



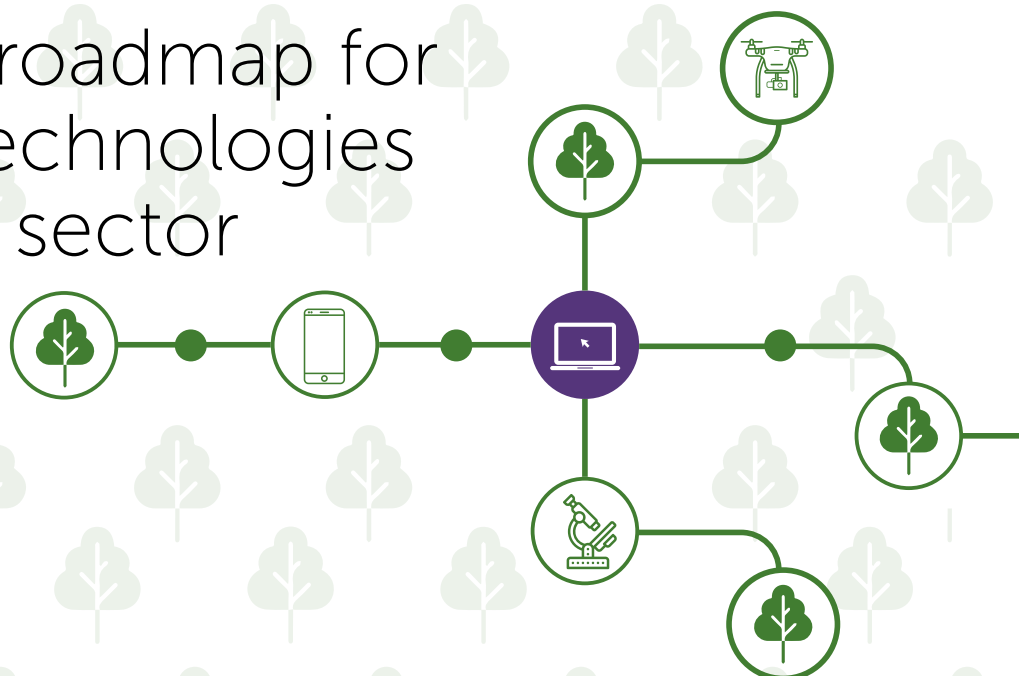
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Asia-Pacific roadmap for innovative technologies in the forest sector



Key messages

- As highlighted by FAO's Third Asia-Pacific Forest Sector Outlook Study (APFSOS III), the use of innovative technologies – from digital technologies, biological technologies, processing technologies and new wood-based products, to social innovations and innovative finance mechanisms – have the potential to revolutionize forest management and to make critical contributions to sustainable development along forest value chains.
- Innovation will be key in the coming decades to meet an increasing demand for wood, other forest products and ecosystem services while halting and reversing deforestation, in line with the commitment taken at COP26 in Glasgow by the international community.
- However, innovative technologies uptake has been slow and uneven in the Asia-Pacific region.

Investments are needed in education, capacity building and infrastructure development to make innovations happen on the ground.

- Two main barriers to innovative technologies uptake and scaling up have been identified, namely: (i) the lack of capacity (in terms of infrastructure and equipment, human capital and financial resources); and (ii) rigid legal frameworks (policies and regulations), often lagging far behind rapidly evolving technologies.
- This brief, building upon state-of-the-art knowledge and extensive consultation of 425 key regional stakeholders, suggests a set of ten overarching recommendations for policy- and decision-makers that are further detailed in 59 specific options to facilitate the dissemination and adoption of innovative technologies in Asia and the Pacific and overcome the main barriers identified above.



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Overarching recommendations

1. Improve the monitoring of forest resources and track illegal logging and illegal trade of forest products
2. Raise awareness of and enhance citizen participation in forest monitoring and sustainable forest management
3. Improve productivity and resource use efficiency
4. Generate new job opportunities and support livelihoods
5. Ensure policy coordination across sectors, actors and scales and create innovative governance mechanisms at all scales
6. Invest in innovative research, extension and capacity development models
7. Elaborate conducive policies and regulations and develop the infrastructure needed to boost innovation and sustainable development in the forest sector
8. Consider the economics of innovation to facilitate the adoption of innovative technologies across contexts and scales
9. Assess the negative impacts of innovative technologies and establish appropriate social and environmental safeguards
10. Strengthen regional cooperation

Innovative technologies for the forestry sector in Asia and the Pacific are a priority issue identified by the 'Third Asia-Pacific Forest Sector Outlook Study' (APFSOS III). In response to this outlook study, FAO and CIFOR, lead center of the CGIAR research programme on Forests, Trees and Agroforestry (FTA), have developed a roadmap on innovative technologies in support of sustainable forest management in Asia and the Pacific. This roadmap was developed through an inclusive and participatory process associating a wide range of key regional forest decision-makers and technical experts, from governments and intergovernmental organizations, from the private sector and civil society organizations, as well as from academia and research institutions.

The first step of the roadmap was to prepare a report building upon the scientific literature, FAO and FTA experience, and the consultation of 425 stakeholders, including regional experts, decision-makers, and youth involved in activities related to the forest sector in the Asia-Pacific region.¹ This policy brief is grounded on that report. It examines the potential and barriers for disseminating and deploying innovative technologies for sustainable forest management (SFM) in the region and provides overarching recommendations, including a further 59 specific options for decision-makers. It delineates and informs the process by which decision

makers and actors can identify: the potential of innovative technologies to advance SFM; their potential impacts; the constraints to technology uptake and scaling up and how to overcome these constraints and facilitate adoption.

1. Framing: concepts and definitions

Forests have multiple and diverse definitions, reflecting both the diversity of forest ecosystems and the diversity of human perceptions and uses of forests. This study uses the widely recognized FAO definition of a forest, defined as a piece of "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ." FAO further distinguishes two categories of forests: naturally regenerating forests (including primary forests) and planted forests. This study also considers trees outside forests, present in a variety of systems, including agricultural tree crops, agroforestry systems, or urban trees. In line with APFSOS III, this study uses the terms "forestry" and "forest" sector to encompass all economic activities that mostly depend on the production of goods and ecosystem services from forests.

