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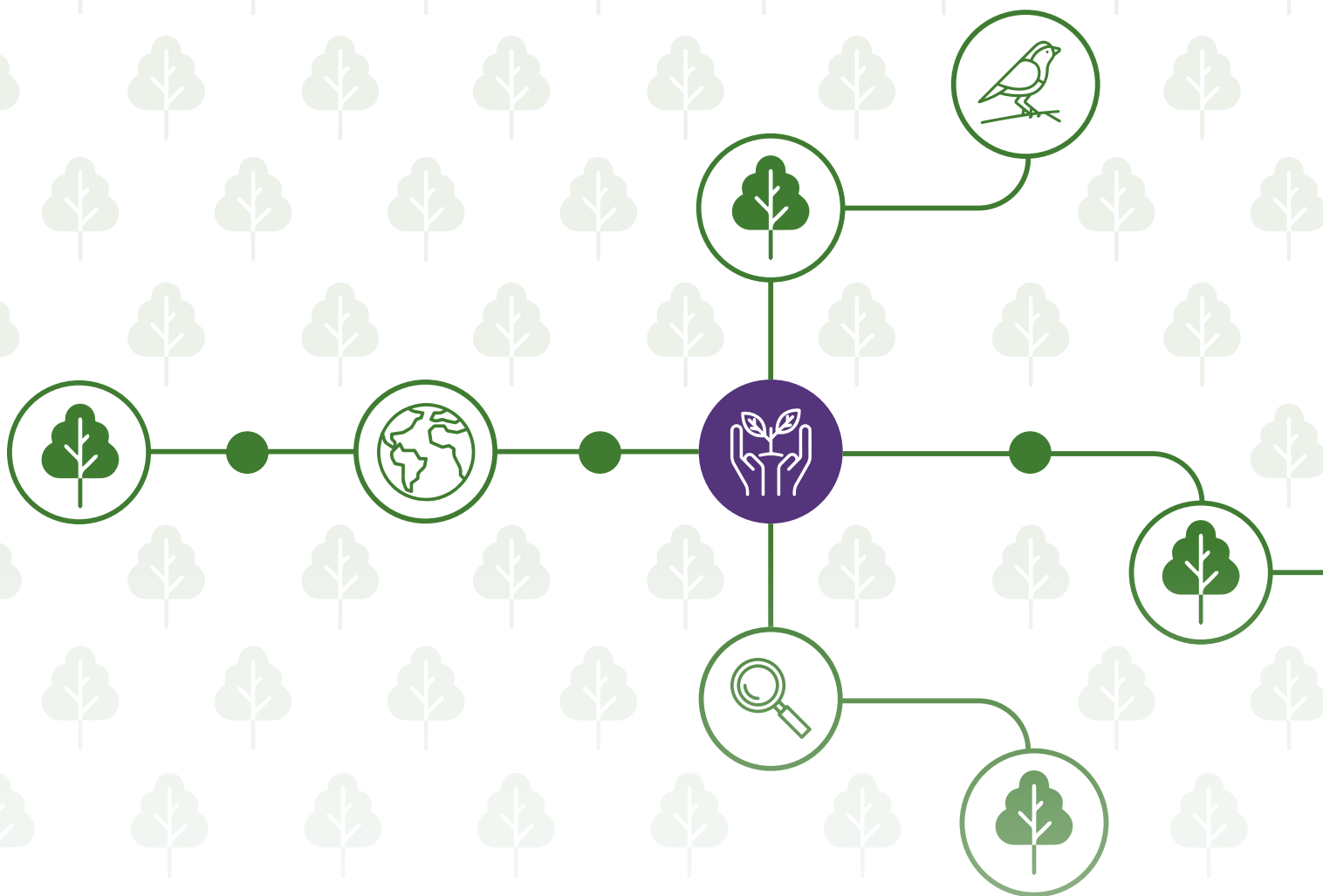


Asia-Pacific roadmap for primary forest conservation

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Asia-Pacific roadmap for primary forest conservation

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Foreword

The Third Asia-Pacific Forest Sector Outlook Study (APFSOS III: FAO 2019) highlighted the urgent need to conserve primary forests – i.e. forests largely unaffected by human activities – and to sustainably manage other natural forests to safeguard biodiversity, ecosystem services, and the quality and health of the physical environment in the Asia-Pacific region. As a follow-up to APFSOS III, the Food and Agriculture Organization of the United Nations (FAO) and the Center for International Forestry Research (CIFOR – the lead center of the CGIAR Research Program on Forests, Trees and Agroforestry, or FTA) initiated a process to develop a roadmap for primary forest conservation in Asia and the Pacific.

This roadmap was developed through an inclusive and participatory process involving key regional stakeholders and technical experts from governments, intergovernmental organizations, the private sector, civil society, academia, and research institutions. The roadmap also builds upon enriching contributions from students and young people involved in forest sector-related activities in the region.

The purpose of the roadmap is to delineate and inform the process by which decision makers and actors can evaluate the status, diversity and trends of primary forests in the region, identify priority areas for primary forest conservation, assess the threats they face, and explore possible ways to address them.

As a central piece of the roadmap, the present study provides a strong evidence base that can help countries and other stakeholders take action at different levels for primary forest conservation. It highlights

the huge diversity of primary forest ecosystems in Asia and the Pacific and shows the increasing pressures they face, driven by population and economic growth in the context of climate change. It describes the range of institutions and mechanisms that can be mobilized at different scales and, finally, suggests six key recommendations for decision makers to enhance primary forest conservation in the region.

The study provides a wealth of information to help countries understand the dynamics at stake in various forest ecosystems in different contexts, thus helping to better prioritize conservation efforts. However, it also highlights the considerable lack of knowledge about primary forest ecosystems in the region, including their diversity, status and trends, eco-floristic variation within and across forest types, and species distribution and population dynamics. The methods presented in this study can help countries and research organizations fill these gaps and develop large-scale (high-resolution) ecological vegetation mapping in the region, as well as more accurate monitoring of forest ecosystems and the threats they face, to better support and orient land-use planning, management and conservation efforts.

Such efforts should be oriented not only towards protecting forests but also towards strengthening connectivity among remaining intact forest fragments. Conserving primary forests requires an evidence-based integrated landscape approach that is coordinated across sectors, actors and scales and involves local actors in decision making, supported by national institutions and international organizations. Such broad engagement calls for building a compelling narrative that acknowledges

the importance and diversity of primary forest ecosystems, as well as the specific roles and responsibilities of the range of actors involved in their conservation. It is indispensable to raise awareness, consolidate broad coalitions of actors, and sustain the efforts needed for primary forest conservation. In so doing, we need to be concerned not only about the protection of primary forests but also about the livelihoods of forest-dependent communities and their legitimate development aspirations.

To conclude this study, this report suggests a practical process in four steps, through which the recommendations can be articulated at different scales (from regional to local) and

adapted to the specific context, priorities and needs of various forest types, countries and categories of actors.

We hope that the release of this publication will mark the beginning of a collective process, possibly led by the Asia-Pacific Forestry Commission and its member countries, to further support and enhance primary forest conservation in the region. We stand ready to make available to countries the wealth of detailed information on primary forest diversity, status and trends gathered during the preparation of this study and to help use this information to support primary forest conservation efforts.

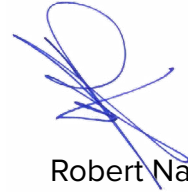
On behalf of FAO



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valuable contributions and support: Robert Nasi, James Roshetko and Riina Jalonen.

This study has been developed through an inclusive and participatory process that associated 425 key regional experts and decision makers from governments, international organizations, the private sector, civil society, academia, and research institutions. Students and young professionals were given a central role in this process as they will be the forest managers of tomorrow. This process is presented in more detail in **Annex 1**.

This study was reviewed by Kasturi Devi Kanniah, Patrick Durst, and Rajan Kotru. Any remaining errors are the sole responsibility of the authors.

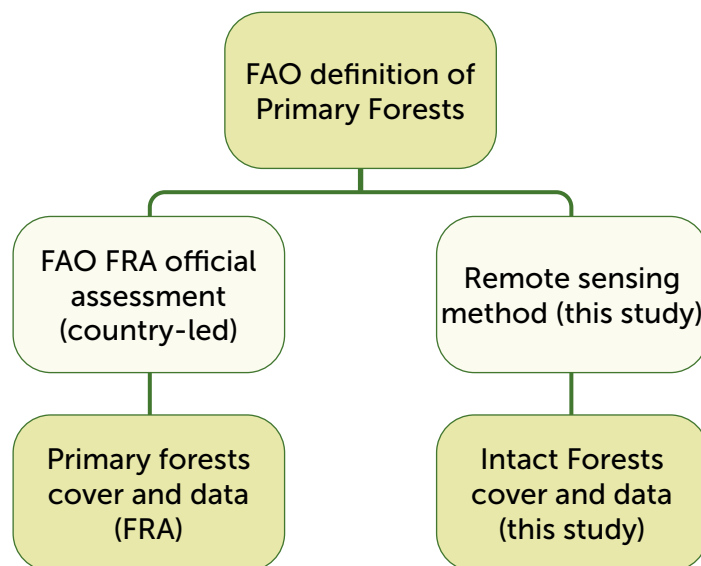
Many thanks also to all colleagues from FAO, CIFOR and ICRAF who provided administrative and technical support for the execution of this study, including the organization of the online workshops and the editing and layout of the final publications. The team included Fabio Ricci, Kallaya Meechantra, Lucya Yamin, Vito Gama Kaparang, Gusdiyanto, Dinny Saputri, Rumanti Wasturini, Irma Taufik, Ming Chun Tang, Sekar Palupi, Gideon Suharyanto, Perdana Maulansya Putra and Daniella Silva.

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Note about the terminology used in this report

This report is about primary forests. A primary forest is defined by FAO as a “naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed” (FAO 2018a). This report uses the same definition. National primary forest areas are officially reported in the Forest Resource Assessment (FRA) regularly conducted by FAO through a country-led process that involves different approaches that vary by country. Forest cover data presented in this report is elaborated using a remote sensing-based methodology. This specific approach was necessary to ground the analysis on natural forest degradation, intactness, fragmentation and threats embracing the full geographic coverage of the region across a large timespan with the same method. This study adopts the term ‘intact forest’

for data and maps generated applying the aforementioned FAO definition of primary forests through our methodology based on remote sensing. The area and geographic extent of intact forests in Chapter 1 of this report may therefore, by construction, be different from the area and geographic extent of ‘primary forests’ as reported by countries in the FRA, which remains the official data source for primary forests. Similarly, the remote sensing methodology employed in this report provides results expressed in terms of changes and rates of change of forest cover. These results may be different from “deforestation” areas, i.e. changes in land use from forest to non-forest as reported by countries in the FRA, which remains the official source for deforestation data.



Note about the geographic coverage of this report

The geographical scope of the roadmap, referred to in this paper as the 'Asia-Pacific region', covers the countries and territories of the FAO region of Asia and the Pacific.¹ It now also includes the Islamic Republic of Iran, previously included in the Near East FAO region, that recently joined the Asia-Pacific FAO region. It also includes five sovereign states in free association with New Zealand or the United States of America (USA), as well as eight Australian, French and USA dependent territories situated in the region. However, it excludes France and the mainland USA, which are situated outside the region. The Russian Federation, despite covering 29 percent of Asia, is also excluded because issues related to Russian forests are usually discussed within the FAO European Forestry Commission.² To account for its huge diversity, the Asia-Pacific region is further divided, for the purpose of this study, in four sub-regions, as defined in APFSOS III (FAO 2019):

- **South Asia:** Afghanistan, Bangladesh, Bhutan, India, Islamic Republic of Iran, Maldives, Nepal, Pakistan and Sri Lanka;

- **East Asia:** China, Japan, Democratic People's Republic (DPR) of Korea, Republic of Korea and Mongolia;
- **Southeast Asia:** this sub-region is further divided between insular Southeast Asia (Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore and Timor-Leste) and continental Southeast Asia (Cambodia, Lao People's Democratic Republic – PDR -, Myanmar, Thailand and Viet Nam);
- **Oceania:** American Samoa (USA), Australia, Fiji, French Polynesia (France), Guam (USA), Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, New Caledonia (France), New Zealand, Niue (New Zealand), Norfolk Island (Australia), Northern Mariana Islands (USA), Palau, Papua New Guinea (PNG), Samoa, Solomon Islands, Tokelau (New Zealand), Tonga, Tuvalu, Vanuatu, and Wallis and Futuna Islands (France).

1 See: <http://www.fao.org/asiapacific/countries/en/> (accessed 28 October 2020)

2 See: https://www.foreststreesagroforestry.org/wp-content/uploads/2020/10/FAO-FTA_Roadmap-Note-on-geographical-scope_DEF.pdf

Executive summary

Following up on the Third Asia-Pacific Forest Sector Outlook Study (APFSOS III: FAO 2019), FAO and CIFOR, lead center of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA), developed a roadmap for primary forest conservation in Asia and the Pacific. The geographical scope of the roadmap, referred to in this paper as the 'Asia-Pacific region', comprises 49 countries and territories.³ To account for its huge diversity, the Asia-Pacific region is further divided, for the purpose of this study, in four sub-regions, as defined in APFSOS III (FAO 2019): East Asia, South Asia, Southeast Asia and Oceania.⁴ This roadmap has been developed through an inclusive and participative process involving 425 key regional stakeholders and technical experts from governments, intergovernmental organizations, the private sector, civil society organizations, academia, and research institutions, as well as selected students and young people involved in the forest sector in the Asia-Pacific region.

This technical paper aims to delineate and inform the process by which decision makers and actors can evaluate the state of primary forests in the region, identify priority areas and priority actions for primary forest conservation, assess the threats they face, and explore possible ways to address them.

The purpose of this technical paper is to gather the knowledge that is needed to identify priority areas and to inform actions to preserve primary forests. It is not prescriptive but gathers information and options relevant to the wide range of contexts found in the region,

so that government and other stakeholders can determine priorities for action at regional, national and local levels. The diversity of contexts spans four main dimensions, that the different chapters of this paper successively cover: (i) level and trends of preservation and fragmentation of forests; (ii) diversity of vegetation types and ecological diversity of types of primary forests; (iii) diversity of threats and risks to forests; (iv) diversity of governance and policy contexts and means of intervention.

The chapters of the study are organized along these dimensions and steps.

The Asia-Pacific region is very large and diverse, and to be effective, the list of priority areas will ultimately depend on nationally and locally determined priorities, properly informed by the above-mentioned four dimensions that frame the national and local context. More accurate knowledge and common identification of these priority areas could help develop efficient conservation strategies at different scales and prioritize conservation efforts within broader landscape perspectives. It is also important to anticipate the emergence of new deforestation or degradation hotspots in the future to allow for strengthened conservation and protection efforts before it is too late.

Key recommendations for decision makers emerging from this work are presented in the last chapter.

1 Remote sensing assessment of primary forest cover in Asia-Pacific

FAO, in its Global Forest Resources Assessment (FRA), defines primary forests as: "naturally regenerated forests of native tree species, where there are no clearly visible indications of

3 See: https://www.foreststreesagroforestry.org/wp-content/uploads/2020/10/FAO-FTA_Roadmap-Note-on-geographical-scope_DEF.pdf

4 See description in "Note about the geographic coverage of this report" on the previous page.

human activities and the ecological processes are not significantly disturbed” (FAO 2018a).

In this chapter, we look at forest cover change, degradation and fragmentation affecting primary forests in the Asia-Pacific region using a consistent remote sensing methodology applied over the FAO/FRA definition of primary forests. This methodology leads to identifying primary forest cover referred to in this study as ‘intact forests’. By construction, intact forest areas identified by remote sensing do not necessarily correspond exactly to the ‘primary forest’ areas as reported to the FRA by each national government (as countries chose their own method and underlying data). This study uses Landsat satellite data to assess historical variation, degradation and fragmentation in natural forest cover between 2000, 2010 and 2020, with the view to subsequently identifying the remaining intact forests. The pertinence of several remote sensing methods was tested to cover very diverse environments, from the Islamic Republic of Iran and Afghanistan to New Zealand and the Pacific, with tropical and equatorial regions in between.

