Food and Agriculture Organization of the United Nations

2024

THE STATE OF THE WORLD'S FORESTS

FOREST-SECTOR INNOVATIONS TOWARDS A MORE SUSTAINABLE FUTURE

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THAILAND. New growth from a tree stump.

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2024 THE STATE OF THE WORLD'S FORESTS

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Food and Agriculture Organization of the United Nations
Rome, 2024

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→ **Projections** indicate large increases in wood demand by 2050. Nearly three-quarters of the world's population uses non-timber forest products.

→ **More innovation** is needed in the forest sector, driven by escalating forest stressors, necessitating new forest management approaches; the shift towards a bioeconomy; and opportunities offered by non-wood forest products.

→ **Four factors** form barriers to scaling up innovation in the forest sector: (1) lack of innovation culture; (2) risk; (3) potential limitations in various forms of capital; and (4) unsupportive policies and regulations.

→ **Five enabling actions** will help scale up responsible and inclusive – and essential – innovation in the forest sector: (1) raise awareness; (2) boost innovation skills, capabilities and knowledge; (3) encourage transformational partnerships; (4) ensure more and universally accessible finance for innovation; and (5) provide an incentivizing policy and regulatory environment.

FOREWORD

The speed at which new challenges to sustainable development are arising is only matched by the rate at which innovations are emerging to deal with them. The incredible ingenuity of humans should give us hope that we can chart a course towards a sustainable planet and avert the threats we face.

Innovation is key for achieving the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) – it is a focus of SDG 9 and it is implicit in all the SDGs and the actions needed to achieve them. Innovation is also an important accelerator for agrifood systems transformation and realizing the three major Global Goals: (1) eradication of hunger, food insecurity and malnutrition; (2) elimination of poverty and the driving forward of economic and social progress for all; and (3) the sustainable management and utilization of natural resources.

But innovation does not arise in a vacuum. Among other things, it requires enabling policies; strong, transformative partnerships; investment; an inclusive culture that is open to and encouraging of new ideas; and a willingness to take calculated risks.

FAO recognizes that science and innovation are crucial ingredients for achieving forest-based solutions. We developed our first-ever FAO Science and Innovation Strategy in 2022, thus setting out how we intend to reinforce the use of science and innovation in our technical interventions and normative guidance. The Strategy, endorsed by the FAO Council at its 170th Session following an inclusive and transparent consultation process, is a key tool for implementing the FAO Strategic Framework 2022–31. It emphasizes the need to consider all scientific disciplines, all knowledge and all types of innovation.

This edition of *The State of the World's Forests* (SOFO) report provides highlights on the state of the world's forests and builds on the FAO Science and Innovation Strategy to explore the transformative power of evidence-based innovation in the forest sector. It presents a comprehensive overview of exciting developments, ranging from new technologies to creative and successful policies and institutional changes, to new ways of getting finance to forest owners and managers. Eighteen case studies from around the world provide a glimpse at the wide range of technological, social, policy, institutional and financial forest-sector innovations – and combinations of these – being tested and implemented in real-world conditions. The publication identifies barriers to and enablers of innovation and enumerates five actions for empowering people to apply their creativity in the forest sector to solve problems and scale up impacts.

FAO's work in forestry is aimed at accelerating progress on forest conservation, restoration and sustainable use towards MORE efficient, inclusive, resilient and sustainable agrifood systems for *better production, better nutrition, a better environment and a better life*, leaving no one behind. This edition of SOFO will inform FAO's work to scale up evidence-based innovation in forestry. I believe it will also support FAO Members and other stakeholders in enabling responsible, inclusive and essential innovation in the forest sector to strengthen sustainability and the resilience of agrifood systems for a better world and a better future for all.

QU Dongyu
FAO Director-General

METHODOLOGY

The content of *The State of the World's Forests 2024* is derived from FAO publications and other peer-reviewed literature, interviews with FAO staff on forest-sector innovations, an analysis of projected wood demand commissioned for the purposes of this report, and 18 case studies. The latter were solicited through a competitive call among FAO staff and key partner organizations and selected based on their novelty; impacts (including potential impacts); potential for scaling up; and support for forest conservation, restoration and sustainable use. The report was prepared at FAO by a technical writing team comprising coordinators, internal and external contributing authors, reviewers, and an editor. A taskforce composed of senior FAO staff guided content development and reviewed chapter drafts.

The report was subjected to peer review by experts in FAO – including staff in FAO regional and subregional offices – and external experts on forest innovation. The writing team revised the draft in light of these reviews to produce the final draft, which underwent executive review and clearance at FAO.

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The State of the World's Forests 2024 was prepared under the overall direction of Wu Zhimin, Director, FAO Forestry Division, by a core technical team comprising Amy Duchelle, Lyndall Bull, Ben Ross, Anssi Pekkarinen, Julian Fox, Sven Walter and Thomas Hofer. It benefited from inputs from the following innovation experts: Fabrizio Bresciani, Vincent Gitz, Eric Hansen, Inge Jonckheere, Cecilia Luttrell, Mokena Makeka, Duncan Mayes, Rajat Panwar, Selvaraju Ramasamy, Ewald Rametsteiner, James Roshetko and Lúcia Wadt; Lauri Hetemäki contributed an analysis of wood demand projections. Alastair Sarre edited the publication, and Annika Cobb, Christine Legault, Malgorzata Buszko-Briggs, Roberto Cenciarelli, Sharon Darcy, Maria De Cristofaro, Donna Kilcawley and Marco Santarnecchi provided additional support. Chapter contributors and reviewers are listed below.

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ABBREVIATIONS

AAD	Action Against Desertification
AFR100	African Forest Landscape Restoration Initiative
AI	artificial intelligence
AIM4Forests	Accelerating Innovative Monitoring for Forests
CBD	Convention on Biological Diversity
CFM	community forest management
CIFOR–ICRAF	Center for International Forestry Research and World Agroforestry
CIJS	customary and informal justice system
CLT	cross-laminated timber
CRU	carbon removal unit
CUBIFOR	Cubicación de Productos Forestales (Scaling of Forest Products) (Guatemala)
EUDR	European Union regulation on deforestation-free and forest-degradation-free supply chains
EUR	euro(s)
FAO	Food and Agriculture Organization of the United Nations
FBS	Farmer Business School
FERM	Framework for Ecosystem Restoration Monitoring
FFF	Forest and Farm Facility
FFS	Farmer Field School
FLR	forest and landscape restoration
FOLUR	GEF-7 Impact Program on Food Systems, Land Use and Restoration
FOROM	Forest Resource Outlook Model
FRA	Global Forest Resources Assessment
FRL	forest reference level
GDP	gross domestic product
GEF	Global Environment Facility
GGW	Great Green Wall
$GtCO_2$	gigatonne(s) of carbon dioxide
ha	hectare(s)
IFRS	International Financial Reporting Standards
INAB	Instituto Nacional de Bosques (National Forest Institute) (Guatemala)
km	kilometre(s)
LEAF	Lowering Emissions by Accelerating Forest Finance
m	metre(s)
MODIS	Moderate Resolution Imaging Spectroradiometer
MRV	measurement, reporting and verification
NASA	National Aeronautics and Space Administration (United States of America)
NDC	nationally determined contribution
NTFP	non-timber forest product
NWFP	non-wood forest product
OECD	Organisation for Economic Co-operation and Development
PILA	Participatory Informed Landscape Approach

ABBREVIATIONS

REDD+	reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
RSS	FRA 2020 Remote Sensing Survey
SDG	Sustainable Development Goal
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SOFO	The State of the World's Forests
SWM	Sustainable Wildlife Management (Programme)
TND	Tunisian dinar
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar(s)
USDA	United States Department of Agriculture

EXECUTIVE SUMMARY

WITH THE WORLD FACING ESCALATING THREATS, FORESTS PROVIDE SOLUTIONS TO GLOBAL CHALLENGES.

- This publication provides updates on the world's forests and examines innovations for scaling up forest conservation, restoration and sustainable use.

ALTHOUGH DEFORESTATION IS SLOWING, FORESTS ARE UNDER PRESSURE FROM CLIMATE-RELATED STRESSORS AND FOREST PRODUCT DEMAND IS RISING.

- **Recent data indicate a significant reduction in deforestation in some countries.** For example, deforestation is estimated to have declined by 8.4 percent in Indonesia in 2021–2022 and by 50 percent in Brazil's Legal Amazon in 2023. The rate of gross global mangrove loss decreased by 23 percent between 2000–2010 and 2010–2020.
- **Climate change is making forests more vulnerable to abiotic and biotic stressors such as wildfire and pests.** Wildfire intensity and frequency are increasing. Boreal forests accounted for nearly one-quarter of carbon-dioxide emissions due to wildfire in 2021. Fires emitted an estimated 6 687 megatonnes of carbon dioxide globally in 2023, which was more than double the carbon dioxide emissions by the European Union due to the burning of fossil fuels in that year. In the United States of America, 25 million ha of forestlands are projected to experience losses exceeding 20 percent of host tree basal area due to insects and disease through to 2027.
- **Global wood production is at record levels, at about 4 billion m^3 per year.** An estimated 2.04 billion m^3 of roundwood was harvested in 2022, which was similar to the volume in 2021. About 1.97 billion m^3 was harvested in 2022 for woodfuel, constituting just under half (49.4 percent) of the total wood harvest; the proportion was much higher in Africa, at 90 percent.
- **Nearly 6 billion people use non-timber forest products**, including 2.77 billion rural users in the Global South. Data are now available on the international trade of pine nuts and forest mushrooms and truffles: combined, global exports of these products was worth about USD 1.8 billion in 2022.
- **Projections to 2050 indicate significant increases in wood demand, albeit in a wide band.** Global roundwood demand could increase by as much as 49 percent (between 2020 and 2050), driven mainly by demand for industrial roundwood, although this projection is subject to considerable uncertainty. Wood-use efficiency increased by 15 percent between 1961 and 2022.
- **Given rapidly changing environmental conditions and rising demands on forests, more innovation is needed in the forest sector.** Three imperatives will drive such innovation: (1) escalating stressors, including climate change, which will require new forest and land management approaches; (2) the shift towards a bioeconomy in which wood will be a major input; and (3) the opportunities offered by the vast range of non-wood forest products for potentially billions of smallholders.

INNOVATION IS REQUIRED TO SCALE UP FOREST CONSERVATION, RESTORATION AND SUSTAINABLE USE AS SOLUTIONS TO GLOBAL CHALLENGES.

- **Innovation is a key enabler of progress towards achieving the Sustainable Development Goals.** It is also an important accelerator for achieving the three Global Goals of FAO Members and enhancing the potential of forests and trees to address global challenges. A vast range of innovations is already having profound influences on the forest sector.

- **Five types of innovation are enhancing the potential of forests and trees to address global challenges:**
  - **(1) technological** (in three subtypes of digital, product/process and biotechnological). For example, open access to remote-sensing data and the facilitated use of cloud computing are enabling digital methodologies that generate high-quality forest data and improve forest management processes;
  - **(2) social**, **(3) policy** and **(4) institutional** – such as new efforts to better engage women, youth and Indigenous Peoples in developing locally led solutions, the promotion of multistakeholder partnerships and cross-sectoral approaches in land-use policies and planning, and support for cooperatives to increase the bargaining power of smallholders; and
  - **(5) financial** – such as innovations in public- and private-sector finance to enhance the value of standing forests, boost restoration efforts and increase access to loans for smallholders for sustainable production.

Combinations ("bundles") of these innovation types can unleash powerful forces for change.

- **Four factors form barriers to scaling up innovation:** (1) lack of innovation culture; (2) risk; (3) potential limitations in various forms of capital; and (4) unsupportive policies and regulations. An organizational culture that recognizes and embraces the transformative potential of innovation can help de-risk innovation processes and empower stakeholders to respond to current and future challenges.
- **Innovation can create winners and losers, and inclusive and gender-responsive approaches are needed** to avoid harm and ensure the fair distribution of benefits among men, women and youth in all socioeconomic and ethnic groups. Efforts to promote innovation must consider and integrate the local circumstances, perspectives, knowledge, needs and rights of all stakeholders.

EIGHTEEN CASE STUDIES ILLUSTRATE THE DIVERSE WAYS IN WHICH FOREST-SECTOR INNOVATION CAN BRING ABOUT POSITIVE CHANGE.

- **The presentation of case studies is an important means for exploring and demonstrating the potential of forest-sector innovation.** Examples examined in this document showcase cutting-edge processes, tools and technologies in various regions and at various scales, providing evidence and knowledge and generating lessons that can be applied in diverse contexts worldwide. They are organized in three categories aligned with forest conservation, restoration and sustainable use.

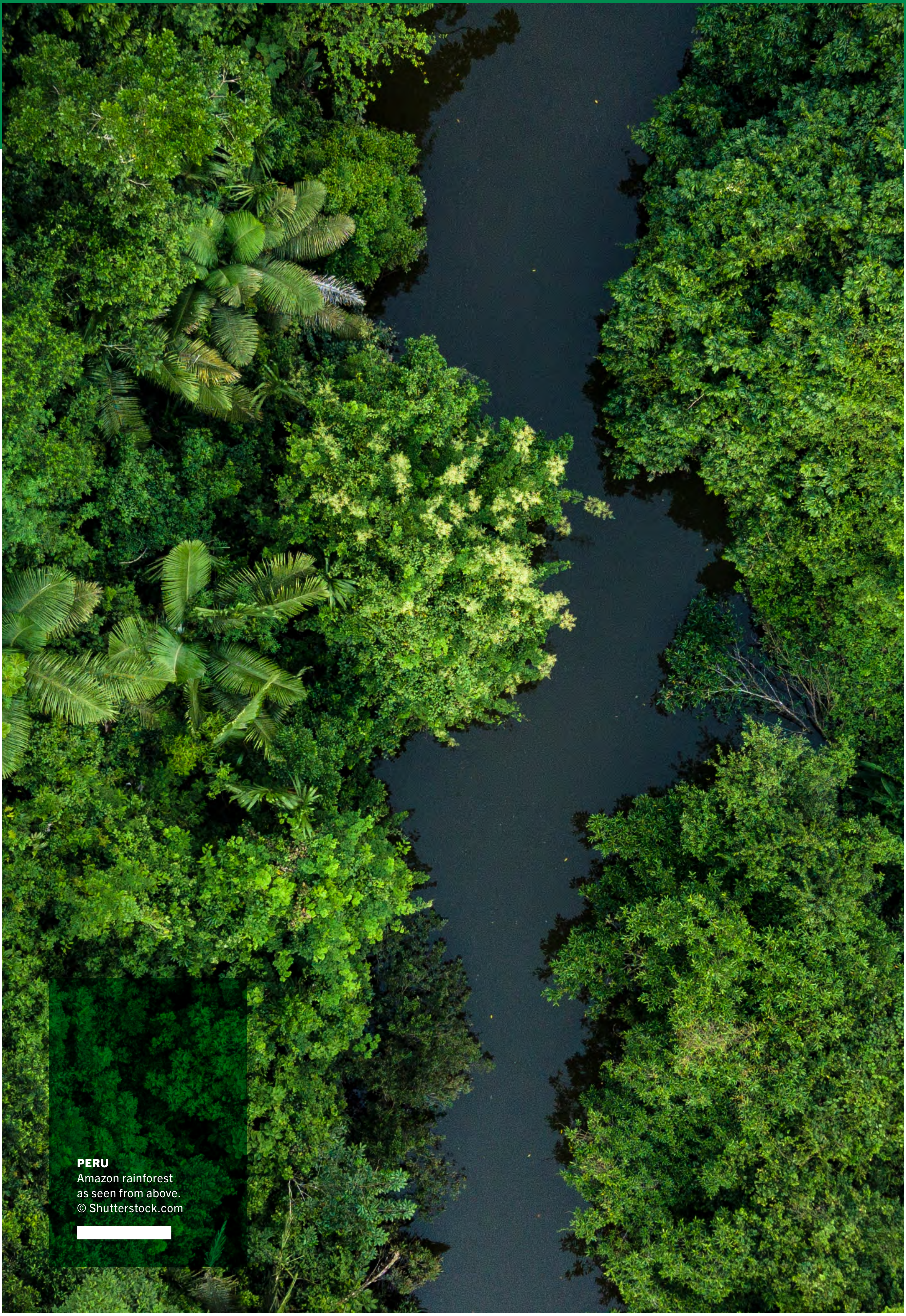
1. **Innovations are assisting efforts to halt deforestation and maintain forests.** They include a model for fostering multistakeholder governance to scale up integrated sustainable landscape management in Kenya and Nigeria; the use of new data on the role of forests in agricultural productivity to finance forest conservation in Brazil; harnessing the power of partnership and technological innovation to reduce commodity-driven forest loss in Ghana; the introduction of new tools and techniques in community forestry in Colombia; and combining science, technology and traditional knowledge to support Indigenous Peoples as forest custodians and enable locally led integrated fire management.
2. **Innovative approaches are bolstering the restoration of degraded lands and expanding agroforestry.** They include developing a new national policy to better support agroforestry in India; integrating the socioeconomic objectives

and nutritional needs of local communities with restoration to combat desertification in the Great Green Wall of the Sahara and the Sahel; the use of geospatial and other digital technologies to collate and disseminate restoration good practices and monitor progress in the implementation of the United Nations Decade on Ecosystem Restoration; enhancing the resilience of traditional water taro gardens in Vanuatu by incorporating new technologies, practices and plant varieties; improving the local governance of forest resources to deliver benefits for agriculture and forest restoration in Morocco and Tunisia; and a long-term project to link agroforestry to carbon trading in Mozambique.

3. **Innovations are helping to sustainably use forests and build green value chains.** They include delivering collateral-free microfinance to small forest businesses through the power of collective organizations in Viet Nam; using new diagnostic tools and methodologies to catalyse legal-reform processes for sustainable wildlife management in 13 African countries; harnessing digital technologies to improve the efficiency of timber-tracking and promote sustainable supply chains in Guatemala; improving connectivity along timber supply chains to reduce waste and increase the viability of sustainable forest management in Brazil, Guyana, Panama and Peru; applying new wood-processing technologies in Slovenia and the United States of America to promote a bioeconomy and enhance earthquake resilience; and enabling farmer-led innovation in sustainable forest and agricultural production through Farmer Field Schools.

INNOVATION MUST BE SCALED UP RESPONSIBLY TO MAXIMIZE THE CONTRIBUTIONS OF THE FOREST SECTOR TO AGRIFOOD SYSTEMS TRANSFORMATION AND OTHER GLOBAL CHALLENGES.

- **Five enabling actions can encourage responsible and inclusive innovation that optimizes forest-based solutions to global challenges:** (1) raise awareness of the importance of innovation and create a culture that fosters innovation to bring about positive change; (2) boost skills, capabilities and knowledge to ensure that forest-sector stakeholders have the capacity to manage innovation creation and adoption; (3) encourage transformative partnerships to de-risk forest-sector innovation, provide opportunities for knowledge and technology transfer, and build appropriate safeguards; (4) ensure more and universally accessible financial resources to encourage forest-sector innovations; and (5) provide a policy environment that incentivizes forest-sector innovations.



PERU
Amazon rainforest
as seen from above.

CHAPTER 1
WITH THE WORLD FACING ESCALATING THREATS, FORESTS PROVIDE SOLUTIONS TO GLOBAL CHALLENGES

KEY MESSAGE

➔ With the world facing escalating threats, forests provide solutions to global challenges. This publication provides updates on the world's forests and examines innovations for scaling up forest conservation, restoration and sustainable use.

The world is facing mounting threats on multiple fronts, and time is running out to take the action needed to avert them. The 2030 Agenda for Sustainable Development, with 17 Sustainable Development Goals (SDGs) at its heart, envisions a world free of poverty, hunger, disease and want and where all life can thrive. But urgent action is required if we are to achieve the SDGs.

Increased emissions of greenhouse gases have caused widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere; the global surface temperature in 2011–2020 was 1.1 °C higher than temperatures in 1850–1900.[1] Human-caused climate change is already affecting many weather and climate extremes in all regions, leading to widespread adverse impacts and related losses and damage to nature and people. Vulnerable communities who have historically contributed the least to current climate change are being affected disproportionately.[1] Human actions threaten more species with global extinction now than ever before. An average of around 25 percent of species in assessed animal and plant groups are threatened, suggesting that about 1 million species already face extinction, many within decades, unless action is taken to reduce the intensity of drivers of biodiversity loss.[2]

Forests and trees offer cost-effective solutions to the climate and biodiversity crises, and they are integral to the transformation to MORE efficient, inclusive, resilient and sustainable agrifood systems for *better production*, *better nutrition*, *a better environment and a better life*, leaving no one behind (Box 1). Halting deforestation and forest degradation can reduce global greenhouse-gas emissions, and forest and landscape restoration (FLR) can remove carbon from the atmosphere. Carbon can also be stored in long-lived wood products. Forests do more for the climate than store and sequester carbon, providing dramatic global cooling through evapotranspiration and via their physical structure and chemistry.[3] This bonus mitigation is complemented by the ability of forests to regulate rainfall and stabilize local climates, helping minimize extreme weather and making forests essential for climate-change adaptation and resilience.[3] Forests harbour most of Earth's terrestrial biodiversity: for example, they provide habitats for about 80 percent of amphibian species, 75 percent of bird species and 68 percent of mammal species.[4] Forests and trees make significant contributions to human food security and nutrition, and agroforestry can increase farmer incomes and the resilience of farming systems and improve agricultural

BOX 1 FORESTRY AND AGRIFOOD SYSTEMS TRANSFORMATION

Forests and trees are essential components of agrifood systems. The removal of forest cover, especially in the tropics, increases local temperatures and disrupts rainfall patterns in ways that compound the local effects of global climate change, with potentially severe consequences for agricultural productivity.[3] Forests provide essential habitat for much of the world's terrestrial biodiversity, which is key for local livelihoods and the resilience of agrifood systems.[7] Wild-harvested forest foods are important for the food security and nutrition of many forest-adjacent people, especially in remote areas in the tropics and subtropics and when agricultural production falls, such as during drought.[8] Agroforestry and other diversified production systems tend to be more resilient than conventional agriculture to environmental shocks and can increase food security and nutrition, as well as crop productivity.[8] Enhancing the benefits of forests for agriculture through forest conservation, restoration and sustainable use is fundamental for the transformation to MORE efficient, inclusive, resilient and sustainable agrifood systems for *better production, better nutrition, a better environment and a better life*, leaving no one behind.

productivity.[5] Forests also contribute in multiple ways to the resilience of communities and livelihoods to threats and crises and to resolving the underlying causes of food insecurity, malnutrition and poverty. They are sources of woodfuel for cooking, wild foods, fodder and materials for shelter; they conserve water resources and provide other ecosystem services; and they buffer extreme weather conditions.[6] ■

THE NEED FOR INNOVATION IN THE FOREST SECTOR

The rapid pace of change, and the urgency of addressing global challenges, demand inventive solutions that are diverse, flexible and adaptable and can be scaled up quickly. It is imperative, therefore, to tap into human creativity and embrace innovation, including in the forest sector.

Recognition of the importance of innovation in all its forms – technological, social, policy, institutional and financial – for the conservation, restoration and sustainable use of forests, trees and associated ecosystems is gaining traction globally. In 2022, the Food and Agriculture Organization of the United Nations (FAO) adopted its first-ever Science and Innovation Strategy[9] to reinforce the use of science and innovation in FAO's technical interventions and normative guidance. The strategy, which was endorsed by the FAO Council at its 170th Session following an inclusive and transparent consultation process, defines innovation as "doing something new and different whether solving an old problem in a new way, addressing a new problem with a proven solution, or bringing a new solution to a new problem."[a] The Science and Innovation Strategy is a key tool for the implementation of the FAO Strategic Framework 2022–31.[10] Its broad and inclusive scope emphasizes the need for transdisciplinarity to consider all scientific disciplines and collaboration between scientists

a The FAO Science and Innovation Strategy also defines innovation in the context of agrifood systems – as a verb (to innovate) referring to the process by which individuals, communities or organizations generate changes in the design, production or recycling of goods and services, as well as changes in the surrounding institutional environment, that are new to their context and foster transitions towards sustainable food systems for food security and nutrition; and as a noun (innovation) referring to the changes generated by this process. Innovation includes changes in practices, norms, markets and institutional arrangements, which may foster new networks of food production, processing, distribution and consumption that may challenge the status quo. The FAO Science and Innovation Strategy defines agricultural innovation as "the process whereby individuals or organizations bring new or existing products, 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 and thereby contribute to food security and nutrition, economic development or sustainable natural resource management."

BOX 2 THE FOREST SECTOR

For the purposes of this report, "forest sector" is defined as the "wide range of activities related to sustainable forest management, the provision and production of timber and other wood and non-wood forest products, the protection of forest ecosystems and biodiversity, and safeguarding the benefits of forests."[14] Thus, it encompasses all activities involving forests,* as well as trees outside forests such as in some agroforestry and urban forestry settings, and diverse stakeholders, including governments, civil-society organizations, producer organizations, cooperatives, private-sector organizations, Indigenous Peoples, vulnerable and marginalized communities, youth and women.

The term "forest-sector innovation" is used here to encompass the range of innovations under this broad definition of the forest sector.

* FAO defines "forest" as land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.[15]

and non-academic stakeholders, as well as all types of innovation, including those stemming from the knowledge of Indigenous Peoples and small-scale producers.

The 26th Session of the FAO Committee on Forestry[11] recognized the potential of forests to help address the impacts of global challenges, including through three interrelated pathways.[b] It invited FAO to engage with Members and the public and private sectors on sustainable development in its three dimensions[c] and to foster science and innovation.

THIS PUBLICATION

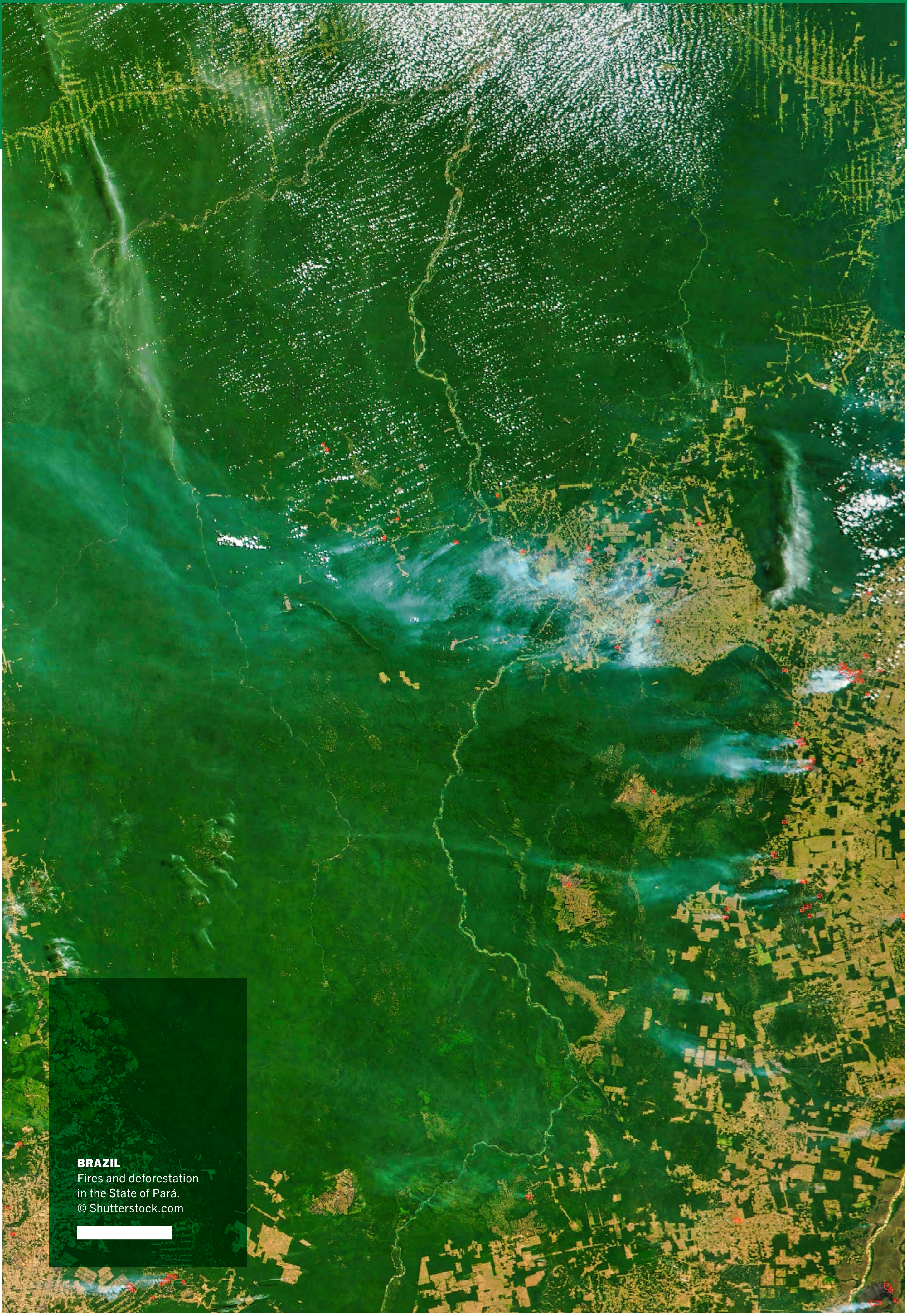
FAO's flagship publication, *The State of the World's Forests* (SOFO), published every two years, presents data and analysis on the interactions between forests and people, with a specific thematic focus. It complements FAO's Global Forest Resources Assessments (FRAs), issued every five years, and other forest-related FAO publications. The present publication, SOFO 2024, provides highlights on the state of the world's forests and builds on the FAO Science and Innovation Strategy to explore the role of innovation in promoting forest conservation, restoration and sustainable use in the context of agrifood systems transformation. It explores the importance of innovation in relation to the FAO Strategy on Climate Change 2022–2031,[12] the FAO Strategy on Mainstreaming Biodiversity across Agricultural Sectors,[13] and other FAO stategies and guidelines by providing an overview of innovations in the forest sector (Box 2 defines "forest sector").

SOFO 2024 has five chapters:

- Chapter 1 is this introductory chapter.
- Chapter 2 draws on FRA 2020,[16] FAOSTAT[17] and other sources to present recent trends in forests globally and projections of wood production, highlighting the importance of forest-sector innovation for tackling challenges.
- Chapter 3 introduces FAO's typology for innovation and provides an overview of the diversity of forest-related innovations.
- Chapter 4 presents 18 case studies on innovative approaches and technologies being used to support the forest sector.
- Chapter 5 discusses enabling actions for scaling up innovations in the forest sector. ■

b The three pathways are: (1) halting deforestation and maintaining forests ("conservation"); (2) restoring degraded lands and expanding agroforestry ("restoration"); and (3) sustainably using forests and building green value chains ("sustainable use").

c Economic, social and environmental.



BRAZIL
Fires and deforestation
in the State of Pará.
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CHAPTER 2
ALTHOUGH DEFORESTATION IS SLOWING, FORESTS ARE UNDER PRESSURE FROM CLIMATE-RELATED STRESSORS AND FOREST PRODUCT DEMAND IS RISING

KEY MESSAGES

➔ **Recent data indicate a significant reduction in deforestation in some countries.** For example, deforestation is estimated to have declined by 8.4 percent in Indonesia in 2021–2022 and by 50 percent in Brazil's Legal Amazon in 2023. The rate of gross global mangrove loss decreased by 23 percent between the periods 2000–2010 and 2010–2020.

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➔ **Nearly 6 billion people use non-timber forest products**, including 2.77 billion rural users in the Global South. Data are now available on the international trade of pine nuts and forest mushrooms and truffles: combined, global exports of these products was worth about USD 1.8 billion in 2022.

➔ **Projections to 2050 indicate significant increases in wood demand, albeit in a wide band.** Global roundwood demand could increase by as much as 49 percent (between 2020 and 2050), driven mainly by demand for industrial roundwood, although this projection is subject to considerable uncertainty. Wood-use efficiency increased by 15 percent between 1961 and 2022.

➔ **Given rapidly changing environmental conditions and rising demands on forests, more innovation is needed in the forest sector.** Three imperatives will drive such innovation: (1) escalating stressors, including climate change, which will require new forest and land management approaches; (2) the shift towards a bioeconomy in which wood will be a major input; and (3) the opportunities offered by the vast range of non-wood forest products for potentially billions of smallholders.

This chapter presents recent data on forest resources and the production of wood products and non-wood forest products (NWFPs)[d] and offers projections on future wood demand.[e] Given the increasing impacts of stressors such as fire and pests on forests, and the multiple roles that forests can play as solutions to global challenges, the chapter discusses the need for innovative approaches to forest conservation, restoration and sustainable use. ■

2.1 RECENT DATA INDICATE A SIGNIFICANT REDUCTION IN DEFORESTATION IN SOME COUNTRIES

Forests covered about 4.1 billion ha (31 percent) of the world's land surface in 2020.[18] The largest part is in the tropics, followed by the boreal, temperate and subtropical climatic domains. More than half (54 percent) of the world's forests is in only five countries – the Russian Federation, Brazil, Canada, the United States of America and China (in descending order, by area). Ten countries account for two-thirds of the global forest area, also including Australia, the Democratic Republic of the Congo, Indonesia, Peru and India (in descending order).

An estimated 420 million ha of forests was converted to other land uses between 1990 and 2020.[18] The rate of deforestation declined over the period, from 15.8 million ha per year in 1990–2000 to 10.2 million ha per year in 2015–2020. The annual rates of deforestation in 2015–2020 were 4.41 million ha in Africa, 2.95 million ha in South America and 2.24 million ha in Asia. The FRA 2020 Remote Sensing Survey (RSS) confirmed the declining trend in global deforestation.[16]

TABLE 1 TOP TEN COUNTRIES FOR AVERAGE ANNUAL NET GAIN IN FOREST AREA, 2010–2020

Ranking	Country	Annual net change (1 000 ha/yr)
1	China	1 937
2	Australia	446
3	India	266
4	Chile	149
5	Viet Nam	126
6	Türkiye	114
7	United States of America	108
8	France	83
9	Italy	54
10	Romania	41

SOURCE: FAO. 2020. *Global Forest Resources Assessment 2020: Main report*. Rome.

https://doi.org/10.4060/cd1211en-tab01

Change in forest area over time is due to two factors: deforestation, and the expansion of forests in areas previously under other land uses. Globally, the net rate of change in forest area, which is the difference between forest expansion and deforestation, is estimated at −4.7 million ha per year in 2010–2020. This was significantly lower than in the two previous decades (−7.8 million ha per year in 1990–2000 and −5.2 million ha per year in 2000–2010). Table 1 shows the top ten countries for annual net gain in forest area in the decade to 2020.

