Food and Agriculture Organization of the United Nations

BIOECONOMY

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Opportunities to conserve and restore biodiversity in agrifood systems through bioeconomy practices

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Opportunities to conserve and restore biodiversity in agrifood systems through bioeconomy practices

Marta Gomez San Juan
Shane Harnett
Isabel Albinelli

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Aim of the paper

From the restoration of water ecosystems through bioremediation in Canada, to the use of environmental deoxyribonucleic acid (DNA) for biodiversity discovery and conservation in the Peruvian Amazon, to the regulatory framework to protect biological resources and traditional knowledge in South Africa, biodiversity is an integral part of the bioeconomy.[1] The sustainable management of biodiversity contributes to addressing food and nutrition security, enhancing resilience, and providing livelihoods to local and indigenous communities that can diversify their activities and generate income.

The paper aims to:

1. provide examples of bioeconomy practices, bioproducts and successful case studies that can support biodiversity conservation and ecosystem restoration, accounting for the trade-offs involved in the developmnet of a bioeconomy; and

2. raise general awareness on the role bioeconomy can play in supporting biodiversity under the different sectors of agrifood systems and bio-based industry, in line with the post-2020 Global Biodiversity Framework discussions, as well as the Food and Agriculture Orgnization of the United Nations (FAO) strategies on biodiversity,[i] climate change,[ii] and science and innovation.[iii]

Box 1: Understanding the Sustainable and Circular Bioeconomy

The bioeconomy can be defined as "the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy" (FAO, 2021).

The bioeconomy covers all economic sectors that rely on biological resources, from primary production (crops, livestock, forestry, fishery and aquaculture) to related processing and service industries (food, feed, paper, textiles, built environment and construction, chemicals and pharmaceuticals, energy). Circular bioeconomy closes the biological resources loop and maximizes the use of residual streams from agriculture, food processing and bio-based industries, by reusing, recycling or composting waste materials and converting them into useful products.

Bioeconomy is a knowledge-based economy, which can harness the power of biosciences and technologies across all sectors to create an innovative and sustainable economic model, which is enhanced by and benefits from traditional practices and knowledge.

However, bioeconomy activities are not necessarily sustainable *per se*, as the development of an economy that is based on biological resources faces several trade-offs.[iv] To address these trade-offs to bring about win-win situations, it is essential that sustainability and circularity criteria are embedded in bioeconomy frameworks. FAO is at the forefront of global discussions to ensure that development of national and regional bioeconomy policies and strategies takes due account of sustainability criteria. As a guide to countries and regions in this regard, the *Aspirational principles and criteria for a sustainable bioeconomy*,[v] developed by the FAO-led International Sustainable Bioeconomy Working Group (ISBWG), cover all three dimensions of sustainability (environmental, economic, social) and the governance dimension.

[1] When FAO refers to “bioeconomy” in this paper, it refers to “circular and sustainable bioeconomy” and related FAO definitions and aspirational principles.

In brief

• Bioeconomy embraces different bio-based value chains and economic activities that highly depend on biodiversity and ecosystem services. Therefore, biodiversity conservation, protection, sustainable use and regeneration, as well as ecosystem health, are essential components of successful bioeconomy strategies and policies.

• A sustainable and circular bioeconomy contributes, directly or indirectly, towards achieving most of the Sustainable Development Goals (SDGs) and especially those on biodiversity: SDG 14, “Life below water", and SDG 15, “Life on land”.

• Biodiversity conservation is a key criterion in the aspirational principles and criteria for a sustainable bioeconomy, developed by the FAO-led International Sustainable Bioeconomy Working Group (ISBWG). These principles and criteria provide a framework for the development of a sustainable and circular bioeconomy that unlocks the potential of nature to provide biological resources, harness the potential of bioprocesses and ensure biodiversity conservation, meeting people’s needs while respecting the ecological boundaries of our planet.

• There are multiple bioeconomy practices with direct and indirect positive impacts on biodiversity, addressing – often simultaneously – the five principal drivers of biodiversity loss (land use change, overexploitation of natural resources, pollution, invasive alien species and climate change). These practices are consistent with the four goals and related sustainability issues addressed in the draft post-2020 Global Biodiversity Framework.[2]

• Bioeconomy products or practices (such as biofertilizers, biopesticides, bio-based plastics, bioremediation or microbiome innovations) can help to reduce soil and water pollution and health risks by decreasing use of chemical fertilizers and pesticides, which are identified among major causes of biodiversity loss.

• A sustainable and circular bioeconomy promotes bioprocesses and circular value chains that allow for more sustainable production patterns that produce more with fewer resources and turn waste into valuable by-products, thereby reducing pressure on our ecosystems.

• The bioeconomy also harnesses traditional and indigenous knowledge, combined with the latest advances in biosciences and innovation, including multiomics, data and DNA sequencing, to enhance biodiversity knowledge and *in situ* and *ex situ* conservation. Combining tradition and innovation, the bioeconomy can empower local and indigenous communities with diversified income opportunities, while making sustainable use of biodiversity and related traditional knowledge.