Chapter 1 develops a remote sensing methodological approach to assess primary forest cover as per the FAO definition. Having first identified natural forest cover, this study assesses the degradation within these natural forests, leading to an estimation of so-called intact forests. By assessing the fragmentation of these intact forests, isolating large core areas and excluding forest edge zones, this study identifies contiguous intact forest cover, which is the best possible estimation, through remote sensing techniques, of what can be considered primary forests as per the FAO definition. The results show that natural forest cover in Asia-Pacific decreased from 667 million ha in 2000 to 609 million ha in 2020, a 3% difference compared to the FRA 2020 assessment on average at the regional level. This work also allows the dynamics of forest cover to be visualized and identifies hotspots of deforestation. Intact forest covers 519 million ha, and there is still an important 378 million ha of remaining contiguous intact forest cover across the Asia-Pacific region in 2020, broader than the 140 million ha reported by countries to

the FRA as ‘primary forests’, according to FAO (2019) based on data from the FRA 2015.

Chapter 1 also highlights the importance of forest fragments, forest margins and edge effects. Degraded forest margins can still play an important role in primary forest conservation by acting as buffer zones to protect the core intact forest area against further degradation, while remaining forest fragments can act as stepping stones for ecological corridors contributing to ensuring or strengthening connectivity among remaining forest fragments and intact contiguous forests.

2 A remarkable diversity of forest types in Asia and the Pacific

Chapter 2 highlights the considerable diversity of primary forests in Asia and the Pacific, which vary depending on bioclimatic conditions, altitudinal zonation and soils characteristics. It describes the 30 main forest formations identified across the region, in line with existing classifications, from tropical mixed dipterocarp rain forests to tropical and sub-tropical seasonal forests and temperate or boreal formations, including more specific forest types such as karst, *kerangas*, peat swamp forests or mangroves, and their variations observed along altitudinal gradients. All lowland forest types are situated in areas that are particularly threatened by deforestation and forest degradation, as are the high elevation formations of the Himalayas. Conservation strategies need to integrate this huge diversity as all and each specific forest type deserve to be preserved.

Chapter 2 also points out considerable knowledge gaps regarding the eco-floristic variations observed within each forest type and about the causes of this variability beyond elevation, soil and climate. This study shows, for instance, that very distinct tree species composition can coexist under very similar climatic and edaphic conditions. A lot also remains to be discovered about ecosystem functioning, species distribution, population dynamics, and the conservation status of many important tree species, especially in the tropics.

At the landscape level, vegetation types are the best surrogates to characterize ecosystems and the ecosystem services they provide. Large-scale⁵ ecological vegetation mapping and related socio-ecological surveys integrating altitudinal zonation, edaphic conditions and vegetation, including floristic information, also need to be developed and become standard in the Asia-Pacific region. Open-access datasets of high-resolution satellite data, eventually complemented by drone surveys, offer huge opportunities for accurate and near real-time monitoring and allow the production of large-scale detailed vegetation mapping over large areas, long periods of time, using consistent methodologies and at reasonable costs. Wall-to-wall on-screen visual interpretation of the vegetation made by experts will remain crucial to establishing such large to very large-scale ecological mapping. At the same time, it will be necessary to organize capacity building and knowledge management at the country level to ensure wide ownership of outputs.

3 Increasing pressures and threats on primary forests: assessing risks

This chapter considers the remaining primary forests, the threats they face, and the dynamics at stake within a broader landscape perspective. Primary forests and natural landscapes in Asia and the Pacific are under increasing pressure and threats driven by population growth, migration, conflict, globalization and economic growth, urbanization, mining and infrastructure development, agriculture and planted forest expansion, forest fires, invasive species, and disease outbreaks. Many of these threats are increasingly exacerbated by climate change.

According to the UN's medium-variant projection, the world's population is expected to grow from 7.7 billion in 2019

to 8.5 billion in 2030 (a 10% increase) and 9.7 billion in 2050 (a 26% increase). In the meantime, the population of the Asia-Pacific region is expected to grow, albeit at a slower pace, from 4.3 billion in 2019 to 4.6 billion in 2030 (a 7.5% increase) and 4.9 billion in 2050 (a 13% increase). The population of Eastern and South-Eastern Asia is projected to peak at 2.4 billion around 2038, while the population of Central and South Asia could peak later, around 2065, at just under 2.6 billion people. The population of Oceania should continue to grow till the end of the century (UNDESA 2019). Demand for food, feed and wood will grow significantly due to both population growth and economic growth, which will exert additional pressure on primary forests.

Agriculture expansion, urbanization and infrastructure development exacerbate forest fragmentation and generate soil, water and air pollution, which can further increase forest degradation. Over-logging and illegal logging are identified as major threats to biodiversity.

Climate change induces a vicious circle by accelerating forest degradation, which may in turn reduce the resilience, mitigation potential and adaptive capacities of forest ecosystems. Due to global warming, climatic zones are shifting poleward and upward in mountainous regions. This climatic shift might occur faster than the migration speed of many plant or animal species and particularly threatens mountain forests. Furthermore, climate change is likely to alter rainfall regimes and the availability of water resources, leading to increases in rainfall throughout much of the region, including greater rainfall during the summer monsoon period in South and Southeast Asia. Climate change will likely increase the intensity and frequency of forest fires, typhoons, floods, droughts, species invasion, pests and disease outbreaks. The local impacts of climate change on biodiversity and ecosystem services are likely to vary across forest types and geographical regions and are very hard to predict due to the low resolution of most climate change models. **Chapter 3** includes a detailed risk assessment of forest fires in Indonesia, Australia and the Himalayas.

⁵ Basically, a small-scale map covers a large geographic region such as the world, whereas a large-scale map shows smaller areas in more detail.

Invasive species affect many natural ecosystems in the region, and their impacts are exacerbated by climate change. Most of these species, especially tree species, have been introduced for economic reasons or through ill-conceived programs of reforestation. Invasive insect pests are often associated with introduced tree species. Islands (including forest fragment 'islands') are particularly sensitive to invasive species. Degradation and fragmentation increase the vulnerability of ecosystems to invasive species, while highly diverse ecosystems, such as tropical rain forests, seem to be more resilient than their temperate counterparts.

Traditional knowledge and wisdom of Indigenous Peoples and local communities (IPLCs), including cultural and religious aspects, play a central role for the conservation of primary forests and for sustainable landscape management in Asia and the Pacific. Many biodiversity hotspots are located in Indigenous Peoples' territories, and deforestation rates are significantly lower in forest areas under the stewardship of Indigenous Peoples. Safeguarding and strengthening the rights of Indigenous Peoples is thus vital to preserving forests and biodiversity and fighting climate change. However, youth out-migration from rural areas affects the transmission of this traditional knowledge, threatening the traditional way of life of Indigenous Peoples as well as the natural ecosystems upon which they depend.

Tensions and conflicts over natural resources (land, forests and water) can lead to armed conflicts and even war, further affecting biodiversity and forest ecosystems. The transfer of land is a major threat, especially land grabbing by large corporations in industries such as mining, oil palm, and rubber.

Many Asia-Pacific countries still lack the technological, financial and human capacities to monitor and sustainably manage their forest landscapes. Conflicting land uses and mandates, incoherent policies across sectors and scales, corruption, weak governance and weak law enforcement, particularly regarding land access and tenure rights, are also detrimental to primary forest conservation. In

some countries, policies still focus too narrowly on timber production only, overlooking the multiple non-timber forest products (NTFPs and ecosystem services that forests can provide.

Chapter 3 ends by modeling future deforestation risks until 2050 to identify priority areas for primary forest conservation.

4 Governance instruments for primary forest conservation in the Asia-Pacific region

Forest governance is both shaped and influenced by a range of actors⁶ and institutions operating at different scales (from the local to the international levels), the actions of each group influencing the actions of others. The dynamics at play between actors, including land use and tenure rights and power asymmetries, are determinant for the preservation and sustainable management of a given forest, or for its designation as PA.

International agreements and instruments do not usually focus on primary forests as such. Instead, primary forest conservation is embedded in or aligned with more global objectives including: the Sustainable Development Goals (SDGs); the climate targets set in the Paris Agreement; the Aichi targets for biodiversity protection; or the forest landscape restoration (FLR) global targets. Regional and sub-regional institutions and instruments provide a bridge between international policies and national actions. Regional cooperation, including South-South cooperation, is critical as some remarkable intact forest massifs cross national boundaries and as many issues related to primary forest conservation and sustainable forest management (SFM) are transboundary in nature. The Asia-Pacific Forestry Commission (APFC) can play an important role in stimulating regional cooperation.

National rules and instruments for forest governance and primary forest conservation

6 e.g. public and private actors, research and academic institutions, civil society, IPLCs.

can include: national commitments that contribute to global objectives;⁷ legal protection frameworks; regulation of land tenure and access rights; regulation of logging concessions or even logging bans; prevention of illegal logging and illegal trade of forest products; land use planning to regulate agriculture expansion, urbanization and infrastructure development; legal incentives such as taxes, subsidies and fiscal transfers; and market-based instruments such as certification schemes or payments for ecosystem services.

Chapter 4 highlights the need to build synergies across sectors, including agriculture, water management and land use planning, and to adopt a more integrated landscape approach (ILA). National policies, rules and instruments frame and orient governance mechanisms at the local level. The active involvement of local actors, Indigenous Peoples and local communities in decision making around primary forest conservation and SFM is critical because these actors not only heavily depend on forest resources for their subsistence and livelihoods but also often hold the best knowledge of their specific ecosystem. Community-based forestry (CBF) is a successful example of participatory approach that needs to be encouraged in the region for primary forest conservation and SFM. The recognition of customary tenure and traditional systems of governance is fundamental to encourage traditional practices that support forest conservation and the sustainable use of forest resources.

5 Mechanisms and tools for primary forest conservation

Protected areas (PAs) are often seen as the main tool to ensure the protection of primary forests. However, PAs cannot be the only mechanism to ensure the protection of primary

forests against deforestation, degradation and fragmentation. First, this study shows that many intact forests and forest types are not covered by national parks and other legally protected conservation areas, and PAs are often established in remote or inaccessible areas (e.g. mountains) with lower levels of threats and of competing demands on land. Moreover, PAs alone are often insufficient to protect the areas where they are established. Hence, while it may be possible in some places to increase the extent of PAs, a range of mechanisms and tools needs to be mobilized at different scales in addition to and in support of PAs.

Chapter 5 examines how various mechanisms and tools can be combined to address a diversity of threats and situations. Legal protection remains the main governance tool for primary forest conservation in the region,⁸ but existing protections are sometimes weakly enforced. Enhancing ecological connectivity between PAs and other effective area-based conservation measures (OECMs), as opposed to increasing the size of a few isolated PAs, is of paramount importance for effective forest and biodiversity conservation as this facilitates species flow, adaptation to climate change and the provision of ecosystem services. Certification and voluntary agreements can help address commercial agriculture expansion as well as wood over-harvesting, either legal or illegal, both of which have been identified as major threats to primary forest conservation in the region. Innovative technologies and the involvement of civil society and IPLCs can improve forest monitoring by providing accurate, real-time, transparent and accessible information about forest status and trends, threats and their drivers. In turn, such an improved monitoring allows more transparent, flexible and reactive governance, thus supporting primary forest conservation and SFM. Finally, adequate financial resources and innovative financial tools that connect large funds to small projects have been identified as a critical condition for the effective conservation of primary forests.

⁷ Such as: the Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs), under the United Nations Framework Convention on Climate Change (UNFCCC), or the National Biodiversity Strategy and Action Plans (NBSAPs), under the UN Convention on Biological Diversity (CBD).

⁸ PAs have increased in past decades and now cover 25% of the total forest area in Asia and 16% in Oceania.

6 Recommendations and roadmap for primary forest conservation in Asia and the Pacific

From the discussions in previous chapters, primary forest conservation requires, among other conditions: (i) an improved knowledge of the different types of forests at finer scales, of their status, trends and functioning, including large-scale ecological mapping and studies on species distribution and species population trends, and the various threats they face, driven by land use, land cover and climate changes; (ii) a compelling narrative, i.e. a shared vision and clear picture of the various values of primary forests and the challenges ahead; (iii) a clear understanding of land tenure and responsibilities; and (iv) efficient mechanisms to connect large funds to small projects. This will allow: (i) the alignment of various sustainable development objectives; (ii) the adoption of cross-sectoral, integrated approaches, particularly at the landscape level, where all of these objectives need to be balanced; (iii) the consolidation and involvement of large coalitions of actors, not only those living close to forests but also distant actors that are somehow connected to forests; and (iv) the harnessing of the potential of innovative technologies to support improved monitoring and reporting, as well as inclusive and participatory governance and decision-making processes.

Six areas for recommendations to enhance primary forest conservation in Asia and the Pacific have emerged from this study and from the collective process of elaboration of this roadmap: (i) explore innovative ways to improve monitoring and reporting on primary forests; (ii) improve the knowledge and understanding of the functioning and dynamics of primary forest ecosystems within broader landscapes to orient land use planning,

management and conservation efforts; (iii) build a compelling narrative for primary forest conservation and consolidate new coalitions of actors; (iv) ensure policy coherence across sectors and scales and promote integrated landscape approaches for primary forest conservation; (v) align sustainable land use, climate action and biodiversity objectives for the conservation of primary forests; and (vi) strengthen regional and international cooperation for the conservation and management of primary forests.

It is a difficult, if not impossible, task to craft a set of recommendations that are simultaneously broad and comprehensive enough to embrace the huge diversity of primary forests in the Asia-Pacific region and of the threats they face, yet precise and operational enough to lead to concrete action plans in specific contexts. These recommendations need to be appropriately articulated, combined and adapted to specific contexts. This is why, beyond the overall framework these recommendations provide, this study also proposes a practical way forward that can help governments and other actors elaborate their own roadmap, adapted to their own context, priorities and needs. This process comprises the four following steps: (i) carrying out an initial assessment, building upon a large scale ecological mapping program, of the current situation of primary forests; (ii) developing a strategy: defining priorities and means of implementation for primary forest conservation and protection; (iii) creating an enabling environment for primary forest conservation and protection; and (iv) acting collectively and individually. This process could be implemented and articulated at different scales in a coordinated way: at the regional and national levels on the one hand, and at the local level on the other hand, in each specific forest identified as a priority area for conservation.

Introduction

Roadmap: background and process

The Third Asia-Pacific Forest Sector Outlook Study (APFSOS III: FAO, 2019), launched in June 2019 during the Asia-Pacific Forestry Week in Incheon, Republic of Korea, highlighted that the conservation of primary forests and the sustainable management of other natural forests are urgently needed to safeguard biodiversity, ecosystem services and the quality and health of the physical environment in the Asia-Pacific region. Following up on this outlook study, FAO and CIFOR, lead center of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA),¹ have engaged in a collaborative effort to develop a roadmap for primary forest conservation in the Asia-Pacific region.

This technical paper, co-published by FAO and FTA, builds upon the scientific literature, FAO and FTA experience and the contributions received during the process. It has been developed through an inclusive and participatory process, involving 425 key regional stakeholders and technical experts from governments, intergovernmental organizations, the private sector, civil society organizations, academia, and research institutions, as well as selected students and young people involved in the forest sector in the Asia-Pacific region. Three online expert workshops were organized: the first in July 2020 to launch the process and start building a strong community around it

(Pingault et al. 2020); the second in March 2021 to discuss the diversity of primary forests in the region, identify the main threats they face, and develop recommendations to enhance primary forest conservation (Pingault et al. 2021a); and the last in November 2021 to discuss the main findings and key recommendations of the technical paper and the way forward (Pingault et al. 2021b). Further contributions to the roadmap were gathered through targeted interviews of key stakeholders in the region.

This study delineates the overall roadmap and constitutes – together with the inclusive process that led to its finalization – the first step of that roadmap, informing future country-based processes by which decision makers and actors can identify: priority areas of intervention and priority actions for primary forest conservation, as well as potential threats and how to address them. The chapters of the study are organized along these steps. A policy brief was also prepared for decision makers, covering the main findings and concrete recommendations emerging from this work.