Preliminary data collected for FRA 2025 indicate a significant reduction in the rate of forest-area loss for some countries that previously ranked among the top ten for this parameter. An initial review of data for Indonesia for 2021–2022 indicated a notable 8.4 percent decrease in deforestation compared with 2020–2021. This is the lowest recorded deforestation rate in Indonesia since the Ministry of Environment and Forestry began tracking annual rates in 1990; overall, the rate decreased by nearly 90 percent over the period.[19, 20] Brazil achieved an extraordinary 50 percent reduction in deforestation in 2023 (compared with 2022) in the Legal Amazon,[f]

d NWFPs consist of goods of biological origin other than wood derived from forests, other wooded land and trees outside forests. Non-timber forest products generally include all NWFPs plus certain woody materials such as woodfuel and small woods.

e The chapter is not intended as a comprehensive report on the state of the world's forests, with data collection for the next edition of FRA (to be released in 2025) still underway; its purpose is to highlight important recent developments in forest resources.

f Brazil's Legal Amazon is formed by the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins and Mato Grosso and also the municipalities of the state of Maranhão located west of the 44th meridian.[21]

which constitutes approximately 60 percent of the country's total area.[22]

The latest data on deforestation on the African continent supports the finding of the RSS,[g] indicating a decreasing rate of deforestation. According to statistics derived using the Global Map of Forest Cover Changes and their Drivers generated by the European Commission's Joint Research Centre, the annual rate of deforestation in Africa decreased between 2016–2019 and 2020–2022 in all subregions and on the continent as a whole.[23] These results should be interpreted with care, however, subject to the country-reported figures to be published in FRA 2025.

Mangroves

Mangrove forests provide hundreds of millions of coastal people with important ecosystem services, sustain a rich food web, and provide regulating services such as coastal stabilization, nutrient absorption and carbon sequestration. In 2023, FAO published the results of a survey of the area of mangroves globally and regionally and analysed changes between 2000 and 2020 with the aim of further understanding the drivers of change and how the relative importance of these might have shifted over time.[24] The study used a methodology that combined remote sensing and local knowledge to estimate mangrove area and change, focusing on land use rather than land cover; it was the first global mangrove study of its kind.

The study estimated the global mangrove area in 2020 at 14.8 million ha, with South and Southeast Asia accounting for nearly 44 percent of the global total. There was a net decline of 284 000 ha in mangrove area globally between 2000 and 2020, which was an overall reduction of about 1.9 percent. The rate of gross global mangrove loss decreased by 23 percent between the two recent decades (i.e. 2000–2010 and 2010–2020), and the rate of gain in mangrove area also decreased slightly. Asia accounted for most of the mangrove losses and gains. The main drivers of mangrove loss between 2000 and 2020 were aquaculture development and natural retraction,[h] followed by conversion to oil-palm plantations, rice cultivation and other forms of agriculture. Note that the data and methods used in the study did not allow the separation of different aquaculture practices, and the class "aquaculture" was therefore used as a catch-all term, although mangrove loss was associated primarily with pond shrimp aquaculture and, in some rare cases, pond-farmed fin fish. Thus, most aquaculture practices do not affect mangroves.

The study highlighted the importance of natural retraction as a driver of mangrove loss. Impacts of climate change such as sea-level rise and extreme weather events threaten mangroves and increase the vulnerability of local communities to disasters. Although the net change in mangrove area globally was negative between 2000 and 2020, the extent of natural expansion surpassed the area lost to natural causes[i] by a substantial margin (63 percent – 294 500 ha compared with 186 200 ha). This unexpected finding demonstrates the resilience of mangroves in adapting to environmental changes and colonizing suitable habitats. The study shows the need to address land-use drivers of mangrove loss, particularly in Southeast Asia and Western and Central Africa, the two subregions with the largest gross loss of mangrove area over the period studied.

FAO continues to improve its processes for forest resource assessments (Box 3). More updated data on deforestation and other forest attributes will be available in 2025, when the next FRA will be published. ■

g According to the RSS, annual deforestation in Africa declined by 23 percent between 2000–2010 and 2010–2018.[18]

h Natural retraction is defined as natural changes or movements in riverbeds, sediment inputs or sea levels that lead to the local extinction of a mangrove ecosystem. Such natural changes were likely exacerbated by the impacts of climate change, such as sea-level rise and more severe weather events.

i Natural causes comprise the impacts of disasters such as tsunamis.

BOX 3 ENHANCING PROCESSES FOR DATA COLLECTION AND DISSEMINATION FOR THE GLOBAL FOREST RESOURCES ASSESSMENT

A range of innovative tools and platforms is changing the way in which land and forest data are collected, analysed and disseminated, including for the Global Forest Resources Assessment (FRA).* As part of the FRA 2020 Remote Sensing Survey, FAO trained more than 800 national experts from 126 countries and collected data at 400 000 locations. In 2018, FAO developed the FRA Platform[25] to reduce the reporting burden on countries, increase the consistency of reported data, and facilitate interactions among collaborators during data collection and analysis. This has the additional benefit of helping improve the dissemination and use of FRA data and other information, including to the public.

The introduction of the FRA Platform has made the data-collection process fully digital. It enables automated cross-checks between reporting tables for consistency, the documentation of the reporting process for institutional memory, the sharing of access to geospatial data and products to support reporting, and the easy downloading of data for further analysis.

For FRA 2025, stronger metadata support is enabling the better documentation of reported figures and underlying data-collection and analysis systems. Enhanced cross-checks and interoperability with previous submissions and reporting cycles via the FRA Platform will also help avoid inconsistencies resulting from human error, reduce the reporting burden and cost on countries, and enable a transition to a flexible reporting process in which countries can update their reports with new data within the five-year reporting cycles.

* See FAO. n.d. Global Forest Resources Assessments. In: *FAO*. https://www.fao.org/forest-resources-assessment/en/

2.2 CLIMATE CHANGE IS MAKING FORESTS MORE VULNERABLE TO ABIOTIC AND BIOTIC STRESSORS SUCH AS WILDFIRE AND PESTS

Wildfire

An estimated 340–370 million ha of the Earth's land surface is affected by fire annually (equivalent to just less than half the land area of the Australian continent).[26, 27] An estimated 383 million ha (based on Moderate Resolution Imaging Spectroradiometer [MODIS][j] data) was burnt in 2023.[28] Note, however, that the actual area burnt likely exceeded this amount, with measurement incomplete due to technical limitations and challenges associated with the detection of small fires, temporal coverage and cloud cover. In sub-Saharan Africa, for example, Sentinel-2 data (at 20 m spatial resolution) indicated a total burnt area in 2019 that was 120 percent greater than that estimated from MODIS data (with a resolution of 500 m). This confirms that fires not mapped by MODIS are yet to be accounted for in global analyses.[29]

Fire is a widely used land management tool for various socioecological purposes,[30] but uncontrolled fires – wildfires – can have significant negative impacts at the local, national and global levels. The frequency and intensity of wildfires is increasing, including in areas not previously affected, particularly due to climate change and land-use change. For example, boreal fire has previously been responsible for about 10 percent of global carbon-dioxide emissions due to wildfires; in 2021, however,

j MODIS is a satellite-based sensor used for Earth and climate measurements.

such fires reached a new high (driven largely by extended drought, which caused an increase in fire severity and fuel consumption) and accounted for nearly one-quarter of total wildfire emissions.[31] There was a record-breaking increase in fire activity in the Northern Hemisphere in 2023.[32] In Canada, an estimated 6 868 fires burnt 14.6 million ha,[33] which was more than five times the 20-year average.

An increase in the frequency and intensity of wildfires, itself largely a consequence of climate change, can accelerate positive feedback loops in the carbon cycle, presenting a challenge for global climate-change mitigation efforts.[34] Satellite observations indicate that, in 2023, fires emitted 6 687 megatonnes of carbon dioxide globally,[k, 28] which was more than double the estimated carbon-dioxide emissions by the European Union due to the burning of fossil fuels in that year (2.6 billion tonnes).[35] Combining Indigenous and other traditional approaches to fire management with modern technologies and knowledge is an emerging innovation in various landscapes around the world.

Pests

Climate change is making forests more vulnerable to invasive species, causing changes in their geographic distribution and seasonal phenology and in aspects of population dynamics.[36] Insect pests and disease pathogens can reduce tree growth and survival, wood quality and the provision of ecosystem services such as carbon sequestration. Forests worldwide are vulnerable to invasions by species from a wide range of taxa.[37] Climate change and poor forest management practices are also leading to increases in outbreaks of native insect pests, such as bark beetles.[38]

The threat to forests posed by pests is considerable: for example, pine wood nematode has caused significant damage to native pine forests in China, Japan and the Republic of Korea, with the Korea Forest Service reporting the loss of 12 million pine trees due to the nematode between 1988 and 2022.[39] In the United States of America, 25 million ha of forestlands are projected to experience losses exceeding 20 percent of host tree basal area due to insects and disease through to 2027.[40]

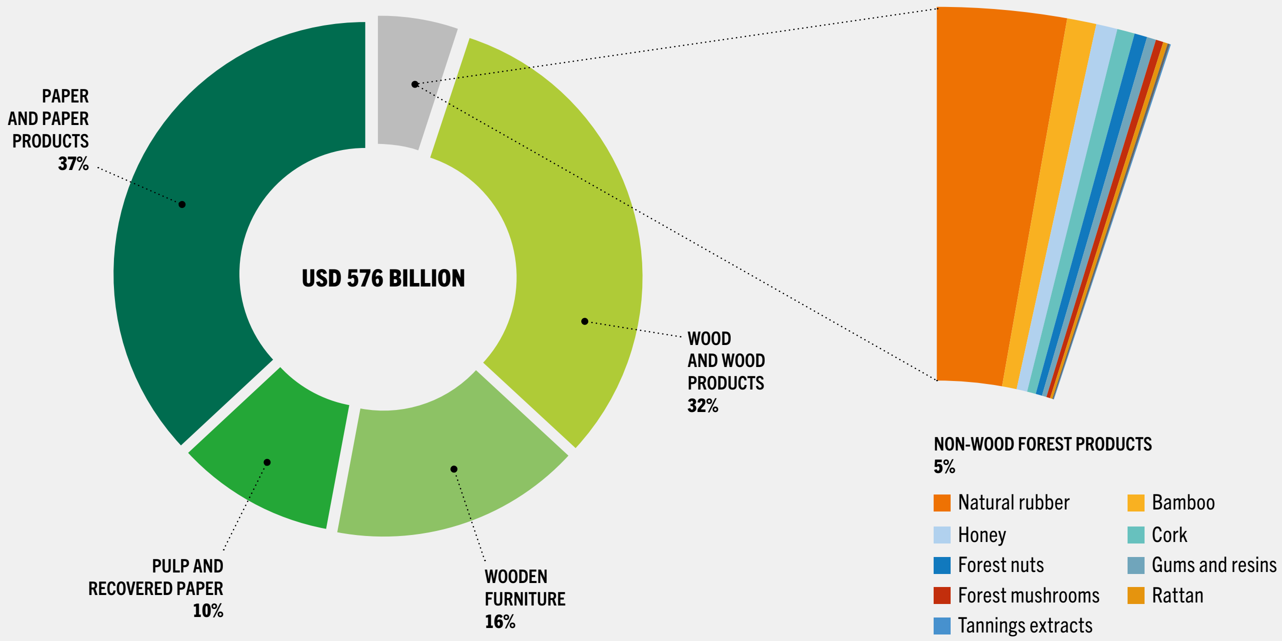
The monitoring of forest degradation, including outbreaks of insect pests and disease, is at an early stage globally. It is also difficult to quantify the economic cost of damage, which encompasses timber losses, the cost of tree replacement, and impacts on ecosystem services and socioeconomic outcomes for local communities.[39] Technological and policy innovations are needed to better understand and address the interrelated drivers of forest disturbances such as fire, pests and diseases – and the effects of climate change on these – and to take more-integrated approaches to their management and enhance the resilience of forests and forest-dependent people.[40] ■

2.3 GLOBAL WOOD PRODUCTION IS AT RECORD LEVELS, AT ABOUT 4 BILLION M^3 PER YEAR

Forest product production and trade statistics have focused historically on wood-based goods, which are the main products derived from forests for which established markets exist. This is changing but, for many forest owners and managers, wood and wood-fibre products are still the most important source of income and employment in forestry and account for most of the value of global forest product trade (Figure 1). This section examines the state of wood production and trade; NWFPs – for which data are increasingly available – are addressed in the next section. Data are less readily available for the monetary returns on forest services and are not reported here. It is recognized, however, that

k The estimate is based on the Global Fire Assimilation System dataset, which assimilates fire radiative power observations from satellite-based sensors to produce daily estimates of emissions from wildfires and biomass burning. Fire radiative power is a measure of the energy released by the fire and therefore of how much vegetation is burnt. Observations of fire radiative power currently assimilated in the Global Fire Assimilation System are the Terra MODIS and Aqua MODIS active fire products.

FIGURE 1 SHARE OF GLOBAL FOREST PRODUCT EXPORTS, BY PRODUCT CATEGORY, 2022



NOTE: Wood = unprocessed wood (roundwood, also called "wood in the rough"; it includes logs, pulpwood, other industrial roundwood and woodfuel); wood products = all transformed/processed products except furniture (charcoal, chips, pellets and briquettes, sawnwood, panels and further processed wood products such as prefabricated wooden houses, doors and window frames). Wooden furniture is also a wood product but is shown here as a separate category.

SOURCES: FAO. 2023. FAOSTAT: Forestry Production and Trade. [Accessed on 29 December 2023]. https://www.fao.org/faostat/en/#data/FO. Licence: CC-BY-4.0.;
and UN Comtrade. 2023. United Nations Commodity Trade Statistics Database. [Accessed on 29 December 2023]. https://comtradeplus.un.org/

https://doi.org/10.4060/cd1211en-fig01

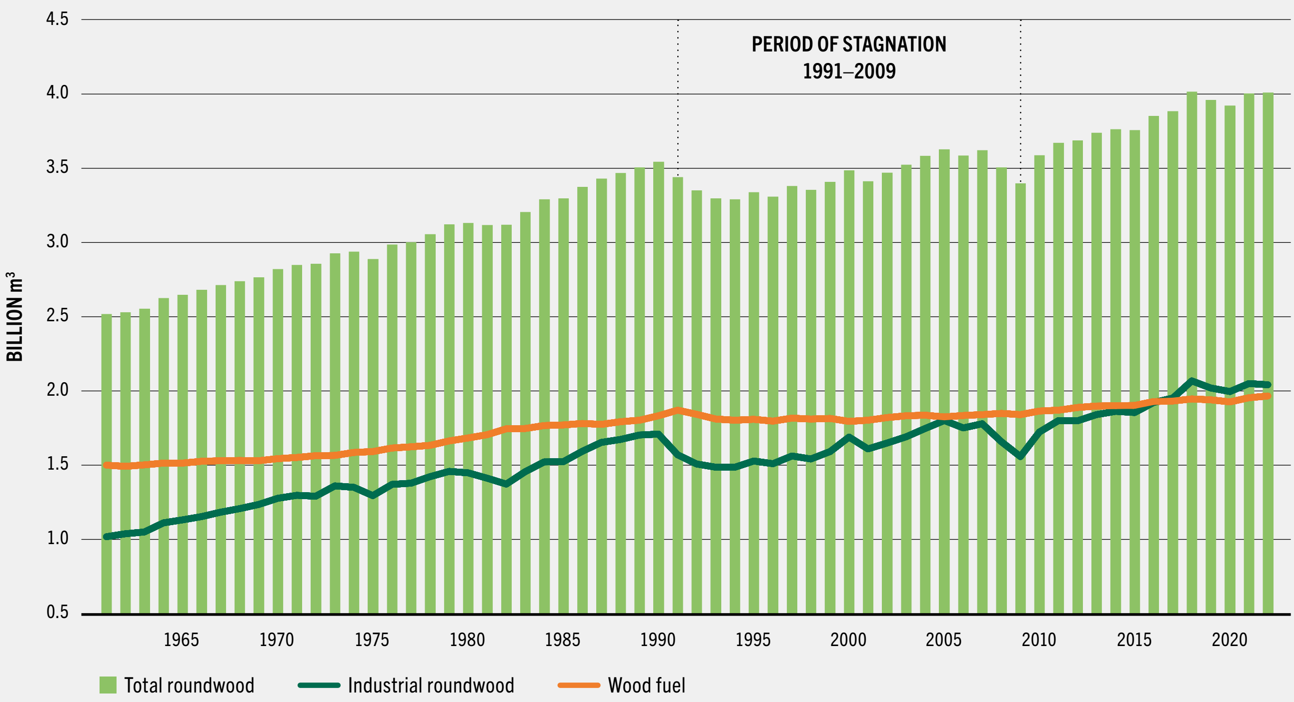
societies are highly dependent on forest services: for example, more than half of world gross domestic product (GDP) is estimated to depend significantly on ecosystem services, including forest services.[4]

Global roundwood removals (also a proxy for global roundwood production and consumption) increased consistently between 1961 and 1990, was relatively steady for two decades at around 3.5 billion m³ per year (Figure 2),[I] and grew again from about 2010. The world produced 13 percent more roundwood in 2022 than in 1990. Given that, in the same period, the world population increased by 50 percent and world GDP per capita grew by 174 percent, the growth of roundwood production may be considered moderate, with wood production per capita decreasing in the last few decades.[41]

World roundwood removals have amounted to about 4 billion m³ annually in recent years, around half of which has been used for fuel, either directly (as fuelwood) or in the production of charcoal and pellets. Most of the remaining 2 billion m³ of wood removals per year has been used as raw material (i.e. industrial roundwood)

I Two political factors were behind the stagnation in the 1990s: the collapse of the Soviet Union, and the reunification of East and West Germany. The world economic slump in 2001–2002 and the 2008–2009 global financial crisis also contributed.

FIGURE 2 **WORLD ROUNDWOOD PRODUCTION, COMPRISING INDUSTRIAL ROUNDWOOD AND WOODFUEL, 1961–2022**



SOURCE: FAO. 2023. FAOSTAT: Forestry Production and Trade. [Accessed on 15 October 2023]. https://www.fao.org/faostat/en/#data/FO. Licence: CC-BY-4.0.

to produce sawnwood, wood-based panels and woodpulp. Most of the woodpulp and recovered paper has been used for paper and paperboard production.[m]

The COVID-19 pandemic had a relatively short-term impact on the production and trade of forest products: after declining significantly in 2020, the global production and trade of almost all major wood-based products reached record highs in 2021. Production and trade declined for most wood products in 2022 due to disruptions to global supply chains, combined with a slowdown in consumer demand and the introduction of new trade restrictions in some countries.

m Detailed data covering 59 wood product categories, 24 product groups and over 245 countries and territories are available in the FAOSTAT-Forestry database at https://www.fao.org/faostat/en/#data/FO

Global industrial roundwood removals were almost unchanged in 2022 compared with 2021, at 2.04 billion m³, which was a record volume (Figure 2). Global trade declined sharply in 2022 – by 17 percent – to 119 million m³, of which 37 percent comprised imports by China. Log export restrictions introduced by the Russian Federation accounted for half the global contraction.[17, 42]

Share of woodfuel in total wood production

Woody biomass, especially fuelwood and charcoal from forests, provides crucial basic energy services for cooking and heating. About 2.3 billion people worldwide (29 percent of the world's population) relied on woody biomass for these purposes in 2021, mostly in sub-Saharan Africa and South Asia.[43] The share of woodfuel in global roundwood production decreased

TABLE 2 ROUNDWOOD PRODUCTION, BY MAJOR USE, 2022

	Woodfuel	Industrial roundwood	Total roundwood
World (billion m³)	1.97	2.04	4.01
Share of total roundwood (%)	49.40	50.60	
Africa + **Asia** + **South America** (billion m³)	1.61	0.79	2.40
Share of world total (%)	82.00	39.00	60.00
Europe + **North America** (billion m³)	0.26	1.17	1.43
Share of world total (%)	13.00	57.00	36.00

SOURCE: FAO. 2023. FAOSTAT: Forestry Production and Trade. [Accessed on 15 October 2023]. https://www.fao.org/faostat/en/#data/FO. Licence: CC-BY-4.0.

https://doi.org/10.4060/cd1211en-tab02

from 60 percent in 1961 to 49.4 percent in 2022 (Table 2), while in the same year (2022), the share was 90 percent in Africa and 60 percent in Asia.[17] Industrial roundwood production exceeded woodfuel production for the first time in history in 2018 (Figure 2).

Woodfuel is generally considered the most affordable and reliable energy source, especially for low-income people in the Global South and those affected by disasters and humanitarian crises. Major concerns arising from the widespread use of woodfuel include its impacts on forest degradation and deforestation, indoor air pollution resulting from burning woodfuel with rudimentary stoves, and the implications for higher-value-added uses of wood.

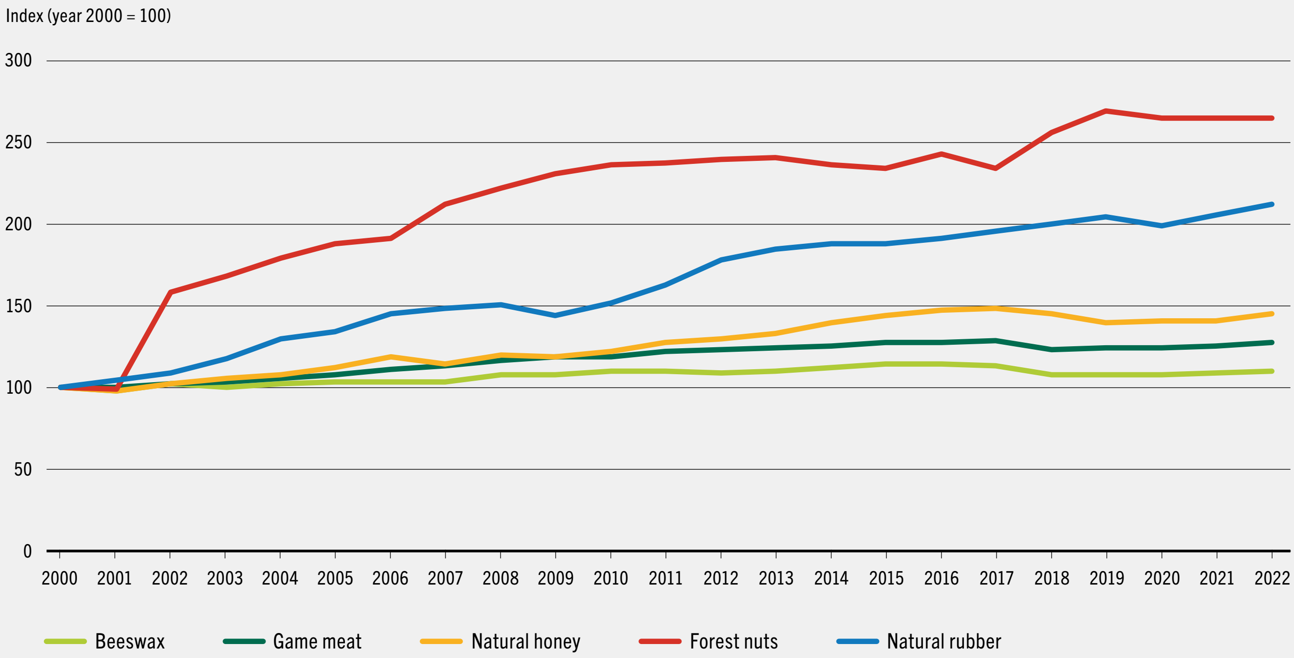
Most (82 percent) woodfuel is produced and used in Africa, Asia and South America; the remainder comprises 13 percent in Europe and North America and 5 percent in the rest of the world (Table 2). More than half the world's industrial roundwood is produced in Europe and North America and 39 percent is produced in Africa, Asia and South America combined. ■

2.4 NEARLY 6 BILLION PEOPLE USE NON-TIMBER FOREST PRODUCTS

It is estimated that 5.8 billion people use non-timber forest products (NTFPs) worldwide, including 2.77 billion rural users in the Global South.[44] About 50 percent of the global population use wild-gathered species (the total number of species used is estimated at 50 000), and 70 percent of the world's poor rely on wild species for food, medicine, energy, income and other purposes.[45] Women play a crucial role in NTFP production, especially in Africa and Asia as the main holders of traditional knowledge, as gatherers of edible wild plants, and in small-scale NTFP trading (men are more likely to own and manage larger businesses). In addition to the physical demands, local social norms, personal safety concerns and domestic responsibilities may limit women's opportunities in NTFP development.[46]

Many NTFPs have significant value. In India, NTFPs support the livelihoods of about 275 million people, with local communities and Indigenous Peoples deriving up to 40 percent of their income from them;[47] in Europe, the value of NWFPs (see definition in footnote d), including in formal and informal markets and for self-consumption, is estimated at EUR 23.3 billion per year.[48] In Malawi, a recent analysis based on a national survey indicated that 22 percent of the population consumes wild green leafy

FIGURE 3 TRENDS IN PRODUCTION VOLUME OF FIVE NON-WOOD FOREST PRODUCTS, 2000–2022



NOTE: Nuts and natural rubber experienced the highest production growth between 2000 and 2022 (165 percent and 113 percent, respectively); honey, game meat and beeswax had smaller increases. There is increasing consumer awareness of the health benefits associated with the consumption of edible forest products such as nuts and honey and growing interest in natural and sustainably sourced ingredients. New technologies have also helped drive growth in production volume. Natural honey and beeswax include both forestry and agricultural products.

SOURCE: FAO. 2023. FAOSTAT: Crops and Livestock Products. [Accessed on 29 December 2023]. https://www.fao.org/faostat/en/#data/QCL. Licence: CC-BY-4.0.

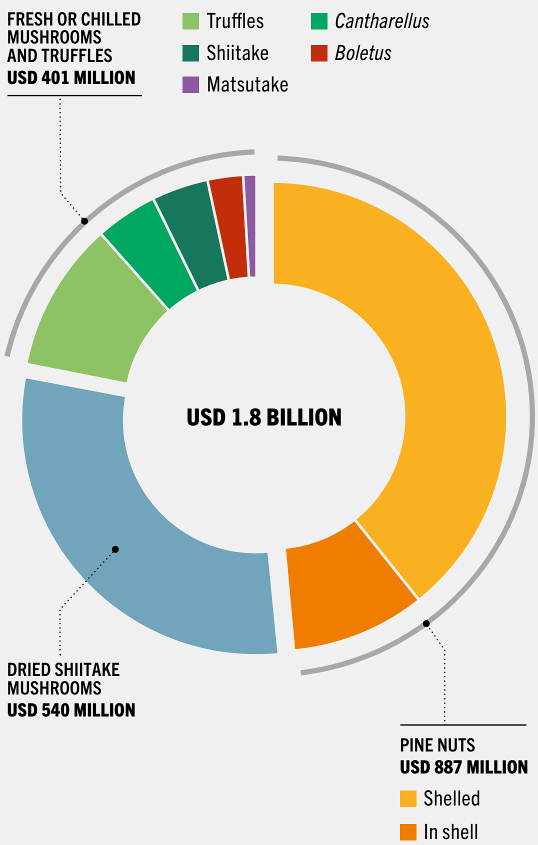
https://doi.org/10.4060/cd1211en-fig03

vegetables, which contributes to meeting daily recommendations for fruit and vegetable consumption.[49] Wildmeat is a traditional food of many Indigenous hunter–gatherers. More recently, its consumption in 62 urban centres in the Brazilian state of Amazonas has been estimated at 10 691 tonnes per year; the monetary value of this consumption (USD 35.1 million) is comparable with the region's fish and timber production.[50] Wildmeat sales in Iquito (in the Peruvian Amazon) have increased at a rate of 6.4 tonnes per year over the last 45 years, in line with urban population growth.[51] Inland fish, whether collected directly by households or through commercial inland fisheries, are often forest products because of their strong dependence on the quality, quantity and timing of freshwater flows from upland, riparian and floodplain forests and on the instream habitats these forests and flows create. Global inland-capture fisheries contributed an estimated 11.4 million tonnes of fish in 2021.[52]

Figure 3 shows trends in the production of five primary NWFPs globally, as reported in FAOSTAT. Overall, production has been on an increasing trend in the last two decades.

New data are available (as of 2022) for pine nuts and forest mushrooms and truffles, due in part to efforts by FAO to introduce new trade codes for NWFPs (Figure 4). It is now (from 2022) also possible to monitor the trade of *Prunus africana* bark (reported to have anti-inflammatory, antimicrobial and antiviral properties in *in vivo* and *in vitro* studies[53]), which has received considerable attention due to concerns about the sustainability of trade.

FIGURE 4 GLOBAL EXPORTS OF PINE NUTS AND FOREST MUSHROOMS AND TRUFFLES, 2022



SOURCE: UN Comtrade. 2023. The United Nations Commodity Trade Statistics Database. [Accessed on 29 December 2023]. https://comtradeplus.un.org/

https://doi.org/10.4060/cd1211en-fig04

The recent increase in data availability for NWFPs is shedding light on a set of forest resources once perceived to have minor market value and to be confined mainly to subsistence use by people living in or near forests. It is increasingly clear that many NWFPs have considerable market value per quantity produced, often comparable with and complementary to those of wood products.[n] There is a need to further improve statistical practices and monitoring for NWFPs to better enable the development of evidence-based policies and programmes that can fully unlock the potential of these resources, including in the context of a bioeconomy. ■

n This is not to lessen the importance of many NWFPs for local and subsistence use, which remains considerable.

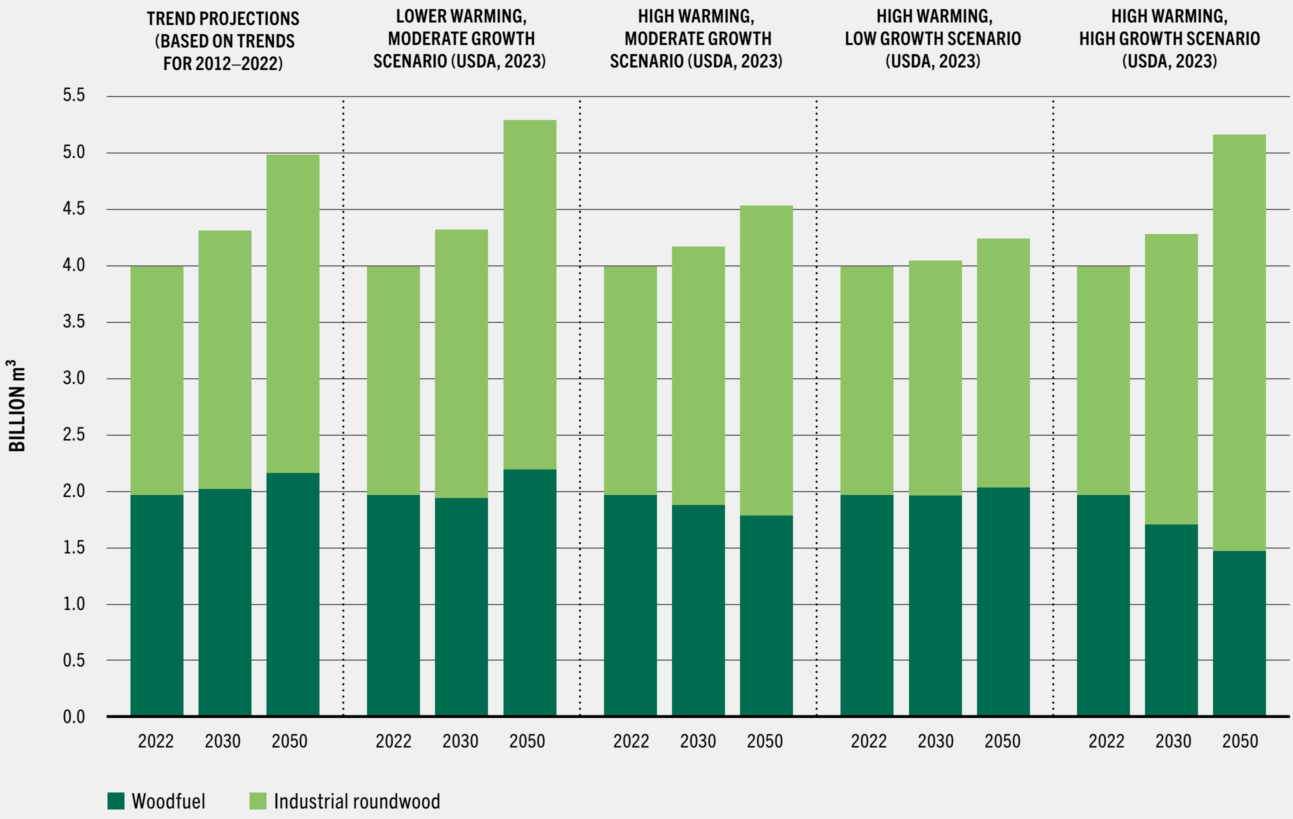
2.5 PROJECTIONS TO 2050 INDICATE SIGNIFICANT INCREASES IN WOOD DEMAND, ALBEIT IN A WIDE BAND

Forests – and their sustainable management – can play important roles in the transformation to a bioeconomy by producing renewable materials and ecosystem services while enhancing biodiversity and supporting livelihoods and income creation. Wood will likely play a key role.

The 2022 edition of SOFO featured an analysis of the potential future role of wood in the bioeconomy. Since then, the United States Department of Agriculture (USDA) has generated new projections of world roundwood and forest product demand using the Forest Resource Outlook Model (FOROM). The projections are made for four scenarios of global climatic warming and economic growth – (1) lower warming, moderate growth; (2) high warming, low growth; (3) high warming, moderate growth; and (4) high warming, high growth – based on the Intergovernmental Panel on Climate Change's four "shared socioeconomic pathways" scenarios,[54] which assume differing climate policies.

Figure 5 shows global roundwood demand according to the USDA projections and trend projections (as estimated for this report – see the note in Figure 5) to 2030 and 2050.[55] The trend projections assume that future roundwood demand changes are in line with trends estimated from data for the period 2012–2022 and can be considered a business-as-usual scenario.

FIGURE 5 **PROJECTIONS FOR GLOBAL ROUNDWOOD DEMAND FOR 2030 AND 2050**



NOTE: This figure excludes the FAO category of "other roundwood" (i.e. roundwood used for tanning, distillation, match blocks, poles, etc.), which accounts for 3–4 percent of total roundwood production.

SOURCES: The trend projections were estimated for this report by L. Hetemäki, University of Helsinki, based on data for the period 2012–2022; data for the USDA (2023) projections were obtained from Johnston, C.M.T., Guo, J. & Prestemon, J.P. 2023. RPA forest products market data for U.S. RPA Regions and the world, 2015–2070, historical (1990–2015), and projected (2020–2070) using the Forest Resource Outlook Model (FOROM), 2nd Edition. In: *Forest Service Research Data Archive*. https://doi.org/10.2737/RDS-2022-0073-2

https://doi.org/10.4060/cd1211en-fig05

According to the projections, world roundwood production will increase by 4–8 percent between 2022 and 2030, depending on the scenario; thus, growth is expected to be moderate in the near future. Production could increase by 6–32 percent between 2022 and 2050 (with uncertainty increasing markedly over the longer period). In terms of roundwood volume, the projected increase to 2050 ranges between 240 million m^3 and 1 200 million m^3, depending on the scenario.