Human population and income growth exert strong pressure to convert forests to other land uses to satisfy growing demand for land, food and tree products, leading to a gradual decrease in global forest area over the past decades. This intensifies the pressure

¹ In this roadmap, the Asia-Pacific region covers the 49 countries and territories listed here: https://www.foreststreesagroforestry.org/wp-content/uploads/2020/10/FAO-FTA_Roadmap-Note-on-geographical-scope_DEF.pdf

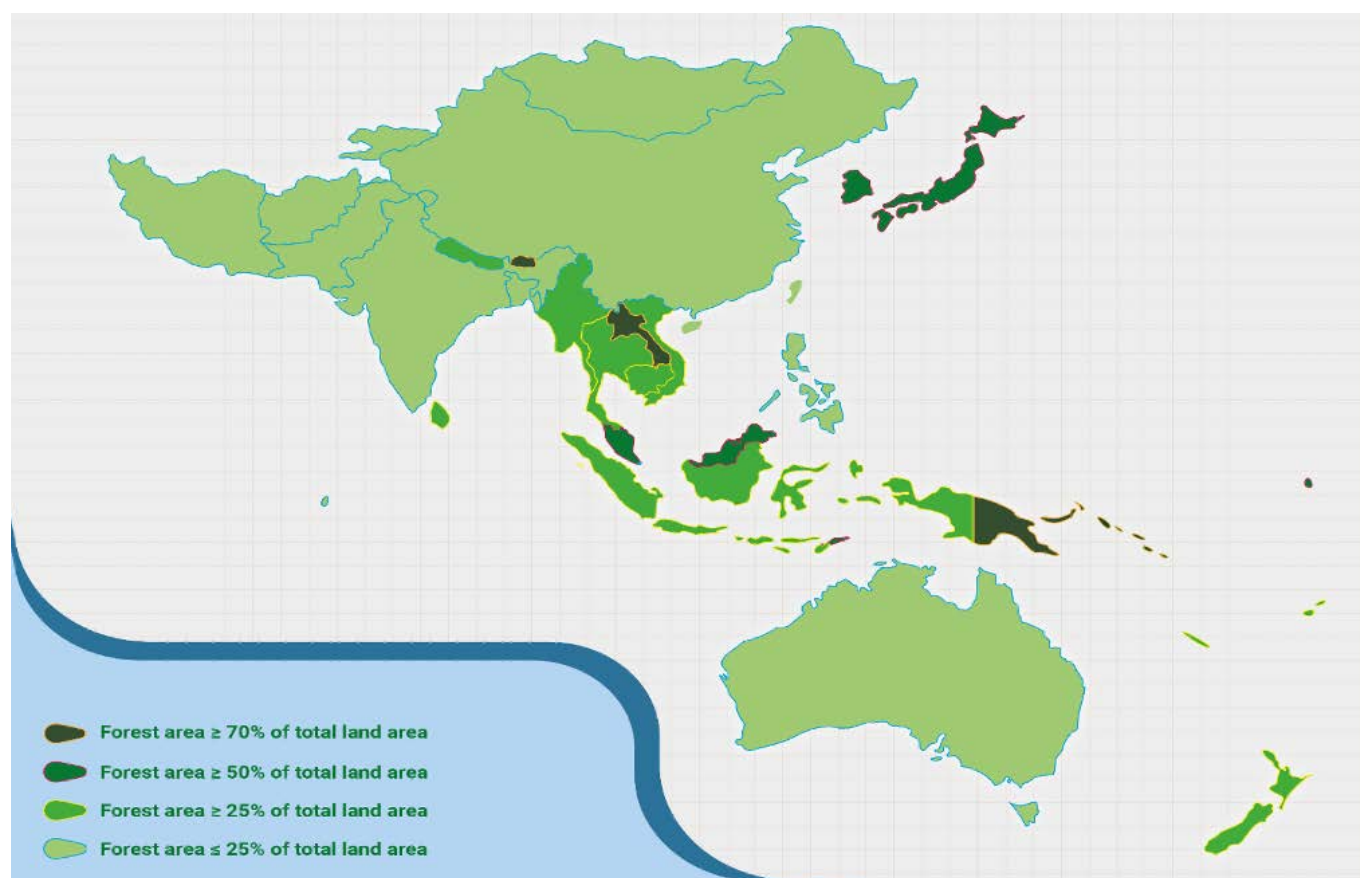


Figure 1. Forest extent in Asia and the Pacific. Source: Roshetko et al. 2022.

on remaining forests, jeopardizing biodiversity, carbon stocks, and the various other ecosystem services forests provide. In contrast to this global trend, Asia and the Pacific have experienced an increase in forest area (see Figure 1) in recent decades as a result of strong afforestation and reforestation policies in some countries such as China, India and Viet Nam. However, total forest area continues to decrease in other countries in the region. Additionally, primary forests are still decreasing at the regional level: according to APFSOS III, based on data from FAO Global Forest Resources Assessment (FRA) 2015, they now cover only 140 million ha, i.e. 19% of the region's total forest area, much lower than the global average (32%). Nonetheless, there are positive trends. The area of forests under legal protection or long-term management plans is continuously increasing in the region, which is showing a strong commitment to advance SDG 15.² Protected areas now cover 25%

of Asia's total forest area and 16% of the Pacific's (compared to an average of 18% at the global level). The percentage of forest areas under long-term management is 64% and 31% respectively, compared to an average of 54% at the global level. The areas of certified forests in Asia and the Pacific are limited (25 million ha and 12 million ha respectively) but have increased since 2000.

Forests and trees make important contributions to most of the 17 SDGs. Whereas the forest sector is often considered conservative, innovative technologies are revolutionizing forest management and forestry value chains. The deployment of innovative technologies in the forest sector has the potential to provide new products and services, improve productivity and reduce costs, reduce waste and improve the efficiency of resource and energy use, thus generating further income and employment opportunities, conserving natural resources and limiting negative social, economic and environmental impacts. As highlighted by APFSOS III, the effective utilization of innovative technologies in

² SDG 15 is "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

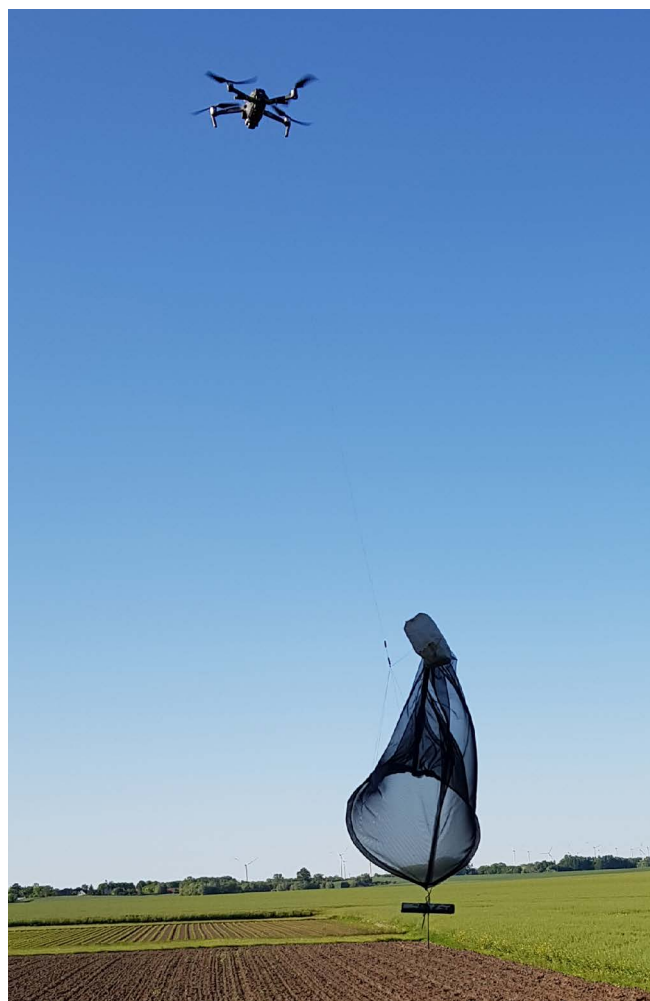


Figure 2. Drones can be used to collect insects to diagnose environmental health issues and assist in developing management options.

