's industrial sector is primarily dominated by agro-food processing, producing items such as beer, soft drinks, and flour. According to the Burundi National Statistical Agency (ISTEEBU)[99], the top ten industrial companies by turnover in 2019 by turnover and employee count were: Brarudi (brewery), OTB (tea), Sosumo (sugarcane), Savonor (palm oil), Azam, Buceco, Minolacs, Afritextile, BTC, and Stecol Corporation. Other notable companies include ODECA (coffee processing), COGERCO (cotton), OHP (palm oil), Imena Society (banana wine), and Burundi Brewery.

A prime example of a bioeconomy project in Burundi is the Catnip malaria initiative. This project aims to reduce malaria prevalence by establishing the largest bio-based health biorefinery in the country at Karire Products Ltd, supported by the *icipe*/Bioinnovate Africa Programme. Essential oils extracted from catnip plants possess mosquito repellent properties, primarily due to the compound nepetalactone. Significantly, nepetalactone is ten times more effective than DEET, a common chemical repellent, without its associated side effects. The use of catnip essential oil offers environmental benefits as a natural, eco-friendly alternative to synthetic insecticides.

[99]ISTEEBU 2019. Cartographie du top 10 des entreprises industrielles au Burundi

What makes this project particularly noteworthy is its public-private partnership involving the University of Burundi and Karire Products. This collaboration encompasses research, cultivation, production, and marketing. The Catnip project aligns with Sustainable Development Goals, the African Union's Agenda 2063, and regional development strategies. Its potential for success and scalability positions it as a potential regional model for the bioeconomy.

Emerging (or future) bioeconomy market/ development opportunities.

While the concept of bioeconomy remains relatively new in Burundi, confined primarily to academic and development circles, the country possesses significant potential in this sector. Its favorable climate, abundant rainfall, and diverse ecological conditions create an ideal environment for year-round crop cultivation. Furthermore, Lake Tanganyika offers a rich aquatic biodiversity that could support a thriving fish processing industry.

Despite these advantages, Burundi faces challenges in realizing its bioeconomic potential. A lack of processing infrastructure leads to substantial post-harvest losses of fruits and vegetables, hindering the development of value-added products. To capitalize on its bioeconomy opportunities, Burundi can focus on value addition for emerging crops like avocado, palm oil, and patchouli. The presence of the region's largest biorefinery at Karire Products provides a platform for processing a variety of plant-based materials. To fully unlock the bioeconomy's potential, increased government engagement and policy support are crucial. This would facilitate investments in processing infrastructure, research and development, and capacity building.

Existing gaps, challenges and needs for action

Burundi's economy is predominantly informal and characterized by small-scale, individual enterprises with limited investment. This fragmented economic landscape hinders resource efficiency and development due to the absence of a formal framework. To address this, Burundi must prioritize building a knowledge-based economy through robust legal and institutional structures. A critical challenge is the shortage of skilled human capital, particularly in science and technology, which further hampers economic growth.

Developing a comprehensive bioeconomy policy and strategy is essential for Burundi. Investing in processing industries, especially agro-food and services, can stimulate economic growth. Regional collaboration, such as the partnership with Tanzania for phosphate extraction, offers opportunities to leverage shared resources and develop joint bioeconomy value chains. A high-level policy dialogue on national bioeconomy strategies was held in October 2023, with EASTECO pledging support for Burundi's bioeconomy development. To advance this agenda, key actions include establishing a specific legal framework for scientific research and revising the decree governing the National Commission for Science, Technology, and Innovation to prioritize bioeconomy development.



6.2 ETHIOPIA

Existing bioeconomy polices, strategies, roadmaps in Ethiopia

The Government of Ethiopia has set Vision 2030: Ethiopia, An African Beacon of Prosperity where building a climate-resilient middle-income economy is one of the key strategic pillars of Ethiopia's Perspective Plan for the period 2021-2030. The plan has been set as a Pathway to Prosperity, that puts the four economic sectors (agriculture, health, industry and the environment) as top priority areas of development. Hence, developing a bioeconomy strategy is crucial to support current government initiatives for proper application of bio-based development activities so as to improve the livelihoods of the society, and to enable national, regional and international partnerships in a coherent and integrated manner.

To meet the above, the national *Bioeconomy Strategy* has been drafted by putting the above sectors as the main pillars. The Bio and Emerging Technology Institute (BETin) has taken the initiatives and leadership roles. The Government representatives, NGOs, researchers, university professors, private industries, policy advisors and experts from various institutions have been participating since the inception. During document preparation bioeconomy strategies of selected countries around the globe were explored. To validate the draft Bioeconomy Strategy and get inputs for the development of a final robust and more inclusive strategy geared towards propelling Ethiopia to a greener, innovative and sustainable economy, a validation workshop was organized in December 2023 in collaboration with UNIDO. Diverse and relevant stakeholders participated including decision makers, senior officials, researchers, academia, industries and the private sector. From the deliberation, significant inputs were obtained to refine the document and make it ready for implementation after endorsement by Ministry of Innovation and Technology (MinT).



Participants during the bioeconomy strategy validation workshop, December 08, 2023, Addis Ababa.

There are also solid grounds for the future implementation of the *National Bioeconomy Strategy*. Appropriate policies, strategies, roadmaps and other related regulatory instruments play important roles in the economic, social transformation and overall development of a country. In Ethiopia various sectorial policies, roadmaps, strategies and regulatory instruments have been developed and are being implemented in order to support the social and economic development of the nation in general and the bioeconomy related development activities in particular. In this regard, the *Science Technology and Innovation (STI) policy* of Ethiopia is an important policy document that focuses on building competitiveness through innovation. The policy identifies biotechnology as one of the key strategic sectors. Ethiopia also has a *Climate Resilient Green Economy (CRGE) strategy*. The CRGE strategy aims to transform Ethiopia into a lower-middle income country by 2025 without an increase in its greenhouse gas (GHG) emissions, while the biotechnology R&D roadmap is designed to use biotechnology as a tool to transform various economic sectors including agriculture, environment, health and industry.