It should be noted that the projections in Figure 5 draw on data describing existing markets. Thus, they do not incorporate new products or future demand for products that may be in the early stages of development. Moreover, the main drivers used in the USDA estimates based on FOROM are economic growth and population growth; the model does not explicitly include (for example) the substitution of forest products and fossil-based products as a driver. Other model limitations include lags in incorporating new data and the aggregation of some product

BOX 4 VALUE-ADDING TO INCREASE THE ECONOMIC BENEFITS OF FORESTS

According to a recent analysis,[58] the European Union accounts for only 3.9 percent of the world's total forest area but for 43 percent of global forest product exports by value (at USD 127 billion in 2022).[17] In contrast, Africa has almost 16 percent of the world forest area but produces less than 2 percent of the value of world forest product exports. This is because Africa uses around 90 percent of the wood harvested as fuel for heating and cooking, and most of its wood exports are unprocessed (i.e. roundwood). Thus, not only does Africa retain less than 10 percent of the value of its timber, its industry creates fewer than 10 percent of the jobs it could generate if a greater share of finished and semi-finished products were produced and exported.[59]

Some countries in Africa are moving to add value to their wood exports. For example, Gabon has banned log exports since 2010 with the aim of encouraging greater in-country wood processing; subsequently, sawnwood production increased almost fourfold between 2009 and 2022 (from 2.8 million m^3 to 10.3 million m^3) and roundwood exports fell to almost zero (from 1.7 million m^3 in 2009 to 0.01 million m^3 in 2022). The Government of Gabon has put in place a range of other policy measures to develop the country's forest sector.[60]

categories (e.g. engineered wood products, biofuels and chemicals).

FAO has made additional estimates to include potential impacts of three emerging forest products considered the most promising wood products for the large-scale substitution of non-renewable materials: (1) mass timber/cross-laminated timber (CLT) for construction;[o] (2) artificial cellulosic fibres from dissolving woodpulp, mainly used in the textiles industry; and (3) woodfuel for bioenergy.[56] Demand for these products is estimated to increase roundwood consumption by up to 272 million m^3 per year by 2050 compared with 2020, amounting to a total increase (baseline + new products) in global roundwood consumption (production) of approximately 49 percent over the period. Note that this projection focuses on demand for wood products. Multiple pathways that combine increased harvesting and processing efficiency, recycling, and planting of forests and trees, including in agroforestry systems and building on restoration efforts, can lead to sustainable wood supply in volumes to meet the increase in demand, supporting the bioeconomy.[57]

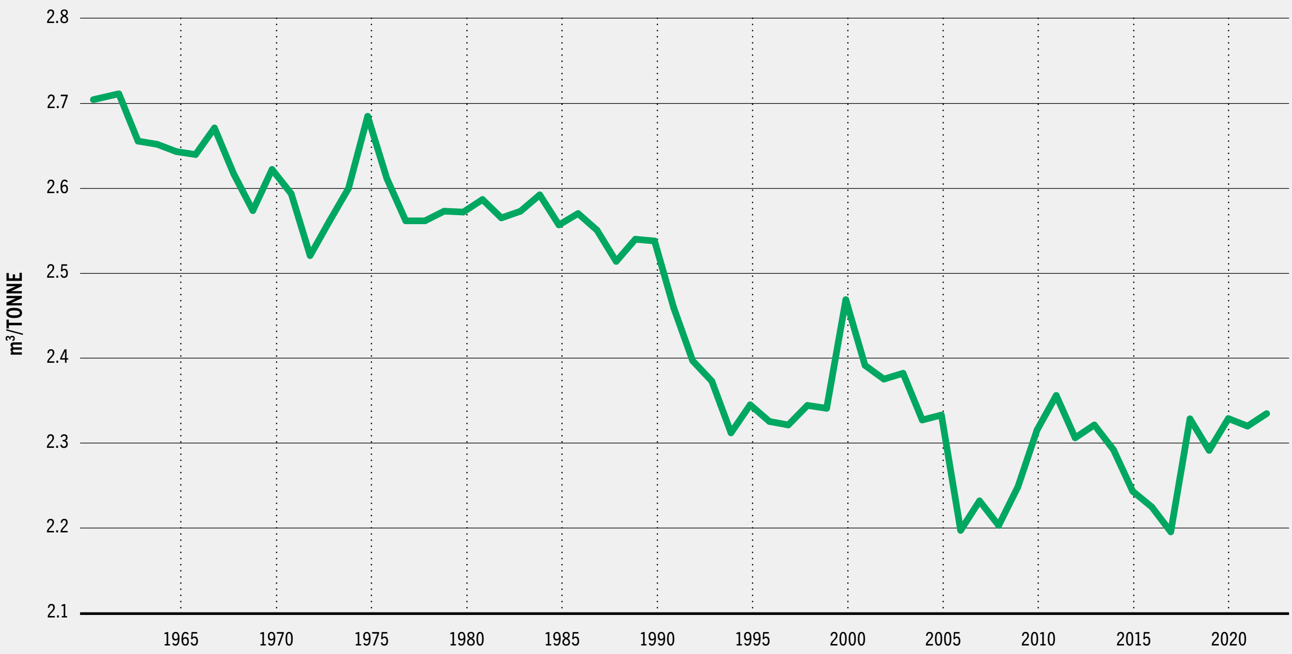
In line with traditional forest-sector outlook studies, the discussion above focuses on volume-based projections for forest products and roundwood. For national economies and forest-sector incomes, however, the value of these products may be more relevant than their volumes (Box 4).

Woodfuel demand likely to decrease

The projections summarized in Figure 5 suggest that woodfuel consumption will increase modestly or decline slightly, depending on which of five future scenarios for economic and population growth are considered. A synthesis of modelling simulations by FAO showed a range of consumption estimates, depending primarily on underlying assumptions about traditional use of woodfuel in developing economies and the future role of wood in the global energy supply.[56] In this synthesis, the estimated global consumption of woodfuel from forests in 2050 varied between 2.3 billion m^3 and 2.7 billion m^3, an increase of 17 percent and 37 percent, respectively, compared with consumption in 2022. Several major trends will shape future woodfuel consumption, including population growth, especially in Africa and

o Mass timber comprises a range of products such as CLT, nail-laminated timber, glue-laminated timber ("glulam"), dowel-laminated timber, veneer-based mass timber panels, post-and-beam, and heavy timber decking, typically produced from sawnwood, veneer and plywood and sometimes a combination of all three, for use in modern multistorey construction.[57]

FIGURE 6 **RESOURCE-USE EFFICIENCY FOR INDUSTRIAL ROUNDWOOD, 1961–2022**



SOURCE: FAO. 2023. FAOSTAT: Forestry Production and Trade. [Accessed on 15 October 2023]. https://www.fao.org/faostat/en/#data/FO. Licence: CC-BY-4.0.

South Asia; the expansion of alternative forms of energy, such as solar and wind; the uptake of more efficient technologies, such as modern cooking stoves; and policies that restrict or encourage woodfuel use.

Industrial roundwood demand likely to increase

Some trends, such as a shift towards a bioeconomy and the development of new products, are likely to increase roundwood demand to 2050 and beyond. Demand for some existing products, such as packaging papers, sawnwood and plywood, is also expected to increase; conversely, production of some traditionally important wood products is declining (e.g. newsprint, printing and writing papers due to a shift towards digital communication), thus reducing industrial roundwood demand for these purposes.

For example, an estimate made for this report[p] suggests that the continued decline of graphics paper production in line with current trends would reduce roundwood demand for that purpose by 133 million m^3 by 2030.

p If the trend observed since 2012 continues, world graphics paper consumption will decline from 93.2 million tonnes in 2022 to 56.3 million tonnes to 2030. Based on the share of graphics paper production held by newsprint, which uses mainly mechanical pulp and recycled paper, it may be assumed that graphics paper production comprises about 90 percent virgin wood fibre and 10 percent recycled paper. Moreover, given that chemical pulp is used mainly for printing and writing papers, it may be assumed that about 86 percent of graphics paper is manufactured from chemical woodpulp and 14 percent from mechanical woodpulp. On this basis, using the FAO wood-conversion-factor multipliers of 4.25 m^3 per tonne for chemical pulp and 2.56 m^3 per tonne for mechanical pulp, it can be estimated that roundwood demand will decline by 133 million m^3 by 2030 should graphics paper production decline in line with the above projection.[61]

Wood-use efficiency

Figure 6 shows that the volume of industrial roundwood required to produce a unit volume of finished sawnwood, wood panels and paper and paperboard declined by about 15 percent between 1961 and 2022,[q] including about 5.7 percent since 2000; in other words, 15 percent more finished product could be produced in 2022 compared with 1961 for the same volume of roundwood. If this trend of increasing efficiency continues for the next couple of decades, it will be possible to produce the same volume of product as today in 2040 using 116 million m^3 less industrial roundwood.

Uncertainties in future wood supply

The future supply of roundwood is prone to uncertainties, such as those arising from policy interventions, economic incentives, the development of planted forests and, more recently, climate-change-related forest disturbances. The higher concentration of carbon dioxide in the atmosphere and higher temperatures associated with climate change could increase the net growth of forests where sufficient water and nitrogen are available. Conversely, climate change is likely to lead to increases in the frequency, intensity, spatial extent and duration of disturbances such as those caused by wildfires, pests, storms and drought,[62] potentially causing significant losses of harvestable biomass. Moreover, climate change could cause long-term shifts in harvest volumes in boreal forests from softwood to hardwood.[63,64]

The impacts of climate change will depend to a significant degree on the extent to which countries are able to increase the resilience of their forests to the changing climate. This, in turn, will depend partly on the policy decisions taken to mitigate and adapt to climate change and to stop biodiversity loss; for example, policies on forest carbon, biodiversity and other aspects could restrict timber production, with some scenarios indicating decreasing wood volumes if non-wood benefits are prioritized.[56]

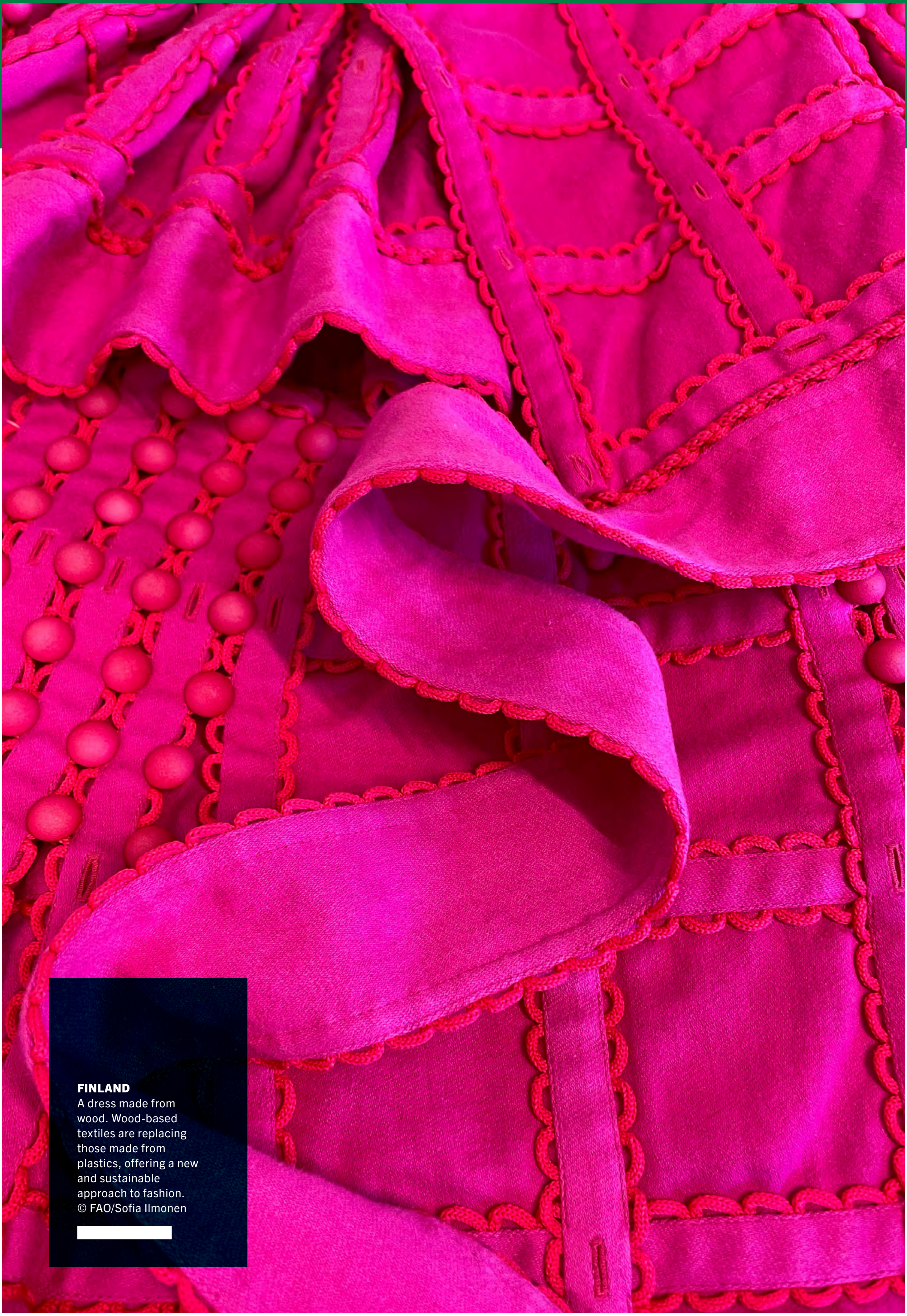
q The volume of those forest products reported in cubic metres in FAOSTAT have been converted to tonnes using conversion factors.

Another factor in the future roundwood supply is the forest area available for production (both planted and naturally regenerated). In 2020, naturally regenerated temperate and boreal forests provided about 44 percent of global industrial roundwood production, with planted forests supplying another 46 percent.[56] Agroforestry and rubberwood plantations also produce industrial roundwood (possibly accounting for the remaining 10 percent),[56] although this has not been analysed systematically.[41] The area and growing stock of naturally regenerated temperate and boreal forests are expected to increase, suggesting the possibility of increasing timber production in them (subject to the uncertainties described above).[65] Some studies estimate that the area of forest plantations could increase by 20 million–40 million ha by 2050 as another means for meeting increased wood demand,[66] although their production capacity would depend on a wide range of factors, such as time since establishment, climatic regime, the species used and the management practices applied. ■

2.6 GIVEN RAPIDLY CHANGING ENVIRONMENTAL CONDITIONS AND RISING DEMANDS ON FORESTS, MORE INNOVATION IS NEEDED IN THE FOREST SECTOR

In the face of rapid economic, social and environmental change, forest managers and users must be adaptable and innovative. Climate change is exacerbating stressors such as wildfire and pests, and the tension between the impacts of these on the one hand and the likely future increase in wood demand on the other implies a need to rethink forest and land management and silviculture. The shift towards a zero-carbon bioeconomy in which wood will be a major input will require downstream innovations to diversify products and uses and increase efficiencies. The opportunities offered by renewed attention to the vast range of NWFPs in the context of a bioeconomy will give rise to innovations aimed at creating and improving value chains and providing livelihood opportunities for potentially billions of smallholders. Given the diverse and increasing demands, new ways will be needed for managing trade-offs between wood, NWFPs and ecosystem services and maximizing synergies among development, biodiversity and climate benefits.

Efficient and pragmatic solutions are needed urgently at scale to drive the greater uptake of innovations. The next chapter shows that science and innovation are already leading to fast-moving changes in forestry – ranging from innovations in forest data collection, to advances in wood technologies, to new means for organizing smallholders and scaling up their economic power. Chapter 4 presents case studies on the introduction of innovations in a wide range of contexts, and Chapter 5 sets out five enabling actions, and associated specific actions, for tapping the power of innovation for forest conservation, restoration and sustainable use. It is increasingly clear that innovation, and its effective deployment, will be crucial for ensuring the future of forestry in a changing world. ■



FINLAND
A dress made from wood. Wood-based textiles are replacing those made from plastics, offering a new and sustainable approach to fashion.
© FAO/Sofia Ilmonen

CHAPTER 3
INNOVATION IS REQUIRED TO SCALE UP FOREST CONSERVATION, RESTORATION AND SUSTAINABLE USE AS SOLUTIONS TO GLOBAL CHALLENGES

KEY MESSAGES

➔ **Innovation is a key enabler of progress towards achieving the Sustainable Development Goals.** It is also an important accelerator for achieving the three Global Goals of FAO Members and enhancing the potential of forests and trees to address global challenges. A vast range of innovations is already having profound influences on the forest sector.

➔ **Five types of innovation are enhancing the potential of forests and trees to address global challenges:**

- **(1) technological** (in three subtypes of digital, product/process and biotechnological). For example, open access to remote-sensing data and the facilitated use of cloud computing are enabling digital methodologies that generate high-quality forest data and improve forest management processes;
- **(2) social, (3) policy** and **(4) institutional** – such as new efforts to better engage women, youth and Indigenous Peoples in developing locally led solutions, the promotion of multistakeholder partnerships and cross-sectoral approaches in land-use policies and planning, and support for cooperatives to increase the bargaining power of smallholders; and
- **(5) financial** – such as innovations in public- and private-sector finance to enhance the value of standing forests, boost restoration efforts, and increase access to loans for smallholders for sustainable production.

Combinations ("bundles") of these innovation types can unleash powerful forces for change.

➔ **Four factors form barriers to scaling up innovation:** (1) lack of innovation culture; (2) risk; (3) potential limitations in various forms of capital; and (4) unsupportive policies and regulations. An organizational culture that recognizes and embraces the transformative potential of innovation can help de-risk innovation processes and empower stakeholders to respond to current and future challenges.

➔ **Innovation can create winners and losers, and inclusive and gender-responsive approaches are needed** to avoid harm and ensure the fair distribution of benefits among men, women and youth in all socioeconomic and ethnic groups. Efforts to promote innovation must consider and integrate the local circumstances, perspectives, knowledge, needs and rights of all stakeholders.

3.1 INNOVATION IS A KEY ENABLER OF PROGRESS TOWARDS ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS

Science, technology and innovation are at the heart of the 2030 Agenda for Sustainable Development and appear in numerous targets in the SDGs. Science and technology have been identified as levers for accelerating progress towards the SDGs while minimizing trade-offs.[67]

Innovation is an important accelerator for agrifood systems transformation and for achieving the three Global Goals of FAO Members[r] in support of the 2030 Agenda and the SDGs by increasing productivity, quality, diversity, efficiency and economic, social and environmental sustainability. In line with the FAO Science and Innovation Strategy,[9] innovation is defined here as "doing something new and different whether solving an old problem in a new way, addressing a new problem with a proven solution, or bringing a new solution to a new problem."

FAO identifies five types of innovation: technological, social, policy, institutional and financial (Table 3). Such a typology is useful for describing the overarching suite of innovations that can be used, depending on objectives and the context in which the innovation is being applied. The typology is used in this document to organize the diverse innovations arising in the forest sector.

Innovations often occur in bundles of innovation types because a web of actors and actions – an innovation "ecosystem" (Box 5) – must align to enable the development and adoption of innovations. For example, advances in open-access remote sensing and increased access to powerful cloud-computing resources (*technological* innovation) have enabled improved national capacities for the sound measurement, reporting and verification (MRV) of reductions in greenhouse-gas emissions. This, in turn, has enabled the development of results-based payments associated with the REDD+ framework[s] under the Paris Agreement on climate change and the growth of forest carbon markets, with a focus on the importance of safeguards (*policy, institutional, financial* and *social*). In the building industry, the adoption of mass timber as an innovation has gained momentum, due in part to factors such as updates to building codes, the possibility and availability of computer-numerically controlled machining, a desire to reduce the carbon intensity of the built environment, and new mechanisms for developing sustainable building models.

Some innovation types are complementary and sequentially necessary – for example, a new policy might require institutional changes in organizations for effective implementation, which, in turn, might require changes in social behaviours and norms. Different types may also have different scales of impact: for example, a social innovation may start at the grassroots level but lead to provincial or national demands for policy change, which may drive wider institutional innovation. Innovation takes time, and different kinds of innovation evolve at different speeds. Policy innovations are enhanced by supportive organizational frameworks and rules. Policy and institutional innovations are more likely to succeed when they overlap and are supported by broader social values and norms.

This chapter provides an overview of innovations in the forest sector, organized according to the FAO typology, with illustrative examples and references to case studies presented in **Chapter 4**. **Chapter 5** enumerates five enabling actions that, if taken, would help unleash the power of innovation to maximize the contributions of forests to addressing global challenges. ■

r (1) Eradication of hunger, food insecurity and malnutrition; (2) elimination of poverty and the driving forward of economic and social progress for all; and (3) the sustainable management and utilization of natural resources.

s REDD+ = reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

BOX 5 INNOVATION ECOSYSTEMS

Innovation is determined by numerous and complex interactions between actors and artifacts (such as products, services and technological tools) within an innovation "ecosystem", which can be defined as "the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors."[68] A well-functioning innovation ecosystem provides the general economic and institutional environment required for innovation to happen.[69] The innovation ecosystem itself is shaped by a range of economic, social, environmental and other factors that affect the operating environment in which an innovation occurs. Within an innovation ecosystem, diverse actors interact with each other and with artifacts and other resources in complex ways that ultimately trigger innovation creation or provide the enabling conditions in which an innovation can be adopted.[68]

Interactions among actors and artifacts are varied and complex: for example, they could include agriculture, forestry, fisheries and aquaculture stakeholders engaging in mutual learning and information exchange to develop integrated approaches for landscape management, or a manufacturing firm embracing new online marketing services that trigger the development of a new wood-based product. Different actors will be motivated by different values and potential outcomes, which themselves can be multifaceted and complex. For example, the private sector may be motivated primarily by profit, but achieving profit may require participation in activities to maintain social licence to operate, which in turn might deliver public goods. Conversely, although the public sector might be driven by the need to deliver public goods, this could require the involvement of the private sector, leading to the development of enabling policies to ensure that private-sector profits can be maintained while also delivering desired public goods.

Because such interactions take place within dynamic systems, they are unpredictable and may yield unintended results. The trajectory and development of innovations is rarely linear; it typically involves complex chains of events and feedback loops in which new ideas are refined and adapted.[70] The creation of innovations can also have broader cumulative or disruptive impacts that ultimately reshape the nature of the operating environment.

3.2 FIVE TYPES OF INNOVATION ARE ENHANCING THE POTENTIAL OF FORESTS AND TREES TO ADDRESS GLOBAL CHALLENGES

FAO has a strong focus on increasing knowledge through evidence and responsible innovation to accelerate agrifood systems transformation, thereby serving the interests of countries and societies, including the most marginalized people, and contributing to livelihoods and food security. Forest conservation, restoration and sustainable use will benefit from emerging innovations across the full spectrum of innovation types (Table 3). The contributions of each innovation type are explored below.

Technological innovation

There has been a surge of technological innovations driving improvements in forest management to support climate and biodiversity action and the development of sustainable forest value chains. Three subtypes of technological innovation are examined here: digital, product/process[t] and biotechnological.

t In the FAO typology and for the purposes of this publication, product innovation and process improvement are largely considered within the technological category, although they are also relevant to the social, policy, institutional and financial types.

TABLE 3 THE FAO INNOVATION TYPOLOGY

Technological	Technology is the application of science and knowledge to develop techniques that deliver products and services that enhance the sustainability of agrifood systems. Technologies are innovative when they are introduced, adapted or used in new ways in a given context.
Social	Social innovation is the development and adoption of new ideas (approaches, products, services and models) to meet social needs and create new social relationships or collaborations. It represents new responses to pressing social demands and existing gender inequalities that affect the process of social interactions and is aimed at improving human well-being and empowering women and the most vulnerable and marginalized peoples. In this publication, social innovation is treated together with policy and institutional innovations.
Policy	Policy innovation comprises novel processes, tools and practices used for policy dialogue, design and development that result in better enabling environments for addressing complex issues. It involves the development or adaptation of legislation, policies and strategies to address emerging challenges and societal needs or inefficiencies in existing systems through integrated approaches and the inclusion of multiple actors. In this publication, policy innovation is treated together with social and institutional innovations.
Institutional	Institutional innovations are new rules, organizations and processes that guide collective action and arise from it. They can involve changes in the operations, governance structures, multistakeholder engagement, participatory decision-making processes and cultural norms of formal and informal organizations and institutional arrangements. They take place when people or organizations strategically mobilize others through network relationships to repair or replace institutions. In this publication, institutional innovation is treated together with social and policy innovations.
Financial	Innovative finance helps generate additional development funds by tapping new funding sources or engaging new partners, enhancing the efficiency of financial flows by reducing delivery times or costs, and improving the outreach of finance to make financial flows more results-oriented and beneficial for youth, women and vulnerable groups.

NOTE: This typology diverges from the conventional business-oriented literature, which typically treats product creation and process improvement as distinct types (Damanpour and Gopalakrishnan, 2001). Product innovation refers to the creation or development of new or significantly improved products or services. It involves introducing novel features or characteristics that enhance value for users, such as inventions or improvements to existing products to meet new demands or solve problems. Process innovation is the implementation of new methods, techniques or systems. It seeks to optimize production methods, streamline procedures, reduce costs, save time or enhance quality by introducing novel approaches, technologies or organizational changes. In the FAO typology and for the purposes of this publication, product innovation and process improvement are largely considered within the technological category, although they are also relevant to the social, policy, institutional and financial types.

SOURCES: FAO. 2022. *Science and Innovation Strategy.* Rome; FAO. 2023a. Technology. Science, Technology and Innovation. In: *FAO*. Rome. [Cited 9 October 2023]. https://www.fao.org/science-technology-and-innovation/technology/en; FAO. 2023b. Innovation. Science, Technology and Innovation. In: *FAO*. [Cited 9 October 2023]. https://www.fao.org/science-technology-and-innovation/innovation/en; and Damanpour, F. & Gopalakrishnan, S. 2001. The dynamics of the adoption of product and process innovations in organizations. *Journal of Management Studies*, 38(1): 45–65. https://doi.org/10.1111/1467-6486.00227

Digital technologies.[u] Advances in remote-sensing technologies and data management and dissemination are helping deliver and communicate forest and land-use data in a transparent way to decision-makers and other stakeholders, thus increasing understanding of the benefits of forests and the need for their conservation, restoration and sustainable use. Open access to remote-sensing data and the facilitated use of powerful cloud-computing platforms have enabled development of methodologies for generating high-quality data to support MRV with environmental integrity under the Paris Agreement and for supply-chain verification, among other purposes (Box 6). The emergence of artificial intelligence brings the promise of greatly increased capacity to analyse huge volumes of remotely sensed data (Box 7).

Other digital innovations have emerged to monitor and protect endangered species, map

u In this publication, the term "digital technologies" is used to refer to devices, systems, electronic tools and software able to generate, store or process data, after the definition used by Đuric (2020).[71]

BOX 6 INNOVATION DRIVING PROGRESS IN MEASUREMENT, REPORTING AND VERIFICATION

The use of remote sensing to assess forest-area change has advanced significantly in recent years, with increases in the quality, availability and abundance of remote-sensing data (particularly because of free access to the Landsat archive and Sentinel satellite data). The capacity of countries to access and analyse satellite imagery to create land-cover (change) maps and collect sample data has improved greatly due to technical innovations and newly developed open-source digital public goods.[73–75] Over 90 percent of forest reference level (FRL) submissions to the United Nations Framework Convention on Climate Change (UNFCCC) have used FAO's Open Foris[76] and platforms such as System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL)[77] to measure, monitor and report on forests and land use.[78]

The science supporting remote-sensing-based estimations of forest area (change) has also advanced,[79–82] leading to, for example, the use of sample-based estimates rather than pixel counts (map area statistics).*[,80, 82–84] The significance of this improvement is illustrated by Sandker *et al*. (2021),[85] who provided two examples in which pixel-count estimates overestimated deforestation areas by a factor of 3 and 15, respectively. The risk of inaccurate area estimates is especially high where change maps are created through post-classification, an approach prone to error escalation.[86] Although pixel counts were the predominant method for assessing deforestation areas in the early years (i.e. 2014–2016) of FRL reporting to the UNFCCC, countries have gradually shifted towards the use of sample-based area estimates.[87, 88] In 2022, all FRLs submitted to the UNFCCC used sample-based assessments for estimating deforestation, providing a strong indication of improvements in data quality.[89]

The increased availability of satellite imagery, coupled with technical and scientific innovation, has enabled systematic land monitoring at different scales. Globally, this has resulted in freely available global maps of tree cover – such as global forest change[90] and tropical moist forests. Several countries have made use of these global products, especially the global forest-change product,[90] as interim steps in their forest-area-change assessments.[85, 91]

Huge leaps forward have been made in the use of space data by countries for measurement, reporting and verification (MRV). All 84 FRL submissions made by 60 forest countries used Landsat as a primary input and 36 also used data from the Copernicus programme. Moreover, many countries are now using high-resolution imagery from Norway's International Climate and Forests Initiative Satellite Data Programme, particularly for collecting reference data. Twenty-one countries have submitted REDD+ results to the UNFCCC, totalling 13.7 GtCO_2 for results achieved between 2006 and 2021 (or, on average, about 0.85 GtCO_2 per year). This climate action has been driven by technical and scientific innovation enabling sound MRV. Nevertheless, key challenges remain, such as the sustainability of country capacity to use space data and innovative technical and scientific approaches for MRV and to meet emerging MRV accounting standards such as the Architecture for REDD+ Transactions/REDD+ Environmental Excellence Standard.[92] Some of these challenges will be addressed through the new United Kingdom of Great Britain and Northern Ireland-funded Accelerating Innovative Monitoring for Forests programme.

* Pixel counting is the reporting of area statistics directly from maps (regardless of classification errors). Most maps carry errors and biases at all scales, especially for smaller area-change classes, and pixel counts are therefore unreliable. Sample unit observations through visual interpretations of remotely sensed data such as aerial imagery and satellite imagery are typically considered of higher quality than map data and can be used not only to provide information on map accuracy but also to correct map area estimates for classification errors and to calculate the associated confidence intervals around estimates.

biodiversity hotspots and assess the health of forest- and tree-based ecosystems. For example, the TreeGOER ("Tree Globally Observed Environmental Ranges") database[72] offers information on the environmental ranges of most known tree species across 38 bioclimatic, eight

BOX 7 REMOTE SENSING AND ARTIFICIAL INTELLIGENCE

The National Aeronautics and Space Administration of the United States of America and the European Space Agency revolutionized access to satellite imagery through their Landsat and Copernicus programmes by opening their archives and data fully to the public from 2008. This resulted in a rapid increase in data use, catalysed considerable innovation and research, especially in the field of time-series analysis, and facilitated operational solutions for global challenges such as climate change and food insecurity.

More spatial and analytic instruments are expected to become operational in the coming years, increasing the volume of digital information available for near-real-time monitoring of the Earth and its resources. Google Earth Engine is a pivotal example of an integrated technology solution that enabled a paradigm shift over the last decade from desktop to cloud computing.[98]

Recent developments have increased the potential of artificial intelligence (AI) for the analysis of remotely sensed data, and its possible applications in forest monitoring are vast. AI will facilitate the automated analysis of a huge volume of existing and future optical, radar and lidar data collected daily by drones, satellites and space stations. It will also enable unprecedented capability for characterizing and monitoring land-surface changes in near real time, attributing causes to these changes, and producing actionable results with more speed and potential impact than ever before.[99]

The mainstreaming of AI large-language models has transformed the way in which software and other digital tools are developed. Deep-learning algorithms can translate, summarize and correct syntax errors in human-generated programming code, leading to significant improvements in the quality and efficiency of automated processing chains and condensing months of human work into days and even hours.[100]

AI can support efforts to halt and reverse deforestation and degradation. For example, zero-deforestation regulations require traceability to the farm or field scale.[101] Conducting due diligence at such a granular level – that is, delineating individual farms, tracking changes in their borders, and characterizing land cover and even land use – becomes feasible only through the automated processing of vast amounts of data. This level of detail and adaptability can be achieved through the capabilities of AI. AI also has huge potential for the control of invasive mammals, plants and invertebrates.

Many concerns exist about the increased use of AI, such as the potential for it to be used to falsify due-diligence evidence. In general, the use of AI should be based on ethical, transparent and inclusive practices that avoid the risk of generating undesirable outcomes.

soil, and three topographic variables. Where ample representative observations exist, the ranges offer preliminary estimates of suitable conditions, which may be especially valuable for lesser-known tree species facing the impacts of climate change.[72]

Technology can facilitate monitoring led by individuals or communities and help bring expertise and diverse intercultural knowledge systems together. For example, the RSS[16] was based on data analysed by more than 800 experts from 126 countries. The Forest Data Partnership (Case study 3) – the aim of which is to improve the traceability of commodities – is characterized by accessibility and inclusivity: it provides a free public registry for farm/field boundaries and a data pipeline that can use public data, enabling anyone with a smart phone to submit and access georeferenced data associated with the value chain of a given commodity. Technological innovations paired with social innovations are bolstering the engagement of local communities and Indigenous Peoples in forest monitoring and MRV (Case study 5) and fire management (Case study 6).

International collaboration and governance around the coordination of forest data collection and sharing among countries can be complex because of differing interests and policies.[93]

Regional organizations such as the Amazon Cooperation Treaty Organization[94] and the Congo Basin Forest Partnership[95] foster collaboration and data-sharing among countries, promoting the exchange of vital environmental data. Determining who owns and controls the data can be contentious, however, with debates on whether it should be the government or the private sector and whether such data should be accessible publicly or treated as proprietary information.[96, 97] Privacy and security concerns also arise, and balancing transparency with the need to safeguard sensitive data – such as the location of endangered species – is challenging.

In all cases, it is important to close the digital gender gap and the rural–urban divide by setting clear targets for the inclusion of women, youth, Indigenous Peoples and rural communities related to, for example, increased access to smartphones and information and communication technologies, digital literacy, and the use of e-commerce and public services.[46] The links between technological and other innovation types (i.e. social/policy/institutional and financial) are further explored in those sections.

Product/process. Various technologies used to manufacture forest products show promise for helping a shift towards a bioeconomy and the development of sustainable value chains for wood products. Almost anything that can be made from crude oil can also be made from lignocellulosic raw materials such as trees, and NWFPs also have huge potential (Box 8).