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the forest sector has the potential to further enhance sustainable forest management and advance many SDGs, provided that progress is made in the following priority areas of work: forest science and research; forest monitoring; forest productivity and wood resource use efficiency; forest governance and tenure, including stakeholder participation and community empowerment; and forest finance and investment.

This study considers innovative technologies in light of these domains and how they can contribute to improve SFM. For the purpose of this study, the term “innovative technologies” embraces both: (i) new technologies in the generation, proof-of-concept, or pilot phases that could become mainstreamed or mature before 2030; and (ii) recent technologies emerging for new purposes

or in new contexts. It is recognized that innovation is contextual and that innovative technologies may emerge directly in the forest sector or be adapted from other sectors.

2. Innovative technologies in the forest sector

This study identifies four main categories of innovative technologies as having the most promising potential to support sustainable development in the forest sector in Asia and the Pacific: (i) digital technologies; (ii) biological technologies; (iii) technical innovations in processes and products; and (iv) social innovations and innovative finance.

Digital technologies can considerably facilitate accurate, cost-effective and real-time monitoring of forest resources and forest value chains. They can facilitate information sharing and capacity development, thus improving transparency and participation and empowering local stakeholders and communities. They can also enable breakthrough innovations in the three other categories; for instance, blockchain technology, securing electronic transactions, opened a new world for innovative finance mechanisms. This category gathers a variety of information and communication technologies (ICT) and geospatial technologies such as drones, satellite-based observations and other remote sensing technologies, laser imaging detection and ranging (LIDAR), radar, acoustic and camera sensor networks, early warning systems, global positioning systems (GPS) and geographic information systems (GIS), blockchain, online collaborative platforms, artificial intelligence (AI), machine learning, mobile phone and crowdsourcing applications, social media and video conferencing.

Biological technologies can facilitate the collection, domestication, selection, breeding, propagation and dissemination of high-quality germplasm and genetic material at a reasonable price. Genetic resources (germplasm) are the most important input in any tree production system, as the genetic and physical quality of the germplasm determines the upper limit of the system’s potential yield, as well as the productivity of other inputs (e.g. labor or agrochemicals). Genetic research and development should prioritize species’ disease resistance, drought resistance, growth, and adaptation to climate change, or adapt wood



Figure 3. The use of geospatial technology to improve forest planning and management can increase yields, decrease waste and costs, and support SFM.

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composition to the different possible uses.³ Innovative tree domestication efforts should expand to include native timber species, non-wood forest species, and other underutilized forest species for local utilization. In the case of these less-domesticated species, the basic selection and use of quality genetic material to improve productivity and income generation is an innovation that requires not only appropriate techniques but also social innovation to effectively deploy improved material to communities and smallholders. DNA profiling can help identify and document the nature and geographic origin of biological samples, thus increasing transparency and traceability along forest value chains and helping track and combat illegal activities and illegal trade.

Process innovations can directly improve productivity and cost efficiency, reduce waste and improve resource use efficiency at all stages of forest value chains. This

category includes: improved silviculture management, including refined site preparation, planting and post-planting practices; precision forestry based on the use of digital technologies; reduced impact logging (RIL) and winch-assisted harvesting; computer numerical control (CNC) machining to optimize product design or wood processing; portable sawmills; spindleless lathe technology to reduce waste and use small diameter logs; drying technologies that reduce energy use and costs; and microwave plasma technologies to enhance wood properties (e.g. improve appearance, durability and water resistance). Process innovations can also create new uses for previously underutilized and hence undervalued wood species, such as fast-growing small-diameter species. The main drawbacks are that process innovations can be expensive and usually require important upfront investments and strong personal skills.

Product innovations have created a new generation of wood-based materials that can substitute non-renewable or more energy- or resource-intensive

³ e.g. low-lignin wood for improved pulp production or high-lignin wood to produce cellulosic derived sugars for bioplastics, biofuels and other products.



Figure 4. Community forestry mechanism strengthen the role and capacity of local communities in the governance, planning and management of locally controlled forests.

© Lok Mani Sapkota

products (e.g. steel or concrete, plastics from fossil fuel) in multiple domains. These products can create new uses for low-value underutilized species, wood scraps from processing mills and other wood waste; greatly increasing wood recovery and recycling rates, thus generating additional economic and environmental benefits. These innovative products include: engineered wood such as cross-laminated timber (CLT), mass timber, medium density fiberboard (MDF), particleboard, oriented strand board (OSB), veneer and plywood; engineered bamboo products; experimental bioplastics; transparent wood to be used as an alternative to glass; bio-based composites and cellulose nanomaterials, with possible applications for paper and packaging, food, health, construction, biosensors and electronics; bioenergy that can reduce greenhouse gases (GHG) emissions and dependence on fossil fuels; and biochar that increases soil carbon storage and enhances soil fertility.

Social innovations are new forms of organization. They often aim to enhance the provision of services and opportunities to society, seeking to provide equitable access to disadvantaged or marginalized groups. They are often multi-sectoral and multi-organizational. Prevalent social innovations in Asia and the Pacific are the concept of community forestry (CF, also called social forestry and community-based forest management), forest and farm producers associating as a diverse group of land managers, and public-private partnerships (PPPs). While established for decades, CF is now more widely used, integrated and recognized. Many

governments promote CF as an effective national strategy to empower local communities, enhance gender equity and empower women and girls, reduce poverty, improve food security and livelihoods, and contribute to biodiversity conservation and climate action. Concurrently, CF has evolved as a mechanism for agrarian transformations, the creation of forest- and farm-based enterprises, the commercialization of locally-produced commodities, and integration with private sector investment and PPPs. Forest and farm producers, collectively and individually, own or manage 65% of the world's land, including locally controlled forests and associated forest- and farm-enterprises. PPPs are social innovations that combine private finance and public resources to implement projects for public benefit.

The long-term horizon of forestry operations makes them less attractive to investors as it leads to high biological, climatic, social, market and political risks. Innovative finance mechanisms have emerged over the last two decades that can address these issues. These include: blended finance associating public and private investors with complementary risk-and-return appetites; impact investment; green, social, climate or sustainability bonds; crowdfunding platforms that open new avenues for small investors and strengthen the link between borrower and lender; payments for ecosystem services (PES); ICT-enabled mobile banking, and financial and e-commerce services that facilitate transactions and access to value chains, credit and markets. These technologies support the development of a viable digital economy where small-scale producers, communities or

organizations can directly market products or services to consumers. Such arrangements promote efficient value chains, avoiding commissions to middlemen, which can reduce transaction costs, increase margins received by the producer (individual, community or organization), and enable lower prices for the consumer.

Sustainable forest management involves a variety of functions that can be grouped in broad categories, including: monitoring and forest management, harvesting, processing, distribution and trade, final utilization in different sectors, information sharing and capacity development, community participation and governance. The use of innovative technologies throughout forest value chains affects these functions and the extent to which they contribute to sustainable development in the forest sector. Innovative technologies can not only perform existing functions better than currently utilized technologies but may also provide completely new functions, products and services. The way that a technology performs a given

function, as well as its positive or negative impacts on people and the planet, may vary significantly across contexts and may be perceived differently by different stakeholder groups even in the same context. In addition, the social, economic and technical contexts are also evolving. Assessing the strengths and weaknesses of each innovative technology in performing these different functions will ground an analysis of their advantages and disadvantages in different contexts.