Additionally, Ethiopia has formulated national biotechnology roadmaps that stimulate the implementation of research and innovation in biotechnology applications. The biotechnology R&D roadmap is designed to use biotechnology as a tool to transform various economic sectors including agriculture, environment, health and industry. Ethiopia also has over twenty national roadmaps related to science and technology development, including a *Technology Roadmap (TRM) for biorefinery development, a TRM for fertilizer industry development, a TRM for chemical industry development, a TRM for pharmaceutical development, a TRM for sugar industry development, a TRM for livestock development, a TRM for crop development, an environment technology roadmap*, and other related roadmaps that are essential for the country's bioeconomy-related development activities.

Ethiopia is also party to the United Nations Convention on Biodiversity (CBD) and the Cartagena Protocol on Biosafety (CPB), all of which form an integral part of the law of the land, according to the Ethiopian constitution. Although Ethiopia is not a party to WTO and UPOV to strictly adhere to international agreements, there are several IPR regimes like *Trademark registration and protection proclamation No. 501/2006* and *Plant Breeders' Right Proclamation No. 1068/2017* that are in conformity with the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement. Patent applications are handled by the Intellectual Property Office (EIPO) and promotes technological development while there is Plant Breeders' rights legislation which is under the jurisdiction of the Ministry of Agriculture. To meet national and international quality standards of bio-based products, there are mandated institutions such as Ethiopian Standard Agency, Ethiopian Food and Drug Administration, the Veterinary Drug and Animal Feed Administration and Control Authority and Environmental Protection Agency when it relates to food and feed derived from genetically modified organisms (GMOs).

Existing, emerging bioeconomy actors or new initiatives

There are several existing and emerging bioeconomy actors and initiatives in Ethiopia that are supporting the development of the bioeconomy in the country. Some that are worth mentioning include:

The Bio and Emerging Technology Institute (BETin): This is a public research institute that focuses on biotechnology research and development in various sectors, including agriculture, health, industry and environment. The institute plays a key role in promoting biotechnological innovation and supporting the bioeconomy in Ethiopia.

Addis Ababa University Institute of Biotechnology (AAU-IOB): AAU-IOB is a research and training institution that promotes biotechnology research, innovation, and capacity building in Ethiopia. The institute collaborates with local and international partners to support biotechnological advancements in the country. About eight other universities in the country also run biotechnology education and development activities, albeit at a lower stage in their human and infrastructural capacity.

Ethiopian Institute of Agricultural Research (EIAR): The Ethiopian Institute of Agricultural Research is a government agency that conducts research and development activities to enhance agricultural productivity, sustainability, and food security in Ethiopia. The institute's work contributes to the advancement of bioeconomy-related initiatives in the country. It is a pioneer institute in the country to apply for environmental release of products of modern biotechnology including GM cotton and maize and has succeeded in obtaining the permit.

Integrated Agro-industrial Park (IAIPs): The establishment of IAIPs is exemplary in the sphere of bioeconomy development in Ethiopia. The idea of IAIP is to integrate various value chain components via the cluster approach. Fresh farm feed and agricultural produce from Rural Transformation Centres (RTCs) will be transported to IAIP where the processing, management, and distributing (including export) activities will take place. Accordingly, the clusters gain economies of scale and positive externalities by sharing infrastructure (power, ICT, waste treatment plants, etc.) and taking advantage of opportunities for bulk purchasing and selling, post-harvest management, training courses, and extension services. Currently, four IAIPs are established in four regional states, namely, Bure (Amhara), Baeker (Tigray), Yirgalem (SNNP) and Bulbula (Oromia). They will have specialized agro-processing units depending on the diversity of products of the agro-ecology zones. For example, Yirgalem IAIP has potential value chains for cereals, coffee, fruits and vegetables, dairy, meat and other animal products.

Yirgalem IAIP along with Bulbula and Bure have also recently started the production of avocado oil. Out of 11 production facilities in Yirgalem IAIP, three of them are occupied by investors: the Sunvado Avocado Oil Company, Doely Processing, and Hebron Coffee.

These actors and initiatives are actively involved in promoting sustainable development, innovation, and economic growth in Ethiopia's bioeconomy sector. By collaborating with government agencies, research institutions, and industry stakeholders, these entities are working to harness the potential of bio-based products, technologies, and processes to address societal challenges and drive inclusive growth in the country.

Bioeconomy initiatives ongoing in Ethiopia

In Ethiopia, there are a few research activities that are adopting the bioeconomy concept and are focusing on innovating in the areas of biomass optimization, adding value to bioresources, converting bio/agro-waste to useful products, and exploring novel uses of bioresources. Some of the key initiatives worth mentioning include research projects initiated by BETin to convert biowastes into value added products:

- Conversion of potato processing wastes into starch and bioplastics
- Conversion of tomato wastes into packaging materials
- Conversion of coffee husks and municipal wastes into biofertilizer
- Conversion of bagasse waste from large-scale sugar processing industries into value added products (chemicals including sodium silicate and rubber). Conversion of this waste into pulp and paper has been tested at the factory scale and has shown promising results as illustrated below.