Primary forest conservation and sustainable development goals

Primary forests (see **Box 1**) provide a wide range of ecosystem services that are essential for climate change mitigation and adaptation, biodiversity protection, food security and livelihoods, and human health and well-being. These multiple ecosystem services include: primary biodiversity reservoirs and wildlife habitats, pollination, soil erosion control, water supply (quantity and quality), water runoff control and flood mitigation, carbon sequestration and storage, climate regulation and adaptation to climate change, the provision of food, feed, medicines, fiber, timber and bioenergy, and

¹ FTA (2011-2021) is one of the CGIAR global partnership's 12 research programs. In carrying out its research, FTA is led by the Center for International Forestry Research, in partnership with Bioversity International, CATIE, CIRAD, the International Network for Bamboo and Rattan, Tropenbos International, and the World Agroforestry, and links with dozens of scientific and development institutions. <https://www.foreststreesagroforestry.org/>

Box 1 Forests: FAO definitions

A variety of definitions of forests and wooded areas are used around the world, reflecting both the diversity of forest ecosystems and the diversity of human perceptions and uses of forests. Most definitions of forests are based on land cover, usually combining criteria of canopy cover, tree height and minimum area, and on considerations of land use. The definition and criteria used determine which ecosystems can be considered forest and impact strongly forest area (HLPE 2017).

FAO global forest resources assessments (FRA, see **Box 2**) have contributed to the harmonization of the definitions and categorizations of forests at the global level, allowing compared analysis across countries at regional or global level. In the FRA, forest is defined as “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 2018a). This definition excludes agricultural and urban tree stands. The FRA 2020 further distinguishes two main categories of forests defined as follows:

- Naturally regenerating forest (or natural forest): “forest predominantly composed of trees established through natural regeneration”;
- Planted forest: “forest predominantly composed of trees established through planting and/or deliberate seeding”. (FAO 2018a)

Among natural forests, a primary forest is defined as a “naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed” (FAO 2018a). This FAO (2018a) definition:

1. “Includes both pristine and managed forests that meet the definition.
2. Includes forests where Indigenous Peoples engage in traditional forest stewardship activities that meet the definition.
3. Includes forest with visible signs of abiotic damages (such as storm, snow, drought, fire) and biotic damages (such as insects, pests and diseases).
4. Excludes forests where hunting, poaching, trapping or gathering have caused significant native species loss or disturbance to ecological processes.
5. Some key characteristics of primary forests are:
 - they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes;
 - the area is large enough to maintain its natural ecological processes;
 - there has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become re-established”.

social values and cultural heritage (Vira et al. 2015; HLPE 2017; Watson et al. 2018; FAO 2019; Gitz et al 2021). As such, effective primary forest conservation is critical to achieve most, if not all, of the Sustainable Development Goals (SDGs).

Yet primary forests and natural landscapes in the Asia-Pacific region are under increasing pressure from a range of threats including: climate change and natural disasters, population and economic growth, overexploitation and illegal exploitation of forests, infrastructure development, agricultural

expansion, competing demands for natural resources (land, water and biodiversity), inconsistent policies across sector and scales, weak governance, migration, and conflict.

Despite an overall increase in forested area in the region since 2000 due to strong afforestation and reforestation policies in some countries, such as China, India and Viet Nam, primary forests have continued to decline in the Asia-Pacific region. According to FAO (2019), based on data from the FRA 2015, primary forests now cover 140 million ha,

representing only 19% of the total forest area in the region, which is much lower than the global average of 32% (see **Box 2** for more information on primary forest assessment in the FRA). Degradation and fragmentation further weaken the functionality and resilience of primary forest ecosystems, i.e. their capacity to provide ecosystem services and to cope with external shocks. Hence, halting primary

forest loss and degradation must be a priority for all countries in the region now and in the next decade to protect people and the planet, especially in the face of dangerous climate change. Some specific ecosystems, such as mangroves, peat swamp forests, limestone forests, cloud and mountain forest ecosystems, may deserve special attention due to their unique contributions and high vulnerability.

Box 2 FAO Global Forest Resources Assessment (FRA)

Since 1948 and every five years now, FAO publishes the Global Forest Resources Assessment (FRA), which collects detailed information from its member countries on the status and trends of the world's forest resources, on forest management and uses. The FRA is the most comprehensive and authoritative global assessment of forests. The latest FRA, published in 2020, gathers information on more than 60 broad variable categories, covering 236 countries and territories around the world for the period between 1990 and 2020. The FRA relies on official data provided by each member country and compiled through a well-established network of officially nominated national correspondents. This network, which is the cornerstone of the whole process, has grown progressively to cover 187 countries and territories, which represent 99.5% of the global forest area. For the countries and territories without national correspondent, the FRA Secretariat directly writes the national report based on available documentation and previous assessments.

Primary forest reporting in the FRA

FAO has reported on primary forest for more than 40 years, since the FRA 1980. The FRA 2020 (FAO 2020) contains information on primary forest area for the years 1990, 2000, 2010, 2015, 2020 from 146 countries and territories representing 81% of the world's forest area. Of the 49 countries and territories of the Asia-Pacific region, 29 provided a complete series for primary forest area for each of the five reporting years, including: seven countries that declared a null primary forest area, 12 that declared a constant area over the whole period, and six that declared a constant area since 2010. Four countries provided incomplete time series, and 16 declared no data at all over the period. Only 30 countries of the Asia-Pacific region declared their primary forest area for 2020, amounting to a total of almost 87 million ha.

The FRA definition of primary forest has progressively evolved through a consultative process with experts. Since the FRA 2010, primary forest is defined as a "naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed" (FAO 2018a). This definition is enriched by explanatory notes, which facilitate consistent interpretation (see **Box 1**). A decision-making tree was also provided in FRA 2020 Guidelines and Specification (FAO 2018b) to support more consistent interpretation and reporting of various forest types, including primary forest.

However, studies have shown that definitions and interpretations still vary considerably across countries. First, the lack of operational guidance on primary forest reporting has resulted in the use of proxies that can vary greatly among countries, including legally established protected areas (PAs), national parks, intact forests, or old-growth forests.¹ Second, information is often lacking or insufficient to understand how the national estimates were actually derived. Third, as illustrated above, time series and trends are often missing or, for lack of better data, some countries report the same value for several reporting years. These issues make it highly difficult to draw any sound conclusion on the real trends of primary forest area at global, regional and national levels and to conduct consistent reporting and meaningful comparisons between countries, raising questions about the relevance of the data submitted to FRA for informing policy and decision making.

¹ The reported primary forest area of some countries may have even increased, as was the case with Japan, when countries use proxies such as protected area or old-growth forest area.

Acknowledging these limitations, FAO is currently conducting a special study on primary forests, involving large consultations at global and regional levels, aiming to improve operational guidance on primary forest reporting, as well as the consistency, comparability, completeness and quality of national data reported to the FRA.

For more information:

- Access all FRA reports and highlights: <http://www.fao.org/forest-resources-assessment/en/>
- FRA data platform, a new way to explore FRA data: <https://fra-data.fao.org/>
- Video summarizing FRA process: <https://www.youtube.com/watch?v=SmMyfNIZ-jQ>

Source: Branthomme and Pekkarinen (2021).

Purpose and structure of the paper

The purpose of this technical paper is to gather the knowledge that is needed to identify priority areas and to inform actions to preserve primary forests. It is not prescriptive but gathers information and options relevant to the wide range of contexts found in the region, so that government and other stakeholders can determine priorities for action at regional, national and local levels. The diversity of contexts spans four main dimensions, that the different chapters of this paper successively cover: (i) level and trends of preservation and fragmentation of forests; (ii) diversity of vegetation types and ecological diversity of types of primary forests; (iii) diversity of threats and risks to forests; (iv) diversity of governance and policy contexts and means of intervention. The paper provides a broad picture of the status, diversity, current trends and future perspectives for primary forests in the Asia-Pacific region and suggest key recommendations for policy and concrete actions around primary forest conservation directed to the relevant stakeholder groups. It does so by using a consistent methodology to identify and map priority areas for primary forest conservation and management in the Asia-Pacific region, based on a set of criteria including: size, level of importance and level of threats. The Asia-Pacific region is very large and diverse, making it hard to draw here an exhaustive list of these priority areas. Such a list will ultimately depend on nationally and locally determined priorities, properly informed by the above-mentioned four dimensions that frame the national and local context. More accurate knowledge and common identification of these priority areas could help develop

efficient conservation strategies at different scales and prioritize conservation efforts within broader landscape perspectives. It is also important to anticipate the emergence of new deforestation or degradation hotspots in the future to allow for strengthened conservation and protection efforts before it is too late.

Chapter 1 describes in detail the extent and trends of natural forests and assesses their intactness and fragmentation level to identify and map the remaining contiguous intact forests. **Chapter 2** highlights the diversity of forest ecosystems in the Asia-Pacific region and considers them within broader landscapes, analyzing at a fine scale the dynamics at stake in surrounding areas that contribute to shape their evolution. **Chapter 3** focuses on the range of pressures and threats facing primary forests, including environmental and anthropogenic threats, socioeconomic drivers, and impacts of climate change. **Chapter 4** addresses issues related to governance and governance tools, rules, instruments, initiatives and institutions at international, regional, country and local levels, and considers the range of actors involved. It identifies main challenges but also explores opportunities for good governance. **Chapter 5** reviews mechanisms and tools for primary forest conservation and examines how they can be combined to address a diversity of threats and situations. Finally, building upon the findings presented in the previous chapters and the discussions held during the expert workshops, key recommendations for primary forest conservation are proposed in **Chapter 6**, which is directed towards the main relevant categories of actors. This report therefore contains a picture of the overall roadmap and constitutes the first step of its roll-out at the scale of the Asia-Pacific region.

1 Remote sensing assessment of primary forest cover in the Asia-Pacific region

Despite an overall increase of the region's forested area since 2000 due to the establishment of restoration and afforestation programs in some countries such as China, India and Viet Nam, the area of primary forests is declining (FAO 2020), along with the ecosystem services they provide, such as food and medicines, biodiversity, water and soil protection, climate regulation and carbon sequestration, amenities and cultural values.

The myth of pristine, untouched tropical rain forest environments has been challenged in the Amazon and Central Africa, with evidence of a more significant human impact than what was previously admitted (Bayon et al. 2012; Levis et al. 2018; de Souza et al. 2018; McMichael et al. 2020; Ellis et al. 2021). However, it is relevant to assess what appear to be the least disturbed forests today, which are generally recognized to be more resilient to global changes² (Kapos et al. 2002).

In addressing such forest 'integrity' (Evans et al. 2021), several concepts have been gaining traction, such as 'intact forest landscapes', which are seamless mosaics of forest and naturally treeless ecosystems with no remotely detected signs of human activity and a minimum area of 500 km² (Potapov et al. 2008; Potapov et al. 2017), 'intactness', which refers to native forest that is free from significant damaging human activities (Watson et al. 2018), the Global Forest Landscape Integrity Index built by combining observed and inferred pressure from human activities (infrastructure, agriculture, deforestation), edge effect and loss of connectivity (Grantham et al. 2020), assessment of

'deforestation fronts' (Pacheco et al. 2021), tropical humid forest degradation (Vancutsem et al. 2020) and tropical forest vulnerability (Saatchi et al. 2021).

This chapter looks at the status and extent of primary forests in the Asia-Pacific region, describing the trends in loss of natural forest cover, degradation and fragmentation. This study focuses on primary forests, as per the FAO definition used for the FRA, in Asia and the Pacific. This chapter develops a remote sensing methodology to describe changes in natural forest cover, degradation fragmentation affecting primary forests and their evolution. Having first identified natural forest cover, ensuring that no planted forests are included, this study assesses degradation within these natural forests, including logged-over areas, leading to an estimation of so-called intact forests. In this study, intact forests are defined as "*forest cover that show no remotely-detected signs of biomass degradation or human impact, and is large enough to maintain its natural ecological processes, including viable populations of wide-ranging species*". Intact forests can still be affected by elements of human pressure not visible from the sky (defaunation), but also by natural abiotic damages (such as storm, snow, drought and fire) and biotic damages (such as insects, pests and diseases). Ultimately, by assessing the fragmentation of these intact forests, isolating large core areas and excluding forest edge zones, the study identifies contiguous intact forests, which are the best possible estimation, through remote sensing techniques, of what can be considered as primary forests as per the FAO definition. By construction, the area and geographic extent of these 'intact forests' do not necessarily correspond exactly to the area and geographic extent

² <https://www.iucn.org/crossroads-blog/202003/primary-forests-a-priority-nature-based-solution>

of ‘primary forests’ as identified by countries and reported to the FRA (which remain the official data on ‘primary forests’) because each country has its own method and underlying data.

This chapter first assesses historical changes in natural forest cover in 2000, 2010 and 2020 by using remote sensing to identify hotspots for deforestation (**Section 1.1**). It then evaluates the intactness of this natural forest cover (**Section 1.2.1**) and its fragmentation level (**Section 1.2.2**) to assess the remaining contiguous intact forest cover in the Asia-Pacific region.

1.1 Historical changes in natural forest cover and deforestation hotspots in the Asia-Pacific region

This study uses Landsat satellite data to assess historical changes, degradation, fragmentation and loss in natural forest cover in 2000, 2010 and 2020, with the view to subsequently identifying planted versus naturally regenerated forest before assessing their intactness.³ The pertinence of several remote sensing methods was tested to cover very diverse environments, from the Islamic Republic of Iran and Afghanistan to New Zealand and the Pacific, with tropical and equatorial regions in between.

As a first approximation, forest cover was analyzed based on global ecological zones (GEZ – FAO 2010) to limit the misclassification of very different forest types in different ecozones (humid, seasonal, temperate, and mountain). In more seasonal areas, remote sensing techniques required the analysis of images in different seasons to determine the best phenological period to identify forest types. In seasonal climate regions, when trees shed leaves during the dry season, grasses or shrubs underneath dominate reflectance readings from satellite sensors, causing forest

cover to be underestimated. The method workflow is detailed in **Figure 1** and **Box 3**. Results are given in **Table 1** and **Figure 2**.

Our results show that Asia-Pacific natural forest cover approximated 667 million ha in 2000, declining to 643 million ha in 2010 and 609 million ha in 2020, a 3% difference compared to the FRA 2020 assessment on average at the regional level.

The methodology followed in this study applies the FAO definition for forest, except that our minimal mappable area was 1 ha instead of 0.5 ha, and young tropical forest fallow areas (<20 years old), although sometimes taller than 5 m, were not included in our natural forest assessment as they are clearly distinguished on color composite images of Landsat satellite data. Although our forest likelihood product does not relate directly to tree cover density mapping, our results were compared with tree cover density maps from Hansen et al. (2013) for areas with open seasonal forest types, such as Australia and India. The differences were not significant: most of our pixels fell into Hansen’s tree cover classes with above 10% of tree cover, meaning our results fulfill the minimal 10% tree canopy cover threshold of the FAO forest definition, although this threshold is questionable for humid tropical landscapes such as those found in Indonesia⁴ and Malaysia.

In tropical countries like Indonesia, Malaysia, or the five countries of the Indochina peninsula,⁵ the specific geometrical features of the plantations allow a distinction between planted and natural forest. This distinction is more complex to render in other regions, especially for more open forest and woodland types in Australia and India, as well as for coniferous forests in China, Japan and Korea. Although reference maps (plantation area mapping, mostly at coarse scale) can be of help in some regions as a guide, we relied on available high-resolution imagery to select visually natural and planted forest training samples for details and cross-checking.

3 We used Landsat-5 TM TOA (1996-2000) for forest cover 2000; Landsat-5 TM TOA (2006-2010) and Landsat-7 ETM+ TOA (2006-2010) for forest cover 2010 and Landsat-8 OLI (2016-2020) for forest cover 2020.