3. Innovative technologies: opportunities and challenges

The adoption, dissemination and scaling up of innovative technologies in the forest sector come with important opportunities and challenges.



Figure 5. Global Forest Watch is an open access platform that provides timely access to reliable information about forests that combines satellite technology, open-access data and crowdsourcing.

Credit: Google Earth Voyager

The growth in human populations and innovative technologies will likely generate major shifts in wood demand and forest value chains. Despite overall economic growth, per capita consumption of wood is decreasing as a result of technology improving resource use efficiency and substituting non-wood lignocellulosic materials, reducing the pressure on remaining forests. Concurrently, the increasing use of previously under-utilized species and wood processing residues or co-products, as well as improved productivity and waste reduction along forest value chains, are improving wood recovery rates and reducing pressure on overharvested species. By creating new uses for wood products and improving wood processing, innovative technologies can enable the development of a circular bioeconomy that contributes to and addresses the challenges of climate change and sustainable development.

The accurate, cost-effective and real-time monitoring of forest and other land resources is among the most important and consequential achievements of innovative technologies. Enhanced monitoring and early warning systems based on a variety of digital technologies can facilitate forest management, prevent risks and limit environmental damage. Many of these monitoring technologies are user-friendly and use open-source tools, applications, and platforms, making data and information more easily available for all stakeholders, particularly NGOs and local communities, and facilitating their participation in decision-making processes. Enhanced access to accurate data can also strengthen local land tenure and access rights,

help track and prevent illegal activities, and mitigate land conflicts. However, innovative technologies can also be misused to facilitate access to resources and their unsustainable exploitation, thus accelerating deforestation and forest degradation and threatening biodiversity. Access to the data generated by monitoring tools, applications and platforms may be restricted by the institution that generated the data or holds the legal rights to the technologies. The use of efficient monitoring technologies could also result in job losses, particularly for low-skill laborers and seasonally employed rural residents. The new job opportunities created are likely to require skill sets that favor people with technical training over local residents.

The large volumes of data and information generated by remote sensing and other innovative technologies can be used to enhance forest planning and management. This includes identifying threats and implementing mitigation strategies. The concepts of improved silviculture management and precision forestry promote the use of data and information from various sources to refine site preparation, planting and operations to improve SFM. RIL and winch assisted-harvesting can increase productivity, log recovery and profitability, while reducing waste and collateral environmental damage. However, innovative technologies can also have negative impacts on forest management, such as by promoting the unsustainable exploitation of natural resources or resulting in the loss of low-skilled jobs.



Figure 6. Community cutting nurseries (gardens) and plantations of improved genetic material established with assistance from forest sector partners support farmers in contributing to landscape restoration, the supply of timber resources, and enhancement of their livelihoods. © Tony Page.

Many innovative technologies can contribute to reduced waste and improved resource use efficiency, thus increasing the profitability of the forest sector and contributing to the sustainable management of natural forest resources. Innovative technologies can also limit pollution and collateral damage to ecosystems. Combining digital technologies and process innovations, such as through CNC, can further improve resource processing, increasing productivity, recovery rates and profitability.

The success of any planting operation depends heavily on the genetic and physical quality of the planting material and on the correct matching of the genetic material selected with the local site conditions. This matching can build upon the wealth of existing intra- and interspecific genetic variation. Genetic improvement programs, however, require time, capital and technical expertise. As a result, genetic improvement activities have often been restricted to a limited number of species, focusing on those of commercial value. Species of local importance have seldom been prioritized. Similarly, improved germplasm is often in limited supply and expensive, which could restrain access by farmers and communities. Participatory multiple-species improvement and delivery programs, conducted with local stakeholders, are important innovations to address those barriers. Additionally, access to genetic material developed by private companies or individuals could be restricted by intellectual property rights (IPRs).

Innovative technologies have the potential to generate further income and employment opportunities through the development of new products and services and of innovative, safer and greener skilled jobs, making the forest sector more productive, sustainable and attractive, in particular for youth, who will be the forest managers of tomorrow. However, the uptake and scaling up of innovative technologies is likely to lead to the loss of some existing low-skilled jobs. This could negatively impact people involved in traditional labor-intensive management systems, who may have limited human or financial capacity to adapt.

4. Enabling the uptake and scaling up of innovative technologies

The Asia-Pacific region shows very high potential for innovation. However, this innovation potential does not necessarily translate to the forest sector and is mainly concentrated in a few countries, with large divides in

innovative capacity across countries within the region. Three broad categories of countries and territories can be identified in the region:

- the “innovation tigers”, which show the highest potential, including: Australia, China, Hong Kong (China), Japan, the Republic of Korea, New Zealand and Singapore;
- the “emerging innovators”, mainly upper-middle-income to low-income developing economies, which show encouraging performances on some indicators and promising potential for innovation uptake and scaling up in the coming decades, including: Brunei Darussalam, Cambodia, India, Indonesia, the Islamic Republic of Iran, Malaysia, Maldives, Mongolia, Nepal, the Philippines, Thailand, and Viet Nam;
- a third group, consisting of countries where particular efforts are needed to build upon the assets they have and develop their own innovation potential that could benefit from regional and international cooperation.

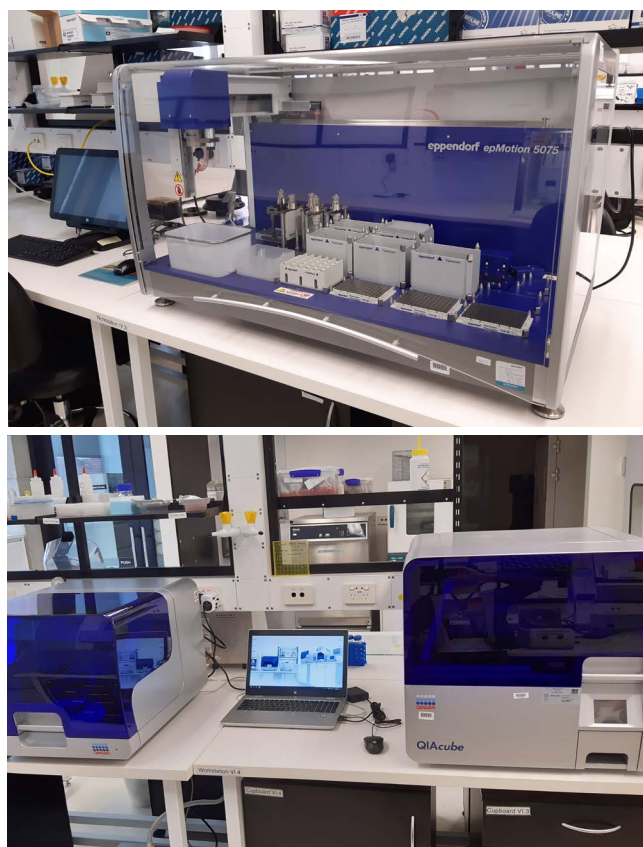


Figure 7. Strategic planning and investment may be necessary to establish laboratories and procure equipment, capacity building and stable operational management.