• The benefits arising from the sustainable use and conservation of biodiversity and related traditional knowledge should be shared fairly and equitably within the bioeconomy, in particular with Indigenous Peoples and local communities.

• Around 23 national and regional bioeconomy-dedicated strategies contain provisions and mechanisms for the implementation of international conventions and protocols, including the Convention on Biological Diversity (CBD) and its two protocols (Nagoya, Cartagena):

  • almost all reviewed bioeconomy-dedicated strategies seek to ensure a sustainable use of biological resources;

  • more than half harness bioscience, biotechnology, and bioinformatics innovations to help collect, handle, store and supply biological materials, including genetic resources; and

  • almost half of the strategies reviewed highlight that the knowledge and benefits arising from biodiversity management should be equitably shared and accessible to everyone.

[2] At the time of writing, the most-up-date draft of the Post-2020 Global Biodiversity Framework dated from June 2022.

1 A new bioeconomy model that can support biodiversity

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The bioeconomy offers a cross-cutting economic model that covers all sectors and systems that rely on diverse biological resources (animals, plants, microorganisms and derived biomass, including organic waste), their functions and principles. This model is driven by knowledge (including traditional and indigenous), modern science, technology and innovation.

FAO not only promotes the sustainable use of biological resources within the bioeconomy, but also their conservation and regeneration, recognizing they are a valuable asset and have to be protected. The importance of valuing biodiversity is embedded in the *Aspirational principles and criteria for a sustainable bioeconomy*, produced by the FAO-led International Sustainable Bioeconomy Working Group (ISBWG), which aim to ensure that the three dimensions of sustainability (environmental, economic, social), alongside good governance, are accounted for.

Within this framework, **principle 2** states that "sustainable bioeconomy should ensure that natural resources are conserved, protected and enhanced, such that under **criterion 2.1** biodiversity conservation is ensured". Recognizing the strong link between biodiversity conservation and ecosystem health, **criterion 2.3** assures that water quality and quantity are maintained and enhanced, while **criterion 2.4** aims at preventing, stopping or reversing the degradation of land, soil, forests and marine environments.

Thanks to its comprehensive nature – from production to consumption and reuse of natural resources – the bioeconomy has the potential to address several interlinked global challenges. These include efforts to tackle hunger and poverty, climate change, ecosystem degradation, and biodiversity loss, in line with the Sustainable Development Goals (SDGs), the Convention on Biological Diversity, the Cartagena Protocol on Biosafety, and the Nagoya Protocol on Access and Benefit-sharing. As an example, at the Twenty-seventh Conference of the Parties (COP 27) to the United Nations Framework Convention on Climate Change (UNFCCC), FAO released a publication highlighting the key role that sustainable and circular bioeconomy can play as a driver in supporting climate action.

There are several ways in which bioeconomy can support biodiversity. For instance, sustainable bioeconomy practices related to afforestation and reforestation can reduce habitat loss and restore ecosystems. Similarly, bioeconomy science and innovation is supporting developments on how to harness the potential of microorganisms and the incredibly diverse microbial environments in which they operate (microbiomes). Microbiomes perform essential functions for soils, crops, animals, forests, humans and their related ecosystems. Microbial-based strategies are an eco-friendly approach to restore degraded ecosystems and enhance biodiversity, while improving the provision of ecosystem services.

Bioproducts, such as biopesticides, biofertilizers, biostimulants and bio-based pest control, can contribute towards reducing environmental pollution and health risks from fertilizer and pesticide use. Improving the soil and plant microbiome is a beneficial activity for a healthier environment, as highlighted in the *Work Plan for the Sustainable Use and Conservation of Microorganisms and Invertebrate Genetic Resources for Food and Agriculture*.[vi] Moreover, bioeconomy maximizes the use of residual streams from agriculture, food processing and forest-based industries, turning them into a range of value-added products, thereby reducing the amount of landfilled waste and pollution, which are a serious threat for biodiversity.

A practical example is the production of compostable bio-based plastics using agricultural residues or food waste, which can substitute fossil fuel-based plastics use and reduce plastic pollution in the agrifood system.

Bioscience, biotechnology, and bioinformatics innovations help in the collection, handling, storage and supply of biological materials, including genetic resources, which are essential to enhance biodiversity knowledge and for *ex situ* conservation. Importantly, the benefits arising from the sustainable use and conservation of biodiversity and related traditional knowledge should be shared fairly and equitably within the bioeconomy, in particular with Indigenous Peoples and local communities.

Bow-fishing in a creek on the Rupununi river.
The Rupununi Region is located in the southwest of Guyana. It consists mostly of large tracts of primary forest, with about 20 percent of its land area covered by natural Neotropical savanna and seasonally flooded wetlands. The region has approximately 24 000 inhabitants, including Indigenous Peoples that rely on subsistence hunting, fishing and farming.