Advances in technologies are increasing efficiency in forest value chains (Box 9). Collaborative platforms and digital logistics hubs have redefined supply-chain dynamics, with significant benefits for harvesters, forest contractors and companies (Case study 16). They can help optimize material flow, reduce costs, enhance efficiency through real-time supply-chain visibility, improve communication, reduce the likelihood of errors and delays, and enable timely decision-making. For example, an app developed in Guatemala is increasing the efficiency and accuracy of volume estimates of logs and other wood products, thus enabling wood processors to better control inventories and supporting legal and sustainable supply chains (Case study 15).

There is minimal research on the adoption of technological innovation in the forest sector in the Global South. Opportunities exist for greater uptake to improve sustainable forest management practices and increase the efficiency of value chains, although more research is required to better understand where most effort should be invested to achieve the greatest impact. It is likely that investment in and adoption of relatively low-tech innovations used by some forest managers and processors for many years could reap significant rewards in other locations. Examples include improved grading, logistics, next-level sawmilling equipment, solar-driven dryers and a transition from traditional woodfuel to modern bioenergy.

Biotechnologies. Innovative technologies are being applied to genetic research and tree improvement to increase yields, resistance to disease and adaptation to climate change.[129] Typically, tree breeding is carried out using recurrent selection involving repetitive cycles of breeding, testing and selection. Forest trees exhibit high genetic diversity, are long-lived, and have late sexual maturity and long regeneration cycles, posing unique challenges for breeders.[69] They are also largely undomesticated, and tree-breeders must often work with wild populations rather than known varieties. Conventional tree-breeding, therefore, is a costly and time-consuming process. Advances in genomics and other genetic technologies, however, have enabled a shortening of the tree-breeding cycle from several decades to less than a decade. "Breeding-without-breeding" is based on the identification of superior trees using DNA markers and advanced pedigree reconstruction methods.[130] In addition, selected genotypes can be tested as a routine part of forest management rather than in dedicated field trials.[131] Breeding-without-breeding offers a rapid, low-cost alternative to conventional tree-breeding. Wildlife management is also drawing on innovations in genetic research to understand and protect populations of (especially endangered) species.[132]

Social, policy and institutional innovation

The relationship between social, policy and institutional innovation in the forest sector is dynamic, and the three types are treated together here.

BOX 8 INNOVATIVE WOOD AND NON-WOOD FOREST PRODUCTS THAT COULD CONTRIBUTE TO THE BIOECONOMY

Wood in the built environment. Wood in construction constitutes an option for long-term carbon storage, thus helping mitigate climate change.[102] It is gaining momentum as a preferred material in the built environment, in part because of technological innovations such as mass timber and wood-derived coatings that can replace fossil-based products.[103] Thermally modified, furfurylated and acetylated wood[104] are examples of technological improvements designed to create long-lasting wood products without the use of toxic treating chemicals. Stranding and veneer technologies are enabling the use of fast-grown timber resources such as eucalypt and poplar plantations for mass timber products.[105]

Significant testing has taken place to understand and manage the fire risk posed by the use of mass timber in buildings. Consequently, good models and understanding of the predictable char rate now exist, and policy standards and regulations, such as Eurocode 5 in the European Union and PRG320 in North America, take fire performance into account. A review of large-scale fire tests on cross-laminated timber indicated that, when adequately protected, the use of this material does not contribute significantly to fire risk, although the review also highlighted the need for more research.[106]

Wood biomass for biorefineries. Biorefineries – manufacturing plants that convert raw biomass into raw materials and end products[107] – typically separate the three primary polymers of biomass into cellulose, hemicellulose and lignin. They are increasingly being used as platforms to produce innovative materials and products that can replace fossil-derived resources.

Wood-based textiles. The manufacture of textiles using wood cellulose fibres grew by 6.3 percent annually between 2000 and 2018 (a significantly higher growth rate than for cotton and synthetic fibres), with wood-based textile fibres accounting for 7 percent of the global market in 2019.[108, 109] The next generation of textile fibres will start incorporating recycled textile fibres, thus supporting greater circularity of materials.

Cellulose-based plastics. Cellulose-based plastics are a type of bioplastic manufactured using cellulose or derivatives of cellulose. They are manufactured using softwood as the dominant raw material, although they can also be obtained from agricultural residues such as corn stover and sugarcane bagasse.

Energy storage. Forestry companies are joining forces with battery producers to replace fossil-derived raw materials such as graphite with carbonized hard lignin extracted from wood.[110] Nanocellulose manufactured from biomass is also being used increasingly in electrochemical energy systems – being porous, lightweight and strong, nanocellulose can enable better ion and electron transfer and therefore increase system efficiency.[111]

Platform chemicals. Significant progress has been made in refining wood polymers into platform chemicals using chemical, hydrolytic and biological conversion for diverse applications, from pharmaceuticals to biobased coatings and adhesives. Novel adhesives, coatings and foams are being commercialized to replace fossil materials such as phenol and polyurethane with lignin and nanocellulose.[112–114] This has significant environmental advantages: for example, the use of birch wood at a biogenic technology biorefinery in Sweden to produce wood-based butanediol, a solvent used in chemical industries, emits 52 percent less carbon dioxide than its fossil-based alternative.[115]

Non-wood forest products. Many wild forest-based foods, including fish, are rich in micronutrients and have high nutritional content.[116, 117] New and existing technologies such as multi-elemental analysis, isotopic ratio mass spectrometry, infrared spectroscopy and nanotechnologies are increasingly being used to explore the nutritional value of forest foods for healthy diets.[118] Growing interest among consumers in healthy and sustainable lifestyles has led to the exploration of bioactive compounds and nutritional attributes in non-wood forest products to produce "nutraceuticals" as functional foods and alternative sources of ingredients.[116, 119, 120] Innovative microfiltration techniques have enabled the increased use of natural wax in food, cosmetics, medicine and packaging.[121–123] Forests also contain a huge diversity of insects with potential for use in the rapidly growing edible-insect industry.[124, 125]

BOX 9 TECHNOLOGICAL INNOVATION IN VALUE CHAINS

Technological innovation has brought considerable change to many industrial wood value chains, often increasing their efficiency. For example, digitalization has enabled the development of automated wood-harvesting operations, in which machines use sensors and artificial intelligence to navigate through forests, identify optimal trees for harvesting, and execute the cutting process with precision. This boosts machine productivity and enhances working conditions for machine operators.

Machine vision is also a key technology in sawmills for wood grading and yield optimization. It enables the detection of surface defects in sawnwood such as knots and cracks and thus facilitates automated lumber grading. It also assists edging and trimming processes to eliminate major defects, thereby increasing lumber value. Laser scanning and computed tomography scanning are used in log breakdown optimization to maximize recovery and yield higher-grade lumber. Machine vision technology, therefore, can play a key role in sustainable wood production by reducing waste and maximizing overall yields, with tangible cost savings and a more rapid return on investment for sawmills.

Technological advances have enabled the design and development of "smart" clothes for monitoring the health and safety status of forest workers (e.g. in wood harvesting and processing). These systems provide real-time monitoring of vital signs such as heart rate, body temperature and physical exertion levels and track environmental factors like air quality and temperature. The collected data are then analysed to identify potential health risks and unsafe working conditions. When anomalies are detected, smart clothing systems generate alerts and feedback to workers, enabling them to promptly address and avoid unsafe practices.[126]

Such innovations have been adopted unevenly, both geographically and along forest value chains. For example, the so-called Fourth Industrial Revolution, or Industry 4.0 – that is, the heralded era of connectivity, advanced analytics, automation and advanced-manufacturing technology – is not widespread in the primary wood-processing industry in the United States of America.[127] In Sweden, research published in 2016 showed that, compared with the high automation existing in forest harvesting, automation adoption was low among Swedish wood processors.[128] The equitable deployment of technological innovations in the forest sector globally will require multistakeholder approaches, transparent partnerships and an enabling policy environment, among other things.

Social innovations emerge from interactions among stakeholders to construct solutions to social needs and problems;[133] a key feature is that they involve participation and enhance inclusion.[134] The early involvement of stakeholders from diverse backgrounds in a multidisciplinary approach fosters ownership and generates innovations that reflect their diverse needs and perspectives.

Social innovations can be bolstered by policy and institutional innovations. Policies set the overarching goals and guidelines, which institutions operationalize by adapting, building capacity, monitoring compliance and providing feedback. Institutions can play pivotal roles in aligning policy mandates, cultivating expertise, developing and enforcing regulations, and serving as platforms for stakeholder engagement, collaboration and knowledge-sharing. Feedback loops between institutions and policies enable adaptive management and continuous improvement.[135] Novel methods to encourage co-creation among stakeholders have helped ensure that social innovations fit well with existing political structures, policy frameworks and local users. They include mechanisms for incorporating Indigenous and customary laws into national regulations, participatory approaches to land-use planning, and community-based wildlife conservation. This is of paramount importance to Indigenous Peoples because it is crucial that the rights to their lands, territories and resources are acknowledged and respected.

Achieving global targets such as those related to climate change and biodiversity requires local action,[136, 137] thus encouraging attention to decentralized, locally controlled and contextually tailored solutions. Innovations in the territorial dimensions of forest-sector policies and institutions have focused on enhancing local governance mechanisms, empowering communities, and promoting sustainable forest management practices in specific landscapes and territories. Institutions also have a vital role to play in guaranteeing inclusion in innovation by engaging marginalized groups such as women, Indigenous Peoples, and small-scale farmers and enterprises.

Various landscape and jurisdictional approaches and related underlying tools – such as the Stakeholder Approach to Risk Informed and Evidence-based Decision-making[138] – have been developed in the last decade to support local multistakeholder processes. As attention increases on local knowledge and the legitimacy of the land- and resource-rights claims of local and Indigenous communities, innovations related to managing Indigenous and community-conserved areas and processes for integrating traditional ecological knowledge are emerging. In the Mondulkiri Forest Venture in Cambodia, for example, 13 NTFP collector groups have registered 13 community forest agreements, which have helped the groups avoid conflicts with forest harvesting concessions.[139]

Working together, local actors – including people of different genders, age groups and socioeconomic status – can build institutional capacity, social capital and skills (e.g. through producer cooperatives) that support advances in sustainability.[134] In the planning and implementation of the Great Green Wall (GGW) initiative in the Sahel (Case study 8), innovations such as women-led restoration committees and new mechanisms for consultative and participatory processes have enabled the co-design of more-effective interventions. In Morocco, the government has put in place a programme of financial incentives to encourage forest users organized in grazing associations to respect the exclusion of grazing from restoration sites, with the communities accountable for the protection of their lands; this has helped restore more than 100 000 ha of degraded land (Case study 11). In Paraguay, the government is providing vulnerable forest communities with income support for reforestation under the FAO-assisted Poverty, Reforestation, Energy and Climate Change project.[140]

Hybrid institutions are emerging in the forest sector with innovative models of governance that combine elements of public, private and community-based management structures.[141] Such institutions have greater capacity to integrate diverse stakeholders and foster multistakeholder partnerships, thus promoting more inclusive decision-making.[142] This is observable in collaborative reforestation projects in Costa Rica, where the government provides incentives for private landowners to participate in reforestation efforts and environmental organizations assist with project implementation and monitoring.[143] Some analyses indicate that the forest governance standards created by voluntary non-governmental certification programmes such as those of the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification have influenced certain government policies, laws and enforcement practices.[144]

Other innovations are designed to encourage cross-sectoral, holistic approaches to land-use policies and planning (see, for example, Case study 7) based on increasing awareness of the interconnectedness of land-use sectors and the importance of integrated approaches for sustainable forest management in landscapes.[145] Such innovations include integrated landscape approaches that consider entire ecosystems; ecosystem-based adaptation to climate change; climate-smart agriculture, combining sustainable farming practices with forest conservation; biodiversity offsetting aimed at achieving net gains in biodiversity; and decoupling agricultural supply chains from deforestation. The OECD–FAO Business Handbook on Deforestation and Due Diligence in Agricultural Supply Chains takes the innovative approach of introducing forest-related concepts to the agribusiness domain to help companies define and implement comprehensive policies for addressing the risks of commodity-driven deforestation to benefit their businesses.[146]

Various organizational innovations are helping increase smallholder engagement in forest management and decision-making.[147] Some involve pooling small producers in larger groups to benefit from larger economies of scale. Organizational setups comprising several levels or tiers of participation or decision-making can optimize the value of smallholder-producer goods by improving market terms. Tiered organizational structures enable different functions to be performed at different levels – such as boosting production capabilities and tenure rights locally, adding value and providing services subnationally, and advocating for policy changes at the national and international levels.[148] In the Plurinational State of Bolivia, El Ceibo, a first-tier producer group representing 1 300 cocoa-producing forest farmers,[149] belongs, in turn, to a second-tier association, COPRACAO, which negotiated with the government for the introduction of a USD 37 million incentive programme that is now benefiting smallholders. In Viet Nam, local cooperatives have formed larger subnational umbrella organizations to boost value-adding, incomes and employment; for example, cinnamon-grower groups such as the Viet Nam Cinnamon and Star Anise Cooperative belong to the Viet Nam Farmers' Union, which has helped improve market access, decision-making and sustainable resource management for smallholder cinnamon producers nationally.[150]

Innovations can increase the access of small producers to markets and larger processing companies. For example, apps for mobile phones can enable producers to make direct connections with buyers and provide market insights and transaction support. Aggregator models such as cooperatives enable small producers to achieve larger product volumes to meet market demand, helping them bypass intermediaries and secure better prices. Digital registries can enhance access to social protection and formalized employment. For example, the Forest and Farm Facility (FFF) facilitated the integration of information from 450 impoverished charcoal producers in Kenya into the Enhanced Single Registry by the National Social Protection Secretariat, thus enabling them to access a monthly USD 30 cash transfer per family through the National Drought Management Authority's emergency drought response programme.[151, 152]

Collective groups of smallholder producers have implemented new benefit-distribution mechanisms and financial oversight to help ensure reinvestment in local priorities. In Brazil, the COOMFLONA cooperative allocates profits from wood and NWFPs towards various funds, including those for healthcare and education, which mostly benefit COOMFLONA members.[153] In Ethiopia, the Aburo Forest Managing and Utilizing Cooperative sells frankincense and maintains transparent financial management through an audit committee.[154] Innovations are also emerging in conflict resolution, justice and tenure security. For example, the La Myang Community Forest Rattan and Bamboo Group Business in Myanmar is resolving conflicts over natural resource use through the legal registration of community forests and the subsequent development of businesses.[155]

Promoting gender-responsive policies, gender-balanced employment opportunities and the implementation of gender-sensitive monitoring and evaluation mechanisms are policy and institutional innovations to ensure the integration of gender considerations. Forest management committees in India's Joint Forest Management programme mandate a minimum female representation of at least one-third of committee members to ensure representation in decision-making processes.[156] In Nepal, it is mandatory for community forest user groups to have strategies for achieving a 50 percent gender balance in their executive committees.[157] Organizational innovations to increase youth engagement include tailored capacity-development programmes, using technology and social media platforms, ensuring youth representation in decision-making forums, conducting educational campaigns and offering internships.

Innovative tools and approaches for forest monitoring are strengthening relationships among local communities, Indigenous Peoples, civil-society organizations and policymakers. ForestLink[158] and Global Mangrove Watch[159] use mobile-phone technology and satellite communications to enable communities to report illegal logging activities in real time. The LandMark[160] platform equips Indigenous and community groups with tools for mapping and documenting their lands (Case study 5), helping reinforce customary claims in forest-rich regions. In China, the "ecological forest ranger" policy provides job opportunities and social protection for poor farmers, complemented by training and skills development; when trained, these rangers patrol at-risk forests, report on forest disasters, and prevent potential damage and destruction of forest resources. The policy highlights important linkages between the five innovation types and has had the dual benefit of alleviating poverty and improving environmental outcomes.[138, 161]

Financial innovation

Financial innovations in the forest sector are increasing, largely to address the need to leverage more finance than currently allocated to forestry; incentivize the transition towards a greener economy; make finance more accessible to small producers; and recognize the value of ecosystem services. Investors view forestry projects as risky, mainly because of factors such as the extended production cycle required to yield high-quality timber and, particularly in the Global South, the informal nature of many forest-related activities.[129, 162–164] A recent review[165] identified the following means for increasing finance in tropical landscapes: an enabling institutional environment; technical assistance; and bringing together diverse funding sources through financial instruments managed by fund managers or project coordinators and using strategies to address scale, risk and investor expectations of returns.

Public (both domestic and international) finance is still the main source of finance for forests and other nature-based solutions.[162] Innovations to leverage more finance from national sources include fiscal reforms, incentives, and sustainable financing schemes with local financial institutions.

New transfer mechanisms for public finance have been developed. In Burkina Faso and the Niger, an innovative investment scheme in FLR and sustainable land management projects is transferring green finance directly to local authorities – in contrast to traditional funding schemes, which tend to pass through project-implementing agencies and non-governmental organizations.[166]

Engaging the private sector in general and private finance in particular can increase the finance available for sustainable forest development and conservation. Such engagement has led to the development of blended-finance models involving, for example, guarantees, green bonds and venture capital and various debt and equity instruments. Innovative developments in pension funds have helped integrate sustainable forest management and conservation principles into investment practices. Pension funds increasingly consider environmental, social and governance factors, engage in impact investing, and support green bonds and sustainable investments focused on the forest sector.

Other innovations are aimed at making finance more environmentally and socially responsible by incentivizing measures to reduce the environmental footprint of investments. Innovations in impact investment in the forest sector are channelling capital towards conservation and sustainability while also generating financial returns. An example is forest resilience bonds, which provide finance for restoration projects and generate returns based on achieved environmental outcomes.

Investors increasingly recognize that financial returns alone are insufficient to evaluate the true sustainability of businesses, especially given heightened environmental risks (as outlined, for example, in the World Economic Forum's Global Risks Report[167]). Sustainability and climate considerations are becoming key criteria for many financial institutions and companies and are increasingly included in their decision-making and reporting. Innovations such as SCRIPT (Soft Commodity Risk Platform), the Task Force on Nature-Related Financial Disclosure, and Trase Finance are designed to increase transparency and mitigate risks associated with environmental impacts and deforestation in soft-commodity supply chains and investments. In collaboration with Global Canopy, FAO is pursuing common rules or standards for "deforestation-free" and "forest-positive" finance.[168, 169]

There have also been innovations in sustainability-related financial reporting standards: for example, the International Sustainability Standards Board has issued the first two IFRS® Sustainability Disclosure Standards (more than 100 countries require companies operating in their territories to use IFRS standards). Australia plans to implement mandatory climate-related financial disclosure requirements, and the European Union has established the Sustainable Finance Disclosure Regulation to promote informed investment choices. The European Union Taxonomy provides a framework for identifying environmentally sustainable economic activities, influencing a transition towards sustainability.[170] Platforms such as FinanceMap and accountability frameworks such as the Accountability Framework Initiative are designed to foster transparency and adherence to sustainable practices in the financial sector.

Finance is being mobilized to reach and help develop the "missing middle",[171] such as small and medium-sized forest enterprises and forest-dependent communities (including Indigenous Peoples), through the development of last-mile financial infrastructure and innovative products better suited to individuals and communities in remote areas.[163, 164, 172] These include tailored financial products, microfinance initiatives and community investment models. Mobile banking has improved financial inclusion significantly. Cooperative models, village savings-and-loan associations and alternative collateral models are being piloted among forest and farm producers and their organizations, with promising results.[173] In Viet Nam, the FFF has facilitated the development of "green funds", an innovative microfinance mechanism that does not require collateral and increases finance availability for small-scale producers (Case study 13).

Traditional financing mechanisms often fail to address market failures related to environmental externalities and the public goods provided by forests. The United Nations Environment Programme (UNEP) estimated that nature-negative financial flows to agriculture in the form of price incentives and fiscal transfers amounted to USD 500 billion in 2022, more than three times the finance for nature-based solutions (nature-positive flows) (USD 154 billion).[162] Innovations aimed at incentivizing the financial sector through better public policies include re-allocating nature-negative subsidies and accounting for and incorporating the social and environmental costs associated with products and activities that negatively affect forests. Innovations in natural capital accounting (which assigns economic values to ecosystem services provided by forests) are emphasizing the integration of ecosystem services valuation and spatial analysis techniques and attempting to integrate social and cultural values associated with forests and mainstream natural capital accounting into policy processes.

Many ecosystem services lack established markets. Operators in forest-based value chains therefore face challenges accessing private finance because their contributions to essential public goods such as ecosystem services go unrewarded, creating an uneven playing field. Innovations have arisen to leverage finance based on markets for ecosystem services (e.g. environmental-performance-based models associated with carbon, water and biodiversity, sometimes called payments for environmental services). In Mozambique, a long-term project is underway to incentivize agroforestry through new carbon trading opportunities (Case study 12); in Uganda, the Sawlog Production Grant Scheme is providing landholders with incentives for reforestation applied through carbon credits.

REDD+ has spurred several financial innovations to incentivize forest conservation and associated greenhouse-gas emission reductions. A key component of REDD+ finance is results-based payments, in which countries receive payments based on verified emissions reductions. The Green Climate Fund was the first source of REDD+ results-based payments under a USD 500 million pilot programme, which approved results from Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Indonesia and Paraguay. Related innovations include the establishment of carbon markets for buying and selling carbon credits generated from REDD+ projects and programmes; finance mechanisms such as green bonds and impact investment funds; jurisdictional and nested REDD+ approaches that link and aggregate projects at different scales and distribute financial benefits to subnational governments, local communities and project implementers; and private-sector engagement through partnerships and corporate investments in REDD+. Innovations in MRV systems, as described earlier, are crucial for verifying results and ensuring transparency in REDD+ finance. ■

3.3 FOUR FACTORS FORM BARRIERS TO SCALING UP INNOVATION

Barriers to the development and uptake of innovations in the forest sector – (1) lack of innovation culture; (2) risk; (3) potential limitations in various forms of capital; and (4) unsupportive policies and regulations – are described below.

Lack of innovation culture

An innovative culture is one that encourages curiosity, creativity and risk-taking,[174] but the prevalent culture may be unfriendly to new ideas and "outsiders", thus limiting the scope of innovation and the willingness to adopt new tools, products, processes and approaches. The various actors in an innovation ecosystem (see Box 5) have strategies and trajectories they tend to defend; such "path dependence"[175] can work against change because vested interests will protect their historical positions and market share.[176] This can have the effect of quelling innovations through market control and lobbying before they have a chance to get off the ground. In some cases, an industry might even fund organizations to suppress innovations from outside their sector as a means for maintaining their positions.[177] Disrupting existing systems to enable innovation is a significant challenge.

A cultural shift may also be required away from the historically dominant view of innovation as primarily a means for improving efficiency, economic gains and competitiveness towards a more aspirational approach. This would acknowledge that innovation is multifaceted and should enable the realization of wide-ranging goals and values, such as those related to viable livelihoods, social well-being and resource conservation and sustainability. A culture that recognizes and embraces the transformative potential of innovation can help de-risk innovation processes and empower stakeholders to look beyond business as usual to respond to current and future challenges. All forest stakeholders can play a role in promoting and supporting an innovation culture that seeks to tackle problems in ways that minimize negative consequences and address the structural barriers to gender equality and women's empowerment.

In many contexts, therefore, developing an innovative culture may require a boost – that is, something that drives the development of skills, routines, behaviours and connections with other actors in an innovation ecosystem that will facilitate innovation creation and adoption. Tools are available to help develop an appropriate environment for sustaining an innovative culture, such as the Create Incentives and Opportunities tool developed by the UN Innovation Network, which presents techniques that can be used to encourage innovation and ultimately to build, within an organization, a culture that fosters innovation.[178] For example, recognizing and rewarding innovation can help foster a conducive culture, and so can incentivizing innovative behaviours by upskilling individuals and aligning projects with personal values and interests. Crucially, an innovation culture also requires the dedication of sufficient time and resources to "being innovative".

Risk

Innovating is inherently risky, with a significant proportion of innovations – perhaps as high as 95 percent[179] – failing to meet the expectations of stakeholders. Avoiding the risks posed by innovation can reinforce path dependence in an innovation ecosystem and hamper innovation creation and adoption (Box 10). The introduction of new products or processes involves a range of transaction costs, and the risk of failure must be considered, particularly in low-capital

BOX 10 THE EXAMPLE OF KATERRA

The mass-timber manufacturer Katerra, a start-up construction company, promised to revolutionize building construction in the United States of America through a new business model of vertical integration and modularization involving mass timber. Although the overall business concept of factory-built housing has significant promise, the company declared bankruptcy in 2021 after investing over USD 2 billion.[181] Other mass-timber manufacturers in North America also declared bankruptcy or ceased operations between 2021 and 2023.
The construction sector is tied heavily to existing relationships and accepted ways of doing business, each of which serves to resist change – it is often easier to continue doing business as usual rather than developing a new relationship with the supplier of a substitute product.

and low-risk-tolerance contexts. Moreover, the adoption of an innovation without proper consideration of the context (that is, whether it is the right innovation for the right place for the right reasons) can have negative impacts. For example, innovations designed for large-scale operations may provide economies of scale for larger companies and increase their competitive advantage, putting at risk smallholders and other marginalized groups and communities.[129] Such risks might be mitigated by facilitating the access of marginalized actors to innovation creation and incentivizing the development of scaled-down and context-appropriate innovations suitable for smaller-scale operations.

In some instances, innovation may be more likely to succeed when the incorporation of traditional or Indigenous knowledge is prioritized. In the realm of data-driven technological innovations, specific risks can also emerge associated with the collection, use and ownership of data, such as those related to market concentration and interactions between smallholders and larger companies and organizations. Policies and regulations can be used to help prevent the emergence of disparities and the unequal distribution of benefits arising from the adoption of technological innovations.[71, 180]

While favouring stability in the short term, prioritizing risk reduction may hamper the innovation necessary for adaptation to evolving environmental conditions, market demands and technological advances. Governments and other stakeholders can help achieve an appropriate balance between risk and stability by supporting opportunities for learning about innovation creation and adoption processes and fostering collaboration.

Potential limitations in various forms of capital

A study by Roshetko *et al.* (2022) on the uptake of innovative forest-sector technologies in the Asia-Pacific region identified potential limitations in various forms of capital – human, natural, physical, financial and social – as a barrier to adoption (Table 4) (the same study cited unsupportive policies and regulations as an additional barrier).[129] This finding is likely to be relevant in other regions and for other innovation types, especially in the Global South. Different countries and regions may be subject to different limitations in the five forms of capital. For example, financial capital may be materially limited in one region and natural capital (e.g. a lack of access to forests and forest products) may be a more significant limitation or barrier in another.

Just as products can be designed for easy disassembly (e.g. to improve the potential for circularity), design for adoption can increase innovation success. One-size-fits-all approaches are bound to end in failure – for example, digital solutions are unlikely to be of use to people with limited access to electricity or the internet (i.e. lack of physical capital). The high cost of

TABLE 4 FIVE FORMS OF CAPITAL, THE LACK OF WHICH COMPRISES A BARRIER TO THE UPTAKE OF INNOVATIVE TECHNOLOGIES BY THE FOREST SECTOR IN THE ASIA-PACIFIC REGION

Human capital	Lack of skills, knowledge and experience; wariness of "new" innovations; uncertainty about potential for unintended impacts arising from innovation adoption
Natural capital	Limited access to forests, land and natural resources and their assets and products
Physical capital	Lack of infrastructure such as roads, markets, electrical power and internet; lack of resourcing to "scale down" and adapt innovations to suit the contextual needs of diverse stakeholders from the bottom up
Financial capital	Limited access to financial capital, credit and value chains
Social capital	Restrictive governance and tenure rights for forests, land resources and their assets and products; limited access to information; lack of transparency; limited participation in decision-making

SOURCE: Adapted from Roshetko, J.M., Pingault, N., Quang Tan, N., Meybeck, A., Matta, R. & Gitz, V. 2022. *Asia-Pacific roadmap for innovative technologies in the forest sector.* Rome, FAO & Bogor, Indonesia, Center for International Forestry Research, CGIAR Research Program on Forests, Trees and Agroforestry.

many innovations restricts their adoption to those with significant resources (financial capital),[182] and top-down approaches are also unlikely to succeed, even if well-designed (social capital). For example, the widespread adoption of improved cookstoves that reduce indoor air pollution and fuel consumption[183] has been hindered by high upfront costs, resistance among users to changing their traditional cooking habits, and the lack of tailored solutions to meet specific community needs; moreover, there has been a lack of recognition of the role of smoke from traditional fires in repelling insects.[184, 185]

A lack of social capital has hindered many innovative forest restoration projects, contributing, for example, to poor planning, inappropriate species selection, poor land preparation, and difficulties in ensuring community engagement and participation (a lack of long-term funding – financial capital – has been another major obstacle).[186, 187] A lack of social capital (e.g. insufficient market access and a lack of training and capacity development) is also a significant contributor to poor success rates in innovations promoting alternative livelihoods based on forest resources such as ecotourism, NWFPs and sustainable wood harvesting, along with a lack of financial capital related to market fluctuations and limited demand for forest-based products beyond local or niche markets.[188, 189] A lack of customary access to land and resources (natural capital) can inhibit the engagement of local communities and Indigenous Peoples in forest-sector innovation.

Unsupportive policies and regulations

The study by Roshetko *et al.* (2022) found examples (in Asia and the Pacific region) of where policy development has lagged the development of technologies and lacked the necessary flexibility and reactivity to enable technology adoption.[129] This is an inherent problem for innovation because, almost by definition, innovations emerge in an existing environment of policies and regulations, which may act to restrict or distort innovation uptake or, in contrast, enable unregulated, potentially risky developments from innovations. This shows the importance of continuously adapted policy and regulatory environments for harnessing innovation. ■

3.4 INNOVATION CAN CREATE WINNERS AND LOSERS, AND INCLUSIVE AND GENDER-RESPONSIVE APPROACHES ARE NEEDED

Policymakers tend to treat innovation as inherently good, with more being better. But innovation may create winners and losers, and it can be accompanied by the loss of entire sectors, the bankruptcy of companies, and the loss of jobs. Moreover, the transformations brought about by innovations can harm the most vulnerable groups and communities,[190] who often have the least capacity to adapt to the ensuing rapid change.[191] For example, improved remote-sensing technologies and techniques are difficult for some to access and use and, in the worst cases, can make it easier for unscrupulous actors to locate the targets of their nefarious activities, such as high-value trees. Improvements in – and the lower cost of – consumer goods can lead to increased consumption (which can be considered undesirable in many contexts).[192]

It is important, therefore, that innovations promote (or, at the very least, are consistent with) economic, social and environmental sustainability; efforts should be taken to avoid unintended consequences and potentially harmful impacts. The concept of "responsible innovation" is an aspirational approach involving a transparent and interactive process by which diverse actors and innovators mutually seek to ensure the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products.[193] It also involves inclusion, which means taking into account and integrating the diverse realities, perspectives, needs and rights of all stakeholders, including local communities, Indigenous Peoples, women, youth and poor and marginalized groups. To ensure that new developments suit the needs of users and minimize potentially harmful impacts, it is essential that traditionally excluded people have a voice.

The integration of diverse views and perspectives, including from outside the forest sector, leads to differential thinking arising from, for example, different knowledge bases, thinking styles and experiences.[194] In other words, the diversity of stakeholders – and power differentials among them – will determine, in part, the diversity of ideas and potential partners that emerge. Moreover, the uptake of innovation among diverse groups is much more likely if those groups were involved in creating the innovation in a truly inclusive way. The potential for innovation, and its uptake, grows as the network of interactions broadens and diversifies. A supportive and conducive culture is an important determinant of innovating responsibly.

Regardless of whether innovations come from inside or outside the forest sector, or whether they involve new technologies and processes or the adaptation of proven solutions in a new context, efforts must be made to avoid perverse impacts. Potential means for avoiding the pitfalls of innovation include learning from other experiences, adopting best-practice principles, and putting safeguards in place. Innovating responsibly provides a way forward for creating a more resilient and sustainable forest sector. ■

PAPUA NEW GUINEA
Innovating tradition to protect ancient forests with the AIM4Forests programme. Technological innovation has vastly improved our ability to monitor the world's forests.
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CHAPTER 4
EIGHTEEN CASE STUDIES ILLUSTRATE THE DIVERSE WAYS IN WHICH FOREST-SECTOR INNOVATION CAN BRING ABOUT POSITIVE CHANGE

KEY MESSAGES

➔ **The presentation of case studies is an important means for exploring and demonstrating the potential of forest-sector innovation.** Examples examined here showcase cutting-edge processes, tools and technologies in various regions and at various scales, providing evidence and knowledge and generating lessons that can be applied in diverse contexts worldwide. They are organized in three categories aligned with forest conservation, restoration and sustainable use.

1. **Innovations are assisting efforts to halt deforestation and maintain forests.** These include a model for fostering multistakeholder governance to scale up integrated sustainable landscape management in Kenya and Nigeria; the use of new data on the role of forests in agricultural productivity to finance forest conservation in Brazil; harnessing the power of partnership and technological innovation to reduce commodity-driven forest loss in Ghana; the introduction of new tools and techniques in community forest management in Colombia; and combining science, technology and traditional knowledge to support Indigenous Peoples as forest custodians and enable locally led integrated fire management.
2. **Innovative approaches are bolstering the restoration of degraded lands and expanding agroforestry.** They include developing a new national policy to better support agroforestry in India; integrating the socioeconomic objectives and nutritional needs of local communities with restoration to combat desertification in the Great Green Wall of the Sahara and the Sahel; the use of geospatial and other digital technologies to collate and disseminate restoration good practices and monitor progress in the implementation of the United Nations Decade on Ecosystem Restoration; enhancing the resilience of traditional water taro gardens in Vanuatu by incorporating new technologies, practices and plant varieties; improving the local governance of forest resources to deliver benefits for agriculture and forest restoration in Morocco and Tunisia; and a long-term project to link agroforestry with carbon trading in Mozambique.
3. **Innovations are helping to sustainably use forests and build green value chains**. They include delivering collateral-free microfinance to small forest businesses through the power of collective organizations in Viet Nam; using new diagnostic tools and methodologies to catalyse legal-reform processes for sustainable wildlife management in 13 African countries; harnessing digital technologies to improve the efficiency of timber-tracking and promote sustainable supply chains in Guatemala; improving connectivity along timber supply chains to reduce waste and increase the viability of sustainable forest management in Brazil, Guyana, Panama and Peru; applying new wood-processing technologies in Slovenia and the United States of America to promote a bioeconomy and enhance earthquake resilience; and enabling farmer-led innovation in sustainable forest and agricultural production through Farmer Field Schools.

This chapter presents 18 case studies of forest-sector innovations drawn from submissions made by FAO staff and partner organizations on their work. They comprise a cross-section of cutting-edge processes, tools and technologies in various contexts globally, organized in three pathways: forest conservation, forest restoration, and sustainable forest use (although many contribute to two or three of the pathways). Each case study can be viewed as a bundle of innovations because each involves more than one innovation and innovation type (i.e. technological, social, policy, institutional and financial, as described in Table 3). For each case study, the authors have subjectively rated the relative importance of each type with a score of 1 to 10, represented illustratively with different-sized leaves.