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Table 1. Key barriers that hinder the uptake and scaling up of innovative technologies

Capital	Constraint
Human capital	Lack of skills, knowledge and experience; wariness of “new” technologies
Natural capital	Limited access to forests, land, natural resources and their assets and products
Physical capital	Lack of infrastructure – roads, markets, electrical power, internet, etc. – and suitable equipment and innovations to scale technologies to all levels of stakeholders
Financial capital	Limited access to capital, credit and value chains
Social capital	Restrictive governance and tenure rights to forests, land, natural resources and their assets/ products, and limited access to institutions, networks and information
Policies	Absent, weak or restrictive legal and regulatory frameworks; inappropriate application or enforcement of those legal and regulatory frameworks

Two main barriers to innovative technologies uptake and scaling up were identified during the development of the roadmap: (i) a lack of capacity (in terms of human, natural, physical, financial and social capital); and (ii) unaligned policies and regulations.

Technology adoption is highly context-specific and very uneven across the region. Upfront costs and investments may be too high for many stakeholders. Local communities may need external support to build capacities and physical infrastructure and access the financial resources needed to harness the opportunities offered by innovative technologies. The challenge is to adapt innovative technologies to smaller scales and to local needs, priorities and circumstances so that they can also benefit smallholders and local communities, even those with limited human and financial resources and limited capacities to embrace innovation.

Demonstration is key to the successful dissemination and uptake of innovative technologies. Full engagement with intended adopters is important to achieve buy-in. Government agencies, conservation organizations, universities and research institutions, the private sector, and communities should also be involved in promoting and demonstrating technologies. Organization and leadership will be essential. The adoption of innovative technologies also requires new operational standards, investment in new equipment, and capacity building in the effective use of the new equipment and implementation of the operational standards. This is a significant investment in capital and time that affects short-term productivity and profitability. Financial and institutional inertia can block or delay the adoption of innovative technologies, requiring consequential investment and capacity building.

Public investment, procurement and support for research and development are powerful tools to support the uptake and scaling up of innovative technologies. Private-sector partners will be crucial for technology transfer and dissemination. It is important that adequate incentives are offered to attract private-sector participation. Establishing trust and clear communication regarding the use, advantages and disadvantages of innovative technologies can enhance their dissemination and adoption. Ownership and IPRs can be a barrier to the development and dissemination of innovative technologies.

In many countries, there is neither a clear strategy to support the uptake and scaling up of innovative technologies in the forest sector nor long-term forestry research for a development perspective, while other countries proactively support the adoption and utilization of innovative technologies. The following factors should be considered to facilitate the adoption of innovative technologies: (i) the technology and its characteristics; (ii) the adopters, either individuals or organizations (private sector, government agencies, civil society, communities); (iii) the larger economic, social and environmental context; (iv) the demonstrated worth of the technology; and (v) communication and dissemination channels that promote the technology.

Capacity building, education and training are required for professionals and local residents to adopt and use the new technology. Meanwhile, the most vulnerable, whose employment is threatened or eliminated by the adoption of innovative technologies, must be accommodated with some form of retraining to avoid being left behind. Priority targets are:

(i) Indigenous Peoples and local communities, women and marginalized groups, who often have a unique



Figure 8. Women and minorities have unique knowledge of and roles in SFM and they should be provided equitable opportunity for capacity building. © James M Roshetko

knowledge of local ecosystem management; and (ii) youth of any gender, rural and professional, to attract them to forestry as a career. Training in the safe operation of the technologies is also essential, particularly with process and product innovations that can be dangerous for the inexperienced. Training and capacity building are required in a wide range of areas: institutional management, leadership, language proficiency, integration of Indigenous and technical knowledge, value chains, marketing, and small business operations. Attention should be given to identifying complementarity and synergies between innovative scientific technologies, traditional technologies and Indigenous knowledge.

Besides capacity building, the successful deployment of innovative technologies requires improved access to credit and markets, as well as adequate infrastructure, equipment and financial resources. Blended finance is particularly useful to facilitate investments in community development, including in infrastructure that supports the adoption of innovative technologies. Payment for ecosystem services (PES) mechanisms and programs can be designed to improve financial or economic returns for non-marketable service provision and to include support for infrastructure, equipment and community development. ICT-enabled mobile banking and financial and e-commerce service technologies can all support the development of viable local economies, where small-scale producers, communities or organizations can directly market products or services to consumers. These arrangements increase returns to producers (whether individual, community

or organizational) by reducing transaction costs, minimizing the role of middlemen, increasing margins, and enabling lower prices for the consumer. Innovative finance mechanisms can provide new ways to match big funds with small projects and finance local community small- and medium-sized enterprises (SMEs) that provide greater employment.

Many innovative technologies facilitate the collection and sharing of accurate real-time data and analysis, strengthening community participation, transparency and accountability in forest governance. Mobile phones, apps, GPS, GIS, drones, online platforms, social media and video-conferencing facilitate direct community involvement in forest monitoring and citizen science, information sharing with other stakeholders, and participation in decision-making. Such technologies can be used to support participatory governance and empower local communities, including by supporting their land tenure and use rights. The full benefits and scaling up of the technologies thus both depend upon and influence governance of the sector. CF schemes seek institutional change, shifting the control of forest resources away from sole dominance by government agencies toward the active involvement of local communities.

Supportive policies and regulations are needed to facilitate the adoption of innovative technologies and appropriate safeguards to limit their negative impacts on the economic, social and environmental dimensions of sustainable development. Policies and regulations should support agile governance, improved communication, research and development, technology

development and transfer, education and capacity-building and promote multistakeholder strategic partnerships with all actors, private and public, involved in innovation. Policies and regulations often lag behind quickly evolving technologies and often target the macro-environment and major actors. A flexible and reactive legal framework that can follow breakthrough transformations and address the specific needs of small-scale actors and local communities is needed to foster innovation uptake and scaling up. Cooperation, collaboration and coordination across countries, sectors and actors at different scales, considering various sustainable development objectives, will be critical in order to align and harmonize policies, strategies, investment plans and plans of action.

5. Innovative technologies for sustainable forestry: key recommendations

This section provides 10 overarching recommendations with 59 specific options to support the uptake and scaling up of innovative technologies for SFM in Asia and the Pacific, as well as a practical way forward for roadmap implementation.

The recommendations emerge from the discussions, evidence and case studies gathered during the preparation of the roadmap.

The overarching recommendations are structured around the two following questions: (i) What are the objectives for harnessing the innovative technologies? (ii) How can the current constraints be overcome to support the uptake and scaling up of innovative technologies?

These recommendations provide a framework to support the uptake and scaling up of innovative technologies to enhance SFM in the Asia-Pacific region. To be useful for policymakers and decision makers on the ground, they are further detailed in actionable options⁴ to be selected and adapted to the local context.

To facilitate the design of a roadmap adapted to specific national or local context, priorities and needs a four-step guideline for practical roadmap implementation, is presented below as Figure 9.

What are the objectives for harnessing the innovative technologies?

Depending on the situation (local conditions, local or national priorities and needs), a range of innovative technologies can be used to fulfill different functions and help various actors pursue different objectives. The recommendations and options below identify four key areas in which harnessing the potential of innovative technologies could support sustainable development, making the forest sector more productive, ecological and attractive, in particular for young people.