4 The Indonesian Ministry of Environment and Forestry uses for instance 30%

5 Namely: Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam.

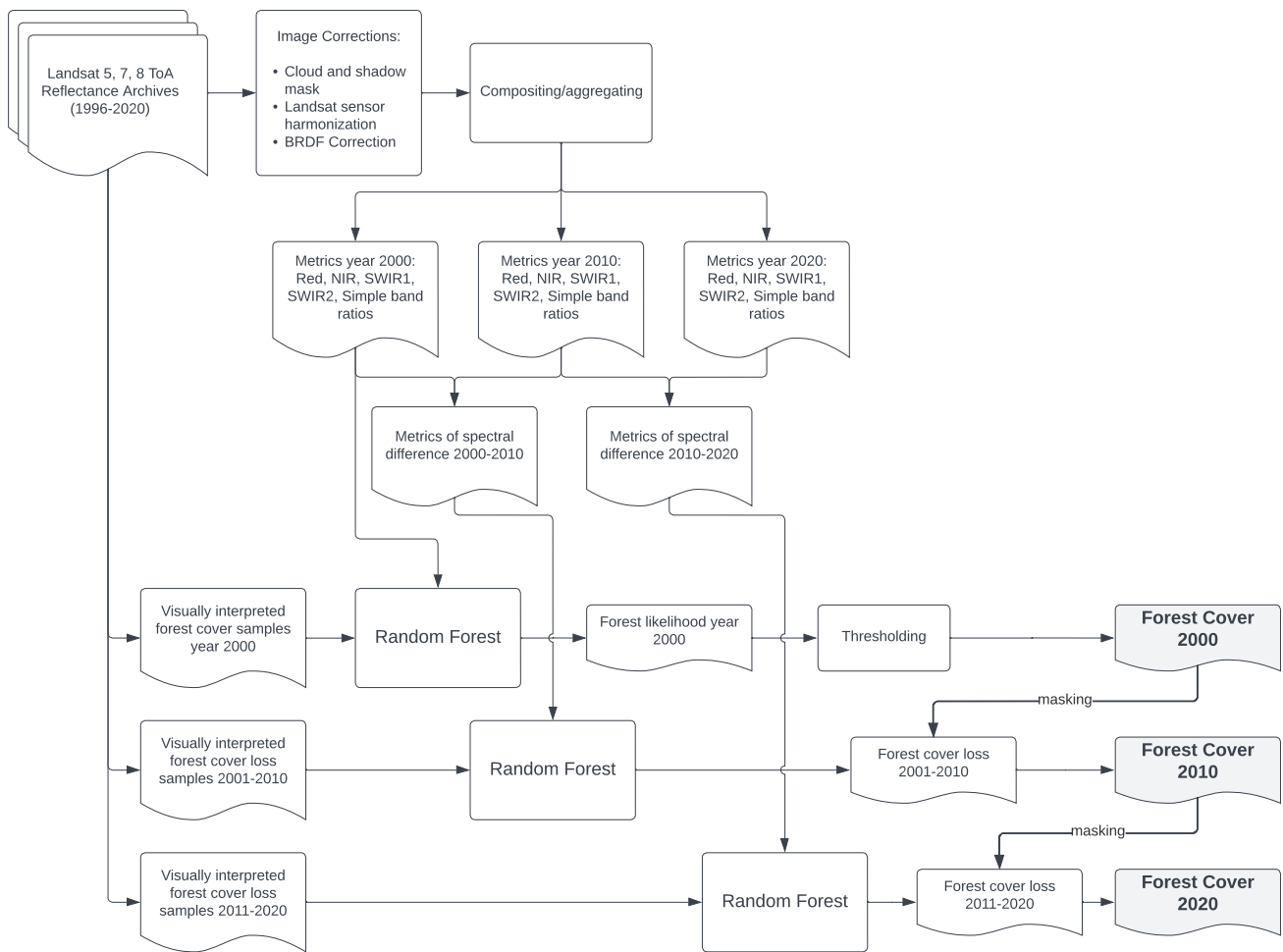


Figure 1 Workflow for remote sensing data processing to assess natural forest cover dynamics between 2000, 2010 and 2020. Note: BRDF: bidirectional reflectance distribution function; NIR: near-infrared; SWIR: short-wave infrared. See Box 3 for methods and terminology.

Box 3 Method used to assess natural forest cover in 2000, 2010 and 2020

Pre-processing

We used Landsat-5 TM TOA (1996–2000) for forest cover in 2000; Landsat-5 TM TOA (2006–2010) and Landsat-7 ETM+ TOA (2006–2010) for forest cover in 2010; and Landsat-8 OLI (2016–2020) for forest cover in 2020. The Google Earth Engine platform (Gorelick et al. 2017) was used to perform image pre-processing to ensure spectral consistency in the detection of forest cover change. This included cloud cover correction, bidirectional reflectance distribution function (BRDF) correction using a script developed by Poortinga et al. (2019), and Landsat TM-ETM+ to OLI harmonization (Roy et al. 2016) with the following dictionary of slope and intercept image constants. Note that the harmonization process was only carried out on Landsat TM and ETM+ data.

$$L_H = L_L \times M_L + A_L$$

Where:

L_H = Harmonized band

L_L = Input band

M_L = Band-specific multiplicative factor (slope)

A_L = Band-specific additive factor (intercept)

We also performed radiometric normalization to identify the same mean vector and covariance matrix for two different images (Landsat TM/ETM and OLI) and used Landsat OLI as the reference.

Processing

The Random Forest classifier, a popular and efficient machine-learning algorithm (Breiman 2001), was used to produce the natural forest cover map. This algorithm can accommodate a large number of datasets, both continuous and discrete data, and is relatively free from overfitting. The Random Forest algorithm classifies the different samples according to the forest likelihood, i.e. the probability (range 0-1) for the sample to have a forest cover. The initial threshold used to distinguish rain forest from non-forest was 0.5. However, the tropical seasonal canopy has different spectral responses, especially in the near infrared and short-wave infrared bands. Hence, seasonal forest versus non-forest covers are better discriminated at a threshold value of 0.3.

The variables fed into the Random Forest model were the near-infrared (NIR), short-wave infrared (SWIR1 and SWIR2 bands), and the simple ratios of the combination of the three bands. These metrics were chosen as they are relatively free from atmospheric disturbances such as haze. Training samples were then collected for forest and non-forest in 2000, 2010, and 2020 and deforestation samples from 2001–2010 and 2011–2020 based on visual observation on Google Earth or using reference forest maps from countries when available. Forest cover in 2010 was determined by overlaying the 2000 forest cover map and 2001–2010 deforestation map, and unchanged forest was defined as forest cover in 2010. Forest cover in 2020 was determined using the same process.

Deforestation maps

We call in this report “deforestation map” the spatial visualization of natural/intact forest cover change, using our remote sensing approach (Fig 1). These “deforestation maps” for 2001–2010 and 2011–2020 were produced using the same method of forest likelihood but using deforestation samples as dependent variables and per-pixel differences metrics as independent variables. For instance, the 2001–2010 deforestation map was produced using per-pixel differences of all metrics from 2001 (NIR, SWIR1, SWIR2, simple ratios, forest likelihood) and all metrics from 2010 (NIR, SWIR1, SWIR2, simple ratios, forest likelihood). The output was deforestation likelihood, later classified into deforested or not deforested using the thresholding approach. The average threshold to optimally distinguish deforested areas was 0.3.

Accuracy assessment

To evaluate how well the classification performed, 30% random samples were used all over the area to assess accuracy at the sub-regional level. The accuracy level was 94% for South Asia, insular Southeast Asia and Oceania, and 92% for East Asia and continental Southeast Asia.

Table 1 Asia-Pacific natural forest cover for 2000, 2010 and 2020, and rates of change 2000–2010 and 2010–2020 for the four sub-regions; data from Landsat-5 TM TOA (1996–2000) for 2000 forest cover; Landsat-5 TM TOA (2006–2010) and Landsat-7 ETM+ TOA (2006–2010) for 2010 forest cover and Landsat-8 OLI (2016–2020) for 2020 forest cover

Sub-region	Natural forest cover (1000 ha)			Change 2001–2010		Change 2011–2020	
	2000	2010	2020	(1000 ha)	Annual rate (%)	(1000 ha)	Annual rate (%)
South Asia	85,073	83,943	81,637	-1,130	-0.1%	-2,306	-0.3%
East Asia	168,092	166,706	158,161	-1,386	-0.1%	-8,545	-0.5%
Southeast Asia	186,553	174,261	155,808	-12,292	-0.7%	-18,453	-1.1%
Oceania	227,528	218,420	214,101	-9,108	-0.4%	-4,318	-0.2%
Total	667,246	643,330	609,708				

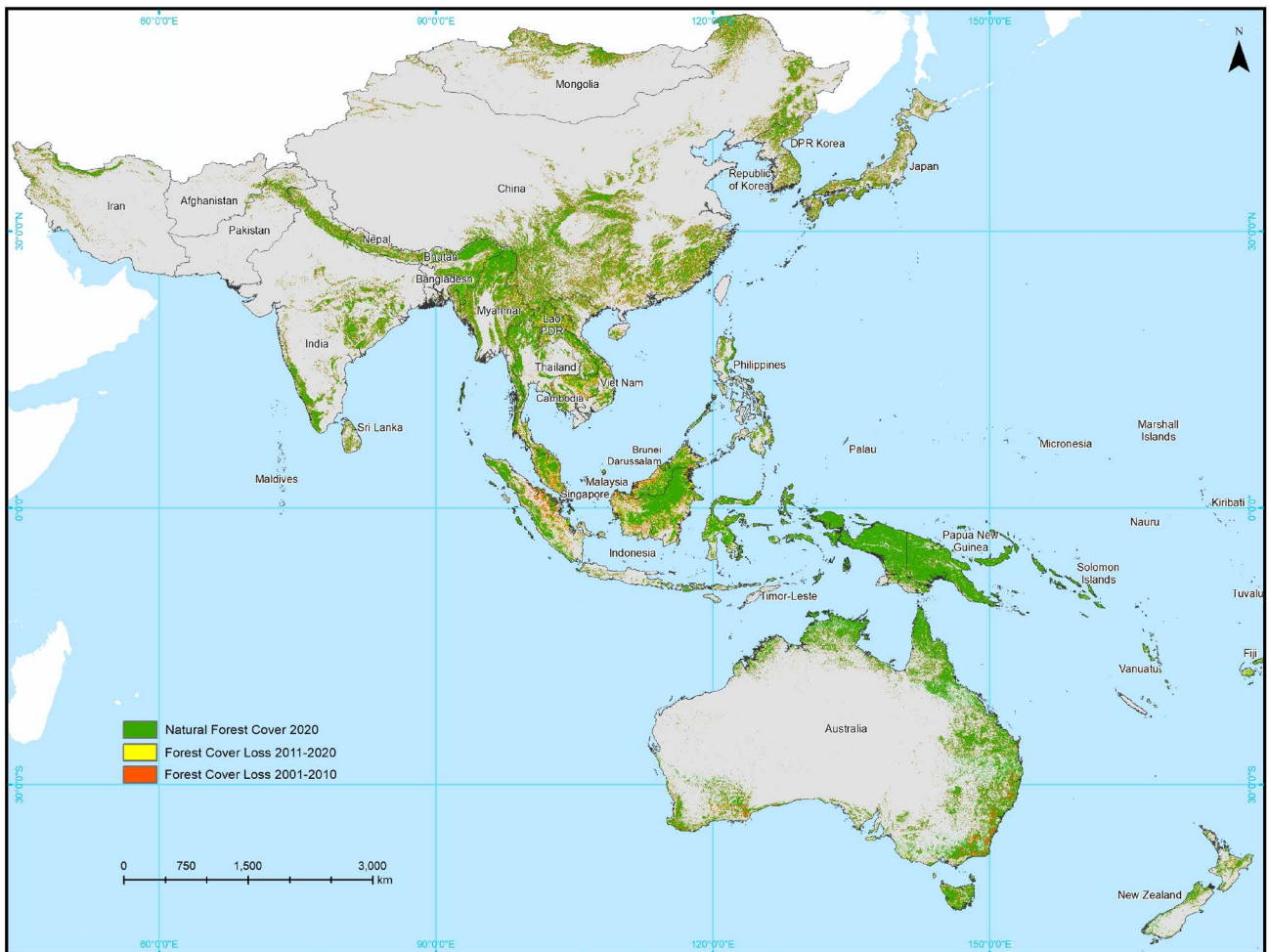


Figure 2 Natural forest cover change, deforestation map 2001–2010 and 2011–2020 for the Asia–Pacific region (detailed maps in Annex, see Box 3 for methods). Source: Authors

The results show a large spectrum of situations in the Asia and the Pacific Region with respect to changes in forest cover, with three main situations : (i) some places with high rates of forest loss in 2010 have kept or even increased these -already high- rates; (ii) in other places, forest loss rates were originally lower but have continued to increase in the last decade, (iii) finally there are areas where a relative stabilization of rates has been observed since 2010.

In addition, we tried to visualize the dynamics of forest area change, looking at areas that exhibit statistically significant clustering in spatial patterns of forest loss, which we call in this report deforestation ‘hotspots’. We used the Getis-Ord spatial statistic tools (Harris et al. 2017). The Getis-Ord G_i^* statistic (Ord and Getis, 1995) can identify the location and degree of spatial clustering of forest loss for

a particular grid cell and surrounding cells. We used a grid cell of 3×3 km. This analysis for the two periods distinguishes the areas with new, intensifying or persistent deforestation hotspots. Some areas may experience persistent deforestation hotspots in both periods, indicating that deforestation in these areas is very severe (see **Figures 3a, 3b, 3c, 3d**).

Examples of intensifying and persistent deforestation hotspots of particular concern include: the Indian states of Nagaland, Manipur and Mizoram; the Chittagong Division of Bangladesh; Kegalle and Vavuniya districts of Sri Lanka; many states in Myanmar (Shan, Kachin, Chin and Sagaing border with India); the isthmus of Kra and Surat Thani and Songkhla provinces in Thailand; Oudomxai, Louangphrabang and Houaphan provinces in Lao PDR; and Kampong Thum and Siem Reab in Cambodia.

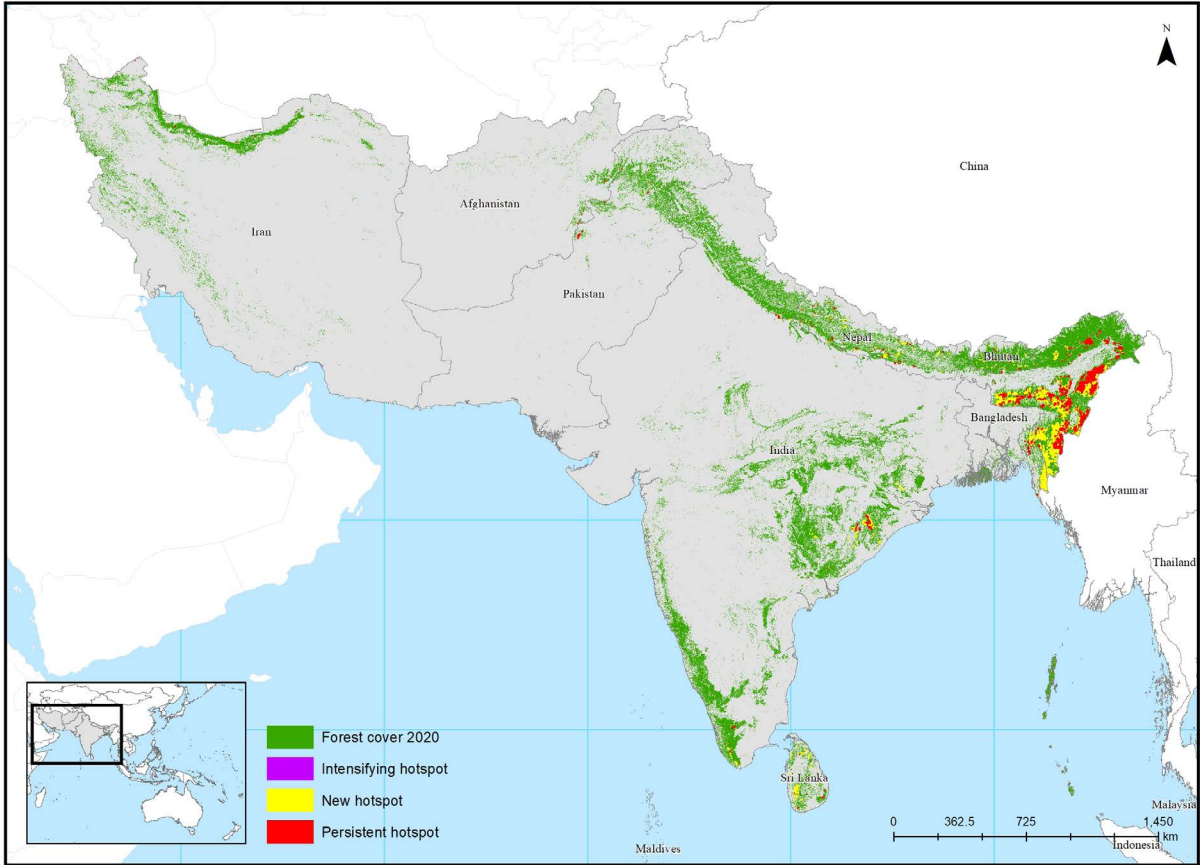


Figure 3a Intensifying and persistent hotspots of deforestation between 2000 and 2020 in South Asia.
Source: Authors