2 How countries are using national and regional bioeconomy strategies to support biodiversity

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Currently more than 60 countries and regions have bioeconomy-related strategies, 23 of which are dedicated bioeconomy strategies (this number is based on an FAO review of all existing strategies as of November 2022). The number is steadily growing and includes countries in most regions globally. While no two bioeconomy strategies are the same, most present common elements; specifically, biodiversity conservation and its sustainable use are a key priority in national bioeconomy strategies.

For the purpose of this paper, the 23 bioeconomy-dedicated strategies[3] were reviewed to establish how countries are leveraging bioeconomy as an effective tool for conserving, restoring and enhancing their biodiversity. Out of these 23 strategies, 20 are national strategies and three are regional. Notably, the 20 countries with a national bioeconomy strategy are all Parties to the Convention on Biological Diversity (CBD) and have submitted National Biodiversity Strategies and Action Plans (NBSAPs).

Almost all reviewed bioeconomy strategies focus on the sustainable use of biological resources to avoid negative impacts such as deforestation and biodiversity loss. Strategies include actions such as conserving and restoring natural habitats and related ecosystem services through reforestation, afforestation and the use of bioproducts. The use of biofertilizers, biopesticides and bio-based pest control are often cited as good practices in the strategies for reducing environmental pollution and health risks from fertilizer and pesticide use. Bioremediation is mentioned as an effective means for achieving soil remediation, including through enhancing the soil microbiome by inoculating microorganisms with favourable properties.

More than half of the reviewed bioeconomy strategies harness bioscience, biotechnology, and bioinformatics innovations to help collect, handle, store and supply biological materials, including genetic resources. These innovations are considered important in enhancing biodiversity knowledge and *ex situ* biodiversity conservation.

Almost half of the strategies reviewed highlight that the knowledge and benefits arising from biodiversity management should be equitably shared and accessible to everyone. This holds greater relevance among developing countries, the bioeconomy strategies of which include explicit references to the importance of utilizing and preserving traditional and local knowledge. To ensure that bioprospecting activities comply with the requirements of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, an increasing number of countries are adopting biopiracy strategies as tools for protecting biodiversity as a part of their bioeconomy strategies.[vii]

[3] Of the bioeconomy strategies reviewed, 20 are national strategies (Austria, Brazil, Canada, China, Colombia, Costa Rica, Finland, France, Germany, Ireland, Italy, Japan, Latvia, New Zealand, Norway, Portugal, South Africa, Spain, Thailand, United Kingdom of Great Britain and Northern Ireland), while three are regional strategies (European Union, Eastern Africa, Nordic Countries). A draft copy of New Zealand's strategy is available, but the strategy has not yet been finalized.

Biodiversity provisions in selected national and regional bioeconomy strategies, by geographical region

Africa

Eastern Africa

The Eastern African Regional Bioeconomy Strategy (2022), addresses the social, economic and environmental challenges in the region through the development of an innovative, but tradition-rooted, economic model based on fair trade values, accounting for the protection and conservation of the region's vital ecosystem services and biodiversity, and related traditional knowledge. One example is the sustainable use of biological diversity to improve health through the development of biopharmaceutical products that harness innovation-driven traditional and indigenous knowledge.

South Africa

South Africa's National Bio-economy Strategy (2013) combines modern science, local biodiversity and indigenous knowledge systems for the transition towards a new economic model. The country's rich biodiversity and indigenous knowledge systems provide significant resources for the national bioeconomy, which accounts for its conservation, protection and enhancement. The regulatory landscape addresses bioprospecting activities that use indigenous knowledge, confidentiality of genetic information and the environmental effects of biotechnological advances. Moreover, the strategy recognizes the threat posed by fertilizers and pesticides to ecosystems and biodiversity health by promoting the use of alternatives such as biopesticides, bioremediation practices and biofertilizers.

Asia

China

China's new plan to spur the bioeconomy during the Fourteenth Five-Year Plan (2022) has a specific focus on the use and protection of biological resources integrated in several sectors, such as medicine, health care, agriculture, forestry, energy, and environmental protection/biosafety. The innovative development of bioeconomy in the country has been inseparable from the institutional guarantee for intellectual property for protecting traditional Chinese knowledge and its innovative applications. The implementation of the strategy is explicitly linked to the Fifteenth Conference of the Parties (COP 15) to the CBD and Post-2020 Biodiversity Framework, including the establishment of the Kunming Biodiversity Fund aimed at supporting sustainable use and conservation of biodiversity in developing countries.

Japan

Japan's National Bio Strategy (2020) proposes a new sustainable socioeconomic model that harnesses the potential of technologies and innovation for the sustainable use of biological resources, while respecting the Regulations on the Use of Living Modified Organisms (Cartagena Protocol) and the Act on the Conservation and Sustainable Use of Biological Diversity.