1. Improve the monitoring of forest resources and track illegal logging and illegal trade of forest products
 - a. Encourage the use of digital technologies to allow more efficient, cost-effective, accurate and real-time monitoring of forest and land resources and facilitate data collection, pooling and sharing.
 - b. Facilitate the use of drones to monitor forest status, trends and threats, particularly in remote, inaccessible or cloudy areas.
 - c. Deploy optical, acoustic or other sensor networks to monitor physical, biological or climatic parameters in forest stands and provide real-time information on forest conditions, while minimizing collateral disturbance to wildlife and their habitats.
 - d. Combine remote sensing and geo-spatial technologies, social media, open-source tools, mobile applications, and collaborative platforms with big data analysis, deep learning models and AI to develop real-time monitoring and early warning systems that can track and help combat various natural or human-induced threats such as wildfires or climatic events; pest, disease or invasive species outbreaks; deforestation; and illegal activities.
 - e. Develop mobile applications to make spatial datasets and alert systems easily accessible in the field, even offline, to optimize forest patrol routes, and to facilitate data collection, sharing and centralized reporting.
 - f. Encourage the use of DNA profiling and of advanced microscopy identification technologies to track illegal logging and illegal trade of forest products.

⁴ To further consider choices of options a matrix linking each option to evidence and case studies is available in Roshetko et al. 2022.

2. Raise awareness of and enhance citizen participation in forest monitoring and sustainable forest management
 - a. Encourage the use of social media and other communication innovations to raise awareness regarding the importance of SFM and conservation, facilitate participation and enhance transparency and accountability in forest monitoring, forest management and along forest value chains.
 - b. Develop mobile applications, as well as open and collaborative online platforms and tools, to encourage citizen science initiatives and facilitate the participation of citizen and local communities in forest monitoring, forest patrolling and SFM.
 - c. Use mobile applications and online platforms to connect small-scale producers to forest value chains (e.g. banks, traders, processing companies, distribution networks and consumers), facilitating their access to markets and credit.
 - d. Develop innovative finance mechanisms, such as crowdfunding platforms or impact investments, that facilitate citizen investment in forest conservation or sustainable management and create a stronger link between borrowers and lenders, thus strengthening stakeholder engagement and sense of ownership.
 - e. Support and scale community forestry, community nurseries, multistakeholder fora, focus group discussions, and other social innovations that empower local communities, Indigenous Peoples, women and other marginalized actors to improve their access to information, give them a stronger voice in decision-making processes, strengthen their control over local forest resources, and support their livelihoods.
3. Improve productivity and resource use efficiency
 - a. Harness the potential of biological and technical innovations in processes and products to: reduce operational costs; increase productivity and profitability; improve energy and resource use efficiency, reduce waste and preserve natural resources; and open new markets and new uses for forest products.
 - b. Invest in low-input multiple species domestication, selection and breeding approaches, more systematically exploring the potential of native or underutilized forest wood and non-wood species to produce germplasm of high genetic and physical quality, with improved characteristics adapted to different uses and to different climate change scenarios, and to preserve biodiversity, especially of threatened or endangered species.
4. Generate new job opportunities and support livelihoods
 - a. Encourage the use of innovative technologies (e.g. digital technologies, biological, technical and social innovations) and innovative finance mechanisms (e.g. blended finance, green/ social/climate funds, payments and rewards for ecosystem services) to generate additional income and employment opportunities, improve working conditions and reduce the workload.

- b. Develop appropriate education courses at primary, secondary and tertiary levels, as well as initial and continuing training programs in forestry, natural resources and innovative technologies, paying specific attention to young people, women, small-scale producers, ethnic minorities and other marginalized groups. Besides the use of innovative technologies, beneficial training topics could include: language proficiency, organizational and leadership skills, marketing, enterprise development, worker safety, and small-business operations.
- c. Accelerate technology transfer and capacity-development to disseminate the new skills needed to apply for innovative, safer and greener jobs (e.g. data collection and reporting through mobile applications, drone operation, remote sensing imagery interpretation, big data analysis, tree-nursery operation and maintenance, automated control of wood processing, engineering of bioproducts, and management of innovative funding and governance mechanisms).
- d. Develop innovative job opportunities, internships and fellowships in the forest sector, to make it more attractive for youth.
- e. Seize the opportunities offered by the development of a circular bioeconomy to generate new and greener job opportunities, and support the livelihoods and resilience of local communities, while reducing pollution, GHG emissions, and improving energy- and resource-use efficiency.
- f. Facilitate the automation of physical tasks, building upon the new possibilities offered by digital technologies and technical innovations (e.g. wireless communications and remote-control technologies, robotics and AI), to reduce the workload and work drudgery, improve worker safety, and optimize wood processing, while saving energy and natural resources.
- g. Use innovative finance mechanisms, such as green and social bonds, crowdfunding and impact investment, to prioritize and support capacity-development and employment generation in local communities and small-scale forest enterprises to enhance their resilience and livelihoods.

- h. Develop shared-value business strategies, mutually beneficial to the private sector and local communities, that facilitate the efficient supply of high-value commodities that meet market specifications and bring local benefits.

How to overcome current constraints to support the uptake and scaling up of innovative technologies

Section 4 explored the main constraints that hinder technology dissemination and adoption. These include: lack of capacity (skills, knowledge and experience); lack of physical or virtual infrastructure (road network, electrical power, internet connection, access to credit or markets); lack of land tenure security and limited access to forest resources; limited access to information, lack of transparency and limited participation in decision-making; restrictive policies and regulations lagging behind the rapid evolution of technologies; and the rapid shifts in wood demand, or weak governance and law enforcement.

These constraints and their relative importance vary across countries and contexts. Technology adoption is highly context-specific and very uneven across the region. To be adopted, a technology must be adapted to the local context (e.g. income and education levels, labor market, infrastructure, cultural values). As a result, access to technology dissemination must follow a decentralized, bottom-up process, starting from local needs and engaging local communities.

The recommendations below aim to overcome these constraints and support the uptake and scaling up of innovative technologies in the forest sector in the Asia-Pacific region and ensure that they effectively contribute to SFM.

- 5. Ensure policy coordination across sectors, actors and scales and create innovative governance mechanisms at all scales

The successful dissemination and adoption of innovative technologies require integrated planning and implementation across sectors, actors and scales, as well as innovative governance mechanisms.

In this context, governments are encouraged to:

- a. Establish a national advisory group on innovative forest technologies, gathering all relevant actors (from public and private

sectors, civil society and research institutions; from researchers to final users) to assess the potential of available or emerging technologies in the national context; to identify priority areas for action and investment in an evidence-based way as well as data needs; and to help the government adapt its policies and regulations to the rapid evolution of innovative technologies.