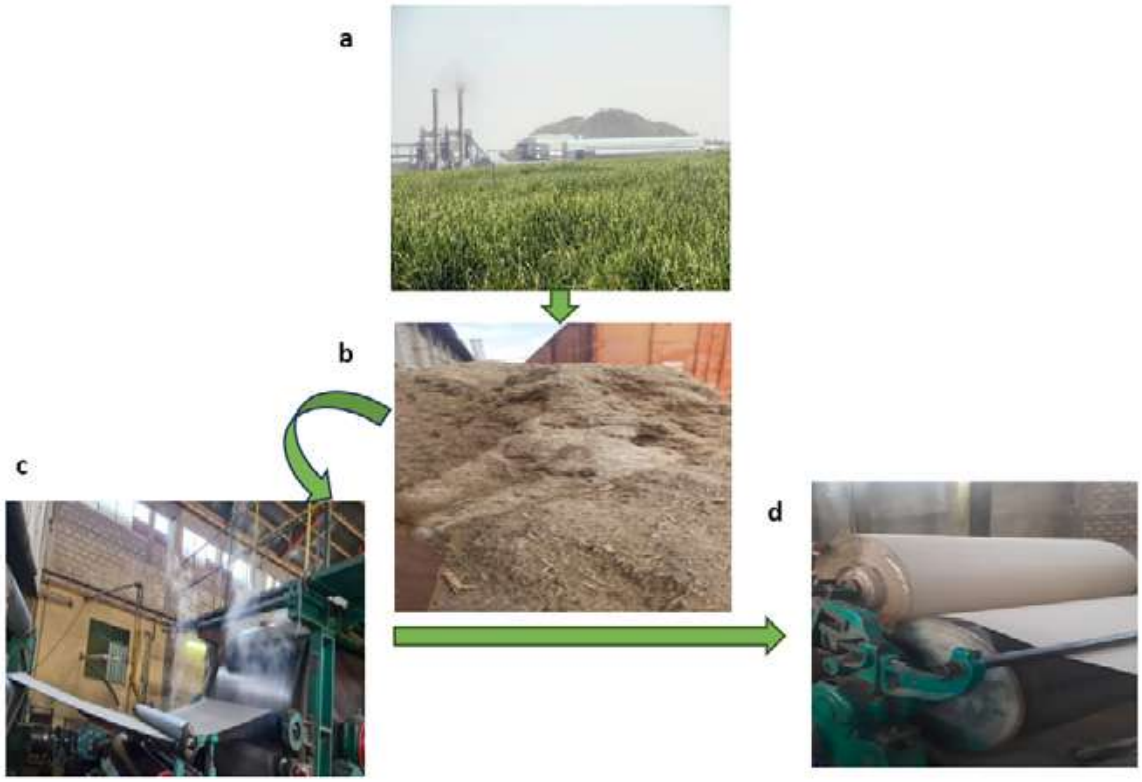


Illustration of conversion of bagasse into paper. (a) Wongi Shoa sugar factory (https://etsugar.com/esig/2023/01/27/wonji-shoa-sugar-factory/, accessed on April 19, 2024) b) Bagasse accumulated in Wongi Shoa sugar factory; (c and d) paper made from virgin pulp out of bagasse at Barguba PLC, Gelan, Ethiopia March 2024.



6.3 KENYA

Existing bioeconomy polices, strategies, roadmaps in Kenya

The Kenyan economy has largely depended on its bioresources for continued growth. For instance, the agricultural, forestry, and fishing sectors in the country contribute more than 30% to the country's GDP. Combined, these three sectors account for 65% of the export earnings, and provide the livelihood (employment, income, and food security needs) for more than 80 per cent of the Kenyan population. In addition, these sectors contribute towards the country's non-agricultural economy by providing inputs and markets for non-agricultural operations such as building/construction, transportation, tourism, education, and other social services. At the same time, this sector is also facing significant challenges such as stagnant or declining productivity levels, under- and overexploitation of land, inefficiencies in the supply chain due to limited storage capacity, lack of post harvest value chains, poor access to input markets and low value addition of most agriculture exports.

Currently, Kenya lacks an overall bioeconomy strategy, policy, or regulations. However, the regulation of bioeconomy in Kenya is organized across various policy frameworks for development e.g. land use policy, tourism policy, climate change policy, water policy, food and nutrition policy among others that may provide support for the implementation of a Bioeconomy Agenda. The *Kenya Vision 2030*[100] for instance, identifies the role that Agriculture plays in National Development. As such, the Government of Kenya has laid out elaborate initiatives to transform smallholder subsistence agriculture into an innovative, commercially oriented modern agricultural sector. Sector specific policies include *The National Biotechnology and Development Policy* (2006), *The National Biosafety Act* (2009), and *The Science Technology and Innovation Act* (2013) which inform the country's vision to transform Kenya into a knowledge-based economy. For the energy industry there is the S*trategy for developing the Bio-Diesel Industry in Kenya* (2008-2012), the *Kenya National Energy Efficiency and Conservation Strategy* (2020) and the *Bioenergy Strategy* 2020-2027. Policies on environment include the *Forest Policy* (2014), the *Kenyan Forest Conservation and Management Act* (FCMA) 2016, *The Environmental Management and Coordination Act* (EMCA), 1999, the *Sustainable Waste Management Act* (2022) and the *Climate Change Act*, 2016 which aims to drive growth of Bioeconomy and increase its contribution towards the annual GDP growth while ensuring conservation of the country's biodiversity and sustainable utilization of bio resources. Lastly, on social issues there is *The Community Land Bill* 2013, *Agriculture and Food Authority Act* 2013, *The Community Land Bill* 2013.

In addition to all these existing policies, the Government of Kenya is also implementing *The Bottom-up Economic Transformation Agenda* (BETA), which is designed to address the current challenges facing the country's economy, stimulate economic recovery and bolster resilience. The BETA agenda is anchored on five major pillars; Agricultural Transformation; Micro, Small and Medium Enterprise (MSME) Economy; Healthcare; Housing and Settlement; and Digital Superhighway and Creative Industry, with the largest impact and linkages to the economy as well as on household welfare. Sectors such as Blue Economy; Education and Training; Environment and Climate Change; Foreign Policy and Regional Integration; Infrastructure; Manufacturing; Service Economy, have been identified as key enablers for the successful attainment of this Agenda. It is therefore envisaged that the deliberate focus on the BETA agenda will spearhead bioeconomy development in the country.

[100]Government of Kenya, 'Kenya Vision 2030' <https://vision2030.go.ke/> [accessed 9 February 2024].