Figure 3b Intensifying and persistent hotspots of deforestation between 2000 and 2020 in Southeast Asia.
Source: Authors

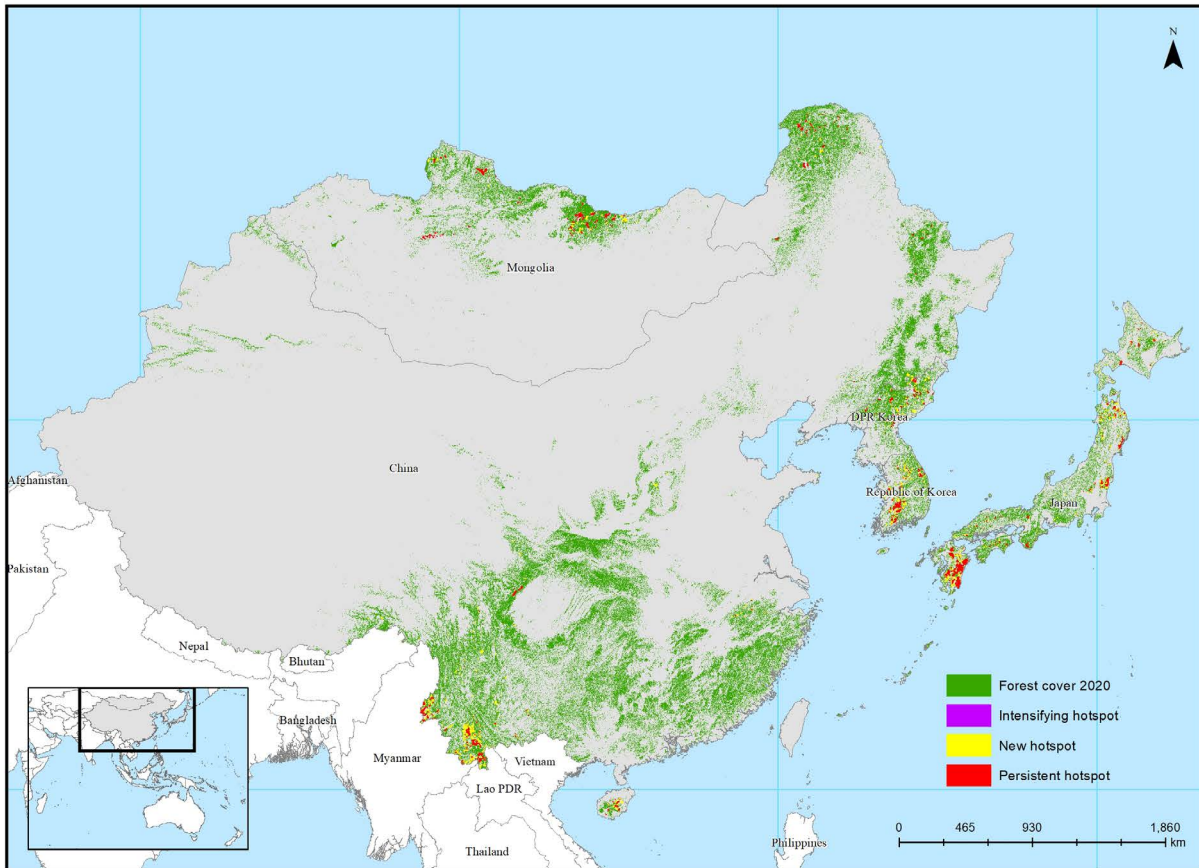


Figure 3c Intensifying and persistent hotspots of deforestation between 2000 and 2020 in East Asia.
Source: Authors



Figure 3d Intensifying and persistent hotspots of deforestation between 2000, 2010 and 2020 in Oceania.
Source: Authors

1.2 Intact forest cover assessment

Forest habitat degradation and fragmentation intensification is a compelling threat to global biodiversity today (Krogh 2019; Fischer and Lindenmayer 2007), particularly in the Asia-Pacific region. In the previous section, the definition of natural forests included former stand degradation such as previous logging operations between 2000 and 2020 or forest regrowth after slash-and-burn agriculture (old fallow forest ≥ 20 years old). This section first assesses the integrity of the remaining undisturbed natural forests, referred to as intact forests. It then analyzes the level of fragmentation of these intact forests, discussing how large is “large enough to maintain natural ecological processes” (FAO 2018a). As a result, it identifies the contiguous intact forest cover, that is the best possible estimation through remote sensing techniques of what can be considered as a primary forest as per the FAO (2018a) definition.

1.2.1 Forest degradation

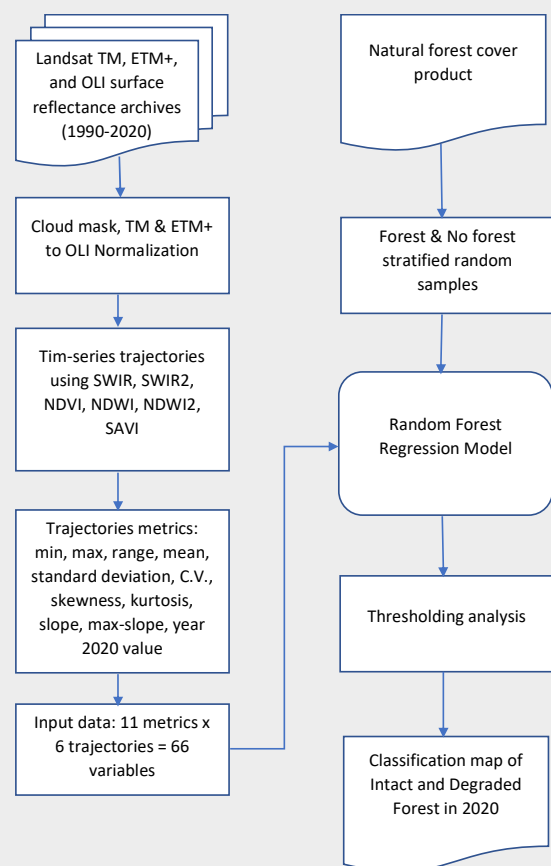
Criteria used to assess forest degradation vary between countries and actors. However, in remote sensing studies, forest degradation is mainly understood as a change in the structure of the forest canopy, an increase in its openness, a decrease in tree density and reduced carbon stocks, leading to a loss in biodiversity and carbon storage (FAO, UNEP and ITTO in Schoene et al. 2007). The method used to assess forest degradation is described in **Box 4**.

The results (see **Figure 5** and **Table 2**) appeared similar to those of the global forest management mapping approach of the Copernicus Global Land Service (Buchhorn et al. 2019; Vancutsem et al. 2020), with some differences in the assessment and surfaces of the ‘disturbed/degraded forest’ classes. The method followed in this study appears more suited to large areas than other time series approaches like Breaks For Additive and Seasonal Trend (BFAST: Verbesselt et al., 2012) or Landsat-based Detection of Trends in Disturbance and Recovery (LandTrendR: Kennedy et al., 2018), which are more appropriate to cover smaller areas.

Box 4 Method to separate degraded forests from intact forests

This study adapted the approach of Wang et al. (2019) to map cumulative degraded forest cover based on a 20-years time series of Landsat imagery. This approach integrates single-date features with temporal characteristics from six time-series trajectories (SWIR, SWIR2, NDVI, NDWI, NDWI2 and SAVI).¹ We modified the method, using Random Forest as a regression, with forest/non-forest sample data, which will then generate forest likelihood. From the forest likelihood value, ranging from 0 to 1, we determined the threshold to separate intact forest from degraded forest. We chose the optimal threshold by visually comparing the result with reference maps (e.g. Vancutsem et al. 2020; Lin and Liu 2016; Roy et al. 2015). In tropical areas, we found that intact forests were optimally classified using a threshold greater than 0.5, while degraded forests were optimally classified with a threshold below 0.5. This method is illustrated in **Figure 4**.

Figure 4 Method to separate degraded forests from intact forests



¹ SWIR, short-wave infrared; NDVI, normalized difference vegetation index; NDWI, normalized difference water index; SAVI, soil-adjusted vegetation index.

This study finds that the remaining intact forests of the Asia-Pacific region still cover 519 million ha and are largely located outside PAs (see **Figure 5**). The forest degradation assessment method used performs very well for most countries in South Asia

Table 2 Intact and degraded forests in the Asia-Pacific sub-regions

Region	Forest area 2020 (1000 ha)		
	Intact	Degraded	Total
South Asia	69,781	11,857	81,638
East Asia	119,086	39,428	158,514
Southeast Asia	130,453	24,311	154,764
Oceania	200,330	13,764	214,094
Total	519,650	89,360	609,010

and Southeast Asia. A few issues were encountered for some regions of Cambodia, India and Australia, for which most of the seasonal dry deciduous were first classified as degraded forests. Our figures may be overestimates for some parts of India and Australia. It is more difficult to assess forest degradation for seasonal, more open forest types, such as those found in Australia, central India, and some parts of the Indochina peninsula. In the state of Andhra Pradesh in central India, much of the Deccan plateau has patches of dry deciduous forests and secondary scrubland, but also some remnant moist deciduous forests and evergreen forests (Rawat 1997). In such landscapes, it is difficult to assess intactness levels using remote sensing techniques. Moreover, many forests that still look structurally intact may actually be ‘empty forests’ where wildlife has already disappeared (see, for instance, Malla et al. (2015) on the forest reserve in the northern part of India’s Eastern Ghats).

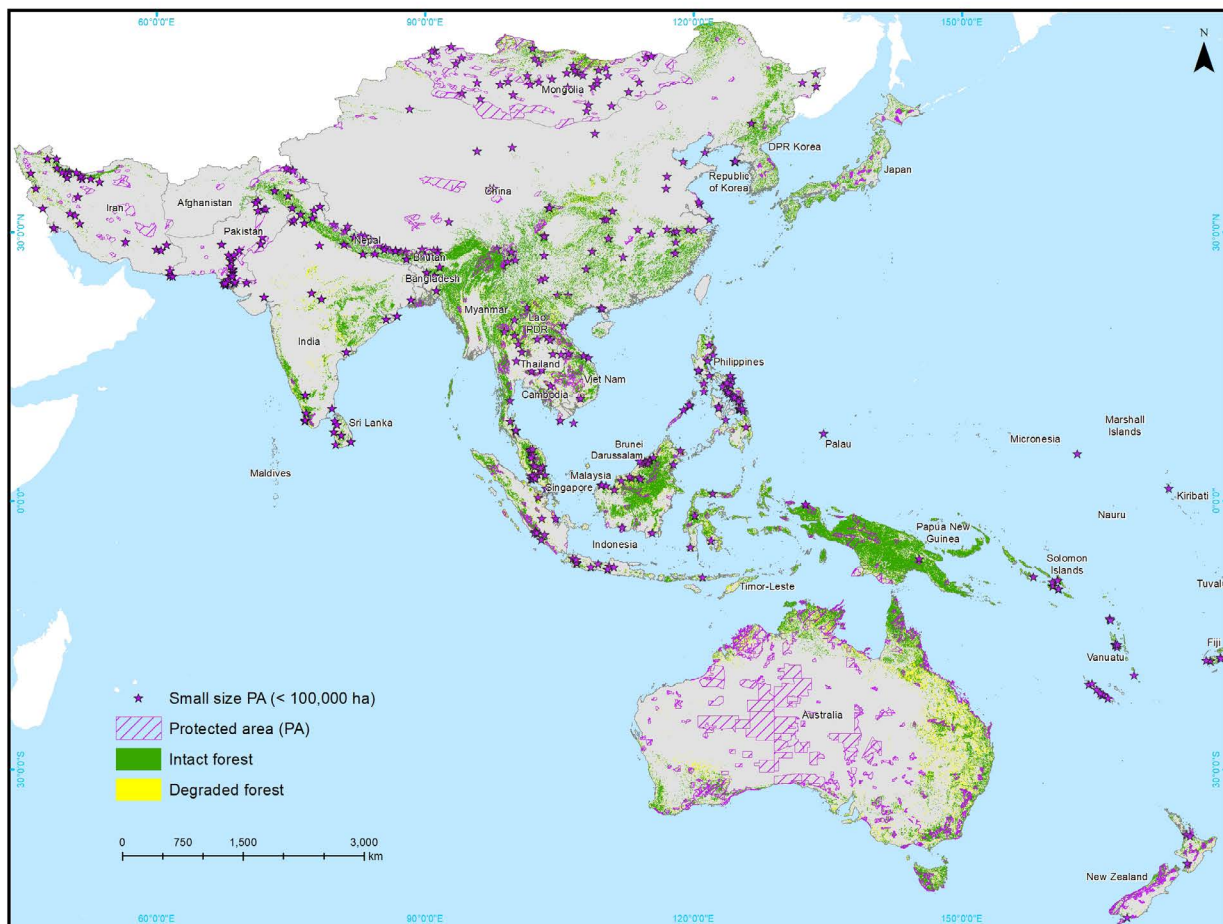


Figure 5 Intact forest cover and protected areas (PAs) in the Asia-Pacific region. Source: Authors

Moreover, it is agreed that the ability of ecosystems to support species and habitat diversity and their capacity to recover from disturbance (resilience) is enhanced if they have little or no human interference, as well as if the area is large enough to support core ecological processes (Kapos et al. 2002). Forest fragmentation is another crucial issue that is addressed in the next section.

1.2.2 Forest fragmentation

Many studies have carried out syntheses to determine the effects of fragmentation on biodiversity (Fahrig 2017; Gardner et al. 2007; Haddad et al. 2015) and ecosystem services (Crooks and Sanjayan 2006; Uuemaa et al. 2013). Infrastructure development, logging operations and agriculture expansion have significantly fragmented forest landscapes in India (Roy et al. 2013), Southeast Asia (Sodhi et al. 2004) and Australia (Woinarski et al. 2014), altering the movement of species, dissemination of seeds and pollination of plants (Hermansen et al. 2017). Few studies provide a comprehensive overview of forest fragmentation in the Asia-Pacific region despite the alarming rates of biodiversity loss observed, particularly in Southeast Asia, where deforestation rates are among the highest in the world.

In scientific discussions around forest fragmentation, the minimal patch size required to ensure viable populations of organisms is still a strongly debated question. Most studies look at fragment sizes, measuring the area of forest fragments in relation to biodiversity and ecosystem functions (Gray et al. 2015; Lucey et al. 2014; Tawatao et al. 2014; Yeong et al. 2016; Mukul et al. 2016; Bernard et al. 2014), while others focus more on isolation and connectivity, edge and core effects (Lucey and Hill 2012; Yue et al. 2015; Gray et al. 2015; Fujinuma and Harrison 2012; Luskin et al. 2017; Nurdiansyah et al. 2016).

In their review, van Hoek et al. (2015) warned against the misuse of threshold values and cautioned against the oversimplification and uncritical application of thresholds as conservation targets. Considering the size of the Asia-Pacific region, the resolution used (100 m) and the limitations of available software for fragmentation analysis (FRAGSTATS:

McGarigal and Marks 1995; GIDOS: Vogt et al. 2019) when dealing with such large amounts of data, this analysis is limited to an illustration of the changes over time of the spatial patterns of forest fragmentation using GIS, pinpointing dynamics in the number of forest fragments, patch and edge density, mean patch size and largest patch index (**Table 3**).

Several size thresholds suggested in the literature were considered to distinguish contiguous forest from forest fragments. Edwards et al. (2011) stated that large expanses of habitat (variously defined as areas over 20,000–500,000 ha depending on the country) should be protected. At the same time, they argued that future agricultural demand can be met by clearing only forest patches below a 1,000 ha threshold. They therefore recommend the development of a new high conservation value⁶ category that will recognize the conservation value of protecting habitat patches of above 1,000 ha within the agricultural matrix. In general, the thresholds used to define intactness in the Asia-Pacific region fall in the range of 20,000 to 200,000 ha (HCV Consortium for Indonesia 2009; Lucey et al. 2017).