- b. Conduct, in collaboration with the other actors in the advisory group, an initial assessment of the current situation regarding the application of innovative forest technologies at national and subnational levels, as well as of their positive and negative impacts for various stakeholder groups, to identify the constraints and needs and define national priorities and plan of actions.
 - c. Elaborate and implement, in collaboration with the other actors in the advisory group, a national roadmap for the uptake and scaling up of innovative forest technologies, articulating the relevant sectors, actors and scales, building upon the recommendations suggested here, and adapting them to national circumstances, priorities and needs. This roadmap should identify research priorities, priority technologies, priority actions and investments, the priority transformations needed in policies and regulations, and the roles and responsibilities of the actors involved.
 - d. Create innovative governance mechanisms at all scales and support social innovations that promote networking between governments and other actors at local to national levels and create the enabling conditions for the engagement of all relevant actors, particularly youth, women, small-scale producers and local communities, in the development, dissemination and adoption of innovative technologies, as well as in their adaptation to different contexts and actors.
6. Invest in innovative research, extension and capacity development models
 - a. Elaborate a national research, development and extension action plan to identify priority areas for research, facilitate the development, uptake and scaling up of prioritized innovative forest technologies, enhance coordination between different actors (e.g. ministries, private sector, research and academic institutions and civil society organizations), and facilitate or guide the allocation of limited available resources.
 - b. Adopt a “blended” multistakeholder research and development (R&D) system, connecting private research to public needs, national priorities and global objectives and facilitating the application and dissemination of findings from public research institutions, including by private actors and civil society organizations.
 - c. Develop transdisciplinary, collaborative and participatory research projects (e.g. citizen science initiatives) and offer internships and fellowships in research projects to people with field experience to better consider the specific context, priorities and needs of local actors in the field, particularly small-scale actors, better integrate scientific and local knowledge, and better support knowledge co-generation and sharing.
 - d. Invest in research and development on emerging technologies that have not yet been commercialized and on the conditions under which they can contribute to sustainable development.
 - e. Invest in innovative research, development, extension and capacity development models regarding the use of innovative technologies in the forest sector (e.g. big data analysis; participatory research and data collection; field and virtual demonstrations of innovative technologies; community of practices; farmer-to-farmer networks; massive open online courses (MOOCs) and other innovative learning models).
 - f. Mobilize additional resources for research, development, extension and capacity development on innovative forest technologies, particularly in developing countries, including through blended finance, impact investments, corporate social responsibility (CSR) programs, and other innovative funding mechanisms.
 - g. Link national forestry education efforts (including research and extension aspects) with the emerging Global Forest Education Project.
 7. Elaborate conducive policies and regulations and develop the infrastructure needed to boost innovation and sustainable development in the forest sector

Innovative technologies and their potential applications are rapidly evolving. The long time frame of tree growth does not match the rapid evolution of technologies and rapid shifts in wood demand. In this changing context, limited infrastructure, as well as policies and regulations, often lag behind technological advancements (e.g. legal restrictions on drone flights or on the use of wood-based products in tall building construction) and may restrict the use of innovative technologies, thus limiting their potential benefits.

In this context, governments are encouraged to:

- a. Harness the improved monitoring capacities offered by innovative technologies (e.g. participatory data collection, drones, satellites, sensor networks, automation or AI) to develop flexible policies, strategies and rules to address the multiple threats and challenges faced by forests and forest value chains in a more reactive and timely manner.
- b. Ensure that the legal framework on intellectual property rights (IPRs): strikes the right balance between the incentive to innovate and technology dissemination; considers national priorities and general public interest; and facilitates access of small-scale actors and marginalized groups to innovation. In particular, IPR regulations (e.g. on biological innovations) should not infringe the rights or control of local populations and Indigenous Peoples over their local genetic resources, traditional crops or land.
- c. Harness the possibilities offered by innovative technologies to facilitate law enforcement. In particular, the legal framework should facilitate the use of remote sensing or crowdsourced data and of DNA profiling and fingerprinting as forensic evidence in legal cases.
- d. Maximize the potential of drones while considering privacy and security issues by adopting transparent regulations adapted to various unmanned aerial vehicle (UAV) models and various activities (e.g. forest monitoring, land tenure claims, pest and disease control, insect sampling) in various sectors (e.g. ecology, forestry and agriculture).
- e. Develop national standards for the use of digital (geospatial and ICT) technologies for forest monitoring to ensure equipment (hardware

and software) compatibility and facilitate cost-efficient data pooling and sharing.

- f. Identify physical, virtual and institutional infrastructure lacking at local to national level to boost innovation and facilitate technology transfer, dissemination and adoption (e.g. road network, electricity and energy grids, internet and communication infrastructure, markets and finance infrastructure, tree nurseries and wood processing plants, R&D and extension systems, governance and institutions, law enforcement system); invest and mobilize resources for infrastructure modernization to address the identified gaps.
 - g. Use innovative finance mechanisms such as blended finance to mitigate the risks (biological, climatic, social, market and political), attract additional resources and facilitate the long-term investments needed to support technology uptake and scaling up in the forest sector, including capacity development and the establishment or improvement of infrastructure.
8. Consider the economics of innovation to facilitate the adoption of innovative technologies across contexts and scales

Many innovative forest technologies have been designed for large-scale operations in specific contexts. Hence, innovative technologies could increase the competitive advantage of large companies, further marginalizing small-scale forest enterprises and local communities, which manage a large part of the forest resources and employ most of the labor force, formally or informally involved in the sector. The challenge is then to “think small” and “scale down” innovative technologies so that they can be adapted to various contexts and also benefit traditional users, small-scale enterprises and local communities, even those with limited human and financial resources and those living in remote areas.

To support technology dissemination, adoption and utilization, research and extension actors (from public and private sectors and civil society) need to:

- a. Demonstrate the social, economic and environmental benefits of innovative technologies in different contexts and for different stakeholder groups, particularly for youth, women, small-scale producers, local communities, ethnic minorities, and other marginalized actors.

- b. Adopt a “bottom-up” approach to facilitate technology transfer and dissemination, starting from an assessment of the needs of smallholders, small-scale enterprises, and local communities, and considering their socioeconomic context, traditions and culture.
 - c. Consider local culture and traditional knowledge and the perceptions and experience of local actors to facilitate technology adaptation and adoption in a specific context.
 - d. As appropriate, provide external support (technical, human, and financial) to small-scale enterprises, local communities or other targeted or vulnerable groups (e.g. youth, women, or Indigenous Peoples) to improve their access to information and to innovative technologies.
 - e. Support the dissemination of high-quality germplasm through participatory multiple species improvement and delivery programs with smallholders and local communities, including through donations or sales at affordable prices, as well as through the establishment of tree nurseries, seed orchards or clonal cutting gardens to develop local seed/germplasm production capacity.
 - f. Adopt innovative harvesting, transportation and processing technologies (e.g. portable sawmill) for use by smallholders and small-scale operators, considering small-business operations, on-site processing, and modern safety standards, and facilitating the use of small-diameter logs and underutilized species.
9. Assess the negative impacts of innovative technologies and establish appropriate social and environmental safeguards

Innovative technologies, if not sustainably used, can produce negative economic, social and environmental impacts, such as: accelerated deforestation and forest degradation; water pollution; soil degradation; the loss of unskilled jobs and local employment opportunities; poverty; food insecurity; increased inequalities and further marginalization of less powerful actors, with limited human or financial capacities to adapt; ethical issues related to privacy, security, control over data and misinformation. The destruction of natural habitats threatens not only biodiversity, but also the traditional knowledge, culture and livelihoods

of Indigenous Peoples and forest-dependent communities. In this context, strong regulations are needed to limit the negative impacts of technologies and enforce appropriate social and environmental safeguards.