Bioeconomy actors

Kenya's bioeconomy has largely been driven by the agricultural sector which has remained resilient during the post-pandemic period. In addition to the agricultural sector, the tourism sector in Kenya has also shown great resilience amidst multiple stressors. The formulation of Tourism Strategy for Kenya 2021-2025 has seen increasing investments in marine and terrestrial conservation, including an increase in protected areas. Forests in Kenya are beneficial to the nation for their products and services. They sustain our environment and provide the resources to run other sectors. Ecotourism generates significant income and employment opportunities for the locals hence contributing to the economic growth of the country. The government, in its plan to support the tourism sector, recognizes the importance of maintaining biodiversity by promoting this niche. A national tree planting Initiative that will see 15 billion trees planted by 2032 was launched by the president. Balancing economic development with conservation efforts is key to environmental preservation and generation of sustainable bio-based products. In 2017, Kenya instituted a ban on single use plastic carrier bags including their production, sale, and use. This law stimulated neighbouring countries such as Uganda and Rwanda to pass similar laws. The actualization for this ban provided the necessary incentives for emerging bio-based industries to provide alternative natural packaging materials. Actors in the agricultural sector ensure a diverse range of food products are available for better nutrition and increased employment opportunities. Farm inputs are also critical in this sector. Agro-products such as Biofix[101], a bio-based fertilizer, has revolutionized the safety of agricultural produce by being affordable yet able to provide the required sources of soil enrichment that safeguards the environment.

Kenya's agro- and bio-processing sector is majorly dominated by large companies that produce sugar, tea, coffee and small-scale fruit-processing, cereals and snacks, vegetable oil, soft drinks and beer as well as dairy and meat processing industries. The majority of these companies are foreign owned multinationals[102].

Feast Foods Processors Limited provides an example of an emerging agroprocessing player in Kenya[103]. Located in Diani, Kwale County, the company has installed modern, state of the art machinery to process mangoes, pineapples, and passion fruits with a processing capacity of up to 100 tons of fruits per day. This venture has led to increased income for nearly 5,000 fruit farmers along the coast of Kenya and significantly reduced post-harvest fruit losses in the region.

Kenya is keen to develop its bioenergy sector. The country has enacted a *Bioenergy Strategy* 2020-2027 whose overarching aim is to put the country on track for 100% access to modern bioenergy services by 2030. The implementation of this strategy will foster areas of bioeconomy, including the use of bioethanol for cooking. One such company that is leveraging on this is the KOKO bioenergy company that is mainstreaming liquid bioethanol cooking fuel as a fast, safe, and affordable alternative to dirty cooking fuels such as charcoal. This cheap readily available source of fuel has revolutionized the cooking across Kenyan homes by providing a healthier alternative to healthier and more effective alternative to charcoal and woodfuel as a source of cooking fuel[104].

[101] 'Biofix, Kenya, Nairobi | Shambaza' <https://shambaza.com/listing/biofix.html> [accessed 9 April 2024].

[102] Christine A. Onyango and Mikah Nyaberi, 'Agro-Processing–a Kenyan Perspective: Enhancing Food Security and Farmers' Livelihoods', Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA) Http://Knowledge. Cta. Int, 2016.

[103] 'Feast Foods Processors Limited – Fruit Processor of Aseptically Packed' <https://feastfoodsprocessors.co.ke/> [accessed 9 April 2024].

[104] 'Koko Fuel Solution - Ethanol Cooker & Ethanol Cooking Stoves in Africa', KOKO Networks | Technology for Life in the World's Fastest-Growing Cities <https://kokonetworks.com/koko-fuel/> [accessed 9 April 2024].



Another potential emerging area for bioeconomy development is the production and utilization of algae for food, pharmaceuticals, fuels, and cosmetics products. For instance, farmers across the country are venturing into the culture of *Spirulina* as a superfood and a rich source of proteins and minerals. Tiwani Spirulina, located in the coast of Kenya in Kwale is one such bio-venture, that cultures Spirulina and packages it into supplement capsules[105].

Research, science, technology, and innovation, provide important drivers for enhancing a bioeconomy in Kenya. To achieve this, the Kenyan government has established bodies and authorities such as the National Commission for Science, Technology, and Innovation (NACOSTI), the Kenya National Innovation Agency (KENIA) and the National Research Fund (NRF) to coordinate innovation and research activities for inclusive economic growth. NACOSTI, as the lead institution for regulating science, has for instance been instrumental in giving advice to the Agricultural and Livestock Parliamentary Committee on the safety of GMOs.

[105]'Tiwani', TIWANI SPIRULINA <http://www.tiwanispirulina.com/> [accessed 9 April 2024].

Existing gaps, challenges, and need for action

Despite the progress in the post-pandemic period, Kenya faces challenges in fully realizing the potential of its bioeconomy. Issues such as inadequate infrastructure, limited access to financing for bio-based projects, and the need for regulatory frameworks to govern biotechnology present hurdles. However, these challenges also open avenues for public-private partnerships, and international collaborations to create a more conducive environment.

Kenya's economy requires robust infrastructure, including transportation networks, energy facilities, and processing plants. Limited infrastructure and lack of renewable energy sources in rural areas hampers the efficient production and distribution of bio-based products, particularly agricultural commodities. Access to finance is critical for bioeconomy actors, including farmers, entrepreneurs, and small and medium-sized enterprises (SMEs). Kenya needs to enhance access to capital through financial institutions and government support programs to enable investment in bio-based projects, infrastructure, and technology adoption. Lastly, there is need for more collaboration between academia and industry to help establish a regulatory framework for the innovations around safe development of genetically modified organisms (GMOs). The regulatory framework is essential to ensure product safety and promote environmental and social wellbeing



A picture showing a KOKO bioenergy company bio-ethanol bioethanol stove



6.4 RWANDA

Existing bioeconomy polices, strategies, and roadmaps in Rwanda

The concept of bioeconomy in Rwanda is considered to be in its infancy stages. Based on a macroeconomic point of view, various Government of Rwanda policies spur a bioeconomy enabling environment. These include the *Science, Technology and Innovation (STI) Policy*, which defines the country's priority areas focusing on national socio- economic transformation, the *"Made in Rwanda"* policy which promotes the consumption of locally made products and enhancement of Rwanda's domestic market through value chain development. Other Policies include the *Strategic Plan for the Environment and Natural Resources sector* (2018 – 2024), *Strategic Plan for Agricultural Transformation* (2017-2024) which highlights the need for technology use for increased productivity and sustainability, *National Pharmacy Policy* (2016), *Rwanda Biodiversity Policy and National Strategy and Action Plan for the Conservation of Biodiversity in Rwanda* which highlights the sustainable use of the biodiversity of natural ecosystems and agro- ecosystems, *Rwanda Green Growth and Climate Resilience Strategy*, and the *National Biotechnology policy*.