In their appraisal of 'Intact Forest Landscapes', Potapov et al. (2017) defined a minimal size threshold for intactness at 50,000 ha. However, for a few species, such as raptors, big carnivores, orangutans or elephants, 50,000 ha might be considered too small. For instance, Marshall et al. (2009) argued that a minimal forest patch size of 50,000 to 100,000 ha is needed to maintain genetically viable populations of orangutans. In the case of the Harapan (hope) Rainforest Ecosystem Restoration concession in Sumatra, 100,000 ha appears to be a critical size threshold illustrating the potential starting point of a decay of the forest. A fragment of a former lowland dipterocarp forest extensively logged over the past 20–30 years, this highly degraded rain forest still supported a high diversity of vertebrates, including elephants and tigers (Harrison and Swinfield 2015). However, the concession is nowadays under pressure not only from invasive species (*Bellucia pentamera*), illegal logging and conversion to oil palm plantations but also from lobbying by

6 See Zrust et al. (2013) for more information on high conservation value categories.

Table 3 Metrics used in this analysis

Metrics	Unit	Description
Number of patches (NP)	None	Number of patches (NP) of the corresponding patch type.
Mean perimeter	m	Average perimeter of a patch for a given patch type. The patch perimeter is a fundamental piece of information available about a landscape and is the basis for many landscape metrics.
Mean patch size	ha	Average area of a patch for a given patch type.
Edge density (ED)	m/ha	Sum of the lengths of all edge segments involving the corresponding patch type divided by the total landscape area.
Largest patch index	%	Equals the percentage of the landscape comprised by the largest patch. As such, it is a simple measure of dominance.
Total edge (TE)	m	Sum of the lengths of all edge segments of a particular patch type in a given landscape.

Source: adapted from McGarigal (1995).

nearby mining companies seeking to build a road across the area⁷ (Engert et al. 2021).

In an assessment of forest integrity in relation to biodiversity for the FRA 2000, using global datasets at a 1 km² resolution, all forest patches larger than 30,000 ha were considered continuous forest (Kapos et al. 2002) while for Tauber (2018), 10,000 ha is an important threshold for which tropical forest fragmentation is near the critical point of impaired percolation⁸ on all three continents, point of fragmentation after which management actions to re-establish connectivity are less likely to be successful.

Besides fragment size, another important consideration is the width of the edge bordering intact forests. Although most environmental and biological changes occur within 100 m from the edge (Laurance et al. 2002), forest disturbances can take place up to 500 m inside fragment margins, and some authors argue that forest can only be considered undisturbed by external factors beyond 1 km or even 2 km from the edge (Ewers and Didham 2007; Broadbent et al. 2008; Chaplin-Kramer et al. 2015; Fisher et al. 2021).

7 Tempo, August 4, 2020 <https://rainforestjournalismfund.org/stories/mining-road-cut-through-sumatran-forest>

8 The percolation theory (Stauffer and Aharony 1994) applied to landscape ecology: the configuration state when only small unconnected patches remain in the landscape.

Some scientists believe conservation efforts should prioritize larger patches where natural processes still work properly. Others argue that all remnant forests are worth considering and even smaller patches should be protected and connectivity among these patches enhanced, such as through ecological corridors. This is related to a long-standing debate on the effectiveness of few large patches vs several small patches for conservation. Few large habitat patches would conserve more species than several small patches, and this principle is used to prioritize the protection of large patches while deprioritizing small ones, albeit without much empirical support. See Fahrig et al. (2020) for a recent critical review on this matter.

Hence this fragmentation analysis considered 100,000 ha, 50,000 ha, 30,000 ha and 10,000 ha as size thresholds. In many countries, forest fragmentation has intensified and intact forest cover has decreased over the past two decades, while the number of small patches, as well as their isolation, has increased. In some countries, forest patches larger than 100,000 ha are the exception. The remaining area of contiguous intact forest is obtained by subtracting the total surface of forest fragments from the total area of intact forests. Following this method, the 519 million ha of identified intact forests in the Asia Pacific region diminish to 378 million ha of contiguous intact forests. This result is broken down at the national level in the following sub-sections, focusing first on the

countries with the highest deforestation rates, mainly in Southeast Asia (Indonesia, Cambodia, Malaysia, Lao PDR, Viet Nam and Thailand). In these countries, forest fragmentation has intensified over the past two decades.

1.2.2.1 Indonesia (Figure 6 and Table 4)

The contiguous forest cover in Indonesia decreased from 81 million ha (47% of the country's total land area) to 69 million ha (40% of total land area) between 2000 and 2020. The number and surface of forest fragments increased on Sulawesi and Papua but decreased on Kalimantan, Sumatra and Java, indicating the imminent disappearance of the lowland forest formations on these three islands.

On Kalimantan, contiguous forest area decreased from 26 million ha to 20 million ha, fragmented forest area decreased from 6 million ha to 5 million ha, and the number of forest patches smaller than 100,000 ha also decreased from 584,100 to 494,300, suggesting that many patches were converted to other land uses. The edge density decreased from 113,650 m ha⁻¹ to 94,200 m ha⁻¹, the mean patch size decreased from 10 ha to 9.8 ha, and the largest patch index decreased from 44% to 31%.

Similar fragmentation patterns were observed for Sumatra, while for Sulawesi, the contiguous forest decreased from 8.5 to 7.3 million ha, and the forest fragments increased from 1.6 to 1.7 million ha. The number of forest patches below 100,000 ha increased from 185,000 to 230,800 patches. The edge density increased from 110,500 m ha⁻¹ to 131,200 m ha⁻¹, while the mean patch size decreased from 8.8 ha to 7.6 ha. The largest patch index also decreased from 42% to 28%, indicating that the fragmentation process produced smaller and more dispersed forest patches during the period.

1.2.2.2 Malaysia (Figure 6 and Table 5)

Malaysian landscapes were once dominated by contiguous forest cover. In 2000, more than half of the total land area of both Peninsular Malaysia and East Malaysia

was covered by contiguous forest (63% and 61% respectively). Between 2000 and 2020, however, this contiguous forest decreased drastically, diminishing from 8.4 million ha to 4.1 million ha in Peninsular Malaysia, and from 12.1 million ha to 7.8 million ha in East Malaysia (31% and 40% of the total land in 2020). The shrinkage of the contiguous forest cover in Malaysia was associated with an increased number and area of fragments.

Almost all parameters on forest fragmentation for Malaysia decreased in number, i.e. mean perimeter, mean patch size, and especially the largest patch index. The mean patch size decreased from 12.9 ha to 9.3 ha in Peninsular Malaysia and from 14 ha to 9.5 ha in East Malaysia.

Over the past 20 years, the largest patch index showed a sharp decline, from 62% to 24% in Peninsular Malaysia and 58% to 31% in East Malaysia. The edge density increased following the increase in the number of forest fragments.

1.2.2.3 Cambodia (Figure 7 and Table 6)

Cambodia's contiguous forest cover decreased from 9 million ha in 2000 (47% of the country's total land area) to 5 million ha in 2020 (26% of total land area). The total forest patch area increased from 1.2 million ha to 2.4 million ha. Over the past two decades, the number of forest patches smaller than 100,000 ha has increased from 168,410 to 313,230, the edge density from 85,360 m ha⁻¹ to 174,095 m ha⁻¹, and the mean patch size from 7.1 ha to 7.5 ha. The largest patch index decreased from 16% to 9%.

1.2.2.4 Viet Nam (Figure 7 and Table 6)

Viet Nam's contiguous forest cover decreased from 7.2 million ha in 2000 (20% of total land area) to 4.6 million ha in 2020 (13% of the entire landscape). On the other hand, the total forest patch area increased from 5.3 to 5.9 million ha. Over the past two decades, the number of forest patches smaller than 100,000 ha has increased from 402,117 to 496,959, and the edge density has increased from 150 m ha⁻¹ to 175 m ha⁻¹. The mean patch size decreased from 13 ha to 12 ha and the largest patch index from 5.5% to 3.4%.

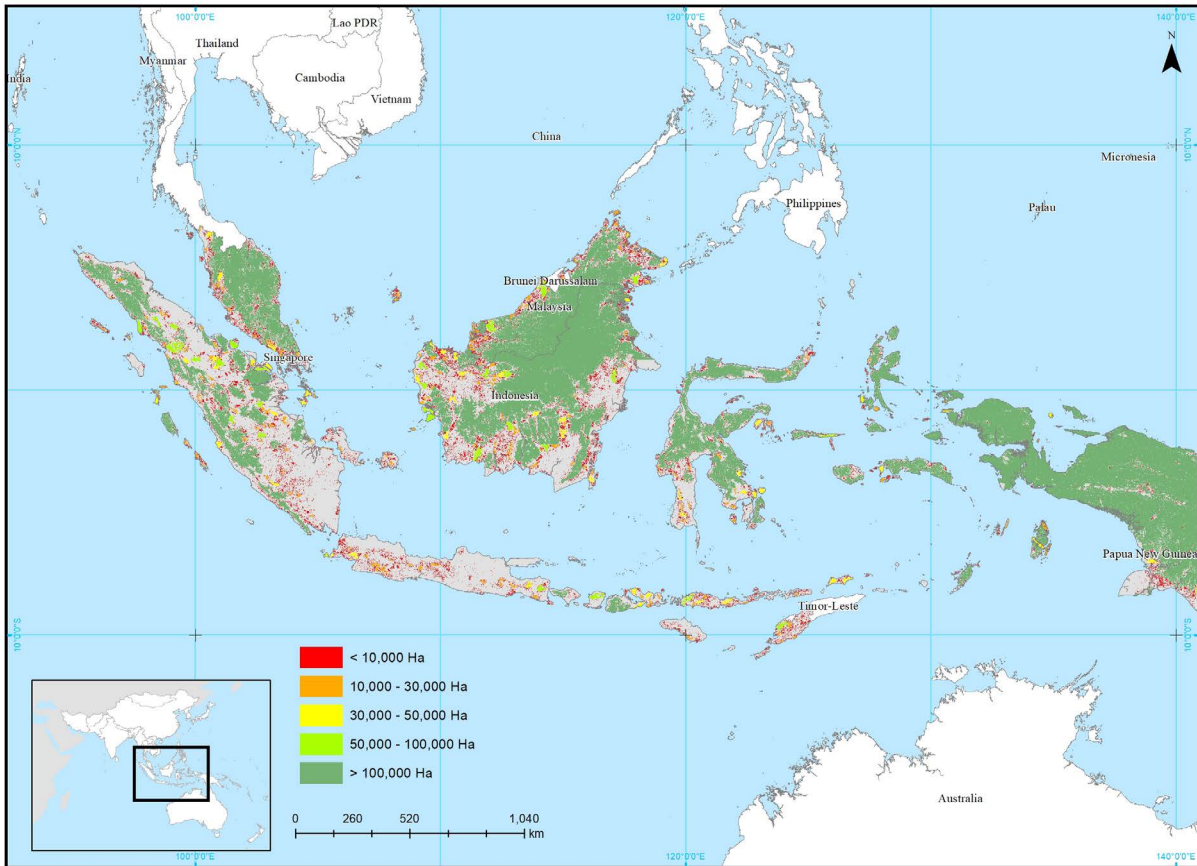


Figure 6a Fragmentation maps of Indonesia and Malaysia in 2000. Source: Authors

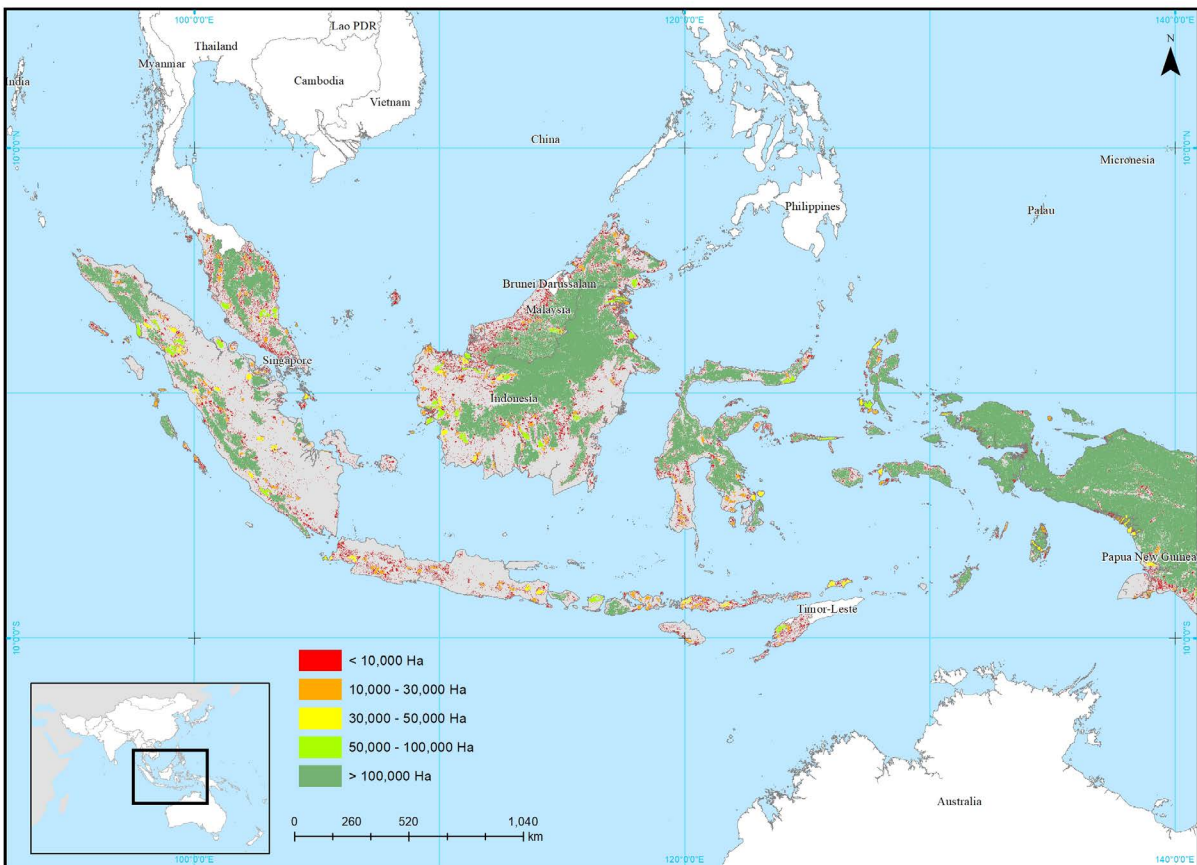


Figure 6b Fragmentation maps of Indonesia and Malaysia in 2020. Source: Authors

Table 4 Fragmentation metrics for the main Indonesian islands

Island	Kalimantan		Sumatra		Sulawesi		Java		Papua	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Total area of contiguous forest (ha)	26,338,560	20,365,325	10,883,200	7,232,315	8,565,270	7,318,915	0	0	35,138,122	33,988,155
Total area of forest patches below 100,000 ha (ha)	5,743,290	4,957,695	5,611,100	4,107,870	1,627,270	1,761,525	1,573,970	1,461,260	984,383	1,179,790
Number of forest patches (NP) below 100,000 ha, by size class										
50,000–100,000 ha	11	13	13	7	0	1	1	0	1	1
30,000–50,000 ha	12	5	12	10	7	2	3	4	3	2
10,000–30,000 ha	42	42	55	40	15	17	15	12	3	6
<10,000 ha	584,060	494,260	522,440	491,540	184,975	230,780	233,000	232,655	93080	120585
Total	584,125	494,320	522,518	491,596	184,997	230,801	233,019	232,671	93,087	120,594
Mean perimeter (m)	1,041	1,019	1,104	985	1,044	994	960	929	1,076	1,057
Mean patch size (ha)	10.03	9.83	10.74	8.36	8.80	7.63	6.75	6.28	10.57	9.78
Edge density (m ha ⁻¹)	113,648	94,198	120,977	101,514	110,499	131,202	167,649	161,995	24,116	30,695
Largest patch index (%)	44.42	30.58	5.70	5.33	42.39	27.90	0.43	0.36	80.48	77.76

Table 5 Fragmentation metrics for Malaysia

Island	Peninsular Malaysia		East Malaysia	
Year	2000	2020	2000	2020
Total area of contiguous forest (ha)	8,404,613	4,064,555	12,079,306	7,874,401
Total area of forest patches below 100,000 ha (ha)	1,313,435	2,177,429	2,806,271	2,807,605
Number of forest patches (NP) below 100,000 ha, by size class				
50,000–100,000 ha	-	3	5	3
30,000–50,000 ha	3	-	5	1
10,000–30,000 ha	13	18	30	17
<10,000 ha	102,018	234,669	199,807	296,619
Total	102,034	234,690	199,847	296,640
Mean perimeter (m)	1,315	1,057	1,254	1,139
Mean patch size (ha)	12.87	9.28	14.04	9.46
Edge density (m ha ⁻¹)	101,455	187,665	126,687	170,776
Largest patch index (%)	62.00	24.14	57.61	31.23

1.2.2.5 Lao PDR (Figure 7 and Table 6)

In Lao PDR, from 2000 to 2020, contiguous forest cover was reduced from 16 million ha to 9.8 million ha, as a result of massive forest fragmentation and conversion to other land uses. In 2000, contiguous forest accounted for 63% of the country's total land area, while only 39% remained in 2020. The number of forest patches smaller than 100,000 ha increased by almost 2.5 times, from 180,887 in 2000 to 443,933 in 2020. In the meantime, the edge density increased from 73,635 m ha⁻¹ to 204,660 m ha⁻¹, while mean perimeter and mean patch size increased from 1,040 m to 1,180 m and 8.3 ha to 9.1 ha respectively. There was a significant decline in the large patch index, from 48% to 17%.