- a. Governments should create and enforce necessary social and environmental safeguard measures to ensure that innovative technologies contribute to the SDGs and do not harm natural ecosystems and vulnerable and marginalized groups.
 - b. Private actors, as part of their CSR, should comply with these social and environmental safeguards and respect the culture and welfare of Indigenous Peoples, ethnic minorities and local communities when deploying and using innovative technologies.
 - c. Civil society, local communities, and research and academic institutions should join efforts in assessing the various negative impacts of innovative technologies, improving monitoring and reporting, strengthening transparency and accountability of public and private actors, suggesting appropriate safeguards and defending the rights and welfare of small-scale actors, local communities and marginalized groups (including women and Indigenous Peoples).
10. Strengthen regional cooperation

Countries and other actors should work together at the regional level to facilitate technology uptake and scaling up, coordinating their efforts, sharing their experiences, and harmonizing their regulations and standards. Regional cooperation, in a world of limited resources, can be more efficient for technology uptake and scaling up than fragmented action by individual countries, which often lack the technical, human and financial capacities to act. The Asia-Pacific Forest Commission (APFC), for example, could play a central role in strengthening regional cooperation to support the uptake and scaling up of innovative technologies in the forest sector.

In particular, the APFC and other regional fora/organizations are encouraged to:

- a. Raise awareness of the potential of innovative technologies to advance the Sustainable Development Goals (SDGs) and encourage global sharing of information on innovative

technologies in forestry through all member countries and other relevant actors of regional importance (e.g. donors, private companies, research institutions, non-governmental organizations).

- b. Develop regional plans on issues of regional importance (such as: technology transfer; international finance for innovative forest technologies; IPRs; interoperability of databases, data pooling and sharing; timber regional and international trade; prevention and tracking of illegal activities; forest conservation transboundary issues; conflicts over natural resources; cross-border challenges such as climate change, pest control, or water management) and on the possibilities offered by innovative technologies to address these issues.
- c. Encourage and facilitate the exchange of experience and lessons learned across member countries about the dissemination and utilization of various innovative technologies in specific contexts.
- d. Align and harmonize regional objectives and national efforts, investment plans, policies, regulations and standards regarding the dissemination and adoption of innovative technologies.
- e. Assist member countries in developing a national roadmap for the uptake and scaling up of innovative forest technologies, building upon these recommendations and adapting them to their national circumstances, priorities and needs.
- f. Encourage, advise and support member countries in adapting their legal frameworks to maximize the social, environmental and economic benefits of innovative technologies, limit their negative impacts, and harness their capacities to facilitate data collection, reporting and analysis; improve monitoring and law enforcement; enhance participation, transparency and accountability; improve productivity and resource use efficiency; and generate income and employment opportunities.
- g. Encourage South–South cooperation on the development, dissemination and use of innovative forest technologies and mobilize resources (human and financial) to support, in particular, the least developed countries in the region.

6. Innovative technologies for sustainable forestry: a practical way forward for roadmap implementation

With this study, FAO and FTA propose a practical way forward for the implementation of regional, national or subnational roadmaps to support the uptake and scaling up of innovative technologies that support SFM in Asia and the Pacific. Such a roadmap could be comprised of four steps as illustrated in Figure 9, namely: (i) conduct a diagnosis, or initial assessment of the current situation; (ii) develop a strategy and set priorities; (iii) create an enabling environment; and (iv) act collectively and individually.

Roadmap implementation can be supported by existing initiatives such as FAO's digital village initiative (DVI)⁵ which targets Asia-Pacific rural transformation through digitalization. DVI principles are: Feasibility – low-cost technology connectivity and internet access with a supportive policy, institutional and educational environment; Inclusiveness – productive links between users, technology developers, digital service providers, government agencies and enabling actors (banks, private sector entities, academia, education and research; and Sustainability – adaptable and affordable technology with broad access for small scale farmers and rural residents, digital literacy with viable capacity building and training infrastructure, and self-sustaining digital platforms capable of dynamic expansion and scaling.

The process of roadmap implementation could be deployed regionally, nationally, sub-nationally in single sectors or within value chains, following the concept of “innovation systems” facilitating cooperation, collaboration and coordination between actors, countries and sectors at different scales and contexts.

At the regional level, it could be based on the findings of APFSOS III and of the report. The APFC could discuss the findings and recommendations of the present study and set regional priorities. It could also invite member countries to conduct the same exercise at national level and to report back at the next meeting of the APFC. The APFC could then finalize a regional strategy and plan of action. Regional priorities would be adjusted, in each member country, to national circumstances, priorities and needs (5c; 10e).⁵ Regional cooperation, including South–South cooperation, will be paramount at this stage given the very unequal rates

5 To further consider choices of options a matrix linking each option to evidence and case studies is available in Roshetko et al. 2022.

of innovation and technology adoption across countries in the Asia-Pacific region (10).

National roadmaps would be led by the government in collaboration with a national advisory group on innovative forest technologies, gathering all relevant actors (from public and private sectors, civil society, and research institutions; from researchers to final users) (5a). As appropriate, plans of actions would be attuned at sub-national levels, in different sectors and forest value chains.

Lessons learned from the elaboration and implementation of these national roadmaps could be

periodically discussed at national and regional levels to foster exchanges in experience across sectors, actors and countries. Based on this feedback, national and regional strategies and plans of action could be revised and adjusted as appropriate.

At the broader global level, the recommendations and roadmap implementation support the FAO Science and Innovation Strategy (CL 168/22), which foresees a world free of hunger and malnutrition, where science and innovation contribute to overcoming complex social, economic and environmental challenges of agriculture, food and natural systems in an equitable way while maximizing synergies and minimizing trade-offs and risks.

1. Diagnosis: initial assessment of the current situation

Identify the challenges and needs for sustainable forest management (SFM) (5b).

Assess the potential contribution of innovative technologies to SFM: opportunities and challenges (5a).

Identify the actors affected (positively or negatively) by the implementation of innovative technologies in the forest sector (5b).

Identify the main barriers to technology dissemination and adoption.

3. Create an enabling environment

Raise awareness and enhance citizen participation in forest monitoring and sustainable forest management (2).

Elaborate conducive policies and regulations (7) to address/overcome the barriers identified above.

Mobilize the resources and develop the infrastructure needed to boost innovation and sustainable development in the forest sector (6f, 7).

Support/invest in research and development, extension and capacity development (6).

2. Develop a strategy and set priorities

Identify research priorities, including priority areas for action and investment, as well as priority transformations needed in policies and regulations (5a; 5c), focusing on:

- the most promising innovative technologies given the identified challenges and needs (5c);
- the most vulnerable groups of actors (e.g. Indigenous Peoples, local and rural communities, small-scale producers, women, youth); and
- the forest ecosystems or forest value chains that are the most fragile, socially, economically and/or environmentally.

4. Act collectively and individually

Define the roles and responsibilities of the different actors involved (5c).

Develop action plans at different levels (regional, national, local) in different sectors for different stakeholder groups.

Ensure policy coordination across sectors, actors and scales and create innovative governance mechanisms at all scales (5).

Experiment and share the lessons learned.

Adapt strategies and action plans accordingly.

Figure 9. A four-step guideline for practical roadmap implementation. (Numbers between parentheses in this figure refer to the recommendations above).

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