Rwanda is well positioned to develop a *National Bioeconomy Strategy* given the current policies that create an enabling environment. The National Council for Science and Technology (NCST) coordinated the consultations for development of *EAC Bioeconomy Strategy*. Currently NCST is collaborating with EASTECO to develop a *National Bioeconomy Strategy/Policy*. A concept note was developed by NCST and submitted for EASTECO to support development of a roadmap that will guide the development of bioeconomy policy. A well-structured strategy for Rwanda will help drive an emerging bioeconomy and identify areas for improvement and development.

Existing, emerging bioeconomy actors or new initiatives in the country

In addition to the current policies and strategies in Rwanda creating an enabling bioeconomy environment, there are a number of actors and new initiatives that contribute to the growth and development of bioeconomy in Rwanda, and indicate the trajectory of the domestication of the EAC strategy. For example, the country has recently launched the establishment of BioNTech mRNA Vaccine Manufacturing Facility which will serve as a confluence point in a decentralised, robust network of end-to-end vaccine manufacturing in Africa. In addition, Rwanda has mandated institutions to oversee product standards and quality including the Rwanda Standard Board (RSB), Rwanda Food and Drugs Authority, and Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA). The approach to patents under the Rwanda Intellectual Property (IP) Law follows the standard approach in line with the requirements of the WTO's TRIPS Agreement, and patent applications and registration are handled by Rwanda Development Board (RDB). There is also a *law no. 005/2016 of 05/04/2016 Governing Seeds and Plant Varieties* in Rwanda, which provides for the recognition and protection of seed and plant varieties and plant breeders rights. Rwanda has developed national Guidelines and Toolkit for Access and Benefit Sharing of Traditional Knowledge Associated with Genetic Resources under the Nagoya Protocol.

Research is an important part of a vibrant, developing bioeconomy and there are several research entities in Rwanda. The university has a mandate to provide science in support of Rwanda's national development agenda. The University of

Rwanda hosts several Centres of Excellence which drive research in various areas, such as on energy, vaccines, data science, IoT, and biodiversity and natural resource management.Other research institutions include, African Institute for Mathematical Sciences; University of Global Health Equity and Carnegie Melo University Africa. Support for innovation is another important aspect of research that will lead to domestication of the bioeconomy. Incubation of good ideas and connecting to investors is yet another component in developing the bioeconomy. There are several initiatives in the country that provide incubation opportunities, including the incubation hub of ICT Chamber, LEAPR LABS, the Swedish-funded incubation centre.

The R&D investment is important to ensure the development of bioeconomy. The Government of Rwanda has established various instruments that supports R&D. These include, the National Research and Innovation Fund that Operates at NCST; The Rwanda Innovation Fund; and the Green Fund.

Emerging (or future) bioeconomy market/ development opportunities.

The establishment of the industrial special economic zone and promotion of *'Made in Rwanda'* provide an indication of the potential for bio-economy development initiatives. For example, there are active projects exploring the shift from traditional bioenergy such as fuelwood or charcoal to processed biofuels such as biomass pellets or ethanol, and increased agricultural productivity and higher value-added production in agro-processing. A focus on increased recycling is expected to increase the availability of biomass for both energy and non-energy uses. Biomass resource planning and modelling bioenergy strategies in Rwanda has provided an opportunity to examine the relationship between the energy use of woody biomass and resource planning related to non-energy products and conservation over time. In addition, the establishment of 'the "*VISIT RWANDA*" has potential impact on tourism development in Rwanda.

Existing gaps, challenges and needs for action

Rwanda has an ambition to leverage the transformative potential of Science, Technology and Innovation (STI) to become a globally competitive knowledge-based economy. This requires knowledge creation, use of technology and more innovation. There are large untapped bioresources (biowaste) from the agro-processing sector (cassava, coffee, tanneries and food processing etc.) for sustainable production of bio based-fuels and energy, improving the local production. "*Made in Rwanda*" (pharmaceuticals, food, feed and fuels), and promotion of eco-tourism in the country could be explored as priorities for bioeconomy development. Efforts have been made by various public and private institutions and development partners to develop value added products and services such as production of refined concentrate of the flower *Pyrethrum*, essential oils, use of biotechnology for mass production of clean planting material of bananas, recycling wastes and turning them into valuable products such as chairs. What needs to be done to foster the bioeconomy in Rwanda consists initially of development of national bioeconomy policy and implementation frameworks as indicated below.

Steps in the domestication of the EAC bioeconomy strategy for Rwanda

1. Feasibility assessment: evaluate existing institutions for their capabilities, strengths and mandates relative to the framework of the EAC bioeconomy strategy and their contribution to developing the bioeconomy in Rwanda
2. Conduct a scenario analysis to establish a common vision for a domesticated bioeconomy strategy, including the key sectors, actors and needs
3. Strengthen the institutions through capacity building (human capacity), infrastructure (laboratories, incubators, processing equipment) and Public Private Partnerships
4. Strengthen research in bioeconomy-based topics and a research agenda related to bioeconomy priorities and promotion of bio-based Innovations
5. Support new entrepreneurs (call for competitive grants, awards. etc)
6. Promote Indigenous biobased knowledge (standardization, regulation and Intellectual Property),
7. Promote R&D performance based on knowledge transfer partnerships (KTP), academia-industry collaboration and financing bioeconomy related activities. Strengthen training, grow the number of researchers, promote a research culture, strengthen connections between research and industry needs, all to jump start bioeconomy.