4.1 INNOVATIONS ARE ASSISTING EFFORTS TO HALT DEFORESTATION AND MAINTAIN FORESTS

Halting deforestation would cut greenhouse-gas emissions significantly[1,v] while helping safeguard most of the Earth's terrestrial biodiversity and maintain key ecosystem services. New science has illustrated the dramatic cooling effect of forests through a range of non-carbon biophysical processes such as evapotranspiration, albedo, aerosols and volatile organic compounds and estimates that tropical forest conservation could provide 20–40 percent more global cooling than previously thought.[195] This additional mitigation of climate effects is complemented by the role of forests in regulating rainfall and stabilizing local to more-distant climates, thereby helping minimize extreme weather and making forests essential for climate-change adaptation and resilience. Future agricultural productivity, especially in the tropics, depends partly on the climate regulatory services that forests provide.

v At current rates of greenhouse-gas emissions.

Global, regional and national efforts to halt deforestation and maintain the world's forests have produced a proliferation of innovations, such as major advances in real-time forest monitoring to enable REDD+ results-based payments and the growth of forest carbon markets. Advances have also been made in the traceability of key commodities towards deforestation-free production, as well as policy innovations to bridge sectors through integrated landscape approaches. Improved understanding of the key forest stewardship roles played by Indigenous Peoples and local communities has fostered innovations towards greater inclusion in policymaking and forest finance.

The following six case studies present innovations aimed at increasing the quality of, and access to, forest-monitoring data and improving land-use planning and management as means for halting deforestation and maintaining forests.

CASE STUDY 1 FOSTERING MULTISTAKEHOLDER GOVERNANCE MECHANISMS TO SCALE UP INTEGRATED SUSTAINABLE LANDSCAPE MANAGEMENT

Location: Kenya, Nigeria

Partners: FAO, Global Environment Facility (GEF), Kenya Forest Service, Kenya Agricultural and Livestock Research Organization, Forestry Research Institute of Nigeria, Nigerian states' REDD+ units, Solidaridad Network

WEIGHTING OF INNOVATION TYPES

The context. The lack of coordination among land-use sectors and stakeholders has hindered efforts to balance forest-related and agricultural goals at the landscape and national scales. In Nigeria, the production of valuable agricultural crops such as cocoa and palm oil has led to serious environmental degradation, including deforestation and a reduction in ecosystem services. In Kenya, the Mount Elgon water-tower landscapes, which are crucial for sustaining local economies and livelihoods, are under threat from agricultural expansion, illegal logging and other human-induced pressures. Integrated landscape approaches linked closely to national policy development and action are helping improve multistakeholder governance mechanisms for solving these and other shared problems. They are also providing opportunities to reduce trade-offs and increase synergies between agriculture and forestry.

The innovation. New methods of internal organization and collaboration are required to achieve long-term sustainable solutions to complex challenges like agriculture-driven deforestation. FAO's Participatory Informed Landscape Approach (PILA) demonstrates how the principles of cross-sectoral collaboration can be embodied in the design and implementation of interventions to improve outcomes on the ground. PILA is a guided, structured and tailored approach that brings together a complementary suite of FAO's state-of-the art tools and methodologies to support integrated landscape management for informed decision-making. Under PILA, countries obtain technical support and expertise from the realms of forestry, crop and livestock production, land and water resources, geospatial data, transformative governance, tenure, finance and multistakeholder processes. By building technical and institutional country capacity, PILA supports landscape stakeholders (including governments and producer organizations) in planning their landscape management in an integrated, inclusive and fit-for-purpose way. Through holistic landscape assessment, PILA captures trustworthy data from household surveys and satellite imagery, working cross-sectorally to ensure better-informed and more-integrated decision-making.

PILA represents an organizational and cultural shift in FAO's provision of support for countries on two fronts. First, it emphasizes inclusiveness throughout the process while enhancing system-wide national capacity to foster country ownership and commitment. Second, it includes and integrates all relevant sectors (e.g. agriculture, environment and planning) at the national level and across FAO technical divisions. Moreover, PILA connects landscapes to national processes by empowering producer organizations to develop their capacities and access new markets and sustainable finance to promote deforestation-free and inclusive commodity value chains, thereby building momentum to achieve desired impacts at scale (Figure 7).

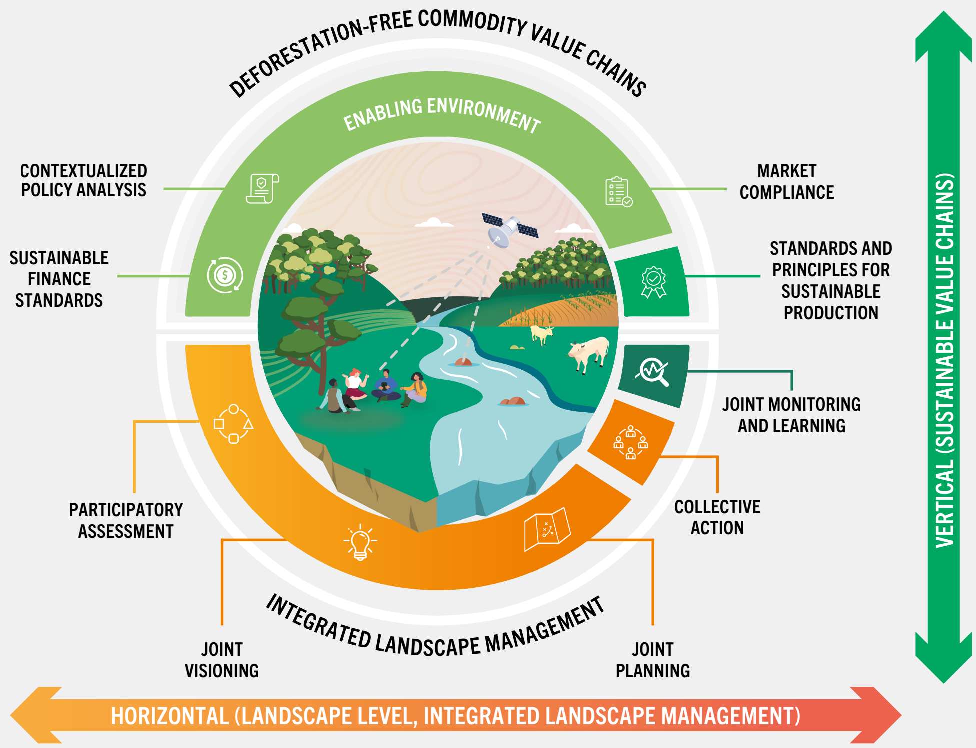
Results and impacts. PILA is being piloted in Kenya and Nigeria under the GEF-7 Impact Program on Food Systems, Land Use and Restoration (FOLUR) to foster greater cross-sectoral collaboration in

CASE STUDY 1

developing and implementing integrated and inclusive landscape management plans. In Kenya, ecosystem restoration and community-based natural resource management in the Mount Elgon water-tower landscapes will be enhanced through integrated participatory planning processes that are strengthening the involvement of local communities in evidence-based decision-making. To enable the landscape visioning exercise and the co-development of sustainable transition pathways, stakeholders require a clear understanding of existing (and future) opportunities in their landscapes for more sustainable production, management, conservation and restoration practices. The application of PILA is also improving the mapping of Kenya's restoration potential (identifying areas where ecosystem restoration is biophysically suitable and most cost-effective) by integrating field data in a geospatial model developed using FAO's Open Foris suite.[76] In Nigeria, PILA is enhancing state-level and local government capacity in integrated geospatial analysis and, in close collaboration with state-level REDD+ units, improving access to high-quality spatial data for better-informed integrated landscape management.

Potential for scaling up. Using a programmatic approach, 25 FOLUR country projects in four regions are expected to strengthen national frameworks for integrated landscape management. PILA is providing innovative support for integrated landscape management targets and their scaling up to the national level. It can be applied across landscapes, commodities and food systems in a demand-based manner, especially addressing agriculture–forestry linkages. The aim is to transfer successes to other countries. PILA could also be replicated in other existing programmes (e.g. the World Bank's Global Partnership for Sustainable and Resilient Landscapes and the GEF-8 Food Systems Integrated Program) that are supporting countries in their integrated land-management and planning processes, guiding the transition towards more diversified and sustainable value chains.

FIGURE 7 A SCHEMATIC OF THE PARTICIPATORY INFORMED LANDSCAPE APPROACH



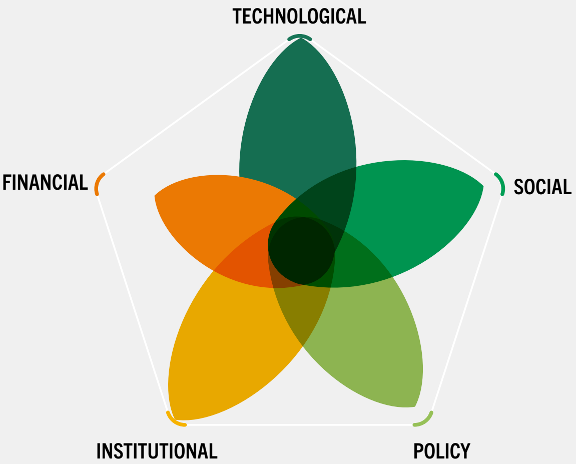
SOURCE: Case-study authors' own elaboration.

CASE STUDY 2 USING NEW DATA ON THE ROLE OF FORESTS IN AGRICULTURAL PRODUCTIVITY TO FINANCE CONSERVATION ON AN AGRICULTURAL FRONTIER

Location: Brazil

Partners: Woodwell Climate Research Center, Amazon Environmental Research Institute

WEIGHTING OF INNOVATION TYPES



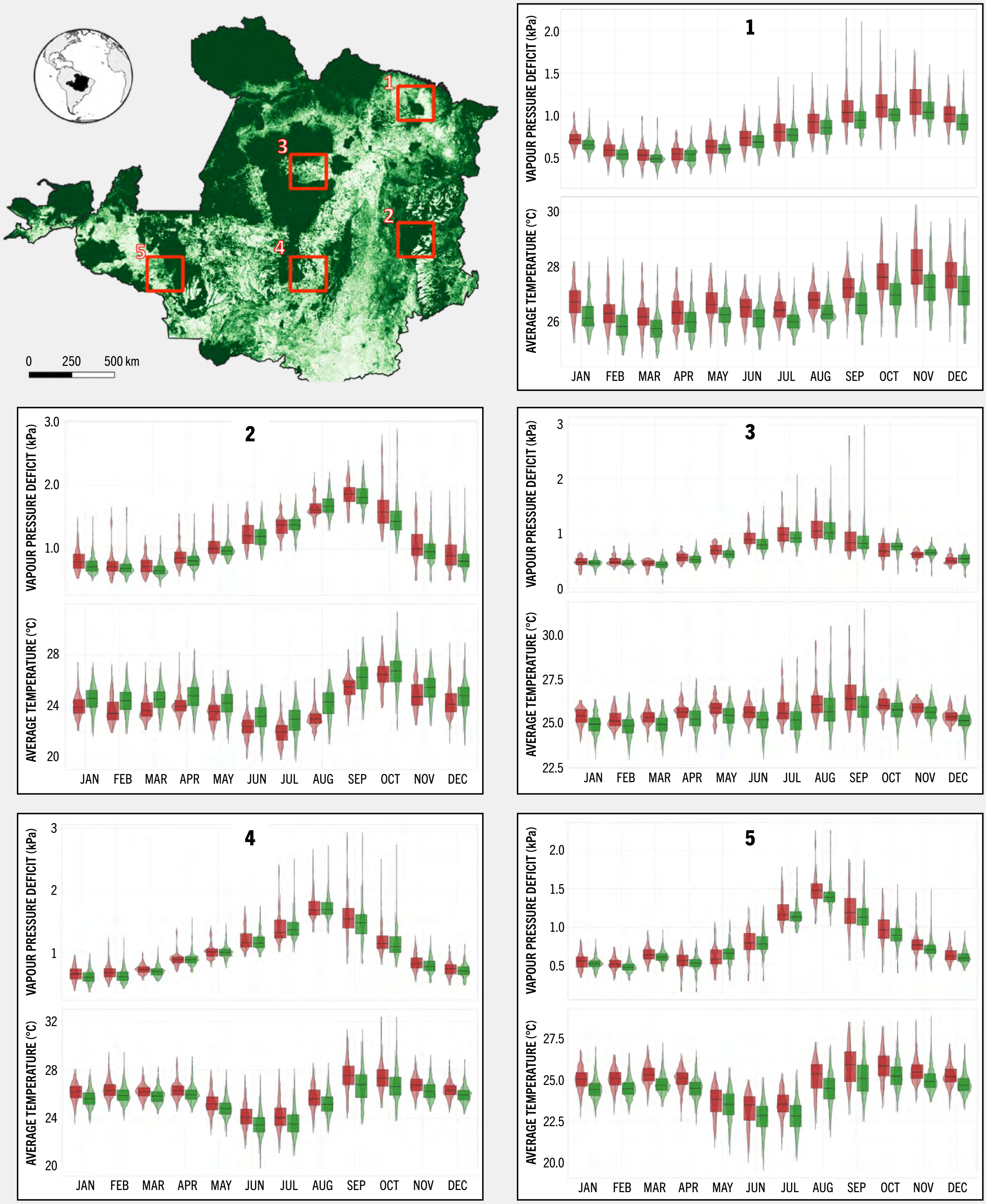
The context. More than 13 percent of Brazil's Amazon–Cerrado Region (ACR, the region comprising the confluence of the Amazon and Cerrado biomes) was cleared for agriculture between 1985 and 2022, including the loss of 5.18 million ha of forests and woodlands.[196] Commodity production plays a vital role in the Brazilian economy: in 2022, for example, record soybean harvests[197] resulted in a 2.9 percent increase in the country's gross domestic product, with associated increases in export revenues. Conversely, deforestation caused by increasing commodity production leads to rises in local temperature and higher vapour pressure deficits, which ultimately reduce crop yields (Figure 8).[198] On average, the percentage of forest cover in the ACR explains 30 percent of the differences in soybean yields across different landscapes due to the cooling benefits provided by forests. Moreover, deforestation reduces the resilience of agricultural crops and livestock during heatwaves and prolonged dry spells – thus, despite an increase in the area under agriculture, overall production may decrease, outweighing any fleeting advantages of deforestation and jeopardizing the long-term goal of enhancing agricultural productivity.[198]

Given the increased intensity of extreme weather events,[199] the benefits of retaining remaining forests in heavily cultivated Amazonian and Cerrado production landscapes are becoming clearer. Economic incentives for forest retention are available, such as the Brazilian government's ecological value-added tax (ICMS) and international REDD+ results-based payments,[200] but more are needed to prevent further deforestation and to support production intensification in already-developed areas.

The innovation. Digital innovations are helping advance understanding in Brazil of the benefits of forests (beyond carbon storage and sequestration) for buffering climatic extremes, including MODIS products such as Land Surface Temperature and Evapotranspiration, TerraClimate's monthly climatic water balance data for global terrestrial surfaces, and MapBiomas's land-use and land-cover data. Tools such as Google Earth Engine and new R packages are facilitating the processing and analysis of the huge volumes of data required for these insights. For example, new digital products have made it possible to determine that regions in the Brazilian Amazon with forested Indigenous territories experience temperatures that are, on average, 2 °C cooler than unprotected areas that are subject to higher deforestation rates.[201]

Results and impacts. The increased knowledge derived from the new digital products makes it possible to better design landscapes that maximize climate resilience and agricultural productivity, for example by indicating the area of forest needed to regulate climate for optimum agricultural production and to ensure connectivity between forest areas to ensure biodiversity conservation. Advances in knowledge and tools are enabling better compliance with environmental laws such as Cotas de Reserva Ambiental (Environmental Reserve Quotas) and Lei para Proteção da Vegetação Nativa (Native Vegetation Protection Law).

FIGURE 8 DEFORESTATION IN THE AMAZON–CERRADO REGION AFFECTING VAPOUR PRESSURE DEFICIT AND MEAN TEMPERATURE IN LANDSCAPES WITH DIFFERING LEVELS OF AGRICULTURAL INTENSIFICATION, OVER A CALENDAR YEAR



NOTE: Observations in deforested areas are in red and observations in forested areas are in green. 1 = Capitão Poço-PA; 2 = Formosa do Rio Preto-BA; 3 = São Félix do Xingu-PA; 4 = Querência-MT; and 5 = Sapezal-MT.

SOURCE: Case-study authors' own elaboration; (map) MapBiomas Project. 2024. Collection 8 of the Annual Series of Coverage and Land Use Maps of Brazil. In: *MapBiomas Brazil*. https://doi.org/10.58053/MapBiomas/VJIJCL and Climatology Lab. 2024. Terraclimate. [Accessed on 14 June 2024]. https://www.climatologylab.org/terraclimate.html Licence: CC0 1.0 UNIVERSAL.

Initiatives like the CONSERV project, which is led by the Amazon Environmental Research Institute, are leveraging mapping capabilities to identify native vegetation surpluses, thereby offering incentives for rural producers to protect forests on their land. CONSERV uses various techniques, such as incorporating technological innovations, providing financial incentives, and enforcing effective mechanisms to prioritize forest conservation in sustainable production practices. To date, it has enabled protection of about 21 000 ha on 23 private properties, potentially averting 2.2 million tonnes of carbon-dioxide emissions. In the past, monitoring environmental restrictions mandated by law was a bottleneck in the nationwide Cotas de Reserva Ambiental system.[202] With the improved technology, however, it is now possible to prioritize areas to maximize local-level climate-change mitigation.

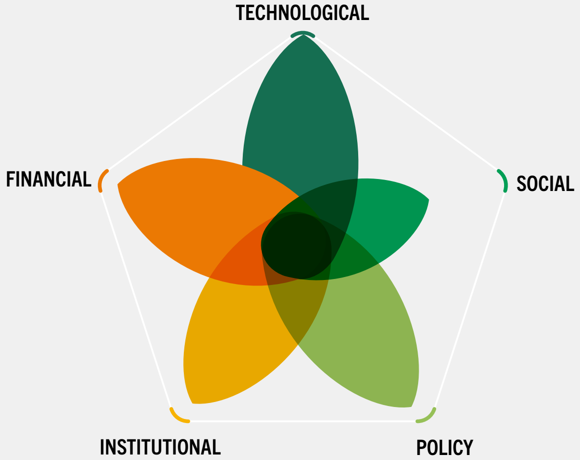
Potential for scaling up. Estimating the value of forests for agricultural production can create new income streams for landowners with potential to cover the opportunity costs of not opening up new forest areas to agriculture. International financial mechanisms will be needed to scale up such schemes beyond Brazil, however, because many benefits of forest ecosystem services extend beyond national boundaries. The process requires a revenue source, which could be based on the user-pays principle, and a process to verify forest conservation. Enforcement is also essential: there would be no demand and subsequently no market without government regulation, the oversight of financial institutions, and supply-chain pressures to enforce landowner compliance. Safeguarding standing forests is crucial for sustainable agricultural systems and needs to be recognized and valued.

CASE STUDY 3 HARNESSING THE POWER OF PARTNERSHIP AND TECHNICAL INNOVATION TO REDUCE COMMODITY-DRIVEN FOREST LOSS

Location: Ghana

Partners: FAO, World Resources Institute, Google, National Aeronautics and Space Administration (NASA), Unilever, United States Agency for International Development, United States Department of State

WEIGHTING OF INNOVATION TYPES



The context. Deforestation has declined in recent decades, but the challenge remains to produce commodities such as palm oil, cocoa, soy and beef sustainably. Recognizing this, regulations on products from deforestation-free supply chains have come into force, such as the European Union regulation on deforestation-free and forest-degradation-free supply chains (known as the EUDR). Improving land-use monitoring and the tracking of commodity supply chains are necessary steps for understanding the impacts of commodities on forests, supporting the design and implementation of effective solutions to address forest loss, and making agricultural production and food systems more sustainable. Regulations such as the EUDR have major implications for commodity producers: in Ghana, for example, cocoa producers may lack access to the technical solutions and data required for compliance.

The aim of the Forest Data Partnership (hereafter "the Partnership") is to ensure access for all stakeholders to consistent, validated, open-source geospatial forest-risk commodity data. Smallholder farmers and Indigenous Peoples – the groups most vulnerable to the requirements of emerging regulations – are especially in need of fit-for-purpose technical solutions (for geolocation) to demonstrate compliance. As part of the Digital Public Good Alliance, FAO is leading the Partnership's innovation workstream on digital public solutions for forest and commodity monitoring.

The innovation. The Partnership has joined forces with the Linux Foundation within the framework of the Sustainable Agriculture for Forest Ecosystems flagship of the Team Europe Initiative Zero-Deforestation hub to develop and deploy free, open-source digital solutions that are compliant with deforestation-free regulations. The Partnership is taking a structural convergence-of-evidence approach aimed at enabling compliance for all producers based on the principles of accessibility, inclusiveness, comparability and interoperability.

The convergence-of-evidence approach streamlines access to analysis-ready data on forests, commodities and land-use change at any scale for all producers, thereby enabling them to generate the data they need to comply with zero-deforestation regulations. It comprises the following building blocks:

- the Open Foris Ground application, co-developed by Google and FAO, to enable users to geolocate or delineate their farm boundaries;
- an asset registry (developed by AgStack of the Linux Foundation), which is a free, addressable and non-discoverable public registry of field/farm boundaries without any other attributions (i.e. fields are anonymous and do not carry personal or any other information); and
- a data pipeline that enables users to fetch publicly available geospatial and temporal data such as land-cover change and land-use layers for a given plot of land, implemented in different digital public goods of the Open Foris suite to assist countries in monitoring and reporting on forests and land use.

Results and impacts. A focus area of the Partnership is cocoa in Ghana, and early outcomes include the development of data baselines and pathways for cocoa linked to deforestation. The approach is being field-tested in Ghana and at the regional NASA-SERVIR hub for West Africa (a partnership between regional organizations building capacities to help countries use information provided by Earth-observing satellites and geospatial technologies). The result is credible, systematic monitoring, verification and accountability towards reducing cocoa-driven deforestation. The processing environment is being made available publicly, and the Government of Ghana is using it to support cocoa producers in providing evidence for EUDR zero-deforestation claims on their farms.

Potential for scaling up. The geospatial data ecosystem made available by the Partnership can be adapted to other commodities and other countries and regions. In addition, data-sharing protocols and geolocation standards produced under the Partnership are regulation agnostic and can be adopted for other uses. FAO is providing similar technical support to Peru and Viet Nam under the Accelerating Innovative Monitoring for Forests (AIM4Forests)[203] programme, leveraging technical innovations developed under the Partnership. Support under AIM4Forests is increasing in 2024, also in light of emerging deforestation-free regulations in the United Kingdom of Great Britain and Northern Ireland and the United States of America. More broadly, the Partnership has potential to catalyse major change through its technical solutions by harnessing the collective reach of United Nations (UN) agencies, large civil-society organizations, and major data and technology companies.

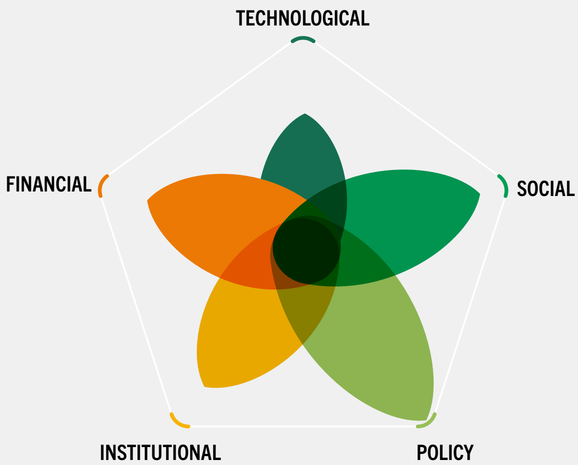
Collect Earth training with Ghanaian remote sensing experts.

CASE STUDY 4 BUILDING NEW TOOLS AND TECHNIQUES INTO EXISTING COMMUNITY FOREST MANAGEMENT MODELS TO ENHANCE FOREST OUTCOMES

Location: Colombia

Partners: FAO, Ministry of Environment and Sustainable Development (MinAmbiente) (Colombia), subnational environmental authorities, community organizations

WEIGHTING OF INNOVATION TYPES



The context. In Colombia, Indigenous-Peoples- and community-managed land and forests comprise about 53 percent of the total land area in the form of Indigenous reserves, zonas de reserve campesinas ("peasants' places") and Consejos Comunitarios de Comunidades Afrocolombianas ("community councils of Afro-Colombian people"). These lands are important for the conservation of both biodiversity and cultures, as well as for carbon storage and water management. Community forest management (CFM) has been practised in Colombia for several decades, but persistent challenges have hampered its effectiveness, including lengthy and uncoordinated local bureaucratic procedures, little understanding of regulations and a lack of sustainable finance.

The innovation. New enabling policies and strategic collaboration have helped revitalize community forest enterprises and strengthen forest governance. Colombia's implementation of a new CFM model is focusing on collaborative governance as a means for reducing emissions from deforestation and forest degradation and contributing to climate action.

A key element of the new CFM model is the forest management and deforestation control strategy, Bosques Territorios de Vida ("Forests – Territories of Life"), developed by MinAmbiente. The strategy was developed using an integrated approach to determine whether novel forest governance approaches could simultaneously halt deforestation, address climate change, contribute to rural sustainable development and manage trade-offs between agriculture and forestry. This required collaboration across ministries (including agriculture), regional environmental authorities, academia, the private sector, Indigenous Peoples and non-governmental organizations. The use of different activities to move towards CFM (e.g. use of timber and non-timber products, financial incentives, establishment of nurseries, agroforestry systems and restoration actions) has allowed partners and external stakeholders to understand that landscape-level interventions can quickly generate real and impactful social, ecological and economic results. Bosques Territorios de Vida involves lines of action focused on recognizing the governance of Indigenous Peoples and of local communities and their traditional practices related to sustainable forest management; promoting and consolidating the forest value chains; and "associativity".[w]

Additional efforts have helped strengthen CFM. In the formulation of the national REDD+ strategy (known as ENREDD+), for example, consultations with community stakeholders demonstrated the potential benefits of incorporating community forestry as a mechanism for meeting the country's climate goals. Integrating it into the system of financial incentives and results-based payments under ENREDD+ has helped provide a more sustainable funding base for CFM; it has also helped improve community-based forest monitoring and increase market access for community forest enterprises.

Other innovative approaches to securing more sustainable sources of funding for CFM include the adoption of the Market Analysis and Development methodology and the intervention logic of the FFF; incorporation of a gender

w In the context of community forestry enterprises, associativity broadly describes the collaborative work of a group of people.

and generational approach; the provision of technical assistance by a multidisciplinary team at each community forestry pilot site; and the contracting of local community organizations to provide logistical and technical services for project activities.

Results and impacts. The knowledge gained from implementing CFM through pilots has improved coordination between forestry and agriculture, which, in turn, has helped improve quality of life for people in rural areas, enabled advances towards the country's climate goals, and increased connectivity among forest areas.

Putting the new CFM model in place has enabled progress towards the implementation of ENREDD+ and compliance with forest laws related to the legal access and use of timber and NTFPs; it has also strengthened the capacity of communities to process and obtain use permits and authorizations issued by the respective regional autonomous authorities. The approach has led to the formal recognition of CFM as a crucial tool for achieving goals on forest conservation, climate-change mitigation and community well-being and encouraged the incorporation of gender and youth perspectives into the design of forest plans and management. Given the importance of CFM for the livelihoods of Indigenous Peoples and Afro-Colombian and local communities, its formal recognition in a policy framework has helped legitimize and make visible the key role of traditional knowledge in forest conservation.

The strategy has enabled new partnerships between community forest enterprises and private-sector intermediaries, with the effect of lowering the cost of market entry for community forestry producers and strengthening the viability of their enterprises, leading to increases in incomes and creating new avenues for forest-based livelihoods. Various cooperation organizations, non-governmental organizations and private enterprises have collaborated under the leadership of MinAmbiente. At the beginning of the process, collective harvesting permits for peasant territories were not widespread, despite being a provision in Colombian law, but successful cases have emerged with the implementation of the CFM model. The most recent national development plan, through Law 2294 of 2023, reaffirms peasant forest concessions in Article 49, creating an opportunity for the implementation of CFM in regions where this was previously unthinkable. The model is being implemented in 12 departments (in which deforestation is prevalent and community forestry has long been practised) and at least 30 CFM initiatives are in operation, mostly in the Amazon. At the national level, some 271 000 ha are subject to CFM, involving the participation of nearly 3 400 families among Indigenous Peoples, peasant communities and Afro-descendants.

Potential for scaling up. The CFM model developed as part of the Bosques Territorios de Vida strategy is promising, thanks in part to its inherent adaptability, Colombia's extensive forest resources, and the presence of collective territories with capacity for forest governance. The adaptability and replicability of the model were demonstrated when it scaled up from four pilots in four departments in 2018 to 30 initiatives in 12 departments in 2023.

The model has considerable potential for community development while helping safeguard natural resources; it can contribute to the fight against climate change and biodiversity loss while enhancing food security and sustainable development. The model has a crucial role to play in the country's Amazon Deforestation Containment Plan.

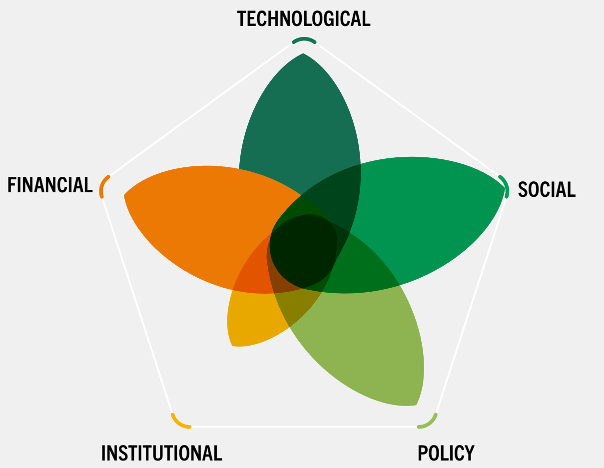
Community leaders tour the territory of the Consejo Comunitario de Comunidades Negras de la cuenca del río Tolo y zona costera Sur, which is carrying out an initiative for conservation and greenhouse-gas emission reductions through community forest management.

CASE STUDY 5 TECHNICAL INNOVATION, CAPACITY BUILDING AND FINANCING TO SUPPORT INDIGENOUS PEOPLES AS FOREST CUSTODIANS

Location: Global

Partners: International Land Coalition, World Resources Institute, members of the LandMark steering group, comprising Indigenous Peoples' Alliance of Nusantara, Asia Indigenous People's Pact, Centre for Sustainable Development and Environment, Coordinating Body of Indigenous Organizations of the Amazon Basin, also representing Global Alliance of Territorial Communities, Ogiek Peoples' Development Programme, Programme intégré pour le développement du peuple pygmée au Kivu, also representing Réseau des Peuples Autochtones et Communautés Locales pour la gestion durables des écosystèmes forestiers d'Afrique, Rights and Resources Initiative, World Alliance of Mobile Indigenous Peoples

WEIGHTING OF INNOVATION TYPES



The context. There is increasing awareness of the key role of Indigenous Peoples as the most effective custodians of vast areas of forest.[204, 205] Pressures and threats to these forest lands and territories are increasing, however, with the expansion of agroextractive activities and infrastructure development. Given their outsized role in biodiversity conservation and climate-change mitigation and adaptation, it is essential that Indigenous Peoples have the human, legal and technical resources to continue their efforts to protect and restore forests, but they remain largely excluded from decisions regarding their territories. Limited technical knowledge and capacity, the lack of legal frameworks recognizing their land and carbon rights, underfunding, and inadequate benefit-sharing and free, prior and informed consent processes present key risks and barriers to the participation of Indigenous Peoples in forest policy mechanisms and emerging opportunities for climate finance.

The innovation. The AIM4Forests[203] programme will deploy innovative technologies alongside technical solutions for Indigenous Peoples in gaining recognition of their territories, improving their forest monitoring capabilities and enabling their engagement in emerging climate finance opportunities. By working with the Global Platform of Indigenous and Community Land, called LandMark,[x] and Indigenous Peoples-led communities-of-practice, AIM4Forests will also foster bottom-up and peer-to-peer learning and knowledge generation, thus helping enable Indigenous Peoples to harness innovative technologies and develop pathways for increasing their participation in global efforts for biodiversity conservation and climate-change mitigation and adaptation.

Results and impacts. AIM4Forests, which began only recently, is helping Indigenous Peoples in their efforts to conduct their own territorial mapping and forest monitoring and to develop their own data and capacity to seek land-tenure recognition and tap into climate-related financing opportunities. This will both strengthen the rights of Indigenous Peoples as stewards of forests and other resources and enable more inclusive, equitable and sustainable benefit-sharing. The increase in mapping and monitoring capacity will ultimately strengthen the position of Indigenous Peoples in claiming results-based payments from conservation and sustainable forest management activities in their territories and the carbon credits to which they are entitled. For example, as of September 2023, 26 governments had submitted eligible carbon finance proposals to the Lowering Emissions by Accelerating Forest Finance (LEAF) Coalition,[y] but only one of these

x LandMark is a global platform for the georeferenced information of Indigenous Peoples and community lands worldwide.

y The LEAF Coalition brings together public and private buyers to purchase large volumes of high-quality forest carbon credits from national and subnational governments that have implemented jurisdictional REDD+ programmes to reduce deforestation. The LEAF Coalition requires the use of TREES [The REDD+ Environmental Excellence Standard], a standard developed by Architecture for REDD+ Transactions for the quantification, measurement, reporting and verification of greenhouse-gas emission reductions and removals from REDD+ activities at a jurisdictional and national scale.

(from the Plurinational State of Bolivia) concerned a recognized Indigenous territory. It is important to ensure that Indigenous Peoples are well placed to participate in climate finance if interested and to obtain a fair share of the benefits.

Potential for scaling up. Although Indigenous Peoples own or manage one-quarter of the world's lands, their territorial rights continue to be unrecognized in many parts of the world.[206] The empowerment of Indigenous Peoples through the mapping of their lands and collection of high-quality data can help increase the visibility of Indigenous territories and support efforts to secure land rights, which is one of the best and most cost-effective ways to prevent deforestation and reduce biodiversity loss and carbon emissions. There is potential to strengthen and replicate Indigenous Peoples-led mapping and monitoring initiatives over vast areas through this project,[203] which can form a basis for their participation in climate financing.