Thailand

Thailand's Bio-Circular Green Economy Action Plan 2021-2027 (2021) focuses on applying knowledge, technology and innovation to create a balance between conservation and utilization of biological resources, introducing a paradigm shift from "nature as resource" to "nature as source of all living organisms".

Europe

European Union

One of the objectives of the updated European Bioeconomy Strategy (2018) is harnessing bioeconomy knowledge to manage natural resources sustainably, specifically for the prevention of biodiversity loss. It has a focus on strengthening the understanding, resilience and status of biodiversity, ecosystems and ecosystem services, and increasing the understanding of microbial biodiversity with a view to developing microbiome-based solutions.

Austria

Austria's Bioeconomy strategy (2019) highlights that bioeconomy must contribute to the protection of soils, forests and biodiversity through research and science in climate-resistant crops and plants, sustainable forest management, and the implementation of organic farming. The strategy also contains specific actions to protect local forests.

Ireland

Ireland's National Policy Statement on the Bioeconomy (2018) highlights that activities in the bioeconomy should not compromise biodiversity resilience or result in biodiversity loss. The amount of extracted biological resources should not have a negative impact on country biological resources, should not exceed the capacity of the environment to replenish itself, and should cause no lasting environmental damage. In evaluating trade-offs, the policy adopts a holistic view, taking into account all biomass, including soil biomass.

Portugal

Portugal's Bioeconomia 2030 (2021) outlines the implementation of a bioeconomy with a strong circular and sustainable profile that looks at the replacement of fossil fuels with carbon from renewable sources, including in agriculture, forestry and in the marine environment (including by-products and waste). One of the strategy action pillars is the protection and enhancement of ecosystem services and biodiversity by ensuring a systematic monitoring of the availability and flows of biological resources.

Latin America

Brazil

The Action Plan on Science, Technology and Innovation in Bioeconomy (2018) and The National Program for Biobased Agricultural Inputs (2020) aim at sustainably exploring the potential of Brazilian biodiversity, including through the development and implementation of omics and bioinformatics technologies, to cover a range of processes and products and to promote sustainable bioinputs. The country presents different bioeconomy strategies at a subnational level. The Amazonas State Bioeconomy Strategy aims for a socio-biodiversity bioeconomy, relying on biodiversity resources and ecosystem services, such as natural regeneration. The State of Pará has "genetic heritage and associated traditional knowledge" as the second thematic axis of its bioeconomy plan.

Colombia

Colombia's National Bioeconomy Strategy (2020) acknowledges that the sustainable characterization, management, and conservation of the nation's biodiversity are means to achieve sustainability and peace. The first strategic areas are biodiversity and ecosystem services, sustainable bioprospecting, traditional knowledge conservation and tourism; the second is "Biointelligent Colombia", which aims to gain deeper understanding of the country's biodiversity through omics studies, data science and biotechnology.

Costa Rica

The Costa Rica National Bioeconomy Strategy (2020) aims to use biological resources to promote social inclusion and equity, through sustainable and fair use and conservation of the country's biodiversity and related knowledge. It is planned to achieve this through biotourism in biological corridors, the promotion of ecosystem services, the development of digital technology applications on conservation areas and the preservation of the country's natural scenic beauty.

North America

Canada

Canada's Bioeconomy Strategy (2019) acknowledges that indigenous communities have a deep understanding of natural capital and have been its most committed stewards for generations. The strategy also recognizes that formal science and traditional knowledge help co-create sustainable practices and explores opportunities to enhance the use of indigenous bioproducts, to the benefit of all communities involved.

Oceania

New Zealand

Within Aotearoa New Zealand's first emissions reduction plan (2022), circular and sustainable bioeconomy is identified as a key strategy that will be implemented for reaching the country's environmental targets. The bioeconomy framework seeks to guide the use of bioresources and is aligned with *Te Mana o Te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020*. One of the country's main objectives for developing a bioeconomy framework is to "protect and restore ecosystems and ecosystem services, with particular attention to indigenous biodiversity". The strategy also includes provisions to accelerate investment in bioeconomy technologies and products that "are developed collaboratively and provide for – and protect – the interests of Māori". New Zealand's circular and sustainable bioeconomy strategy has not yet been implemented.

3 What is FAO's role in supporting bioeconomy policy development for biodiversity?

More than 60 ministers of agriculture at the Global Forum for Food and Agriculture 2015 issued a communiqué advocating for FAO to take the lead in guiding global policy discussions on sustainable and circular bioeconomy in food and agriculture. This led to the creation of FAO's Towards Sustainable Bioeconomy Guidelines project – supported by the Government of Germany – and the formation of the FAO-led International Sustainable Bioeconomy Working Group (ISBWG).