6.5 TANZANIA

Overview of Bioeconomy development in Tanzania

Tanzania is endowed with diverse biobased resources that contribute significantly to the country's economy. The production of bioresources in Tanzania encompasses various sectors including agriculture (crop production, livestock and fisheries) and biodiversity (forestry, and wildlife). Agriculture is the major economic production in Tanzania, contributing to 29.1% of GDP, employing more than 65.5% of the population, producing 65% of raw materials required by industrial sectors and 30% of exports. There is also a growing focus on value addition to agricultural products including cereal, fruits, nuts and cassava products as well as establishment of fish, meat, dairy and leather processing plants. The rich biodiversity in the country provides opportunity for biomass production and provides major functions like carbon sinks, nutrient cycling, climate change resilience and adaptation, pollination and seed dispersal.

Existing polices and strategies for bioeconomy development in Tanzania

Tanzania has been developing and implementing various bioeconomy related activities to harness the potential of bio-based resources in the country but has not yet developed an explicit bioeconomy policy, strategy or framework for guiding bioeconomy development in the country. Tanzania through Commission for Science and Technology (COSTECH) has encompassed bioeconomy strategy in the current strategic plan as one of the targets to be implemented before 2026. However, a number of supporting tools from bioeconomy related aspects are already in place. These tools include; *National Bioenergy Strategy, Biotechnology strategy, Tanzania Biomass Energy Strategy, Environmental policy, STI policy, National Agriculture Policy, national Forest Policy, Climate Change policy and Industrialization policy*. These tools harness the potential of bio-based resources in the production of innovative products for sustainable economic growth, improved livelihoods and enhanced environmental management within the country's bioeconomy.

Emerging bioeconomy actors

Bioeconomy is one of the rapidly evolving economic drivers in Tanzania, driven by technological advancements, environmental and climate change concerns and demands for sustainable alternatives products and processes. The major emerging actors in bioeconomy development in Tanzania include; agribusiness companies, renewable energy companies, biotechnology startups, forest and agriculture biomass producers, higher learning and research & development institutions, government agencies, policy makers and non-government organisations. For sustainable growth of bioeconomy, Tanzania has been supporting the establishment of innovative clusters through a triple helix model. The emerging bioeconomy actors active in these clusters include: Sokoine University of Agriculture (SUA) food processors, Kiwango leather cluster, Mbeya rice cluster, Shiwamiki sisal fibres processors, Babati bee keeping among others. Below are examples of the bio based emerging clusters in Tanzania.

Zanzibar Seaweed Cluster Initiative (ZASCI): ZASCI brings all seaweed farmers and processors, marketing and researchers under one umbrella where they have one voice and are able to collaborate under the triple helix pillar. The objective of the ZASCI is to promote production and marketing of seaweed bio-based products including cosmetics, carrageen, pharmaceuticals, food products and food additives.







KIWANGO Leather Cluster: Focuses on producing eco-friendly leather commonly known as Organic Lleather uniquely processed using organic chemicals from locally available resources. KIWANGO Leather Cluster is dedicated to environmental sustainability while maintaining quality.

Emerging bioeconomy market opportunities.

Tanzania is experiencing rapid growth of markets for biobased products as societies increasingly demand sustainable renewable products. There is a rapid demand for organic food products, pharmaceuticals and nutraceuticals formulated from natural products, renewable energy and biofuel produced by forest waste, agricultural residue and energy crops.

Existing gap on bioeconomy strategy

While most of bioeconomy related sectors have in place a policy, strategy or framework to guide biobased resource utilization in the county, Tanzania still lacks the explicit legal and institutional frameworks such as bioeconomy policy and strategy that that support bioeconomy development.

Challenges for bioeconomy development in Tanzania

Capacity building: knowledge of the bioeconomy development is inadequate among the key stakeholders
Access to finance: Limited access to financing options for innovators, farmers and entrepreneurs constrains investment in bioeconomy projects

Commercialization of biobased products: Most of the small-scale bioeconomy actors fail to commercialize their products due to bureaucracy and logistics involved in registration of their products for commercialization

Inadequate Infrastructure: Limited infrastructure and equipment such as storage facilities, processing plants, and transportation network stifle efficient utilization of bioresources value chains. Most bioeconomy production is at small or medium scale.

Action to be taken for bioeconomy development in Tanzania

- Government should invest in education and training and foster collaboration between academia and industry to build the capacity of innovators, and entrepreneurs to drive bioeconomy development in the country
- Financial institutions, government and development partners should create affordable credit and innovative financing mechanisms tailored to the needs of biobased enterprises for fostering growth and sustainability of bioeconomy.
- Government should support young innovators and entrepreneurs to register their biobased products to market
- Government should improve infrastructure to enhance bioeconomy value chains and facilitate distribution of biobased products.
- Government should establish clear and consistent regulatory frameworks to provide stakeholders with certainty and facilitate sustainable bioresource management



6.6 UGANDA

Existing bioeconomy polices, strategies, and roadmaps in Uganda

The bioeconomy and a growing biobased manufacturing sector. is an emerging opportunity for economic development, job creation and growth in Uganda. Uganda's unique geographical location, diverse agro-ecological zones, and rich biodiversity give a comparative advantage in the production of biomass, which is a key input into a thriving bioeconomy. *Vision 2040* aims to transform the Ugandan society from a peasant to a modern and prosperous society with a goal to improve household incomes and improve quality of life of Ugandans[106]. Uganda's economy has continued to impress over the post-COVID-19 recovery period with GDP growth expected to recover to 5.7% during FY23 and economic growth expected to accelerate to above 6% per year in the medium-term[107].

Uganda exports mainly raw materials and semi-processed products fetching lower prices in the world market. A large part of the export earnings in Uganda are currently based on export of raw materials, especially export of unprocessed agricultural products which are facing increased global competition (e.g., coffee, chili, fruits, tea). Uganda's total exported commodities were estimated as follows; coffee (US$ 555M), gold (US$ 416M), dried legumes (US$ $98.4M) fish fillets (US$87.1M), cocoa beans (US$74.9M). Exports to United Kingdom of essential oils, perfumes, cosmetics, toiletries were only US$ 815,000. The share of Uganda's agro-industrial products in the global market is only 0.17 percent competing with countries that are highly integrated in the global value chains[108].