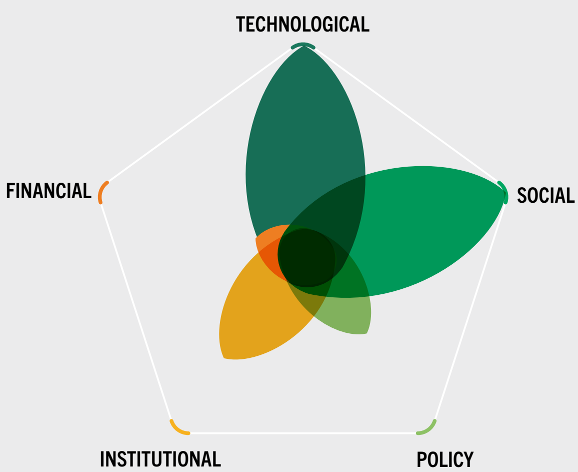
Concession negotiations in the village of Bethany, Guyana, offer Indigenous youth an opportunity to learn the boundaries of their customary land, helping develop intergenerational custodianship.

CASE STUDY 6 INTEGRATING SCIENCE, TECHNOLOGY AND TRADITIONAL KNOWLEDGE TO IMPROVE FIRE MANAGEMENT DECISION-MAKING

Location: Global in concept, piloting in Southeast Asia

Partners: Global Fire Management Hub partners, Korea Forest Service, German Federal Ministry for Food and Agriculture

WEIGHTING OF INNOVATION TYPES



The context. Wildfires are burning longer and with greater severity in forests, peatlands and permafrost regions, and the length of fire seasons is increasing in many parts of the world.[34] Climate change and land-use change are projected to make wildfires more frequent and intense,[34] and there is a need, therefore, to invest more in wildfire prevention and preparedness. The many negative impacts of wildfire disproportionately affect the poorest, who have the least capacity to adapt to changed fire regimes. Contemporary fire management and decision-aid tools are often based on new technologies and fire science, but they may lack adequate consideration of the importance of fire as a land-management tool, especially in the Global South, and they may fail to incorporate the vast fire management knowledge held in Indigenous and other traditional communities.

The innovation. The Global Fire Management Hub,[z] led by FAO and partners, is supporting communities and countries in their efforts to develop local-level fire management decision-aid

z https://www.fao.org/forestry-fao/firemanagement/101248/en/

tools that integrate traditional and scientific knowledge and the latest technologies aimed at reducing the negative impacts of wildfires on livelihoods, landscapes and climate. The innovation is based on the premise that fire problems that affect communities require community-led solutions. It provides a procedure for quantitatively integrating fire science and traditional fire knowledge – thereby "walking on two legs", as some Indigenous leaders put it.

The fire management decision-aid tools under development are based on:

- **models** – the existing fire-danger-rating and early-warning systems;
- **data** – the latest information on fire weather, climate, fire activity, and fuels and vegetation; and
- **knowledge** – incorporating Indigenous, cultural and traditional fire management knowledge and expertise.

Fire management decision aids are being constructed for wildfire management (prevention, detection and pre-suppression) and prescribed-burn planning, including traditional and Indigenous fire use. They are linked directly to fire behaviour, which is estimated using physical models quantified by fuel consumption and rate of spread, based on fire weather and vegetation data (this measure of the potential for fire to start, spread and cause damage is the product of a fire-danger rating system). A fire early-warning system delivers knowledge of future fire-danger conditions and provides an input to planning and decision-making, weeks and even months ahead of the fire season; it can incorporate drought indices, local traditional knowledge of weather systems and trends, and climatic influences. The tools are being co-developed with local communities based on their fire knowledge and best practices. The approach is being piloted in Southeast Asia in the context of the Assuring the Future of Forests with Integrated Risk Management mechanism.

Results and impacts. People can be empowered by new fire management decision-aid tools that combine modern science and technology with the fire management knowledge, expertise and needs of local communities and Indigenous Peoples. These tools can enable local fire managers to use fire-danger and early-warning information to anticipate and prepare for wildfire threats and to plan and safely conduct traditional burning practices. Communities may be able to implement integrated fire plans in advance of extreme fire-danger conditions, including for prescribed burns aimed at achieving traditional fire and land management goals.

Potential for scaling up. The innovative fire management decision aids developed will provide a blueprint for national fire agencies and similar activities worldwide, a methodology for integrating fire science and traditional knowledge, and examples of community-based fire management decision aids. The outputs will be integrated into the Global Fire Management Hub, which is receiving broad international support as a way to strengthen country capacities for integrated fire management, including through a focus on communities, thus ensuring wide outreach and uptake.

Forest fire on mineral soil in Jambi, Indonesia.

PHILIPPINES
Planting mangroves increases the resilience of coastal communities.
© FAO/Benjo Salvatierra

4.2 INNOVATIVE APPROACHES ARE BOLSTERING THE RESTORATION OF DEGRADED LANDS AND EXPANDING AGROFORESTRY

Almost 75 percent of the world's total land area, particularly forests, rangelands and wetlands, has been negatively affected by degradation and transformation, and this figure is likely to increase to more than 90 percent within 30 years.[207] The annual economic loss linked to ecosystem degradation is estimated at USD 4.3 trillion–20.2 trillion, with negative impacts on 3.2 billion people.[208]

FLR is gaining momentum in response to this challenge, as demonstrated by the UN General Assembly's declaration of the Decade on Ecosystem Restoration (2021–2030). FLR typically involves entire landscapes in which many land uses interact, and its objective is to restore the biological productivity of degraded areas and create long-term carbon sinks in restored soils and vegetation. According to the Global Partnership on Forest and Landscape Restoration, more than 2 billion ha of the world's deforested and degraded landscapes have potential for FLR. The global mitigation potential of reforestation and afforestation through FLR by 2050 is estimated at 3.9 GtCO_2 per year.[209]

Restoration through agroforestry has the potential to address diverse global challenges. Agroforestry systems tend to be more resilient than conventional agriculture to environmental shocks and the effects of climate change. Depending on the system and local conditions, agroforestry systems can contain 50–80 percent of the biodiversity of comparable natural forests;[210] increase food security and nutrition by serving as a safety net; and boost crop productivity. There is renewed interest in agroforestry as a transformative solution to the climate crisis, as demonstrated by its inclusion in the nationally determined contributions (NDCs) of 40 percent of non-Annex I Parties to the UN Framework Convention on Climate Change for both mitigation and adaptation.[211, 212] Moreover, about half the 73 developing countries with REDD+ strategies have identified agroforestry as a means for addressing deforestation.[211] The Intergovernmental Panel on Climate Change's Sixth Assessment Report makes specific reference to agroforestry as an effective climate-change adaptation option.[213]

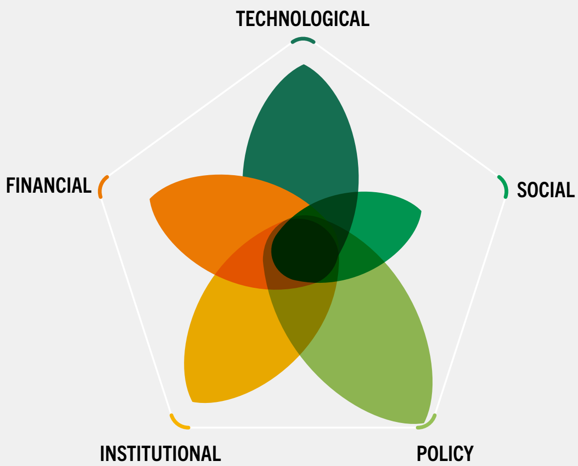
The following six case studies provide examples of innovations in FLR and agroforestry with potential for scaling up.

CASE STUDY 7 DEVELOPING A NEW NATIONAL POLICY AND STRENGTHENING THE ENABLING ENVIRONMENT TO SCALE UP AGROFORESTRY

Location: India

Partners: Ministry of Agriculture and Farmers Welfare (India), Center for International Forestry Research and World Agroforestry (CIFOR–ICRAF)

WEIGHTING OF INNOVATION TYPES



The context. India has a long history of agroforestry as a traditional land management system and has been heavily involved in agroforestry research for at least 50 years. Past estimates of the area under agroforestry in the country ranged from 17.4 million ha to 23.2 million ha.[214] Until recently, however, agroforestry had not received comprehensive technical or institutional support, and nor had it been covered by the mandate of any ministry. Thus, agroforestry had generally fallen through the cracks of policy domains – a problem that is not unique to India and reflects agroforestry's multifaceted nature at the intersection of agriculture, forestry, the environment and rural development. Agroforestry requires diverse expertise in tree, crop and livestock management. A lack of comprehensive extension services makes agroforestry adoption difficult for farmers; in addition, a lack of recognition by government extension services of the agroforestry knowledge held by local farmers makes it harder to improve the performance of existing agroforestry practices and to foster innovation. Other barriers include inadequate regulatory frameworks and incentives (and in some cases restrictive regulations), a lack of institutional finance and safety nets for farmers, the unavailability of high-quality planting material, and inadequate market access. These and other challenges have meant an insufficient enabling environment for the expansion of agroforestry in India.

The innovation. Acknowledging these structural issues, the Government of India, through the Ministry of Agriculture and Farmers Welfare and facilitated by CIFOR–ICRAF, developed the intersectoral National Agroforestry Policy in 2014. The policy aims to address bottlenecks in scaling up agroforestry and remove barriers to adoption in a systemic manner. The policy's goals are to increase productivity through agroforestry and to meet the increasing demand for timber, food and non-timber forest products. The policy is also crucial for achieving India's goal of increasing national tree cover by 33 percent, thereby contributing to the country's NDC. The overarching objective is to contribute to improving the livelihoods of rural farming populations, ensuring food security and protecting ecosystems.

The policy was the first in the world to promote agroforestry at a national level. By bridging various areas of natural resource management, it enabled the convergence, strengthening and expansion of existing agroforestry mandates and programmes and simplified regulations related to the harvesting and transportation of trees grown on farmlands. Under the policy, a land-records database and a market information system have been developed to ensure land-tenure security and market access. A common platform has been provided to empower all stakeholders to jointly plan and identify priorities and strategies; enable greater interministerial coordination, programmatic convergence and financial resource mobilization; and leverage capacity development and technical and management support.

Results and impacts. The National Agroforestry Policy has provided multiple monetary and non-monetary incentives to promote agroforestry in the country; in 2016, for example, the Government of India approved its first agroforestry budget, worth USD 150 million. The policy has helped increase the number of trees outside forests: one year after it came into effect, the Forest Survey of India reported an increase of 88.7 million m^3 in the total volume of trees outside forests. According to the most recent estimate, agroforestry is now being practised on more than 28.4 million ha in India,[214] and an estimated 65 percent of the country's timber and almost half its woodfuel come from trees grown on farms, although the potential is far greater.[215]

The existence of strong policy support for agroforestry has triggered investment in technologies to assist uptake, such as numerous mobile applications that are proving useful in overcoming gaps in extension services and enabling farmers to leverage technologies and adapt agroforestry to their own situations. For example, Odisha State released an agroforestry app (developed with support from CIFOR–ICRAF) in 2021 that provides, in a single platform, comprehensive information on trees and crops and packages of practices. The app enables farmers and extension workers in the state to identify the right agroforestry species for farms and provides them with detailed information on integrated agroforestry systems, the availability of planting material, and the location of nurseries. Upon the entry of key parameters, such as district, season, topography, land use and intervention type, the app makes recommendations on suitable crops, trees and agronomic practices and suggestions for beneficial tree and crop combinations. The app has been downloaded by users in more than 120 countries (despite being intended only for Odisha State), indicating a clear demand for this type of support.

Potential for scaling up. India's National Agroforestry Policy paved the way for other countries that have now developed their own agroforestry policies or strategies, including the Democratic People's Republic of Korea, the Gambia, Kenya, Nepal, Rwanda, South Africa and the United States of America; Nepal's (2019) national policy was founded on India's experience. Developing national policies and strategies is a key pathway for creating enabling environments and sustainably scaling up agroforestry.

To complement these policy innovations, apps are an important solution for overcoming gaps in extension services and enabling farmers to leverage technology and adapt agroforestry to their contexts. A global agroforestry app could be developed using existing databases with capability to be adapted to local contexts through national partnerships. Such an app would enable continuous improvements with new data and strengthen monitoring, design and implementation.

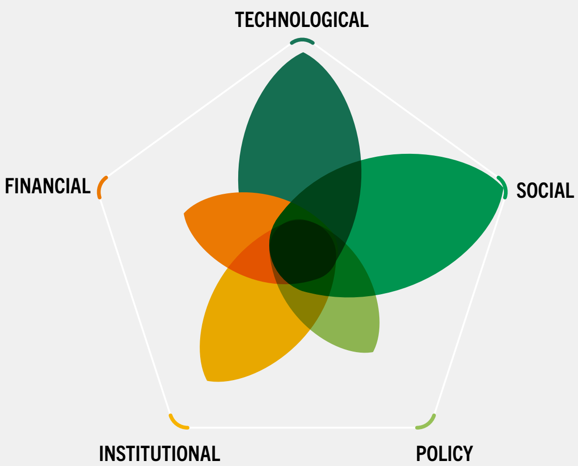
Worker tending tree seedlings in an agroforestry system at a Forestry Research Institute nursery in Uttarakhand, India.

CASE STUDY 8 INTEGRATING THE SOCIOECONOMIC OBJECTIVES AND NUTRITIONAL NEEDS OF LOCAL COMMUNITIES INTO RESTORATION TO COMBAT DESERTIFICATION

Location: Burkina Faso, Eritrea, Ethiopia, the Gambia, Mali, Mauritania, the Niger, Nigeria, Senegal and the Sudan

Partners: FAO, Great Green Wall national agencies and coordination units, village communities, Pan-African Agency of the Great Green Wall

WEIGHTING OF INNOVATION TYPES



The context. The African Union launched the GGW initiative in 2007 as an urgent response to the detrimental effects of desertification, drought and climate change in the Sahel. Few of the initiative's large-scale restoration actions, however, seek to address the socioeconomic challenges facing dryland communities, such as food insecurity, malnutrition and poverty, contributing to an overall low success rate for restoration outcomes. Conversely, land degradation and associated biodiversity loss, coupled with increasingly harsh environmental conditions, have contributed to persistent acute malnutrition in the region, and many people suffer prolonged periods of hunger. International interventions in the Sahel have inadequately considered the potential of restoration for addressing malnutrition, particularly "pre-farm gate" – that is, consumption pathways that optimize the use of native plant diversity to improve nutrition outcomes.

The innovation. Recognizing the close relationship between landscapes and livelihoods, FAO's Action Against Desertification (AAD) programme[216] developed a blueprint for large-scale restoration that builds climate and nutritional resilience into its interventions. The core innovation has been to put the plant knowledge and interests of rural communities at the heart of the intervention process, prioritizing their species preferences for planting and their socioeconomic needs. One-third of the more than 200 wild species preferred by communities are food plants, and they also have high market value. Many wild plant species, including many used as food, are typically rich in micronutrients and have very high nutritional content.[116, 117]

Five main value chains were also developed for NWFPs derived from wild plants with the aim of increasing incomes and thus providing an incentive to conserve native agrobiodiversity, as well as offering immediate economic relief for households (particularly benefiting women and youth). Wild edible tree fruits and nuts were a particular focus, given that FAO assessments in Sokoto state, Nigeria, found these to be consumed by up to 86 percent of households.

In addition to planting the right species at the right time, the supply of genetically diverse, high-quality tree seeds is crucial for restoration. A germplasm mobilization assessment conducted in six GGW countries by FAO in collaboration with research institutes in Ghana and Kenya in 2019 showed that relying exclusively on official public seed systems (e.g. national tree seed centres) was insufficient for large-scale restoration because of supply bottlenecks. FAO's innovative model of engaging and training rural communities living in the vicinity of natural seed stands enables those communities to not only select their preferred species and restoration objectives but also to directly perform seed-saving and tending functions. Women-led cooperatives have made it possible to supply the seeds (and other genetic material) needed to meet restoration targets. These cooperatives represent social innovations that are enabling communities to roll out and scale up the science of seed selection, collection and propagation.

Results and impacts. Over six years, FAO worked with more than 100 000 households in 600 villages to collect 150 000 kg of seeds from 110 selected resilient native woody and herbaceous plant species on more than 100 000 ha of degraded agrosilvopastoral lands. Independent remote-sensing assessments of regreening and growth rates revealed positive impacts, including – unexpectedly – an increase in vegetation for (on average) 1 km beyond restored plots, with communities gaining quick returns by harvesting grasses as fodder for livestock. The consultative and participatory process was vital for responding to the urgent need for revegetation that addressed nutrition, health and livelihoods. Food-insecurity experiences[aa] declined sharply – from 46 percent to 15 percent in Senegal, from 69 percent to 58 percent in the Niger and from 90 percent to 25 percent in Nigeria. The interventions sequestered an estimated 0.384–1.27 million tCO_2 equivalent of greenhouse gases. Communities were motivated to manage the broad spectrum of planted vegetation, contributing to an average of 60 percent seedling survival and impressive growth rates after three rainy seasons.[218, 219]

Potential for scaling up. The GGW seeks to restore 100 million ha of degraded lands in the Sahel between 2021 and 2030, an unprecedented opportunity to develop biodiverse, resilient and nutritious landscapes. The success of FAO's AAD programme derives from social and organizational innovations spanning the agriculture, forest and health sectors and including women-led restoration committees, consultative planting processes and nutrition-sensitive restoration. These, combined with technological innovations such as mechanized land preparation for efficient rainwater harvesting, are now essential components of restoration, climate action, biodiversity conservation and sustainable use in the region.[220–224] Given that the GGW is far from achieving its 100-million ha goal, it is imperative to find effective ways of increasing the rate of restoration. The innovations described here offer scope for doing so by empowering local communities to use restoration for their clear benefit, and they also have significant potential in dryland agrosilvopastoral systems elsewhere, such as in Southern Africa and Central Asia.

aa The assessment used FAO's Food Insecurity Experience Scale.[216]

Harvesting wild fonio (*Panicum laetum*) in Action Against Desertification restoration plots in Burkina Faso in the first planting year.

CASE STUDY 9 DEVELOPING THE FRAMEWORK FOR ECOSYSTEM RESTORATION MONITORING PLATFORM THROUGH COLLABORATION AND DATA INTEROPERABILITY

Location: Global

Partners: FAO, UNEP, Convention on Biological Diversity (CBD), Taskforce on Monitoring, Taskforce on Best Practices, other partner organizations

WEIGHTING OF INNOVATION TYPES

The context. The UN General Assembly declared 2021–2030 as the Decade on Ecosystem Restoration with the aim of supporting and scaling up efforts to prevent, halt and reverse the degradation of ecosystems worldwide. Co-led by FAO and UNEP, implementation of the Decade is facilitated through extensive collaboration with countries, UN agencies and partner organizations. To streamline implementation, five taskforces have been established as part of the Decade's governance structure, with FAO leading the Best Practices Taskforce and the Monitoring Taskforce.

There is a need for effective tools, platforms and data to increase access to restoration-related data, information and indicators and to guide decision-making and the monitoring of progress. A major response to this challenge is the collaborative development of a platform called the Framework for Ecosystem Restoration Monitoring (FERM) through the joint efforts of the FAO-led taskforces.

Parties to the CBD have adopted an ambitious restoration target, Target 2, as part of the Kunming–Montreal Global Biodiversity Framework – it is to "ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and marine and coastal ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity." As the lead agency in the Best Practices Taskforce and the Monitoring Taskforce, FAO is responsible for supporting the CBD Secretariat and Parties in developing the monitoring and reporting methodology for the Target 2 indicator, which focuses on the area under restoration. The operationalization of FERM is crucial for assisting countries in collecting and reporting data on areas undergoing restoration.

The innovation. FERM leverages the latest geospatial technology to serve as the official monitoring platform for tracking global progress and disseminating good practices throughout the UN Decade. It also supports countries in monitoring and reporting areas under restoration towards Target 2.

FERM builds on and complements established global, regional and national reporting procedures and aligns with their objectives, targets, criteria and indicators. By consolidating these efforts in a unified framework, FERM aims to reduce the reporting burden on countries by providing individuals, communities and countries with access to the geospatial data, methodological guidance and monitoring tools they need for tracking the progress of ecosystem restoration initiatives.

FERM operates on the principle of interoperability, building on existing efforts to map, monitor and comprehensively report areas under restoration. Through the collaborative network of partners in the FAO-led taskforces, FERM works with partners such as the GEF, Restor, the International Union for Conservation of Nature's Restoration Barometer, the UN Convention to Combat Desertification's Land Degradation Neutrality reporting platform, the Great Green Wall Accelerator, the UNEP–World Conservation Monitoring Centre's Nature

Commitment Platform, and the Brazilian Restoration Observatory to map the data they are collecting to common parameters, facilitate data-sharing and quality-checking, and identify opportunities for alignment.

The integration and interoperability of monitoring tools and platforms can enhance and simplify the user experience for restoration practitioners. For example, FERM integrates projects and data from the GEF into the UN Decade Monitoring Framework. Efforts are ongoing to compile, share and integrate data from other platforms, and organizations are working to integrate data exchange and interoperability into FERM.

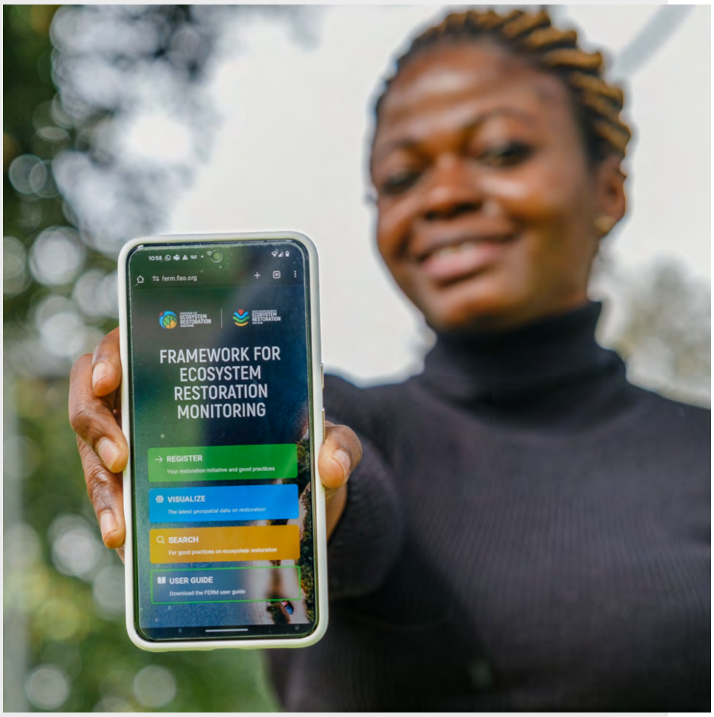
Results and impacts. FERM includes:

- the FERM geospatial platform, which enables the visualization of progress and provides indicators and data that are crucial for monitoring ecosystem restoration. It is interactive, and it can generate data and maps and create compelling narratives of restoration impacts. Using remotely sensed geospatial data and statistical time series, the FERM platform facilitates analysis of public and private restoration-related data at the global, regional, national and subnational scales;
- the FERM registry, which streamlines the collection and harmonization of area-based data related to ecosystem restoration initiatives, projects and programmes and simplifies interoperable data exchanges with other platforms. The FERM registry also enables the documentation of good practices associated with the registered initiatives. As of February 2024, the platform had 355 registered users from 80 institutions, 150 initiatives had been documented across 57 countries, and 20 good practices had been submitted. The FERM registry will serve as the official entry point for countries to report on Target 2; and
- the FERM search engine, which disseminates restoration good practices collected from four collaborating platforms, including the FERM Registry, thereby offering stakeholders access to over 1 500 good practices (as of February 2024). Users can efficiently search, filter and access a wide range of good restoration practices according to their specific needs.

Potential for scaling up. As the official monitoring platform of the UN Decade and for Target 2 of the Kunming–Montreal Global Biodiversity Framework, FERM will be strengthened over time and in response to the needs of countries, CBD Parties and restoration practitioners.

FAO is working with partner organizations towards data harmonization and interoperability to improve FERM functionalities. Case studies on data exchange will be introduced to provide insights into and examples of successful practices and innovations. A dashboard will be incorporated, offering compiled data on ecosystem restoration and comprehensive information on progress towards commitments, area under restoration (disaggregated by country, ecosystem and initiative), and good practices. It will display these elements spatially using geospatial data and provide interactive maps for data visualization and links to national databases, thereby improving transparency. These features will be accessible at the global and national levels.

FERM enables on-the-ground data collection through mobile devices.

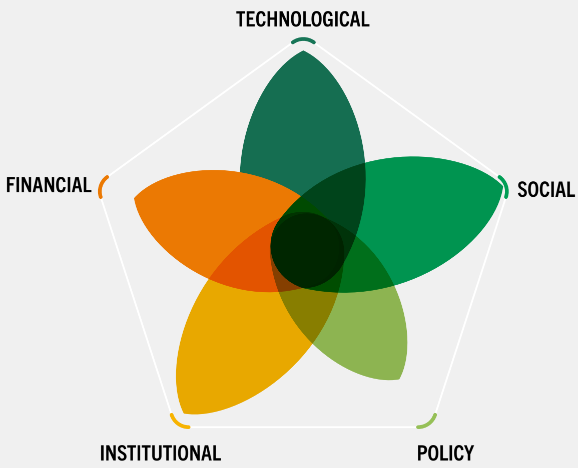


CASE STUDY 10 ENHANCING THE RESILIENCE OF TRADITIONAL WATER TARO GARDENS BY INCORPORATING NEW TECHNOLOGIES, PRACTICES AND PLANT VARIETIES

Location: Vanuatu

Partners: FAO, Vanuatu Department of Agriculture and Rural Development (Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity)

WEIGHTING OF INNOVATION TYPES



The context. The continued provision of forest ecosystem services is crucial in Vanuatu for meeting food-security challenges. Taro – a root vegetable that is a food staple in Vanuatu – requires a sustained supply of water at all stages of production to maintain yields and support plant development, particularly during dry seasons. Water taro gardens are a traditional agroforestry practice in the country that makes use of the nutrient- and water-quantity-regulating functions of forests to produce taro and other crops. Water taro gardens are able to recover quickly from disasters and climate shocks and stresses and have been important for maintaining local food security during supply-chain disruptions. The deterioration of forests, however, has reduced the capacity to provide water for the gardens, posing a threat to the viability of this agroforestry system and to local food security and livelihoods.

The innovation. Consultations led by the Vanuatu Department of Agriculture and Rural Development were held with Indigenous Peoples, local communities, government agencies and other stakeholders to identify challenges, needs and opportunities related to improving the productivity and resilience of water taro gardens. With technical and funding support from FAO related to resilient agroforestry systems, analysis was conducted on the suitability of locations for the expansion of gardens, as well as on gaps in knowledge, inputs and technology. Based on this, a package of innovative approaches was introduced to strengthen the sustainability of water taro gardens in the face of climate change. For example, climate-resilient water taro varieties and training programmes on sustainable water management practices were introduced. Complementing this, new practices and technologies have been adopted, such as drip irrigation; improved small-dam-construction, water-diversion and rainwater-harvesting techniques; and water-efficient farming practices such as aquaponics.

Results and impacts. The package has helped improve water-use efficiency and increase water availability throughout the year. Importantly, improved approaches for sustainable forest management, including biodiversity conservation, have helped maintain the recharge function of water sources for taro fields.

The provision of tools and equipment for the construction and maintenance of gardens has also helped address issues such as soil erosion. Taro gardens are often located on steep slopes, which increases the risk of soil erosion during heavy rain. To prevent it, existing agroecology techniques not previously used widely by farmers in Vanuatu have been introduced, such as contour farming, terracing, and cover crops such as legumes, grasses and green manure. Farmers have also drawn on approaches informed by traditional knowledge to boost the productivity and resilience of water taro garden systems, including companion planting to minimize plant pests, mulching, composting, and crop rotation.

By adopting a suite of innovations, Vanuatu farmers have been able to maintain the viability of their water taro systems, with a total of 419 ha in production in 2023.[ab] This is important given the role these systems play in ensuring the stability of local food-supply chains, as they did in the aftermath of twin cyclones in March 2023. The innovations are also enabling farmers to increase yields, reduce their vulnerability to climate change and enhance their livelihoods.

Another important result has been the improvement of water management practices. Through the work to improve the sustainability of water taro gardens, communities have become more aware of the need to conserve and manage water resources efficiently. This has led to a reduction in water waste and an overall improvement in water quality, including through reduced runoff, more efficient water use, reduced leaching of fertilizers and chemicals, and less soil erosion.

In addition to these benefits, taro water gardens are contributing to the preservation of traditional knowledge and practices. Taro cultivation has long been an important part of Vanuatu's cultural heritage, and the continued development of the water gardens has helped ensure that this knowledge is passed on to future generations.

Potential for scaling up. In Vanuatu, there is an opportunity to expand the area of water taro gardens by refurbishing abandoned gardens over a total area of about 1 033 ha by 2030. This would produce a projected 14 500 tonnes of taro annually,[ac] which would be about three times the production in 2023 due to the increased area under cultivation and increased yields per hectare from improved management. A survey showed widespread community acceptance, with more than 50 percent of farmers across Vanuatu adopting the innovations. Scaling up will involve trade-offs between taro cultivation and other economic activities such as tourism and infrastructure development.

An aerial view of a traditional water taro garden landscape.

ab The estimate is based on data provided by the Vanuatu Department of Agriculture and Rural Development.

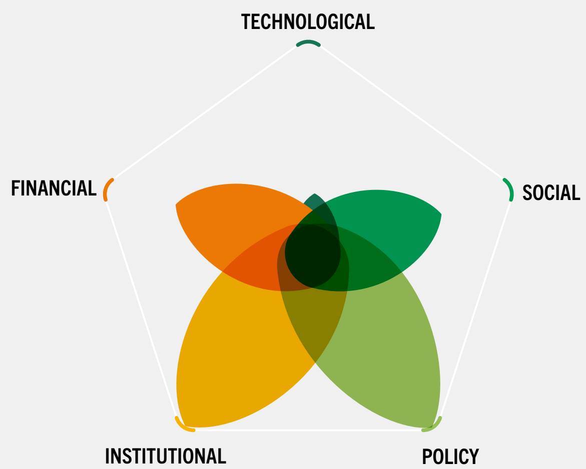
ac The projection is based on estimates made by FAO Vanuatu and government officials.

CASE STUDY 11 IMPROVING THE LOCAL GOVERNANCE OF FOREST RESOURCES TO DELIVER BENEFITS FOR AGRICULTURE AND FOREST RESTORATION

Location: Morocco and Tunisia

Partners: FAO, International Center for Agricultural Research in the Dry Areas

WEIGHTING OF INNOVATION TYPES



The context. In many dryland areas in North Africa, forest and rangeland policies encourage restoration initiatives that encroach on the grazing lands of pastoralist communities. Grazing is a widespread practice that can have negative impacts on forests, especially when there is overstocking, a loss of traditional practices, and an absence of community involvement. When conducted sustainably, however, through a practice known as silvopastoralism – that is, the integration of grazing, tree cultivation and restoration – grazing and restoration can both thrive.

Promoting silvopastoralism through forest and rangeland policies brings significant benefits for both land restoration efforts and pastoral communities. It can enhance quality of life and the local environment and economy, thereby representing a win–win for all stakeholders.

The innovation. In Tunisia, the Sustainable Silvopastoral Restoration to Promote Ecosystem Services project implemented by FAO, the International Center for Agricultural Research in the Dry Areas and the *Direction Générale des Forêts de Tunisie* focused on enhancing the productivity and resilience of silvopastoral systems through sustainable practices. This included an innovative approach involving the reseeding of ecosystems with sulla (*Hedysarum coronarium*), a native legume, which serves as a valuable source of grazing biomass for livestock and contributes to soil and water conservation. The project also assessed the regeneration of various shrubs and trees, such as saltbush, carob, medic tree and cactus pear, to support livelihoods while providing shade for crops and fodder for livestock.

For silvopastoral systems to flourish, more inclusive policies and good governance are needed to create an enabling environment for grazing with trees. Morocco initiated an innovative compensation programme using a legal framework established in 2002, under which the state offers financial incentives to forest users – organized in local grazing associations – who agree to respect the exclusion of grazing from restoration sites. Through their associations, communities are accountable for the protection of their lands; they schedule grazing periods to avoid overgrazing and allow land to recover.

Results and impacts. Soil protection and rehabilitation are important impacts of the programme. In Tunisia, the biomass yield at sulla reseeding sites was assessed as ten times higher than at the control site, showing the importance of silvopastoral systems that enhance the pastoral value of natural ecosystems. The cost of feeding livestock was TND 0.35 (about USD 0.12) per head per day at the restored site, compared with TND 0.90 (about USD 0.30) at the control site. This cost reduction highlights one of the significant benefits of the silvopastoral system – it is a more economically efficient and sustainable approach to livestock management.

In Morocco, the number of grazing associations and members has increased steadily since the start of the compensation programme. By 2019, more than 175 local grazing associations had been created and 101 000 ha of dryland forest had been closed to grazing to enable restoration, with association members compensated for their conservation efforts. The increase has coincided with an improvement in reforestation success rates and a significant reduction in grazing offences.

Potential for scaling up. Two lessons arising from these efforts can support their scaling up. The first is the importance of multifunctional land use in restoration projects. In Morocco, integrating grazing and other land uses is providing benefits for both the environment and local communities. The second lesson is that good governance involving local communities in decisions taken by government ministries is vital for ensuring long-term sustainable land use. In Morocco, the co-creation of the compensation programme by government, local communities and pastoralist groups is a fundamental aspect of its success; it is noteworthy that the scheme is funded through a levy on wood imports, which has facilitated its upscaling.[ad]

In Tunisia, community-based organizations have proved an essential ingredient in the success of the silvopastoral project. Through such organizations, agreements have been developed between the silvopastoral community and local authorities to control grazing based on the availability of forage and livestock demand using accurate estimates of carrying capacity.

ad This financing mechanism has been challenged under World Trade Organization rules but maintained because the government demonstrated that Moroccan wood has a higher cost than imported wood.

The increased community involvement has made more prominent the importance of local knowledge in managing silvopastoral systems. It is essential that government policies recognize this and link it with scientific research as a basis for policy decisions.

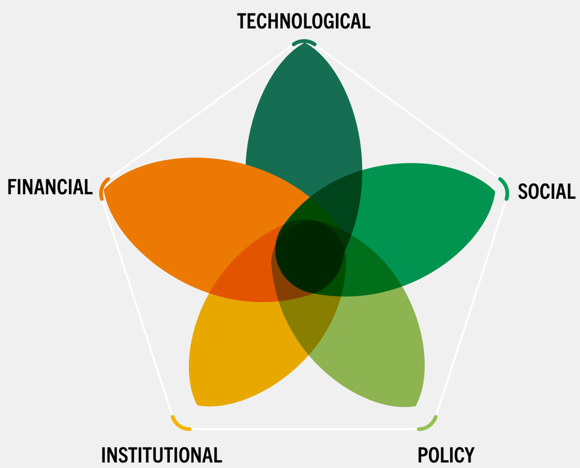
Sheep grazing on an improved pasture site in Tunisia.