Since then, FAO has developed a suite of bioeconomy knowledge products and supported countries in developing bioeconomy policies and strategies that facilitate the achievement of the Sustainable Development Goals (SDGs), including those related to sustainable production and consumption, food security and nutrition, climate change, biodiversity, and the environment.[viii] FAO has institutionalized this work through its Bioeconomy for Sustainable Food and Agriculture programme priority area, part of the Better Environment pillar of the FAO Strategic Framework 2022–31. Through this dedicated programme, FAO collaborates with countries to improve the sustainability of agrifood systems with bioeconomy solutions at three levels: technological, organizational and social. The Organization's work in pilot countries and regions supports the identification of sustainable and circular opportunities to harness biological resources, including related knowledge, science, technology, and innovation.

FAO convenes global policy discussions around the sustainability of bioeconomy innovations, including on topics such as microbiome science, new food sources, biopesticides, biofertilizers, biotechnology-based plastics and other biomaterials, including vaccines, waste reduction and biomass reuse. The Organization works with partners to establish criteria for the sustainability of many of these innovations, address ethical issues, identify priorities for technology use and development, and provides guidance.

Box 2: Biodiversity and the Aspirational Principles and Criteria for Sustainable Bioeconomy

Building on the *Aspirational Principles and Criteria for a Sustainable Bioeconomy*, which provide a framework for the conservation, protection and enhancement of natural resources and biological diversity, FAO supports Members in developing and implementing bioeconomy strategies, through guidance documents on good practices, policies, tools and indicators. Country level collaborations include:

- **URUGUAY:** FAO has been supporting Uruguay since 2018 in implementing a participatory process for the development of its bioeconomy strategy. FAO has also been mapping public policies and private sector initiatives that pave the way for the implementation of the bioeconomy strategy that has a strong conservation component as a country trademark and value addition in international markets.
- **NAMIBIA:** The National Commission on Research, Science and Technology (NCRST), a coordinating agency under Namibia's Ministry of Higher Education, and FAO are working together to develop Namibia's Bioeconomy Strategy 2023–2028. The comprehensive National Bioeconomy Strategy proposes a cross-cutting approach to addressing food insecurity, the impacts of climate change and natural resource scarcity. The strategy promotes the use of biological sciences and indigenous knowledge.


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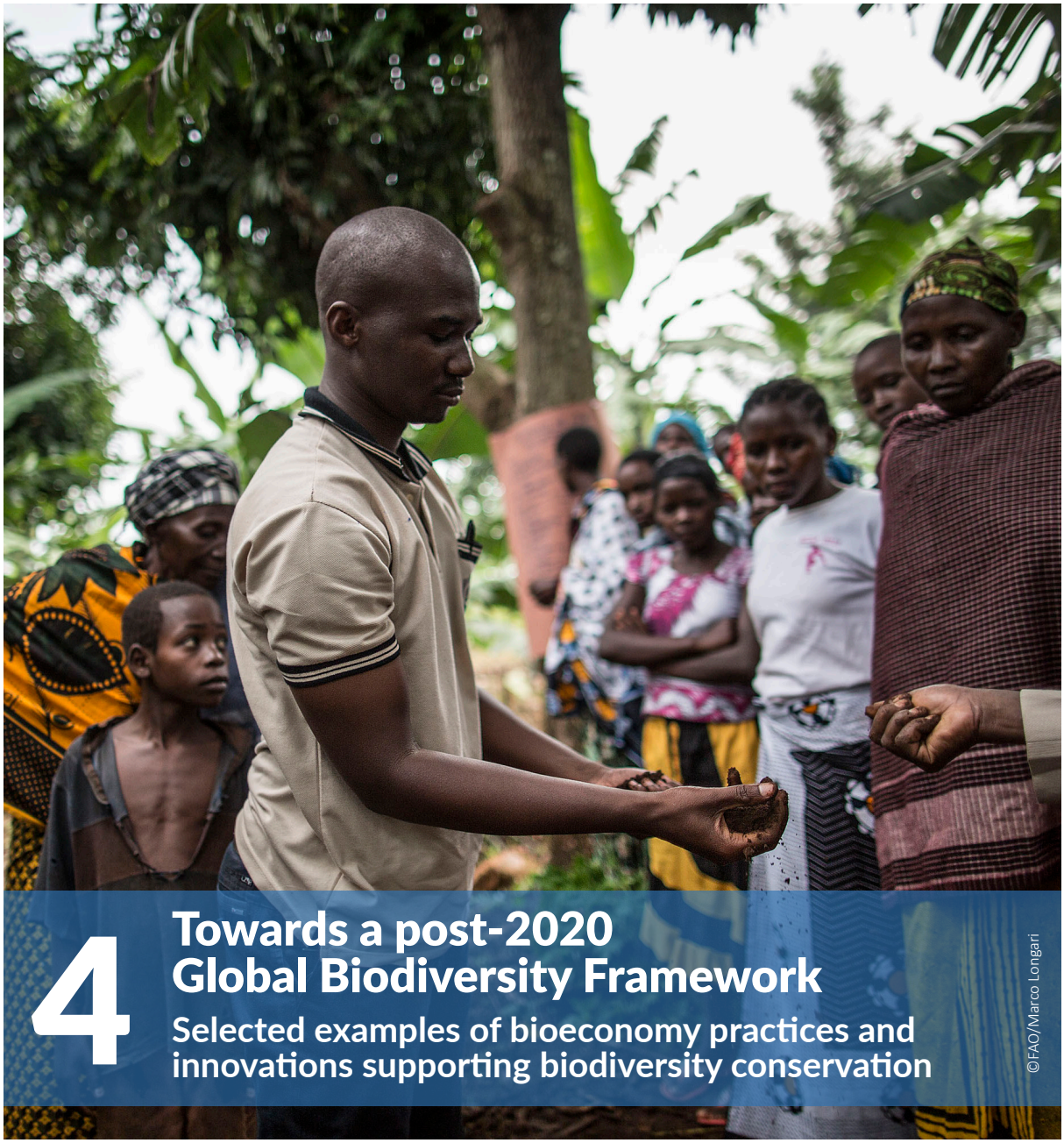
A recent FAO compendium of bioeconomy good practices and policies[ix] collects several examples of practices and guidelines through which the bioeconomy can contribute to biodiversity conservation, prevent the depletion of natural resources, and regenerate ecosystem services. The document highlights three main areas of bioeconomy action for supporting sustainable use and conservation of biodiversity:

1. Bioeconomy development should help **maintain the diversity of genetic resources** – Under this area, an example is the FAO *Voluntary Guidelines for the Conservation and Sustainable Use of Farmers' Varieties/Landraces*, which include good practices for the conservation and sustainable use of plant genetic resources to improve resilience in farming systems and tackle loss of diversity and the continuing reduction in the total number of different varieties grown.

2. Bioeconomy activities should help **maintain the diversity of ecosystems** – For example, the FAO Globally Important Agricultural Heritage System (GIAHS) programme aims to protect sustainable agricultural heritage practices utilized in designated outstanding landscapes of aesthetic beauty located in specific sites that combine agricultural biodiversity, resilient ecosystems and a valuable cultural heritage.

3. Bioeconomy strategies should seek to **maintain the functioning of ecosystem services** – FAO's *Guide for Establishing and Maintaining Pest Free Areas* provides good practices on phytosanitary procedures in the implementation and maintenance of pest free areas and areas of low pest prevalence, including through the use of biological control agents.



4 Towards a post-2020 Global Biodiversity Framework

Selected examples of bioeconomy practices and innovations supporting biodiversity conservation

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The agenda of the concluding part of the Fifteenth meeting of the Conference of the Parties (COP 15) to the CBD in Montreal, Canada, in December 2022, includes the proposed finalization and adoption of the Post-2020 Global Biodiversity Framework, to replace the previous Aichi biodiversity targets. FAO is providing support to the negotiations on the new framework, as well as co-hosting a side event with the Government of Canada on "Achieving Post-2020 targets through Sustainable Bioeconomy in Agrifood Systems". The four examples provided in this section explore how bioeconomy can support biodiversity and align with the suggested streamlined text for the four goals in the draft post-2020 Global Biodiversity Framework.[4] Each example in this section is accompanied by an illustrative case study.

[4] At the time of writing, the most up-to-date draft of the Post-2020 Global Biodiversity Framework was from June 2022.

1 Preventing loss of habitats and enhancing ecosystem resilience

BIOECONOMY EXAMPLE: Sustainable bioeconomy practices reduce habitat loss, through the restoration of healthy ecosystems that protect and enhance biodiversity.

Farmlands, forests, and aquatic environments provide the biological resources and ecosystem services that are the main components of the bioeconomy, from biomass to bioproduction processes. Sustainable and circular bioeconomy practices and processes seek to tackle unsustainable consumption and production patterns, preserve the integrity, connectivity and resilience of ecosystems, and prevent degradation and habitat loss.

Bioeconomy solutions, ranging from the increased use of plant-based food, to the use of bio-based plastics from agrifood residues, to the application of biofertilizers and biopesticides, contribute to habitat protection and restoration of degraded or polluted ecosystems, which is the main objective of the UN Decade on Ecosystem Restoration, led by FAO and the United Nations Environment Programme.

Bioremediation is the process of treating and detoxifying environmental contaminants in soil, water or other environments by taking advantage of natural biological processes using plants (phytoremediation), microbes (soil inoculation, biostimulation, bioaugmentation), fungi (mycoremediation) or even animals such as fish (biomanipulation). It is used to restore polluted soils, wetlands and freshwater ecosystems.