Development of Uganda's biobased industries thus offer opportunity for reducing Uganda's negative trade balance. Like other countries in the region, Uganda is a net importer and therefore has a negative net trade position. This trade position is attributed to the fact that a large share of the country's exports are unprocessed agricultural products. Analysis of the top ten exports for the year 2017 shows that apart from minerals and oil, agriculture and fisheries products comprise 42% of the country's total exports. Coffee, tea, cereals, fish, vegetables, sugar products and tobacco made the bulk of the exported agriculture and fish products.

Currently, Uganda has illustrated the potential and promise of bioeconomy in achieving its national development aspirations by underscoring the emphasis on research, science, engineering and Innovation (STEI), to create a competitive upper-middle-income country. Uganda has a *National Fourth Industrial Revolution (4IR) strategy* for becoming a continental hub that enables a smart and connected society. The strategy uses a three-part framework to identify key opportunities, enablers, delivery mechanisms, converging digital, physical, and biological technologies

[106]Uganda, Vision 2040, The Uganda Green Growth Development Strategy 2017/18–2030/31, n.d. https://www.greengrowthknowledge. org/sites/default/fi les/downloads/policy

[107]https://www.worldbank.org/en/country/uganda/overview

[108]Economic Commission for Africa (ECA) (2017), An ABC of Industrialization in Uganda: Achievements, Bottlenecks and Challenges.

Current efforts underway to develop a policy and legal framework for bioeconomy in Uganda

Uganda is a signatory to relevant international conventions, including the Convention on Biological Diversity, Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCC), the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from the Convention on Biological Diversity, Uganda also ratified the Cartagena Protocol on Biosafety and The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

The government of Uganda has deliberately introduced new or reformed old laws, policies, and action plans that characterize the bioeconomy as an integral part of national development. This includes the *Renewable Energy Policy for Uganda* (2007) which proposes use of bioenergy power generation and the transport sector for promotion of green economy development, The *Uganda Green Growth Development Strategy, National Biodiversity Strategy and Action plan, the Agricultural Sector Development Strategy and the National Environment policy. The National Biotechnology and Biosafety Policy* (2008) is a guiding framework on biotechnological innovations and safety issues in handling biological organisms, Other relevant policies include the *National Industrialization Policy* 2008; the *National Science, Technology and Innovation (STI) Policy* 2009, the *National Trade Policy* (2007) and *Buy Ugandan Products Build Uganda (BUBU) policy*.

Uganda's *National Intellectual Property Policy* of 2019, sets out to establish an appropriate IP infrastructure that supports innovation and creativity, develops human capital for the IP value chain, and enhances the utilization of IP systems[109]. The IP policy supports the development of a framework to protect traditional knowledge (TK) and traditional cultural expressions (TCEs), and to create a digital database of TK and TCEs with a view to protecting cultural heritage from unauthorized exploitation. The government of Uganda through the Office of the Prime Minister has initiated development of a fully-fledged law on biosafety and biosecurity that shall provide a regulatory framework for the safe use and application of modern biotechnology and handling of dangerous pathogens.

The Uganda *Green Growth Development Strategy* and *Green Economy development strategies* guide the transition from conventional economic development models to a green economy. The Ugandan government has committed to support technological innovation by increasing the innovation fund to help anyone with scientific ideas that need to be developed into business idea. Currently, a major gap is the lack of policy and strategy on development of bioeconomy in Uganda resulting in technology adoption bottlenecks and unsustainable production and under-utilisation of biological resources in Uganda.

[109]NARO (National Agricultural Research Organization), NARO guidelines for intellectual property management, Government of Uganda, 2018. https://www.firi.go.ug/other%20publications/NARO%20IP%20guidelines.pdf

Existing, emerging bioeconomy actors or new initiatives in the country

The Government has established the National Science, Technology, and Innovation System (NSTIS) coordinated by the Science, Technology and Innovation Secretariat at the Office of the President (STI-OP) under the direct oversight of H.E the President. This signifies the importance Government has placed on STI for national development. The Pathogen Economy Bureau is one of the strategic value chains identified in Uganda's new STI roadmap is to spur growth through the "pathogen economy". The bureau supports the development of investable tools, products, and services to monitor, prevent, and treat the effects of pathogens in the "One Health" approach. This is a collaborative effort that recognizes the connection between people, animals, plants, and their shared environment with a goal to achieve optimal health outcomes for all. The Government of Uganda through the Uganda National Council for Science and Technology and with support from the People's Republic of China (PRC) is implementing the National Science, Technology, Engineering and Innovation Skills Enhancement Project (NSTEI-SEP) to enhance the technological skill base of Ugandans to participate in strategic national infrastructural projects and manufacturing industries especially leather products.

The Government of Uganda, through the Uganda Investment Authority (UIA) plans to establish twenty-seven industrial parks, including four regional science and technology industrial parks making a total of 31. The completion of these industrial parks will add value to locally available raw materials thus boosting the agricultural and mineral sectors. Currently, there are three Government-owned industrial parks within the Kampala-Mukono region. These include the Kampala Industrial and Business Park (KIBP), Namanve, Luzira Industrial and Bweyogerere Industrial Parks.

Additionally, there are a number of bioscience-based incubation centres, the National Agricultural Research Laboratories food bioscience centre and pilot plant, the Makerere University, the CURAD (Consortium for enhancing University Responsiveness to Agribusiness Development), and the Uganda Industrial Research Institute incubation centre all of which have received assorted financial support to help start-ups accelerate into the marketplace. Generally, Uganda has made a modest start in biosciences research and technology development with a number of bioscience activities initiated by Ugandan individual scientists and institutions. Uganda has set up several research facilities to support the R&D of vaccines, diagnostics, and therapeutics. A state-of-the-art level 2 Biobank Facility at Makerere University serves as a repository for human biological materials including blood, saliva, urine, faecal matter for R&D and testing of vaccines, drugs, and diagnostic kits. Currently, over 20,000 samples have been collected; The in-vitro studies facility at the Uganda Virus Research Institute was established to carry out preclinical studies to support the development of vaccines, therapeutics, and diagnostics. The Biomarker Research Centre a facility at Makerere University was established to strengthen Uganda's capacity to develop point-of-care disease diagnostic and prognostic assay kits, with the mission of reducing overdependence on the importation of diagnostic kits and to also innovate better diagnostic technologies locally.