1.2.2.6 Myanmar (Figure 7 and Table 6)

In Myanmar, contiguous forest cover decreased from 33 million ha to 27 million ha, while the forest patch area increased from 5.7 million ha to 7.9 million ha. The number of forest patches smaller than 100,000 ha increased from 724,080 fragments in 2000 to 940,050 in 2020. In the meantime, edge density increased from 103,350 m ha⁻¹ to

141,740 m ha⁻¹, mean perimeter from 1,100 m to 1,160 m, and mean patch size from 7.9 ha to 8.4 ha. The large patch index decreased slightly from 16% to 15%.

1.2.2.7 Thailand (Figure 7 and Table 6)

In Thailand, contiguous forest cover decreased from 13.8 millions ha in 2000 to 12 million ha in 2020. Thailand's forest landscape is now broken up into smaller and more dispersed forest fragments. The total number of forest patches smaller than 100,000 ha increased from 543,805 in 2000 to 589,105 patches in 2020. In the meantime, mean patch size increased from 7.9 ha to 8.4 ha, and edge density from 95,120 m ha⁻¹ to 98,225 m ha⁻¹. The mean perimeter decreased from 967 m to 922 m, while the largest patch index percentage decreased from 16.8% to 15.4%.

1.2.2.8 The Himalayas

Forest landscapes in the Himalayas are quite fragmented (see examples in **Figure 8**). This fragmentation can be natural, caused by deep cuts out in the mountain ranges with many non-forested valleys. In the lower Himalayas (below 2000 m), however, fragmentation between 1998

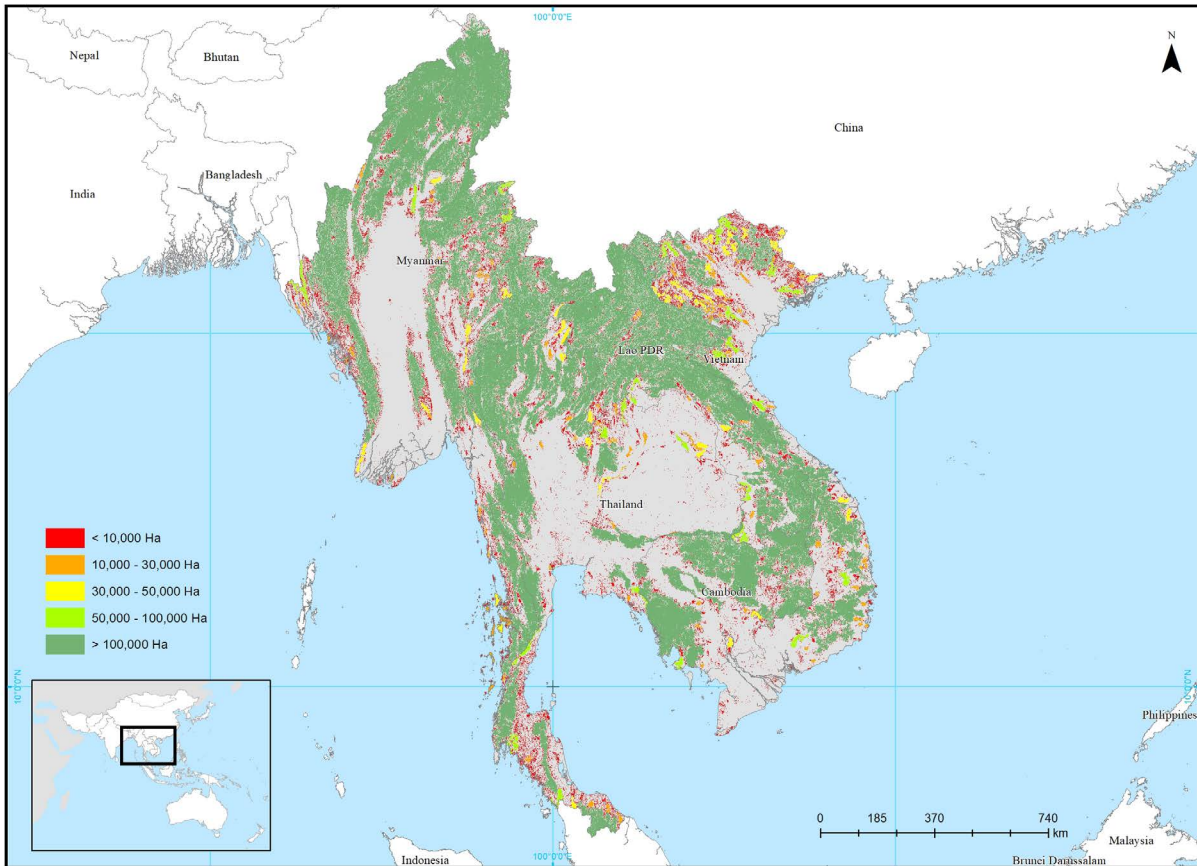


Figure 7a Fragmentation map of Cambodia, Viet Nam, Lao PDR, Myanmar, and Thailand in 2000.
Source: Authors

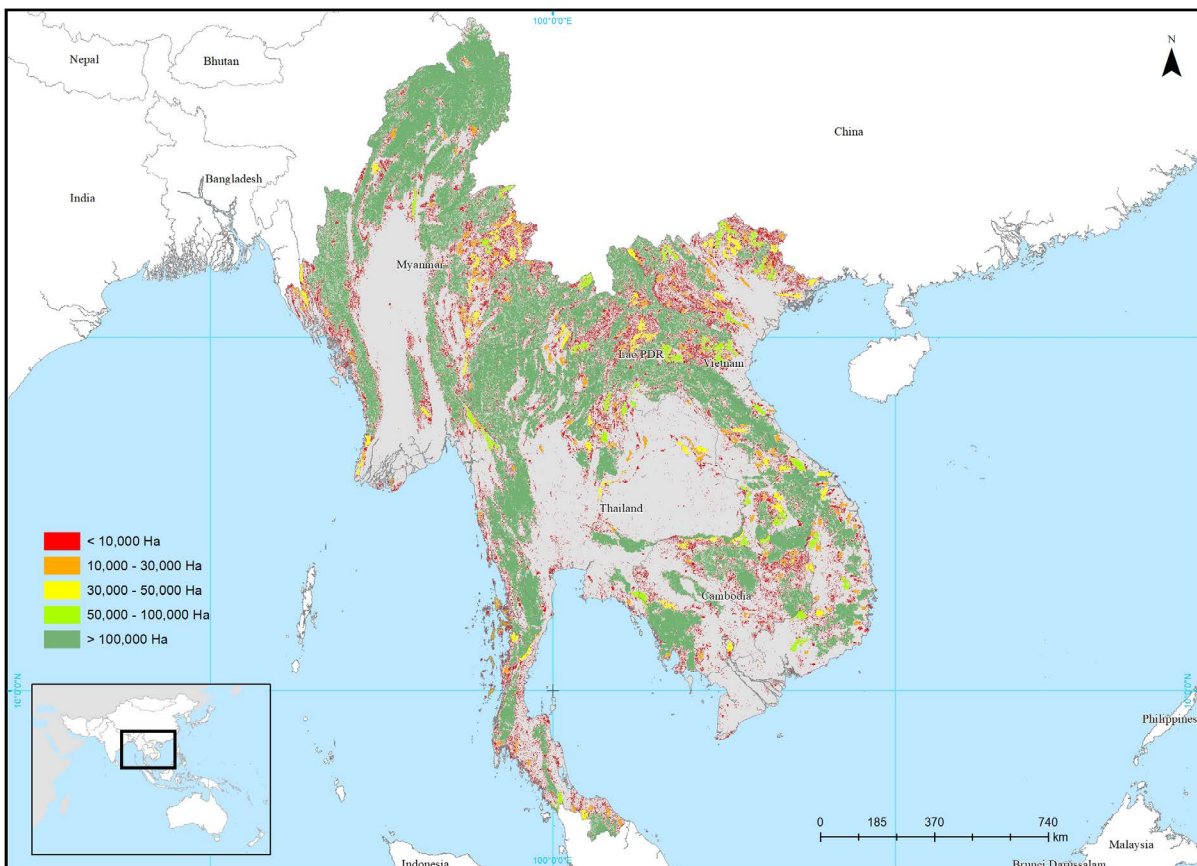


Figure 7b Fragmentation map of Cambodia, Viet Nam, Lao PDR, Myanmar and Thailand in 2020.
Source: Authors

Table 6 Fragmentation metrics for Cambodia, Viet Nam, Lao PDR, Myanmar and Thailand

Countries	Cambodia		Lao PDR		Viet Nam		Myanmar		Thailand	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Total area of contiguous forest (ha)	9,047,125	4,924,502	16,012,510	9,787,696	7,180,497	4,616,379	33,061,371	27,189,370	13,775,502	12,061,068
Total area of forest patches below 100,000 ha (ha)	1,195,054	2,355,223	1,496,133	4,046,104	5,337,178	5,901,632	5,722,290	7,881,843	4,445,128	4,102,146
Number of forest patches (NP) below 100,000 ha, by size class										
50,000–100,000 ha	1	2	3	9	11	16	5	6	7	4
30,000–50,000 ha	2	5	3	12	18	13	11	17	8	8
10,000–30,000 ha	5	10	8	18	37	48	31	51	29	33
<10,000 ha	168,402	313,210	180,873	443,894	402,051	496,882	724,034	939,977	543,761	589,060
Total	168,410	313,227	180,887	443,933	402,117	496,959	724,081	940,051	543,805	589,105
Mean perimeter (m)	968	1,062	1,040	1,180	1,322	1,248	1,099	1,161	967	922
Mean patch size (ha)	7.1	7.52	8.3	9.1	13.27	11.88	7.90	8.38	7.90	8.38
Edge density (m ha ⁻¹)	85,362	174,095	73,635	204,657	150,030	175,006	103,350	141,737	95,119	98,226
Largest patch index (%)	16.44	8.50	47.93	17.14	5.48	3.36	16.10	14.51	16.77	15.36

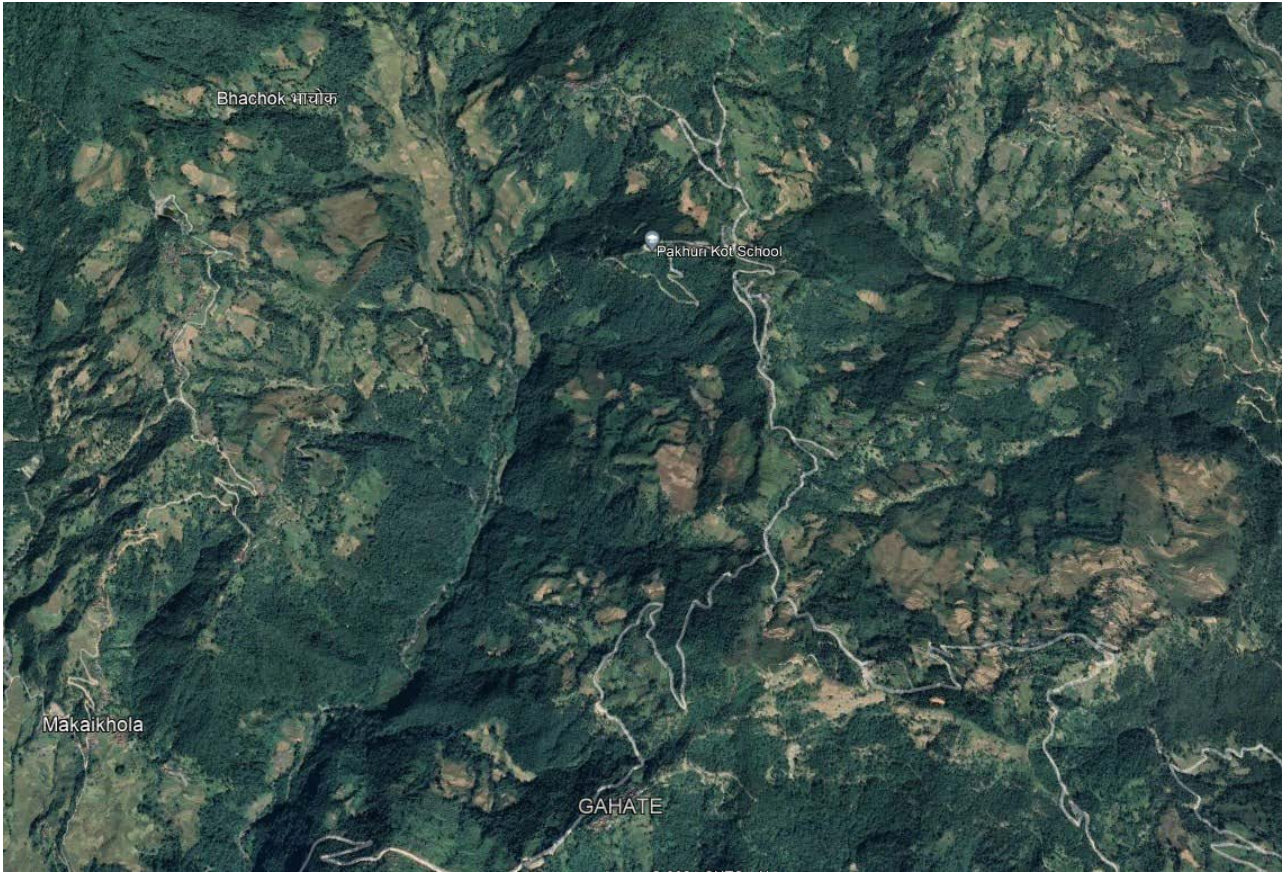


Figure 8a Example of fragmented forest landscape in Nepal. Source: Google Earth

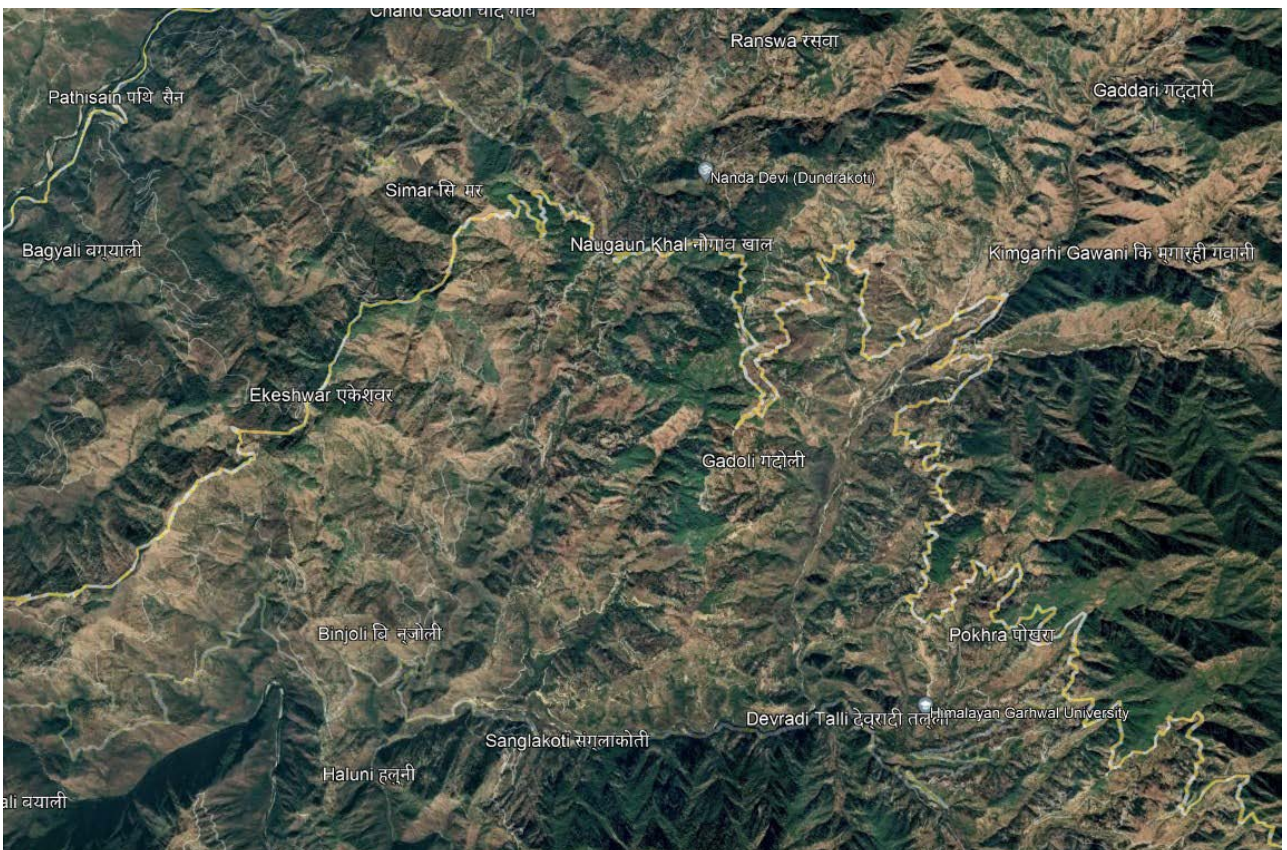


Figure 8b Example of fragmented forest landscape in Indian Himalaya. Source: Google Earth