CASE STUDY

RESTORING WATER ECOSYSTEMS THROUGH DUCKWEED REMEDIATION

Lake Winnipeg, Canada, the eleventh largest freshwater lake in the world, is important for protecting biodiversity. Nutrients and other contaminants from various sources throughout the lake's basin contribute to the deterioration of water quality, with negative consequences for biodiversity. To avoid further ecosystem degradation and habitat loss in Lake Winnipeg caused by high pollutant loads, the International Institute for Sustainable Development (IISD) used duckweed to remove phosphorous and nitrogen compounds from the ambient water. The plant could remove up to 91 percent of the phosphorus from the wastewater (MacLean, 2019). To reduce phosphorous loading to nearby waterways, provisions were made for the duckweed to be harvested every three to five weeks. The IISD Experimental Lakes Area (IISD-ELA) programme in Canada has been exploring the use of various plants and floating wetlands for the bioremediation of freshwater systems. Similarly, in the United States of America, duckweed has been used at a wastewater treatment plant in North Dakota cleaning water for over 10 000 people.

2 Reducing pollution for a healthier environment

BIOECONOMY EXAMPLE: Bioeconomy products, such as biofertilizers, biopesticides and bio-based pest control reduce loads of harmful chemicals to the environment and improve ecosystem health.

The application of chemical fertilizers and pesticides and the use of plastics in agriculture can lead to soil pollution and loss of soil biodiversity. Many chemical-based pesticides are broad spectrum, meaning they kill non-target as well as target organisms, including beneficial insects. These pesticides are often lost via water run-off, spray drift and non-target deposition, which may have undesirable impacts on ecosystems and biodiversity. Biopesticides and biocontrol methods are much less likely to leave harmful residues in the soil or water, and their appropriate use can help to restore soil health, thus providing a cost-effective way to support crop yields. Bioeconomy embraces practices and bioproducts that can support, enhance and restore soil microbiome biodiversity, leading also to above-ground biodiversity conservation.

Healthy soils are critically important to ensure resilience of crops under changing climate conditions and in the face of weather extremes (drought, floods and heat stress).

Plants and animals above and below ground depend on the complex processes and interactions that take place in the soil and enable life on earth. Healthy, biodiverse soils allow us to grow a variety of vegetables and plants needed for conserving biodiversity and ensuring good human nutrition. Soil biodiversity is also an important source of the chemical and genetic resources that are needed for the development of new medicines (e.g. penicillin).

CASE STUDY

FAO EMPLOYS BIOPESTICIDES IN 2020–2021 DESERT LOCUST OUTBREAK

Biopesticides are pesticides derived from nature-based sources such as animals, plants, bacteria, and certain minerals (Warra and Vara Prasad, 2020). During the 2020–2021 desert locust outbreak, FAO successfully employed biopesticides and insect growth regulators (IGR) in the Greater Horn of Africa and in Yemen. In the region, the use of biopesticides and low-impact conventional pesticides exceeded 15 percent of the total pesticide use – a significant achievement compared with other similar emergencies in the last three decades. Moreover, in Somalia about 236 000 hectares were treated with biopesticides. Biopesticides for locust control don't affect beneficial insects, which can continue pollinating plants and supporting the local ecosystem. Moreover, they don't hurt other wildlife and have limited or no negative impact on plants, meaning they can be used in nature reserves, wetlands and other areas with bodies of water.

3 Increasing knowledge about biodiversity using molecular biology techniques

BIOECONOMY EXAMPLE: Bioeconomy uses bioscience, biotechnology, and bioinformatics innovations to help enhance biodiversity knowledge and conservation.

"Embracing new technologies to make and measure progress" is one of six areas to strengthen delivery of the post-2020 Global Biodiversity Framework. A sustainable bioeconomy uses biotechnologies for conserving and enhancing biodiversity and ensures that the benefits from the utilization of biological resources (including genetic material) and associated traditional and local knowledge are shared, protected and valued.

Omics data, such as digital sequence information, and related technologies can support monitoring of environmental impacts and species that are most at risk of extinction in affected ecosystems. They are also currently used for animal health and improving crop resistance to stresses and pathogens. Multiomics and whole genome sequencing also help to understand better the composition and impact of biostimulants and other biological products.

These techniques should be combined with field studies to compare the environmental impact under different biophysical conditions. Social sciences provide knowledge to understand the barriers and incentives of adoption of these biological products and techniques by farmers.

Bioeconomy also employs the power of bioinformatics and multiomics technologies to decode the composition of the soil microbiome, the functions of the microorganisms therein, and how these microorganisms and their environment interlink with plant and human health.[xiii] For example, some innovative companies are now giving farmers the possibility to analyse their soil composition using a technology that combines DNA sequencing with artificial intelligence (AI) and employs a global database of microorganisms and soil samples. Farmers can thus better understand and monitor how their soil microbiome might impact crop growth and improve soil carbon sequestration.

CASE STUDY

ENVIRONMENTAL DNA IN THE PERUVIAN AMAZON FOR BIODIVERSITY DISCOVERY AND CONSERVATION

Environmental DNA, one of the most groundbreaking techniques for biodiversity research, was successfully used by the World Wildlife Fund (WWF) during a monitoring expedition in Peru in 2018. The expedition was part of an Amazon-wide initiative with partners in Bolivia, Brazil, Colombia, Ecuador and Peru, aimed at designing biodiversity conservation strategies. WWF's team took water samples from different rivers and streams visited. As each organism moves through its environment, it sheds tiny skin cells and body fluids that carry its DNA, leaving a temporary genetic trace of its existence. Thanks to molecular techniques, scientists were able to identify DNA traces from species present in the area.