Emerging bioeconomy market/ development opportunities.

The National Agricultural Research Organisation (NARO), adopting and scaling up its research outputs, works with organizations such as East African Breweries to facilitate the use of cassava in beer production. NARO has also partnered with Kamtech Logistics Uganda Limited to produce ethanol from dried cassava, and it has worked with Serere Sorghum Producers and Processors Association to increase the utilization and commercialization of sorghum in products such as bread, cakes, and wheat flour. In addition, NARO has developed products such as extracts from local natural heritage coffee, skin care products, apiculture for honey, Naleng for shea nut butter, coffee scrub, and Aflasafe a biological control product for aflatoxin control.

Ticks are among the most important vectors of pathogens that cause some of the most devastating tick-borne diseases (TBDs) in the livestock sector in Eastern Africa, resulting in loss of productivity and mortalities. NARO and Makerere University have initiated programmes for Anti-tick vaccines for tick control in Uganda. NARO has also started construction of a multipurpose laboratory and vaccine production facility to accelerate vaccine production efforts.

The Joint Clinical Research Centre (JCRC), Makerere University College of Health Sciences, and the Uganda Virus Research Institute have been instrumental in building research capacities in the medical and health sciences fields. The JCRC has recently initiated the development of gene therapy to address intractable diseases such as HIV-AIDs and Haemophilia (a blood clotting disorder).

The Pharm-Biotechnology and Traditional Medicine Center (PHARMBIOTRAC) at Mbarara University of Science & Technology, accelerates the development of medicines from traditional natural herbs into commercial products. Among the key products from this Centre are CovideX (a COVID treatment herbal product), liquid and gel formulation hand sanitizer.

Although the private sector in Uganda is still small both in numbers and size, knowledge intensive biosciences based MSMEs have started to emerge. The dominating MSMEs in the cosmetics related sub-sector include: Movit Products Limited, Avis Ltd, and Samona products Ltd among others. In the agriculture related subsector, the space is dominated by MSMEs such as Agro-genetic Technologies Ltd and BioCrops Ltd using agricultural biosciences based techniques to produce disease-free planting materials of different crops such as bananas and coffee, The AROMA Honey Toffee Limited produces sweets from honey, AFRI banana Ltd produces vacuum sealed matooke, BOBO Eco Farm pioneers the production of protein and fat concentrates for animal feeds from insects reared on biowaste.

Emerging health issues provide an opportunity for strengthening Uganda's Bioeconomic R&D Ecosystem. Zoonosis, epidemics and pandemics, the emergence of antibiotic-resistant organisms and non-communicable diseases necessitates development of novel drugs, vaccines and diagnostic systems. The government of Uganda has implemented a variety of grant mechanisms to support science and innovation in this area including the Makerere University grant, Science, Technology and Innovation Office of the President grants, Science Granting Councils Initiative granting system.

Uganda also plans to establish a Pathogen Economy industrial park at Busunju and a National Microorganism Biobank Facility in the country as well as a centre of excellence for Herbal Medicine Research at Rukararwe Bushenyi. These initiatives will accommodate technological infrastructure such as research laboratories, technology development workshops, prototyping facilities, and testing & analytical facilities to facilitate the entire product and technology value chain to final commercialization.

Existing gaps and, challenges

The development of a vibrant bioeconomy in Uganda is currently hampered by several constraints. There is unsustainable production and underutilisation of living materials and services thereof in Uganda due to limited research and innovation and value addition capability to bioresources. This is attributed to among others; lack of an enabling policy, legal and regulatory environment; weak coordination of bioeconomy stakeholders; sub-optimal productivity of biobased enterprises; low use of alternative sustainable bioinnovations because of low awareness; and unfavourable market conditions. Uganda's research and innovation capacity is still uncompetitive and requires significant upgrading since science, technology is not operating at its full potential, while initiatives to facilitate innovations to full commercialization are scattered and disjointed across the sectors. Many institutions do not have a well-defined research strategy, instead most research is designed in response to requirements of funding agencies and not demand driven. Lack of requisite infrastructure to support biomanufacturing is a key factor limiting Uganda's industries from producing high value biobased products.

Funding towards research remains below international trends. Government investment in R&D has been increasing although not commensurate to global trends. For instance, Government budget allocations for R&D budget allocation has only increased by 3.5% since 2021. Even then, government funding towards research remains less than a quarter of a percent of GDP (0.23%). There is also limited adoption and use of existing and emerging technologies/innovations that could improve the production and delivery of better goods and services that can help meet the SDGs.

There is therefore the need to provide a favourable and enabling environment to reduce the technological bottlenecks affecting the growth of the country's bioeconomy through development of a bioeconomy policy and regulatory framework as well as a national strategy.These would (i) increase stakeholder awareness and acceptance of bioinnovations and empowering the citizens respond to bioeconomy opportunities, (ii) support establishing infrastructure to facilitate current and future industrial bioeconomy development,(iii) promoting the development of a circular economy (iv) promote provision of adequate financing for R&D, start-ups and incubators and capacity development in areas of strategic importance for growing the bioeconomy.

In conclusion, a bioeconomy offers potential to modernize economic sectors and is greatly central to Uganda's Vision 2040 and to its National Development Plans, especially in terms of the country's aspiration to reduce its dependence on fossil energy and increase sustainable clean bioenergy. Uganda has made efforts to advance bioeconomy and with the experiences gained these can be used to close the gaps especially advancing current institutional, innovation and funding structures for fostering the development of bioeconomy. Developing the bioeconomy offers a significant opportunity for achieving the Sustainable Development Goals (SDG) at the global level, while at the same time serving as a strategic instrument for addressing new challenges emerging from the global crisis. Advances in science and technology and existing experiences, fully support expectations in this sense. However, effective progress will be only possible if Uganda strategies evolve within a coherent and harmonized global framework.



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ISBN 978-9914-772-58-6
9 789914 772586

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