CASE STUDY 12 LINKING A 20-YEAR-LONG AGROFORESTRY INITIATIVE WITH CARBON TRADING TO FOSTER SUSTAINABLE PRACTICES

Location: Mozambique

Partner: FAO

WEIGHTING OF INNOVATION TYPES



The context. Rural Mozambique faces numerous environmental challenges. Climate change is leading to erratic rainfall patterns, prolonged droughts and destructive floods. Drought and flooding may both occur in a single cropping season, with devastating impacts on the food security, livelihoods and socioeconomic sustainability of smallholder farmer households and communities. Smallholder farmers – who make up nearly all (98.7 percent) of the 4.3 million farmers in Mozambique[225] – mostly practise traditional farming methods such as shifting cultivation, which, despite benefits, may contribute to the degradation of natural resources and lock smallholders into poverty. Agroforestry is emerging as a sustainable solution in Mozambique for the environment and the well-being of smallholder farmers.

The innovation. FAO is in the first year of implementing a pilot initiative to expand agroforestry in Mozambique through PROMOVE Agribiz, a programme funded by the European Union. The agroforestry models being introduced, adapted to Mozambique's various agroecological zones, feature the following innovations:

- **Diversification** – agriculture production is being diversified by increasing the range of products and income sources while also increasing food security and climate-change mitigation and adaptation. Additional products are linked to existing value chains.
- **Long project duration with private-sector partnerships** – the project will span 17–20 years (the typical duration of carbon-credit registered projects), far exceeding the typical lifespan of donor-funded projects (3–5 years). The project involves a strong partnership with private-sector actors, including Acorn (a Rabobank programme), Plan Vivo, Farm Tree, and buyers of carbon removal units (CRUs),[ae] which enhances sustainability and will ultimately facilitate the transition of project management to a private entity when the project ends.
- **Project budget invested in incentives** – the donor funds are being used as initial capital to generate income through the sale of CRUs (the minimum value of which is EUR 20 per unit). In this project, EUR 2.5 million contributed by the European Union is projected to generate EUR 10.7 million through carbon trading. Smallholder farmers are expected to benefit from the sale of CRUs through the project, with technological advances enabling the measurement of carbon stock on areas as small as 0.25 ha. It is expected that 80 percent of the CRUs produced will be paid to smallholder farmers after the third year either through credits or other benefits, such as capacity development.
- **Digitalization and technology** – information technologies accessible to smallholders are enabling cash transfers and the registration of farm units by mobile phone. Agricultural inputs, including seedlings, are being subsidized through e-vouchers. Carbon stocks are being measured and verified, with real-time accountability.

ae Institutional buyers of Rabobank-registered projects include Luigi Lavazza SPA, Microsoft Corporation, Pelican Rouge Coffee Roaster BV, Nationale Postcode Loterij and Standard Chartered.

- **Capacity development** – the Farmer Field School (FFS) methodology has been adapted to agroforestry.

Results and impacts. Under the project, about 22 000 smallholder farmers have received training in agroforestry practices through 700 FFSs and 700 learning plots and 5 000 are expected to join the agroforestry-for-carbon-trade pilot. About 120 000 trees have been planted for training purposes, and 37 community nurseries have been established within the FFS network.

By the end of the project, the 5 000 beneficiaries of the initiative are expected to have planted 1.7 million trees on about 5 000 ha of land. Smallholders have the potential to sequester up to 4 CRUs per ha per year during the 17–20-year duration of the project, with payments beginning in the third year based on annual carbon sequestration.

FFS manuals have been enriched with this experience. The involved smallholder farmers have embraced agroforestry enthusiastically, fostering a shift towards sustainable and climate-resilient farming methods. The traditional agriculture paradigm is evolving towards sustainable agriculture, emphasizing minimal-input consumption (e.g. only organic fertilizers); improving nutrition (e.g. dietary diversification) and income at the household level (an estimated 20 percent increase); enhancing soil nutrients; conserving water reserves; promoting biodiversity; and increasing the climate resilience of farms.

Potential for scaling up. The PROMOVE Agribiz agroforestry model is being adopted in another project (funded by the Government of Italy and implemented by FAO) in Mozambique. Depending on the availability of finance, it could be expanded to include the other 17 000 FFS members in PROMOVE Agribiz.

Continuous support and capacity development is needed to ensure that farmers can implement and maintain agroforestry in the long term. Ensuring the integrity of CRUs and the cost-effectiveness and accuracy of measurement is also a challenge.

Farmer facilitators planting seedlings to establish an agroforestry system during training in Angoche district, Nampula Province, Mozambique, in September 2023.

4.3 INNOVATIONS ARE HELPING TO SUSTAINABLY USE FORESTS AND BUILD GREEN VALUE CHAINS

Forests and the renewable products derived from them can reduce reliance on non-renewable resources (which currently account for around 70 percent of all material demand)[226] while also supporting livelihoods and rural economies. Reversing the trend of increasing material extraction while promoting sustainable consumption and production patterns is essential for achieving the SDGs.

Opportunities exist for sustainably sourced wood to substitute for a wide range of carbon-intensive materials, including in the building and construction, textile, and energy sectors. The need to decarbonize the building and construction sector is especially urgent. The built environment is responsible for an estimated 37 percent of annual global greenhouse-gas emissions;[227] moreover, it is estimated that 3 billion people (40 percent of the world population) will need access to adequate housing by 2030.[228] Minimizing the impacts of the built environment is essential, therefore, for a transition to a bioeconomy. It is estimated that replacing conventional materials with mass timber in the built environment could reduce global emissions by 14–31 percent.[229] Exciting initiatives are being launched to show what can be achieved with wood: for example, Sweden's capital city, Stockholm, announced in mid-2023 its plan for the world's largest "wood city", boasting 250 000 m^2 of floor space, 7 000 office spaces and 2 000 homes.[230]

Sustainably meeting increased resource demand for forest-based biomass will require boosting supply through a range of means, including increased resource-use efficiency and the avoidance of wood loss and waste in harvesting. In addition to creating and adopting innovations for harvesting and wood processing, further efficiency gains can be obtained through the cascading use of wood raw materials.

As the global approach to forest management increasingly emphasizes the multiple values of forests, and the demand for healthy and sustainable products continues to rise, numerous noteworthy innovations are also emerging regarding NWFPs. NWFPs provide nearly half the world's population – including 70 percent of those living in extreme poverty – with crucial lifelines by helping meet a wide range of fundamental needs, including food security.[44]

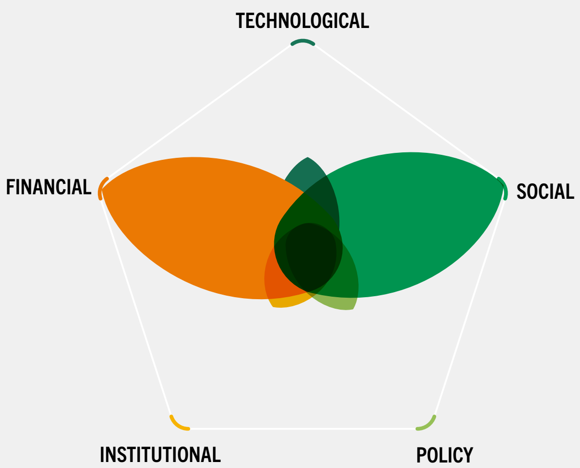
The following six case studies present innovations aimed at enhancing the sustainable consumption and production of forest products to support a bioeconomy and rural livelihoods.

CASE STUDY 13 DELIVERING COLLATERAL-FREE MICROFINANCE TO SMALL FOREST BUSINESSES THROUGH THE POWER OF COLLECTIVE ORGANIZATIONS

Location: Viet Nam

Partners: FFF, comprising FAO, International Institute for Environment and Development, International Union for Conservation of Nature, AgriCord

WEIGHTING OF INNOVATION TYPES



The context. Microfinance enables rural agricultural communities to access financial services that were previously out of reach and thereby to expand their operations and livelihood opportunities. In addition to providing business and value-chain opportunities, microfinance initiatives support resilience and climate adaptation and provide social services to communities.

Until recently, however, a significant segment of rural forest and farm producers in Viet Nam was underserved. In 2016, fewer than 20 percent of forest and farm producer organizations had access to loans, despite a significant forest and farm sector in which communities manage forest resources and agricultural activities. The need for lengthy business plans, which smallholder forest and farm producers lacked capacity to prepare, meant they were unable to access the initial capital investment needed to diversify or increase their incomes through longer-rotation plantations and value adding. Recognizing the role of local communities in sustainable forest management and this finance gap, the FFF[231] has worked to extend microfinance services to forest and farm producers through innovative finance.

The innovation. In 2021, the FFF facilitated the development of "green funds", building on an existing support fund for farmers that has been operational since 1996. The Viet Nam Farmers Union (VNFU) acts as the lending body for green funds and the pre-existing support fund, which operate without the requirement of collateral, thus making them accessible to small-scale producers, who often face challenges in obtaining traditional bank loans.

Green funds provide forest and farm producers with access to loans of up to USD 1 000 without lending interest. The loan amount and terms are tailored to the needs and capacities of borrowers, with a rotating loan term of around 12 months. FFF support has increased the capacity of lenders to assess these needs and raised local awareness of the services available through the organization of other meetings with local authorities and other stakeholders.

Results and impacts. Through green funds, the number of producers with access to finance has more than doubled, with 53 percent of forest and farm producer organizations supported by the FFF now able to pursue sustainable land management practices such as agroforestry and long-rotation timber cultivation, benefiting the environment and livelihoods.

Green funds have enabled a 10–30 percent increase in producer income. A producer who applied to his producer organization for a loan after recognizing the potential for further diversification and increased income through a long-term timber rotation scheme provides an example of how the mechanism works. The forest and farm producer organization, which is part of VNFU, was well-acquainted with this producer's capabilities and could confidently assess his repayment ability, ultimately providing him with a loan to initiate the timber plantation.

The green funds mechanism is relatively new. Most loans issued to date have been to establish long-rotation timber covering more than 200 ha and for investment in diversified production and organic production under forest canopies across 56 ha.

The innovative finance approach is fostering trust in local communities, enabling income growth through diversified ventures, and addressing the unique needs of small-scale producers, who may lack support from conventional banks. Additionally, it contributes to sustainable land-use practices by enabling the integration of timber production into existing agricultural frameworks. The approach is helping strengthen cooperatives, which, for the first time, can offer retirement plans and medical insurance to their members.

Potential for scaling up. As the green funds mechanism matures, it will enable more cooperatives to expand their financial services to members. Savings associations and microfinance allow the establishment of new enterprises based on identified market gaps and provide strong opportunities for local value-chain development. They can also support climate-change adaptation and mitigation at the local level and serve as important social safety nets in communities.

Forest community finance is also being developed in other countries supported by the FFF, such as the Plurinational State of Bolivia, Ghana, Madagascar and Nepal. Notably, the approach has gained significant traction in women's organizations, increasing gender equality in financial access. The approach, which represents the adoption and adaptation of tried and tested financial mechanisms in new contexts, has significant potential to further empower forest smallholder organizations worldwide.

Group discussion on climate-resilient landscapes and improved livelihoods in Viet Nam.

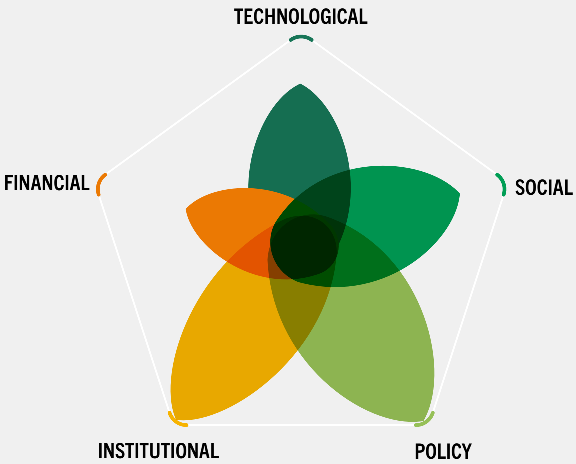
© Viet Nam Farmers' Union/FFF

CASE STUDY 14 THE LEGAL HUB: USING NEW DIAGNOSTIC TOOLS AND METHODOLOGIES TO CATALYSE LEGAL-REFORM PROCESSES FOR SUSTAINABLE WILDLIFE MANAGEMENT

Location: Chad, the Congo, the Democratic Republic of the Congo, Egypt, Gabon, Guyana, Madagascar, Mali, Senegal, the Sudan, Suriname, Zambia, Zimbabwe (and other countries to be added in 2024)

Partners: FAO, CIFOR–ICRAF, French Agricultural Research Centre for International Development, Wildlife Conservation Society

WEIGHTING OF INNOVATION TYPES



The context. Millions of people in the tropics and subtropics depend on wild meat for food and income. Demand is growing, particularly in urban areas, and overhunting is posing a threat to many wildlife species and increasing food insecurity for those who depend on these resources, such as Indigenous Peoples and other local communities.[232] Ensuring sustainable use that both supports livelihoods and maintains wildlife populations requires a community-rights-based approach to sustainable wildlife management.[af]

An enabling legal framework for such an approach should reflect the diversity of interests; it might also need to recognize legal pluralism, including customary and informal justice systems (CIJSs). This is difficult to achieve, however, with many legal and regulatory systems struggling to keep pace with changing global environmental and social norms and requirements. For example, few CIJSs are recognized in statutory laws due to limited stakeholder participation in law-making. Moreover, the complexity of legal language and the chaos of certain legal systems make it difficult for the public to know the applicable rules.

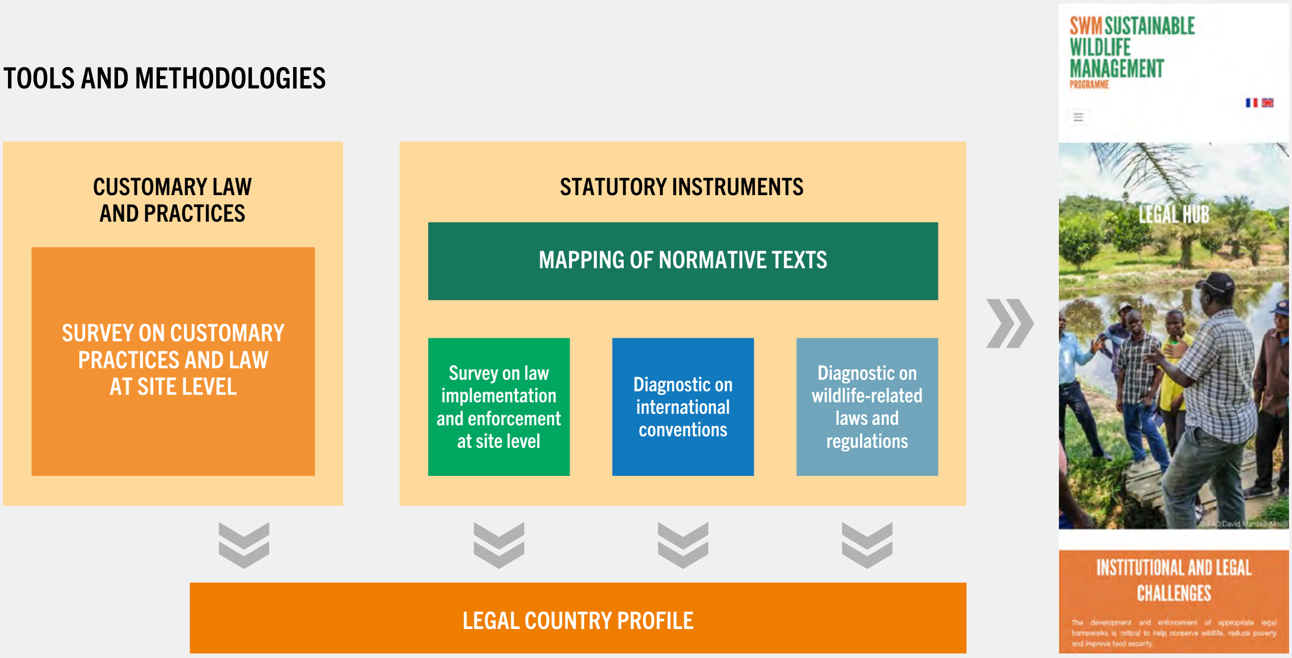
Laws pertaining to wildlife management must be accessible to all. Moreover, reform efforts must be transparent, consultative and participatory if their aims are to be achieved. Previous experience, including work conducted within the framework of the European Union Forest Law Enforcement, Governance and Trade Action Plan, has shown that the effective engagement of civil-society stakeholders and local communities in law-making processes is only possible if there is access to and understanding of legal information.

The innovation. The Legal Hub, launched by FAO's Sustainable Wildlife Management (SWM) Programme in 2021,[234] compiles legal profiles of countries prepared by national experts under the guidance of the FAO Legal Office[235] using SWM Programme legal diagnostic tools (Figure 9). The profiles, which are reviewed and validated by governments, are designed to improve understanding of the strengths and weaknesses of existing statutory legal frameworks. They include mapping the frameworks and identifying barriers to the implementation and enforcement of laws. In addition to addressing the difficulties of accessing and understanding existing legislation, the platform summarizes the requirements of relevant international conventions and customary norms and practices. Thus, the Legal Hub offers a centralized, user-friendly access point to legal texts across sectors[ag] relevant to sustainable wildlife management in 13 countries (to date), as well as in-depth descriptions of customary norms and practices.

af A community rights-based approach to sustainable wildlife management ensures that local and Indigenous communities have equitable participation and inclusion in all project activities; are empowered in their legal use and sustainable management of natural resources; and are strengthened in their capacity to manage and benefit from wildlife.[233]

ag These include land tenure/planning and inland water resource management; hunting/fishing and wild meat distribution; protected areas and ecotourism; human–wildlife conflicts; and animal production, animal health and food safety.

FIGURE 9 TYPES AND SOURCES OF INFORMATION THAT FEED INTO A GIVEN LEGAL COUNTRY PROFILE IN THE LEGAL HUB



SOURCE: Sartoretto, E., Nihotte, L., Tomassi, A., Gnahoua, D., Wardell, A., Goessens, A. & Cheyns, E. 2022. Improving the legal and institutional framework for sustainable wildlife management. Poster presented at XV World Forestry Congress, 2022, Seoul, Republic of Korea. FAO, Center for International Forestry Research, French Agricultural Research Centre for International Development and Wildlife Conservation Society.

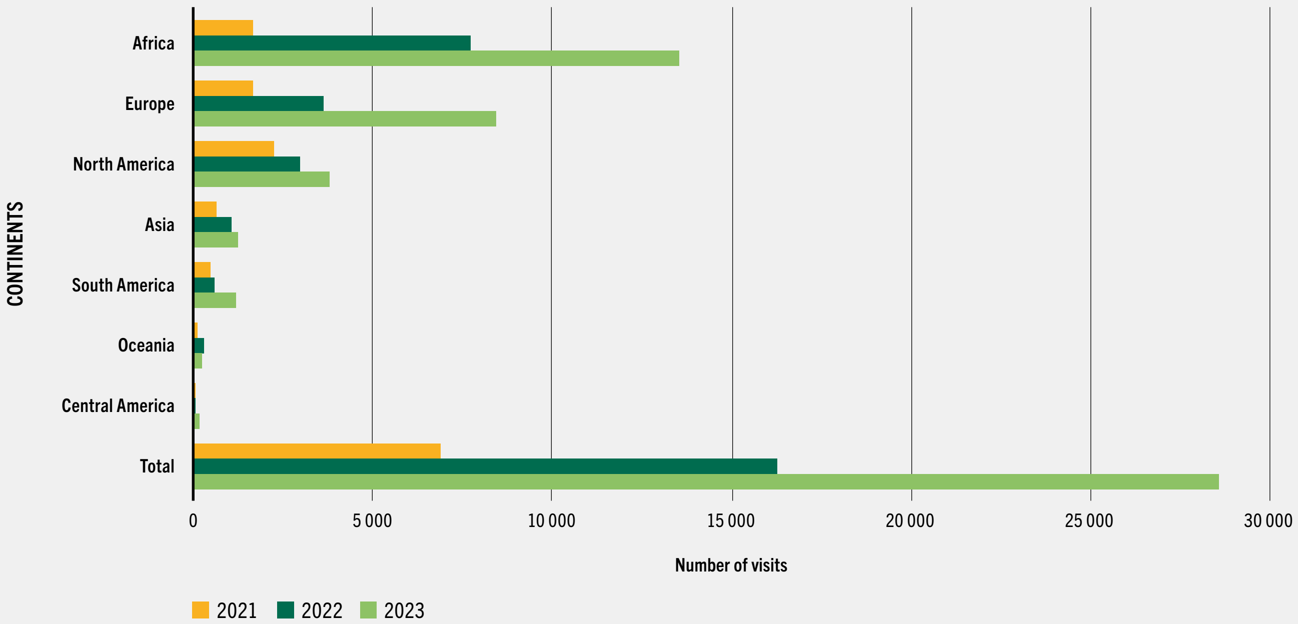
Results and impacts. By providing stakeholders with a greater understanding of existing statutory and customary laws and regulations, together with science-based knowledge from the SWM Programme and other initiatives, the Legal Hub is helping catalyse legal-reform processes to support sustainable wildlife management. The multisectoral approach is also encouraging a One Health[ah] perspective in law development by examining the coherence and interrelationships of legislation across sectors as they relate to the wildlife–human–livestock–ecosystem interface. According to the principles of equity and parity proposed by the One Health High-Level Experts Panel,[236] each legal domain should consider its impact on the health and well-being of all, including humans, animals, plants and ecosystems, and enable multisectoral coordinated interventions. Moreover, the Legal Hub's focus on customary norms and practices allows it to leverage local-level rules and agreements to help translate the One Health approach into action.

The Legal Hub has been used to guide, inform or trigger the following multiple participatory national and subnational legal-reform processes:

- **Botswana** – drafting of a bill on community-based natural resource management, including widespread national consultations;
- **Chad** – drafting of the Law on Environment to reflect principles in the Convention on Wetlands (Ramsar) and African-Eurasian Migratory Waterbird Agreement;
- **the Congo** – a review of a new law on wildlife and protected areas;

ah One Health is an integrated approach recognizing that the health of people is closely connected to the health of animals and the shared environment. It aims to ensure that experts, policymakers and stakeholders in multiple sectors work together to tackle health threats to animals, humans, plants and the environment.

FIGURE 10 NUMBER OF VISITS TO THE LEGAL HUB IN 2021, 2022 AND 2023



SOURCE: Case-study authors' own elaboration.

- **the Democratic Republic of the Congo** – drafting of a policy on wildlife use and a potential future wildlife law as part of a multistakeholder exercise;
- **Gabon** – drafting of a national strategy on wild meat, as well as a series of legislative and regulatory reforms on community hunting and trade;
- **Guyana** – drafting of legislation on inland fisheries and aquaculture as part of a process supported by the SWM Programme and the development of food-safety regulations on wild meat;
- **Madagascar** – a revision process for Ordinance No. 60-126 on the country's hunting, fishing and wildlife protection regime through a multistakeholder legal working group; and
- **Zimbabwe** – informing of a review of the Parks and Wildlife Act and the drafting of the relevant regulation, and also informing of the Community-Based Natural Resource Management Policy and the Communal Land and Forest Produce Act.

The Legal Hub website received nearly 20 000 visits in 2023, almost double the number in 2022 (Figure 10), of which more than 11 000 were from users in Africa. This suggests that the Legal Hub is being used increasingly to inform discussions on reforming wildlife management legislation. Moreover, the Legal Hub is playing an important and perhaps pivotal role in raising awareness among decision-makers in government.

The influence exerted by the Legal Hub is illustrated by the following quote from Dr Rosalie Matondo, Minister of Forest Economy, the Congo (personal communication, 2023):

> This platform allows us to have in one single place all the information from the Republic of the Congo that is related to the management of wildlife and protected areas. Hence, this platform not only allows researchers and students to find information they can use in their research work, but also allows us, the decision-makers, to see what developments we have made within the legislation and regulations framework for the

management of wildlife and protected areas. And it also allows us to question ourselves and propose the reforms that we have talked about, because we must always look back in order to move forward.

The cross-sectoral nature of the Legal Hub is enabling dialogue among departments and ministries in different sectors, which historically have had limited interactions, thus helping overcome institutional silos.

Potential for scaling up. The Legal Hub has expanded rapidly since 2021, with the continuous addition of new information and participating countries. Its approach and tools can be replicated in other countries and regions and used to engage national and local actors in informed multistakeholder dialogues on policy and legal reforms. Factsheets and educational materials and modules are being developed to help reach and inform all stakeholders.

Although the platform has focused to date on sectors relevant to sustainable wildlife management, its scope will be expanded to include other aspects of natural resource management, such as land conversion, forests, pesticides and biotechnology. The hub approach will further accommodate the guiding principles of some key international legal instruments and initiatives of international programmes and organizations to better reflect new agendas, as well as the SDGs. The members of the Collaborative Partnership on Sustainable Wildlife Management[237] and other external partners have agreed to participate in a review.

CASE STUDY 15 HARNESSING DIGITAL TECHNOLOGIES TO IMPROVE THE EFFICIENCY OF TIMBER-TRACKING AND PROMOTE SUSTAINABLE SUPPLY CHAINS

Location: Guatemala

Partners: Instituto Nacional de Bosques (Guatemala), International Tropical Timber Organization

WEIGHTING OF INNOVATION TYPES

The context. Obtaining accurate estimates of log volumes in transportation is important for sustainable forest management and trade – yet the conventional measurement method is time-consuming, inefficient and involves high operational costs. For example, measuring log volume typically requires measuring the faces of all visible logs in the transported stack to calculate the "stacking factor" – that is, the ratio between the total volume of stacked wood and the volume of solid wood.

The Instituto Nacional de Bosques (National Forest Institute – INAB) of Guatemala is working to encourage legal and sustainable forest value chains and advance sustainable forest management by improving policy frameworks, statistics and timber-tracking systems. As part of this work, the development of faster and more accurate methods for assessing the volume of logs and other wood products in transit was identified as a priority need.

The innovation. A project funded by the International Tropical Timber Organization has developed and implemented several mechanisms to improve traceability in forest production chains in Guatemala. One of these is a log-scaling manual, *Guía Práctica para la Cubicación de Productos Forestales* ("Practical Guide to Forest Product Scaling"), which covers logs and other wood products (woodfuel, offcuts and sawnwood) that are traded or transported in Guatemala. The project team recruited software experts, who, working closely with field staff, developed a smartphone app using the methodology, products and formulas set out in the log-scaling manual to calculate log volumes requiring only photographs and a few simple measurements.

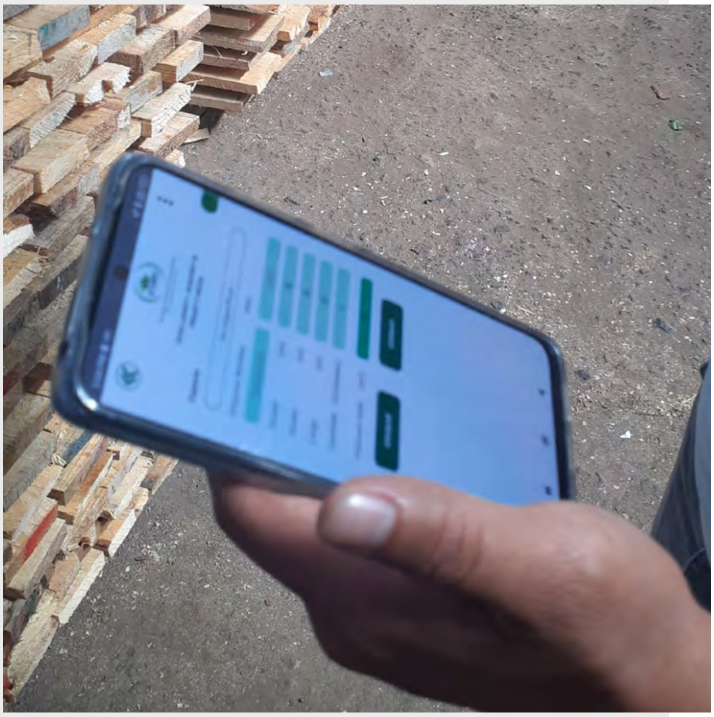
The app, called *Cubicación de Productos Forestales* ("Scaling of Forest Products"), known as CUBIFOR,[ai] is simple to use because it requires only a photograph of the stack of logs (or other wood product), either on the truck or in the mill yard or other location, plus the average width and length of the stack, to estimate volume. The app recognizes each log face, calculates the average diameter and stacking factor, and generates a report with the resultant scaled volumes, which can be downloaded in Excel and PDF formats. The app also enables the scaling of logs for products such as sawnwood, rectangular boards, round billets, sawdust, chips, fuelwood, wood pieces and charcoal.

Results and impacts. The app is helping advance sustainable forest management and strengthen the capacity of forest companies in Guatemala to control their inventories while also improving the efficiency of activities requiring the quantification of timber volumes. This has the benefit of boosting legal and sustainable wood supply chains and enhancing competitiveness by reducing the time and cost of obtaining authorizations from government authorities. Officials at forest checkpoints now have an efficient, cost-effective means for confirming the details on bills of lading and other shipping documents accompanying wood in transit, helping ensure legality and meet administrative requirements.

Mills that have been using CUBIFOR are reporting that it is helping them in controlling, tracking and measuring wood shipments. INAB is still rolling out the app for field use, which has clear potential to assist it and other authorities in monitoring and controlling forest operations and thereby combating illegal logging and illegal timber trade.

Potential for scaling up. CUBIFOR can be replicated in other countries in the tropics, thereby assisting companies to improve their systems for controlling, tracking and measuring wood shipments and helping authorities combat illegal logging and illegal timber trade.

CUBIFOR provides a wide range of innovations and benefits to its users such as the digitization and review of their regular reports.



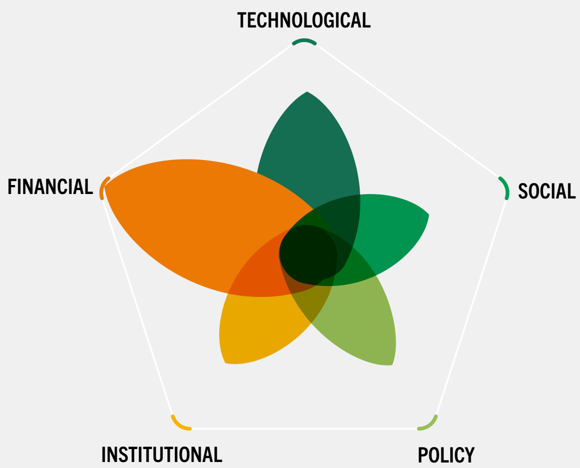
ai CUBIFOR, a free Android app in Spanish, is available from Google Play.

CASE STUDY 16 IMPROVING CONNECTIVITY ALONG TIMBER SUPPLY CHAINS TO REDUCE WASTE AND INCREASE THE VIABILITY OF SUSTAINABLE FOREST MANAGEMENT

Location: Brazil, Guyana, Panama, Peru

Partners: Naturally Durable Inc., FAO

WEIGHTING OF INNOVATION TYPES



The context. The increased use of engineered wood products in the construction sector has the potential to deliver climate-change mitigation and adaptation benefits. As indicated in Chapter 2, the substitution of wood-based products for non-renewable materials is likely to see global demand for industrial roundwood increase considerably by 2050, including in the construction sector. The international consumer market practice of purchasing larger dimensions and longer lengths of timber, however, generates significant wood fibre waste. Additionally, the high cost of wooden buildings compared with other construction materials is often mentioned as a potential barrier to wider use.[238]

Improving production and consumption efficiencies for tropical wood,[aj] including by reducing fibre waste and costs, will be important for meeting increased wood demand and ensuring that wood remains an attractive material for construction. Modern modular approaches to construction have brought about significant improvements in efficiency and the optimal use of high-value species. Most design concepts can be modularized to enable the use of lower-value species for hidden parts such as brackets and cleats. Among other things, this requires forest product purchase orders for smaller pieces and underused species. Collaboration along supply chains to improve understanding of the precise requirements of specifiers, architects and construction managers will enable sawmills to provide customized, efficient solutions and provide opportunities for sharing information, such as on lesser-used species and opportunities for increasing their more effective use, thereby reducing pressure on species in high demand.

The innovation. The timber trading company Naturally Durable Inc. instigated a novel approach to collaboration along timber supply chains by seeking to apply wood-waste-reduction strategies at sawmills in Forest Stewardship Council-certified forests in Brazil, Guyana, Panama and Peru. The company saw an opportunity to reduce costs for clients (and therefore boost their competitiveness) while using lesser-used species by applying precise specifications. This involved establishing formalized collaborative relationships with stakeholders along supply chains to encourage "precisely specified wood purchases". The company promoted greater coordination among harvesters, sawmills, traders and architectural millwork companies to enhance integration during the design, manufacturing and installation phases of construction projects. Practically, this involved collaboration and co-development across various stages of the process, including the drafting of architectural and shop drawings and the creation of purchase orders, shipping documents and invoices.

The impact. Naturally Durable Inc.'s innovative collaborative approach has enabled the communication of piece-specific purchase orders to remote forest sawmill production managers, which has improved wood-use rates

aj There is less of an issue with underused species in the temperate and boreal regions due to the predominance of plantations and the limited number of species in natural stands, and where efficient processing facilities are generally well-developed.

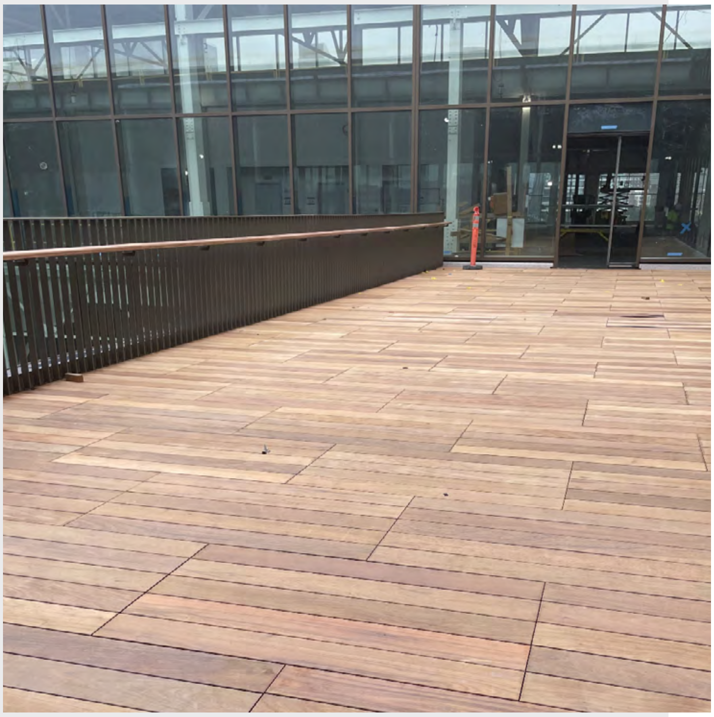
by enabling the economically viable use of smaller logs and shorter pieces.