This environmental DNA gave an important overview of the biological diversity *in situ* of more than 200 vertebrate species registered.

Gathering such knowledge helped governments, the private sector, conservationists and other stakeholders to better prioritize conservation actions and understand risks and economic value of biodiversity in an area.

WWF News. 2018. *Ambassadors of the Amazon: satellite monitoring of river dolphins helps protect their home.* https://www.wwf.org.pe/?335742/Ambassadors-of-the-Amazon-satellite-monitoring-of-river-dolphins-helps-protect-their-home

4 Promoting global scientific cooperation to implement the Convention on Biological Diversity Protocols

BIOECONOMY EXAMPLE: The benefits arising from the sustainable use and conservation of biodiversity and related traditional knowledge are shared fairly and equitably within the bioeconomy, in particular with Indigenous Peoples and local communities.

Access and benefit sharing (ABS) arrangements allow for a fair and equitable sharing of the benefits arising from the sustainable use and conservation of biodiversity and the related traditional knowledge, in particular with Indigenous Peoples and local communities, who are an important part of many bioeconomy strategies. This follows the Nagoya Protocol on Access to Genetic resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, and is in line with the third objective of the CBD, which ensures "a fair and equitable sharing of the benefits from genetic resources".

In particular, bioprospecting (or biodiversity prospecting activities) and related trade activities need to be conducted sustainably. Bioprospecting is the systematic search for biochemical and genetic information in nature to develop commercially valuable products for pharmaceutical, agricultural, cosmetic and other applications. Many countries follow guidelines for engaging in a sustainable bioprospecting. Bioprospecting is also linked to biotrade, which includes the collection, production, transformation and commercialization of goods and services derived from native biodiversity, under criteria of environmental, social and economic sustainability. Bioprospecting and biotrade are important considerations covered in the *Aspirational principles and criteria for a sustainable bioeconomy*, drafted by the FAO-led International Sustainable Bioeconomy Working Group. The principles and criteria reflect the provisions of the Cartagena Protocol on Biosafety (CPB) governing international trade of living modified organisms resulting from modern biotechnology.

CASE STUDY

FROM FARMER TO PHARMA

The Farmer to Pharma programme of the government of South Africa has helped promote and protect the sustainable commercial use of national plant resources and related indigenous or traditional knowledge within bioeconomy. The programme has capitalized on natural biodiversity and applied biotechnologies to create a viable national bioeconomy and deepen the role of indigenous crops in food security.

The programme has done this in a number of ways, including engaging in the equitable exploration and sound exploitation of biological resources (bioprospecting) in ways that do not have negative impacts on other species and are replicable. South Africa has put in place a range of mechanisms and regulations for bioprospecting and intellectual property rights (e.g. the National Environment Management: Biodiversity Act, 2004: Regulations on Bio-prospecting and Access and Benefit-Sharing) to protect community rights and interests regarding indigenous biological resources and traditional knowledge.

Key terms

Bioproducts: The term encompasses all products made from biological resources, and includes, among others, food, feed, biofuels and bio-based products (pulp and paper, timber for construction, bio-based cosmetics and fibers for clothing).

Biotechnology: Based on the definition of "biotechnology" in Article 2 of the Convention on Biological Diversity, the term "agricultural biotechnologies" encompasses a suite of technologies from low-tech ones such as artificial insemination, fermentation techniques, biofertilizers and nuclear techniques, to high-tech ones involving advanced DNA-based methodologies – including genetic modification, i.e. genetically modified organisms (GMOs), genomic selection, whole genome sequencing and gene editing – and multiomics technologies (see Omics below).

Bio-based industries or bio-industries: Refer to the application of biotechnology in production systems to make bioproducts or bio-based products.

Bioprospecting: The exploration of biodiversity for new resources of social and commercial value.

Omics: Refers to a field of study in biological sciences that ends with -omics, such as genomics, transcriptomics, proteomics, and metabolomics, which are used to explore the roles and relationships of the various types of cell molecules.

Agricultural innovation: Is the process whereby individuals or organizations bring new or existing products, practices, processes or ways of organization into use for the first time in a specific context in order to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability, thereby contributing to food security and nutrition, economic development or sustainable natural resource management.

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This publication aims to inform a global audience about the pivotal role bioeconomy can play in halting biodiversity loss, while contributing to food security and nutrition, and poverty reduction, and supporting science and innovation.

The publication emphasizes the importance of Indigenous Peoples and local communities as guardians of both biodiversity and many traditional bioeconomy practices.

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Office of Climate Change, Biodiversity and Environment

Bioeconomy@fao.org
www.fao.org/in-action/sustainable-and-circular-bioeconomy

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, Italy

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