The Commonwealth Pier Revitalization Project[239] – a major ocean-pier revitalization project in Boston, United States of America – provides an example of the impact of piece-size specification and enhanced collaboration along the value chain. The installation contractors specified 29 532 m^2 of decking (amounting to five ocean-freight containers). In 2021, Naturally Durable Inc. instructed two Forest Stewardship Council-certified decking manufacturers to produce all lengths in increments of 31 cm. In 2022, sawmill piece-count records were matched to a spreadsheet analysis of the lengths needed at all project locations. Location-specific drawings determined the exact lengths to be used during installation and a specific section of the project was able to use only short pieces (2–5 feet lengths, or about 61–152 cm). Installation crews were provided with detailed shop drawings. Using this approach, the actual installation required only 24 358 m^2 of decking, thus achieving a 17.5 percent gain in wood-use efficiency. The sawmill earned an additional EUR 9 300 (about USD 9 800) through the sale of short pieces, the project contractors saved approximately USD 86 000, and the installation crew reduced the time it needed to install the decking. The gain in efficiency also cut the shipped volume by 37 m^3, which reduced transport-related greenhouse-gas emissions.

Opportunities for scaling up. Collaboration among architects, construction managers and sawmills can result in wood-use efficiency gains at any scale. The method can be applied to all architect-specified wood products in built environments globally when embedded in design and construction management software.

Dissemination of the precisely-specified-wood-purchase approach requires management decisions seeking to enhance the economic and environmental sustainability of wood use. It demands the appropriate education of architects and engineers to ensure wide understanding of the use of wood as a construction material and specifications focused on wood properties rather than species. It also requires close communication along supply chains and between project developers and forest managers and traders. The dissemination and use of software and educational programmes is crucial but underdeveloped.

Boston Commonwealth Pier decking.



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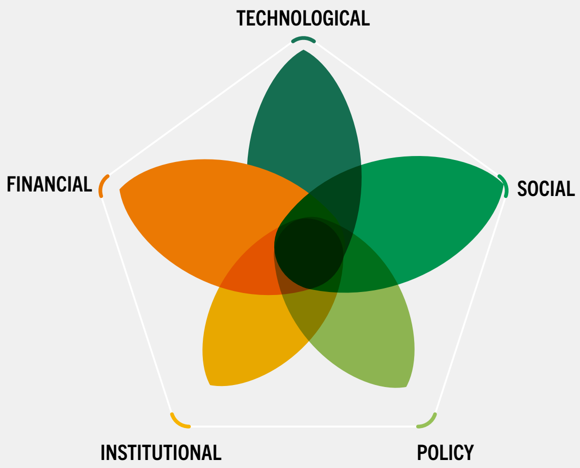
CASE STUDY 17 APPLYING NEW WOOD-PROCESSING TECHNOLOGIES TO PROMOTE A BIOECONOMY AND ENHANCE EARTHQUAKE RESILIENCE

Location: Slovenia, United States of America

Partners: Institute for Civil Engineering (Slovenia); National Science Foundation (United States of America), Colorado School of Mines, University of Nevada, Lehigh University, Washington State University, LEVER Architecture, Englekirk Structural Engineering Center at the University of California, Oregon State University, Forest Products Laboratory, United States Forest Service

WEIGHTING OF INNOVATION TYPES



The context. Seismic events are common in many parts of the world, and they can cause significant injury and loss of life due to building collapse. This is a problem shared by countries transitioning from rural living to urbanization and by already highly urbanized countries with older, more traditional urban structures not designed for seismic events.[240] It is estimated that the population in global earthquake-prone areas such as the Pacific Rim and the Mediterranean–Asia belt will increase threefold by 2050, to almost 600 million people.[241] The building of new seismically resilient buildings and the upgrading of existing urban structures are essential. Building collapse is commonly a result of inadequate design and poor building practice. Therefore, there is a need to share best-practice engineering, design and building methods between countries and regions.[240]

The innovation. Mass-timber technologies are offering alternatives to reinforced-concrete building systems. One of these, CLT, was launched commercially in the 1990s and now has an annual global production volume of about 2 million m^3 (valued at almost USD 1.3 billion in 2022). A compound annual growth rate of production of up to 14 percent is expected for the next decade.[242] The use of mass timber in construction is gaining momentum globally due to its low carbon impact, with traditional concrete and steel construction each contributing 8 percent or more of global carbon-dioxide emissions.[243] An important attribute of wood when used in construction is its low weight-to-strength ratio combined with its ductility (the ability to deform and bend before it breaks).[244] Overall, mass timber has the potential to increase the resistance of tall buildings to earthquakes.

Results and impacts. The NHERI Tallwood project led by the Colorado School of Mines (funded by the National Science Foundation) designed and built a ten-storey mass-timber tower at the University of California, San Diego, United States of America, on a giant external shaking table. The building was subjected to multiple earthquake cycles of up to 7.7 on the Richter scale.[245] Special attention was applied to the jointing methods used between floor panels, columns and sheer walls and non-structural components such as facades, which provided the structure with additional flexibility during simulated earthquakes, thereby ensuring that the joints didn't break, the building didn't collapse, and non-structural elements remained attached.[246] The test showed that a ten-storey timber tower using mass timber and a flexible metal jointing system could withstand once-in-a-generation-scale earthquakes with no damage; moreover, the building would be fully usable afterwards.[245]

At the Institute for Civil Engineering in Ljubljana, Slovenia, CLT panels were used to simulate structural reinforcement of older concrete-structure buildings built before tighter seismic building codes came into effect.[245] The project tested the impact of applying CLT panels to the outside sheer walls of a two-storey concrete building. First, a concrete post-and-beam and masonry wall and floor structure was built on a shaking table, and various scales of seismic shaking were applied to measure performance and the level of swaying and damage to the structure and connections. Then, a similar structure was built and CLT elements fastened to the outside of the masonry infill walls, and the same seismic testing was carried out. The results showed that the addition of CLT external bracing panels provided a 34 percent increase in resistance and a 25 percent increase in displacement capacity compared with the non-CLT-reinforced concrete/masonry structure. Thus, the structural reinforcement of older concrete buildings with mass timber could be a viable way of upgrading existing concrete buildings, potentially including buildings already exposed to seismic damage.[247]

The two projects demonstrated that the use of mass-timber building elements and systems for both new builds and renovation in earthquake-prone regions could be a technically viable method of construction and renovation (the study didn't carry out an economic viability assessment). This could be significant for regions where increasing urbanization offers an opportunity to adopt best-practice mass-timber construction design and connection systems through knowledge transfer. The potential to maintain existing concrete/masonry structures and strengthen walls with mass timber is an option that would be much less disruptive than replacing existing buildings that lack adequate seismic resistance. In addition, several projects have shown that mass-timber elements can be used to increase the height and occupancy of existing concrete buildings, which can increase the value of the real estate and provide additional, relatively low-cost housing and office space. Recent overbuild upgrades using mass timber include those at 55 Southbank Boulevard, Melbourne, Australia, and 80 M Street SE, Washington, DC, United States of America, in which the light weight, strength and ductility of mass timber have enabled the extension of commercial buildings upwards for mixed-purpose usage.[248, 249]

Opportunities for scaling up. A challenge for projects using mass timber is the construction of full-scale buildings, which is time-consuming and costly and requires strong collaboration. The NHERI Tallwood project deployed expertise from several universities in Japan and the United States of America and engaged strongly with industrial producers of mass timber and connector systems. There is an opportunity for the transfer of evidence-based knowledge and best-practice design to regions where urbanization is increasing in seismically prone areas. The potential to use wood as a reinforcement material in existing concrete structures could cost-effectively increase their seismic resistance and even increase building height and thermal performance. Woodrise and the World Conference on Timber Engineering are good platforms for increasing awareness of these technologies.

Innovation Tall Timber Project.

CASE STUDY 18 ENABLING FARMER-LED INNOVATION IN SUSTAINABLE FOREST AND AGRICULTURAL PRODUCTION THROUGH FARMER FIELD SCHOOLS

Location: Global

Partners: FAO, Global Farmer Field School Platform

WEIGHTING OF INNOVATION TYPES

The context. Today's agrifood systems pose significant challenges due to the detrimental impacts of unsustainable business-as-usual practices, which are contributing to climate change and natural resource degradation,[250] and there is an urgent need for their transformation. A crucial step for this is to address the challenges faced by small-scale producers and family farmers. Family-run farms constitute about 90 percent of the 608 million farms globally; of these, 84 percent are smallholder farms operating on 2 ha or less. Despite using only 12 percent of total agricultural land, they contribute around 35 percent of the world's food supply.[251] The impact of family and small-scale farming extends beyond livelihoods, directly shaping ecosystems through land management practices. Yet capacity development, learning and education programmes for smallholders are lagging in many countries.

The innovation. Over the past three decades, FFSs have emerged as a highly effective capacity-development approach that enables rural people to innovate with clarity and purpose and fosters social skills crucial for rural transformation. By centring learning and innovation around farmers, FFSs contribute to individual, household and community empowerment while aiding ecosystem restoration. The discovery–learning approach in FFSs is particularly beneficial because it facilitates learning and innovation in sustainable agriculture, food systems, forestry, livestock, integrated pest management, fisheries, aquaculture, value chains and market connections.[252] The innovative approach, grounded in an enhanced understanding of agroecological dynamics and farmer-led experimentation, has enabled tens of millions of farmers worldwide to sustain or enhance productivity while reducing their reliance on external inputs.

Results and impacts. The forestry applications of FFSs have proven highly impactful by fostering ecological literacy and unleashing creative problem-solving capacities. FFSs have played a crucial role in cultivating "response – ability", which is the capacity of small-scale producers to creatively address challenges in agriculture, food production and natural resource management through enhanced knowledge and technological development. Experiences with FFSs in Africa, Asia and the Americas show the significant potential of the approach in inclusively bolstering the restorative capabilities of rural communities and advancing sustainable small-scale agriculture and forestry production.[253]

FFSs have empowered family farmers globally to acquire the knowledge, skills and social organization necessary for regenerative natural resource stewardship in small-scale and family farming. It has been estimated that, over the past 30 years, about 20 million people from 119 countries have graduated from FFSs.[250] In addition to addressing practical issues, FFSs foster self-esteem, unlock creativity and promote social organization.[254]

An FAO stocktake identified forest- and tree-related FFS applications involving over 200 000 producers in more than 20 countries across Africa, Asia and the Americas, addressing challenges in, for example, fruit-tree production, woodlots, community forestry, soil and water management, and protected areas.[255] In Mozambique, the PROMOVE Agribiz project (Case study 12) is supporting 22 000 small-scale farmers in advancing agroforestry production and business incubation and to access carbon credits for their agroforestry efforts.

A curriculum-based participatory approach germane to FFSs is that of Farmer Business Schools (FBSs). FAO developed the FBS concept to strengthen the capacities of service providers and farmers in transitioning from subsistence to market-oriented farming and "farming as a business". The FBS curriculum is designed to guide farmers over the full farm business cycle, with basic concepts and exercises in business planning, farm management and financial literacy. The FBS approach has been implemented across Asia, Africa and the Near East since 2005 in various settings, including fragile contexts at the humanitarian and development nexus. Hundreds of FBSs have benefited tens of thousands of men and women farmers in enterprises spanning crops, horticulture and agri-processing, catering for local consumption and export.

Potential for scaling up. Growing demand for people-centred and environmentally sound rural development positions FFSs at the forefront of the transition toward more sustainable agriculture and forestry. FFSs involve building partnerships to support small-scale producers; applying insights from people-centred development to forestry and agroforestry; promoting inclusion and social organization at various levels; investing in synergies between agriculture and forestry training; and financing business incubation for income opportunities linked to local-level ecosystem restoration initiatives.

In India, the Government of Andhra Pradesh State, Rythu Sadhikara Samstha (a state government institution) and FAO are implementing the Andhra Pradesh State Community Managed Natural Farming programme, which is adapting the FFS concept to natural farming and soil health regeneration through agroforestry and intensive polycropping. The aim of the programme is to enable the transition of 6 million agricultural producers to regenerative agriculture by 2030.[256] CARE International plans to expand farmer field and business schools to 35 countries, support 25 million producers, engage farmers in global markets via a certification model, and promote government adoption.[257] FFSs and FBSs can also play significant roles in scaling up action on ecosystem restoration by developing the capacity of smallholders and producer organizations to undertake local restoration initiatives, for example in the context of the African Forest Landscape Restoration Initiative (AFR100).[ak]

A Farmer Field School group learning session in Malawi.

ak AFR100 is a country-led effort to bring 100 million ha of land in Africa into restoration by 2030 (see afr100.org).

SENEGAL
In Koyli Alpha people from the community work in the tree nursery created as part of the Great Green Wall initiative.
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CHAPTER 5
INNOVATION MUST BE SCALED UP RESPONSIBLY TO MAXIMIZE THE CONTRIBUTIONS OF THE FOREST SECTOR TO AGRIFOOD SYSTEMS TRANSFORMATION AND OTHER GLOBAL CHALLENGES

KEY MESSAGE

➔ **Five enabling actions can encourage responsible and inclusive innovation that optimizes forest-based solutions to global challenges:** (1) raise awareness of the importance of innovation and create a culture that fosters innovation to bring about positive change; (2) boost skills, capabilities and knowledge to ensure that forest-sector stakeholders have the capacity to manage innovation creation and adoption; (3) encourage transformative partnerships to de-risk forest-sector innovation, provide opportunities for knowledge and technology transfer, and build appropriate safeguards; (4) ensure more and universally accessible financial resources to encourage forest-sector innovations; and (5) provide a policy and regulatory environment that incentivizes forest-sector innovation.

5.1 FIVE ENABLING ACTIONS CAN ENCOURAGE RESPONSIBLE AND INCLUSIVE INNOVATION THAT OPTIMIZES FOREST-BASED SOLUTIONS TO GLOBAL CHALLENGES

Innovations typically emerge as a result of numerous complex interactions among actors within an innovation ecosystem. Note, however, that innovation ecosystems possess unique characteristics depending on context. In addition, the complexity of the global forest sector means that responsible innovations should be created and adopted in ways that are tailored and appropriate for the specific contexts within which they are being created and adopted. Whether at the organizational, jurisdictional or global levels, robust, well-functioning innovation ecosystems require an appreciation for creativity and collaboration; appropriate knowledge and skills, collective learning systems, governance mechanisms and risk management frameworks; and adequate natural, human and financial resources.

Innovations in the forest sector are likely to be most effective when they integrate science and traditional knowledge through inclusive practical approaches. Investment in integrated research and development is needed to drive technological advances, process optimization and the development of adaptive products; build skills and knowledge; and create templates for bridging the disparate frameworks of science and traditional knowledge. Governments are often the main supporters of research and development, but the real-world application of innovations is dependent largely on funding and investment from, collaboration with, and uptake by the private sector and civil society.

Innovation can create winners and losers and, if poorly conceived, can exacerbate existing inequalities and marginalization. To minimize such risks, innovation creation and adoption processes should be inclusive and contextually appropriate, and they should support the participation of all forest stakeholders, thereby helping ensure that innovations are right for the place, people and challenge. Typically underrepresented stakeholder groups that should be empowered and supported in innovation and related processes include the following:

- **Women.** Gender imbalances exist in many segments of the forest sector worldwide,[258] yet gender equality in an organization helps harness diverse perspectives and talents for innovation and problem-solving and enhance organizational (including financial) performance.[195] Therefore, forest-sector innovation processes must work to ensure gender equality.[259]
- **Indigenous Peoples, smallholders and rural communities.** Genuine collaboration among researchers, technicians, Indigenous Peoples, smallholders and rural communities will enable the integration of science and traditional and Indigenous knowledge. This can reduce the risk that innovations will be culturally inappropriate and increase their positive impacts.[260]
- **Youth.** Young people often drive innovation,[261] and their inclusion can also help improve forest governance and decision-making processes.[262] Efforts to better harness the abilities of young people are crucial for effective innovation processes.

Many groups have essential roles to play in enabling innovation, including the following:

- **national governments,** such as by implementing national standards, incentives and policies for innovation, supporting (including financially) research and development, outreach and promotion, and facilitating collaboration;
- **international organizations**, such as by assisting with standards-setting, innovation knowledge management, outreach and promotion, facilitating collaboration, providing funding, and developing supportive policy guidance;
- **educational institutions**, such as by assisting with innovation research, education, training and outreach;
- **research and development bodies**, such as by creating, testing and sharing evidence-based innovations and related approaches and methodologies;
- **the private sector**, such as by creating and adopting innovative approaches and products, providing training opportunities, contributing to research and development (including financially), and supporting communication and advocacy; and
- **civil society**, such as by creating and adopting innovative approaches and products, advocating for change, raising awareness, fostering collaboration, providing grassroots insights, driving social entrepreneurship and ensuring accountability.

Drawing on existing literature and the case studies in Chapter 4, five key enabling actions are described below for the development of robust forest-sector innovation ecosystems and the creation and adoption of responsible innovations. Specific actions are also suggested, mainly for the consideration of national governments and international organizations.

1. **Raise awareness of the importance of innovation and create a culture that fosters innovation to bring about positive change.**
   Innovation requires a conducive culture that encourages curiosity, creativity, questioning and risk-taking.[186] How these cultural elements are harnessed and promoted by an entity (such as a company, institution or country) depends largely on its historical legacies, value systems and beliefs, but the core goal must

be to provide a positive context that enables the entity to embrace reflection on its ongoing practices, contemplate change, and identify actions to effect positive change. In many contexts, developing an innovation culture will require awareness-raising – that is, activities that increase understanding of the benefits that innovation can deliver.

Possible specific actions for governments and international organizations:

- Generate and demonstrate the use of approaches to increase organizational innovativeness and support a culture that fosters responsible and inclusive innovation. This could include examples illustrating the power and scope of collaborative innovations and the role that an innovation culture can play in supporting forest conservation, restoration and sustainable use and achievement of the SDGs.
- Provide tools for organizations to assess and continuously improve their innovation culture and use of innovations, including for data and information management to guide inclusive and evidence-based decision-making.
- Conduct regular stocktakes of innovative activities in the forest sector to identify opportunities and challenges for innovation.
- Provide incentives for all forest-sector stakeholders to participate in collaborative efforts seeking innovative solutions to common challenges.

2. **Boost skills, capabilities and knowledge to ensure that forest-sector stakeholders have the capacity to manage innovation creation and adoption.**
A vibrant forest education sector is essential for developing the skills and knowledge necessary to maximize the contributions of forests and trees to the SDGs and to achieve the Global Forest Goals, and an understanding of innovation is a central component of this.[263] The forest education sector will be better able to leverage opportunities in other sectors for scaling up innovation when it is well connected to research and business incubation.

Organizations tend to neglect the need for the "soft" skills that enable effective human interactions, but these are essential components of responsible and inclusive innovation processes.[264] In addition to developing technical skills, therefore, the forest sector should cultivate the necessary soft skills for managing innovation processes, techniques and methodologies.

Possible specific actions for governments and international organizations:

- Collect and organize information and resources on education programmes, educator networks, partnerships and communities of practice in the broad area of innovation in the forest sector.
- Conduct needs assessments to understand which innovation capacities and skills are lacking in the forest sector and prioritize their incorporation in education programmes.
- Develop guides for boosting innovation skills, knowledge and capabilities in the forest sector.
- Support peer-to-peer learning platforms and integrated field programmes to enable the extension of innovative good practices related to innovation and to test innovative techniques and methodologies.
- Support improvements in technical and innovation knowledge in forest-related extension services and encourage communities to develop innovative solutions using delivery methods such as FFSs and other vocational training institutions.
- Support research and development to increase the evidence base on all innovation types for making progress in forest conservation, restoration and sustainable use. Learnings could be integrated into forest-sector education and training, including tertiary and other vocational training institutions, to encourage a broader understanding of forest-sector innovation.

Possible specific actions for education and research institutes:

- Incorporate innovation (emphasizing responsibility and inclusivity as core

BOX 11 USING INNOVATIVE PARTNERSHIP APPROACHES TO HELP DRIVE PROGRESS IN THE UNITED NATIONS DECADE ON ECOSYSTEM RESTORATION

FAO and the UN Environment Programme are co-leading implementation of the UN Decade on Ecosystem Restoration worldwide. The two FAO-led taskforces described in Case study 9 have catalysed powerful partnerships among a diverse group of restoration stakeholders to create a shared vision of ecosystem restoration, align collaboratively, address capacity and technological gaps, and drive evidence-based innovation. In three years, the taskforces have created a foundation and enabling environment for the UN Decade, with the following accomplishments (among many others):

- a common vision on ecosystem restoration created by publishing *Principles for Ecosystem Restoration*;
- *Standards of Practice for Ecosystem Restoration* published to guide implementers in developing effective restoration projects that reflect the principles of ecosystem restoration;
- the Capacity, Knowledge and Learning Action Plan for the UN Decade developed; and
- technological innovation advanced through the development of the Framework for Ecosystem Restoration Monitoring (described in Case study 9).

By enabling strong collaboration among highly diverse actors, the two FAO-led taskforces, and three other taskforces in the UN Decade framework led by the World Bank (Finance Taskforce), the International Union for Conservation of Nature (Science Taskforce) and the UN Major Group for Children and Youth (Youth Taskforce), are helping overcome a lack of alignment on ecosystem restoration, a lack of finance and capacity, and difficulties in providing transparent monitoring and reporting. In this way, they are enabling the dissemination of successful innovations to a global network of practitioners and policymakers and celebrating and supporting country leadership on restoration innovation, thereby helping translate ambitious commitments on restoration into effective action on the ground.

elements) into forest education curricula and training materials.
- Facilitate integrated innovation research, drawing on science and traditional knowledge.
- Develop research on diverse innovation types (and bundles of innovations), which should be collaborative to ensure it is demand-driven, contextually appropriate and capable of generating practical tools.

3. **Encourage transformative partnerships to de-risk forest-sector innovation, provide opportunities for knowledge and technology transfer, and build appropriate safeguards.**
Transformative partnerships involving governments, the private sector, civil society, research and academia, women and youth, Indigenous Peoples and local communities are needed at all levels to support the creation and uptake of responsible innovations in the forest sector.[265] Innovation hubs and other networking modes promote interactions among stakeholders and enable collaboration, the transfer of knowledge and skills, and positive spillovers (i.e. the unintended effects of interactions that support the scaling up of innovations). The partnerships arising from long-term engagement among diverse stakeholders can be transformative: that is, they can deliver system shifts from unsustainable to more sustainable systems.[266] The approach taken in the UN Decade on Ecosystem Restoration shows the power of innovative partnerships to enable the creation and uptake of innovations (Box 11).

The forest sector increasingly seeks to collaborate across sectors (including within and between governments and organizations),[267] in part to gain access to the knowledge and skills of other sectors. Such collaboration (e.g. to share data and to jointly define problems and design programmes) can lead to the development of innovations that otherwise might not arise.

Possible specific actions for governments and international organizations:

- Assess existing platforms for science–policy–practice knowledge exchange with a view to ensuring that the knowledge arising is accessible to all.
- Optimize the use of existing regional and global forums, such as regional forestry commissions and multistakeholder platforms, to identify needs and opportunities for nurturing and scaling up responsible and inclusive innovation in the forest sector.

4. **Ensure more and universally accessible financial resources to encourage forest-sector innovations.** The risks associated with innovation creation and adoption can be high. This is especially so in the Global South, where trade-offs among competing objectives are often also substantial, thus limiting the investment available.[268] Increasing access to funding and finance – including to small producers and rural communities – is a prerequisite for robust innovation ecosystems and to enable the scaling up of forest-sector innovation. Increasing finance availability can help address systemic issues that are holding back the scaling-up process (e.g. by addressing externalities in sustainable forest management) and incentivize virtuous cycles of investment that reinforce further innovation.

   Possible specific actions for governments and international organizations:

   - Help countries access finance for innovations that directly support forest conservation, restoration and sustainable use.
   - Provide financial incentives for the development of innovations that generate public goods and particularly benefit Indigenous Peoples, women, youth and small producers.
   - Reduce the risks associated with innovation by encouraging organizations and universities to work together in teams through the partial funding of collaborative research and development processes.[269]

5. **Provide a policy and regulatory environment that incentivizes forest-sector innovation.** Complementary and coherent sets of policies can help stakeholders navigate complexities and path dependencies within an innovation ecosystem by building their capabilities. There is a need to establish policies that help de-risk innovation processes and minimize the potential disparities and unequal benefits of innovation. Cirera and Maloney (2017)[270] described a "capabilities escalator", in which an innovation ecosystem evolves to increasingly support higher-level capabilities within the ecosystem. This concept offers a basis for guiding the development of robust and supportive policies. The three stages of the escalator comprise the development of science, technology, engineering and mathematic skills, managerial and organizational capabilities, and basic infrastructure (stage 1); increasing the quality of research and innovation, building technological capabilities and incentivizing research and development (stage 2); and long-term research and development, technological programmes and collaborative innovation projects (stage 3). The right policy mix supports moving from stage 1 to stage 3.

   Possible specific actions for governments and international organizations:

   - Provide best-practice advice on policy, regulatory and legal frameworks for optimizing the enabling environment of innovation ecosystems, maximizing positive intended outcomes, minimizing trade-offs and putting in place safeguards where major risks exist.
   - Adopt socioculturally appropriate, evidence-based, best-practice policy and regulatory practices that support the development of responsive and inclusive innovation in the forest sector while ensuring safeguards are in place to minimize disparities and the unequal distribution of benefits.

Unlocking the power of innovation

Billions of people already have a stake in forests and trees because of the benefits they bring, from wood products and NWFPs, to ecosystem services such as climate regulation and habitat provision, to their positive roles in human health and well-being. Evidence suggests that the world is on the brink of major environmental changes, with consequent potentially highly negative implications for poverty, hunger, food insecurity and malnutrition. Solutions are needed quickly and at scale, and forests and trees have a clear role to play through conservation, restoration and sustainable use. To realize the potential of forests and trees, the power of responsible, inclusive innovations needs to be emphasized and invested in.

The enabling actions listed above offer a starting point for work to minimize the barriers to and maximize the positive impacts of responsible and inclusive innovations. They are designed to be mutually reinforcing and not implemented in isolation. For example, skill and knowledge development hinges on financial resources and targeted policies, which, in turn, can foster collaboration that leads to cultural change towards a better appreciation of responsible and inclusive innovation.

Opportunities for innovations in the forest sector are vast, with exciting prospects for improvement across all five innovation types. More research is required to provide the evidence base to increase knowledge on the impacts of, and priorities for, innovation in the forest sector.

The adoption of any forest-sector innovation should be accompanied by robust monitoring and evaluation and adaptive management based on learning. Emerging technologies and advances in behavioural science increase the options for understanding the impacts of innovation.

Embracing the potential of forest-sector innovation requires safeguards to ensure it is done responsibly and inclusively. Ultimately, this will mean that the right innovation is adopted in the right place for the right reasons. Innovations must reflect and be sensitive to the needs, aspirations and unique circumstances of end users and other beneficiaries. Unlocking the power of innovation offers a means for more-rapid progress on meeting our collective forest goals and embracing a more sustainable future. ■

GLOSSARY

The definitions provided here are for the convenience of readers and are not necessarily official FAO definitions.

Agricultural innovation. The process whereby individuals or organizations bring new or existing products, 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 and thereby contribute to food security and nutrition, economic development or sustainable natural resource management.[9]

Agroforestry. A collective term for land management systems in which woody perennials are deliberately integrated spatially or temporally on the same land management units as agricultural crops and/or animals to create economic, social and environmental benefits.[271] The three main types of agroforestry systems are: (1) agrosilvicultural (trees combined with crops); (2) silvopastoral (trees combined with animals, including aquaforestry – that is, trees with fish); and (3) agrosilvopastoral (trees, animals and crops).

Bioeconomy. The production, use, 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.

Cross-laminated timber. A prefabricated engineered wood product consisting of at least three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross-oriented and bonded with structural adhesive to form a solid wood element. Panels are prefabricated based on the project design.[272]

Deforestation. The conversion of forest to other land use, whether human-induced or not.[15]

Forest. Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.[15]

Forest and landscape restoration. A planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes. It does not seek to recreate past ecosystems given the uncertainty concerning the past, the significantly altered conditions of the present and anticipated but uncertain future change. It does seek, however, to restore forested ecosystems that are self-sustaining and that provide benefits for both people and biodiversity. For this reason, the landscape scale is particularly important because it provides the opportunity to balance economic, social and environmental priorities.[273] FLR typically seeks to improve resilience, productivity and socioeconomic value from restored forests and landscapes, benefiting human well-being, local livelihoods and the environment. It aims to seek a balance between restoring ecosystem services (e.g. biodiversity, soil and water conservation) and productive functions of land for agriculture and related uses that provide food, energy and other products and services for sustainable livelihoods.

Forest degradation. The long-term reduction of the overall supply of benefits from forests, which includes wood, biodiversity and other products and services. In the FRA, countries are requested to indicate the definition of forest degradation they use in assessing the extent and severity of forest degradation.[18]

Forest ecosystem services. The benefits people obtain from forest ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, wastes and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling.[274] Forest ecosystem services are the services derived from forests – they include the production of ecosystem goods; the provision of habitat for wild species; climate and water regulation; soil formation and conservation; the generation and maintenance of biodiversity; pollination; pest control; seed dispersal; cultural values; and aesthetic beauty.[275]

Forest expansion. Expansion of forest on land that, until then, was under a different land use, implying a transformation of land use from non-forest to forest.[15]

Forest pathway. A development approach involving forests, of which the following three are identified in SOFO 2022:[4] (1) halting deforestation and forest degradation as a crucial element for reversing the drivers of climate change, biodiversity loss, land degradation, desertification and the emergence of zoonotic diseases ("halting deforestation and maintaining forests", also "halting deforestation"); (2) restoring degraded forests and landscapes and putting more trees into agricultural settings as cost-effective means for improving natural assets and generating economic, social and environmental benefits ("restoring degraded lands and expanding agroforestry", also "restoration"); and (3) increasing sustainable forest use and building green value chains to help meet future demand for materials and ecosystem services and support greener and circular economies, particularly at the local level ("sustainably using forests and building green value chains", also "sustainable use").

Forest sector. The wide range of activities related to sustainable forest management, the provision and production of timber and other wood and non-wood forest products, the protection of forest ecosystems and biodiversity, and safeguarding the benefits of forests.[14] Thus, it encompasses all activities involving forests, as well as agroforestry, and diverse stakeholders, including governments, civil-society organizations, the private sector, Indigenous Peoples, vulnerable and marginalized communities, youth and women.

Forest-sector innovation. The process whereby new or existing products, processes or ways of organization, relevant to the forest sector are brought into use for the first time in a specific context to increase effectiveness, competitiveness, resilience to shocks and environmental sustainability. This publication identifies five types of innovation: technological, social, policy, institutional and financial. Forest-sector innovations can help make progress along the three forest pathways – that is, allowing for the enhanced conservation, restoration and sustainable use of global forest resources.

Innovation. Doing something new and different, whether solving an old problem in a new way, addressing a new problem with a proven solution or bringing a new solution to a new problem. In the context of agrifood systems, "to innovate" refers to the process by which individuals, communities or organizations generate changes in the design, production or recycling of goods and services, as well as changes in the surrounding institutional environment, that are new to their context and foster transitions towards sustainable food systems for food security and nutrition. Innovation is also used as a noun to refer to the changes generated by this process. Innovation includes changes in practices, norms, markets and institutional arrangements, which may foster new networks of food production, processing, distribution and consumption that may challenge the status quo.[9]

Innovation ecosystem. An innovation ecosystem provides the general economic and institutional environment required for innovation to happen.[68, 276] It is shaped by a range of economic, social, environmental and other factors. Within the ecosystem, a diverse network of actors interact with each other and with artifacts (such as products, services and technological tools) in complex ways that ultimately trigger innovation creation or provide the enabling conditions in which an innovation can be adopted.

Net forest gain/loss/no change. "Forest area net change" is the difference in forest area between two FRA reference years. It can be positive (gain), negative (loss) or zero (no change).[15]

Non-wood forest products. Goods of biological origin other than wood derived from forests, other wooded land and trees outside forests.[277]

Non-timber forest products. All NWFPs plus certain woody materials such as woodfuel and small woods.

Other land with tree cover. Land classified as "remaining land area", spanning more than 0.5 ha with a canopy cover of more than 10 percent of trees able to reach a height of 5 m at maturity (e.g. orchards and agroforestry systems).[15]

Other wooded land. Land not classified as "forest", spanning more than 0.5 ha; with trees higher than 5 m and a canopy cover of 5–10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.[15]

Scaling up. Expanding, replicating, adapting and sustaining successful policies, programmes or projects in geographic space and over time to reach a greater number of people. In innovation, applies equally to the creation of new products, processes and ways of organization and the broad adoption of existing innovations in new contexts.

Smallholders. Small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than 1 ha to 10 ha. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption.[278]

Soft commodity. A term generally used to refer to commodities such as coffee, cocoa, sugar, soybeans and oil palm that are grown rather than mined.

Soft skills. People's abilities to communicate effectively with each other and work well together.

Transdisciplinary science. The methodology that addresses topics across and beyond disciplines, through a comprehensive and holistic framework. In this context, it engages disciplines and interdisciplinary research, but should also consider the collaboration between professional scientists and diverse non-academic stakeholders, either individuals or institutions, in order to benefit from and contribute to their understanding of a problem and their specific knowledge. Transdisciplinarity involves interaction at every step of a scientific endeavour.[279]

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THE STATE OF THE WORLD

2024 THE STATE OF THE WORLD'S FORESTS

FOREST-SECTOR INNOVATIONS TOWARDS A MORE SUSTAINABLE FUTURE

Innovation is essential for achieving the 2030 Agenda for Sustainable Development and the Sustainable Development Goals. It is also an important accelerator for the transformation to more efficient, inclusive, resilient and sustainable agrifood systems and for achieving global goals such as the eradication of hunger and poverty and the sustainable management and use of natural resources.

But innovation does not arise in a vacuum. Among other things, it requires enabling policies; strong, transformative partnerships; investment; an inclusive culture that is open to and encouraging of new ideas; and a willingness to take calculated risks.

This edition of *The State of the World's Forests* (SOFO) provides highlights on the state of the world's forests and explores the transformative power of evidence-based innovation in the forest sector, ranging from new technologies to creative and successful policies and institutional changes, to new ways of getting finance to forest owners and managers. Eighteen case studies from around the world provide a glimpse at the wide range of technological, social, policy, institutional and financial forest-sector innovations – and combinations of these – being tested and implemented in real-world conditions. SOFO 2024 identifies barriers to, and enablers of, innovation and enumerates five actions for empowering people to apply their creativity in the forest sector to solve problems and scale up positive impacts.

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