and 2018 was mainly due to human activities such as urbanization, agricultural expansion and infrastructure development, primarily for roads, dams or hydropower plants (Uddin et al. 2015; Sharma et al. 2016; Gu et al. 2020; Kotru 2021). In addition, landslides and snowfall also shaped vegetation patterns at higher altitudes (Sahana et al. 2018).

1.3 Conclusion

Natural forests in the Asia-Pacific region, particularly in the tropics, have experienced high and even accelerating deforestation rates during the last two decades. This study identified intensifying and persistent deforestation hotspots of immediate concern. Forest fragmentation has also accelerated, with a general increase in the number of smaller patches of the lower size classes (below 30,000 ha and below 10,000 ha). Degradation was also significant, mainly in fragmented landscapes bordering primary forests. However, a noteworthy surface of intact forest remains often, but not always, in remote, steep and difficult-to-access terrains. Most of these intact forests are located outside PAs, often with lower protection statuses such as 'watershed protection forest areas'.

The study validates a replicable remote sensing methodology for the analysis of the degradation and fragmentation of natural forest cover at a regional and national scale, producing the first consistent region-wide maps of remaining intact forests and intact contiguous forests in the Asia-Pacific region.

Having first identified natural forest cover, ensuring that no planted forests are included, we assessed degradation within these natural forests, including logged-over areas, leading to an estimation of intact forests. Ultimately, by assessing the fragmentation of these intact forests, isolating large core areas and excluding forest edge zones, the study identifies 378 million ha of contiguous intact forest, that is the best possible estimation through remote sensing techniques of what can be considered primary forest as per the FAO (2018a) definition.

However, it should be acknowledged that this remote sensing approach – a bird's eye

view from the sky – may be biased towards overestimating the extent of some intact forest cover, especially in the drier zones of central and east India, some Australian woodlands, and boreal forests in northern China and Mongolia. In these places, the heterogeneity of the forest landscape mosaic and the lack of reliable information about conditions on the ground make the interpretation of some satellite images difficult. Moreover, many forests that still look structurally intact may actually be 'empty forests' (Redford 1992) where wildlife has already disappeared.

Another difficulty encountered in classifying the disturbances was in deciding whether forest fires were natural or anthropogenic in some places. Forest fire is a natural component of the dynamics of some ecosystem types (e.g. fire climax forests in the boreal zone and many Australian woodlands), but human development and climate change have significantly altered natural fire regimes. We focused on the anthropogenic fire zone (Indonesia, Himalayas and Mongolia) to assess degraded forest cover over the past 20 years as a result of fires.

Another weakness of our approach was uncertainty in identifying past disturbances, such as shifting cultivation, low-intensity selective logging and even industrial logging before 2000. In the case of industrial logging operations prior to 2000, the assumption is that these lands have already been transformed into agricultural use. These areas followed a well-known land use sequence consisting of logged-over forests being abandoned by concessionaires, followed by intense illegal logging using former logging road networks, until the forest was so depleted that agricultural ministries could justifiably advocate transforming the land into agricultural plantations.

Existing primary forests (inside and outside PAs) will not be resilient to climate change if further degradation and fragmentation intensify around them, since the smaller the patch, the lower its capacity to adapt and the more likely it is to be converted to other land uses. This is why the management of forests, within broader landscape, requires a thorough understanding of the various forest types and vegetation of the surrounding matrix. The following chapter will review the state of knowledge in this regard.

2 A remarkable diversity of forest types in Asia and the Pacific

The first chapter captured trends and the status of intact forests in the Asia-Pacific region, emphasizing features such as natural versus planted, continuous versus fragmented, and healthy versus degraded.

Beyond simple forest versus non-forest approaches, ecosystem or vegetation classification and zoning have long been used for conservation prioritization. These can be rooted in biogeographical science (Udvardy 1975; Moronne 2015), looking for phytogeographic or faunistic domains such as endemic bird areas (EBAs; Stattersfield et al. 1998), or using the concept of ecosystem geography science of Bailey (2009) that led to ecological regionalization and the concept of 'ecoregions' (Olson et al. 2001; Olson and Dinerstein 2002; Dinerstein et al. 2017).

In line with previous world vegetation or forest formation classification initiatives (UNESCO 1973; Legris and Blasco 1979) and with agro-climatic classifications such as the Global Agro-Ecological Zones Database (GAEZ) (Fischer et al. 2002; Hutchinson et al. 2005), FAO developed a Global Ecological Zones system (GEZ; FAO 2012), adopted by the Intergovernmental Panel on Climate Change (IPCC) to report on greenhouse gas (GHG) emissions. Furthermore, the whole principle of conservation priority zoning was recently revised by Sayre et al. (2020) in their global classification of the world's ecosystems at a spatial resolution of 250 m.

However, all of these global initiatives and models are only usable at a small to very small scale⁹ (1:250,000 and smaller)

9 A small-scale map covers a large geographic region such as the world, whereas a large-scale map shows smaller areas in more detail.

with recognized limitations when applied to sub-regional or local contexts (Lee 2009). While recognizing the necessity for broad classifications for global purposes, there is a crucial need for larger-scale approaches to classifying forest formations and types for the operational management and conservation of local ecosystems at the landscape level. There is a need to recognize the specificity and relative importance of local types of forests, and to address natural dynamics, species population distribution, and variations in floristic composition within each forest type.

Remaining intact forests should not be dealt with in isolation but put into the context of their surroundings, looking at the whole landscape vegetation mosaic. At the landscape level, vegetation types are the best surrogates to define and map the underlying ecosystems in terms of regulating, supporting, provisioning and cultural services (de Boer 1983; Folke et al. 2004; Yap et al. 2010). FAO (2012) recognized this approach, stating that "an alternative route for a new FAO Global Ecological Zoning map would be to determine EZs independently of the national or regional maps by using a more objective approach, notably by relying solely on climate and altitude data to delimit zones, taking into account potential vegetation, and vegetation classification".

Large-scale (1:50,000 and larger) ecological vegetation mapping is an essential tool for the characterization, evaluation and management of intact forests and their surroundings in the Asia-Pacific region. This information is not yet fully available.

After a brief reminder of the biogeographical settings of the Asia-Pacific region, emphasizing complex patterns of species distribution that are not yet fully understood (**Section 2.1**), a

framework for a future larger-scale ecological zoning of the Asia-Pacific forest formations is proposed (Section 2.2), followed by a review of their respective importance for biodiversity and ecosystem services (Section 2.3).

2.1 Biogeography

A recent phylogenetic classification of the tropical forests clearly distinguished two major floristic regions, the American-African and Indo-Pacific regions (Slik et al. 2018).

Biogeographically (Figure 9), the Asia-Pacific region, covering the Himalayas, South and Southeast Asia, East Asia and Oceania (Oceanian, Australasian, Indomalayan, and

Palaearctic realms), represents a remarkable cradle of the evolution of many organisms, including the first flowering plants (viz. *Amborella* in New Caledonia) and first songbirds (in Australia). The region is located at the crossroad of two paleo-continent where Asiatic elements of Laurasia origin meet Australian elements of Gondwanan origin (Turner et al. 2001). Moreover, it contains many endemics that contribute to the region's 10 biodiversity 'hotspots' (the Himalayas, Japan, the Western Ghats in India, Indo-Burma, the Philippines, Sundaland, Wallacea, southwestern Australia, eastern Australia, and East Melanesia, as identified by Myers et al. 2000).¹⁰ The Asia-Pacific region also includes seven of the world's 17 megadiverse countries:¹¹ Australia, China, India, Indonesia, Malaysia, PNG, and the Philippines.

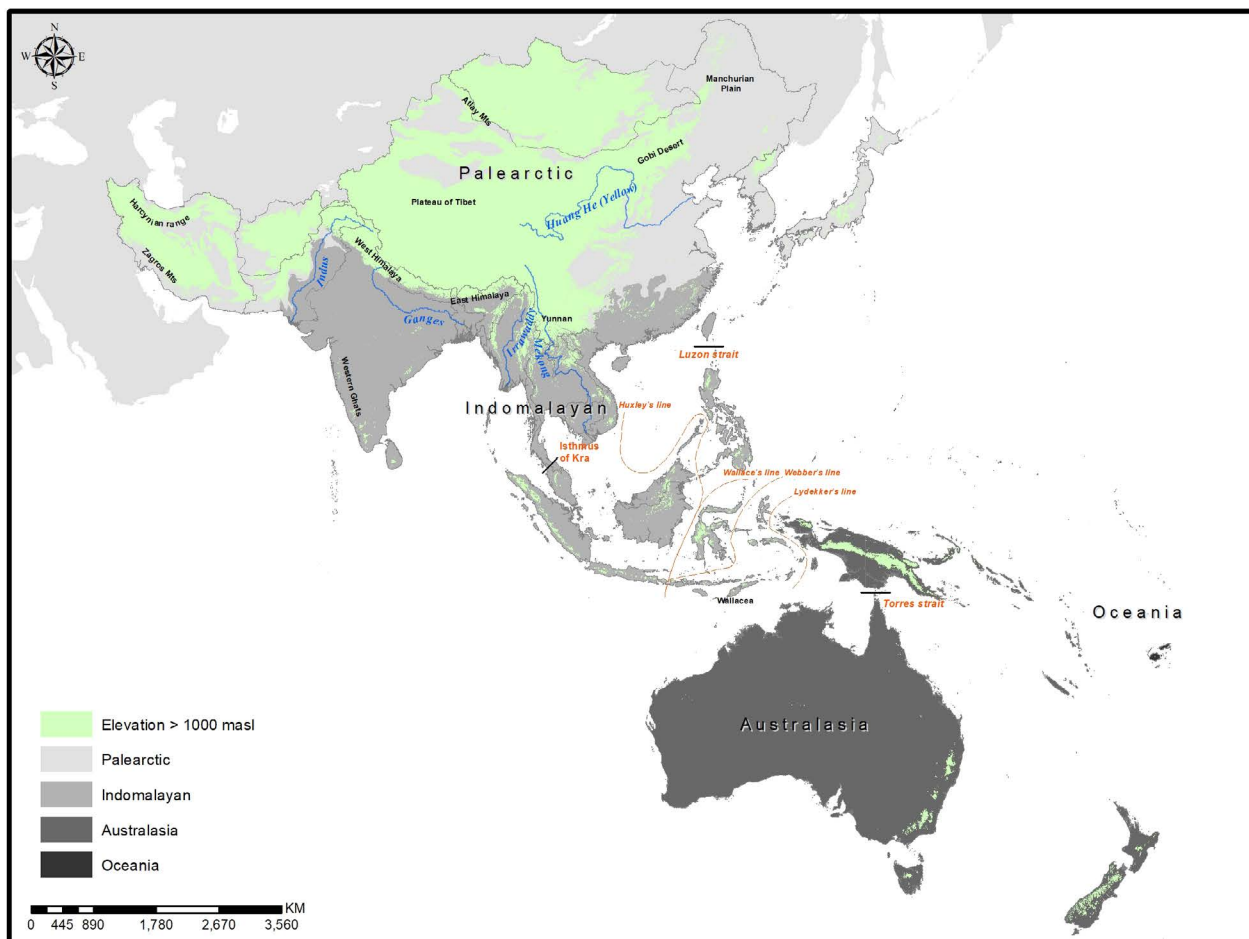


Figure 9 Biogeography of the Asia-Pacific region. Source: Authors

¹⁰ For more information on the world's 36 biodiversity hotspots, see: <https://www.conservation.org/priorities/biodiversity-hotspots/>;

¹¹ See: <https://www.worldatlas.com/articles/ecologically-megadiverse-countries-of-the-world.html>

Central Asia and the Iranian plateaus are home to dry steppes and deserts, with forests in the southwest confined to the Zagros mountains. Further north, the Hyrcanian forests belong to the Palearctic domain (Ebadi et al. 2020; Gholizadeh et al. 2020), as does northern Afghanistan, while the influence of the Indian monsoon creates a sub-tropical transitioning zone further south.

The Himalayas runs from northwest to southeast, with almost a 10-degree difference in latitude between the northernmost part of Pakistan and eastern Nepal. As a result, the climate in the northwestern Himalayas is more temperate than that further southeast (Mani 1974). In Kashmir, Ladakh, and northern Pakistan, like elsewhere at altitudes above 3,500 m, there is a notable species element from the West and North Asian Palaeartic realm. Far more North, Asian and European species are found in the northwestern region more than in the southeastern (Halberg 2015). In South Asia, the boundary of the Palearctic is mainly altitudinal, transitioning to the Indomalayan realm at around 2,000–2,500 m.

The eastern Himalayas, part of Myanmar, and Yunnan province in southwest China form a significant part of the Indo-Burma biodiversity hotspot, which lies to the east of the Himalayas. This region is located in a transitional zone with the Sino-Japanese floristic region in the east, the Sino-Himalayan floristic region in the west and the Palaeotropic floristic region in the north. Xie et al. (2004) divided China into four phytogeographic areas (northeast, northwest, southeast and southwest), covering 27 biogeographic regions, demonstrating the stark differences between biophysical and biological divisions. A recent phylogenetic analysis further divides Yunnan into seven floristic regions instead of the five formerly recognized (Li et al. 2015). Molecular phylogenetic and biogeographical studies of angiosperms will bring further development.

In continental Southeast Asia, high mountain peaks form islands of Palearctic flora (van Steenis 1972) as far as central Myanmar (Mount Nat Ma Taung 3,000 m), northern Viet Nam (Mount Fan Si Pan, 3,140 m), southern China, and even in the high mountains of the island of Taiwan (Yushan 3,952 m). To the far northeast,

China, the Korean peninsula and Japan are home to 18 phytogeographic regions (Qian et al. 2003) under warm and cold temperate climate, with coniferous, broadleaved, and mixed forests before reaching Palearctic domain further north.

The phytogeographical region of Malesia alone, which stretches the whole length of the Malay Archipelago to the Bismarck archipelago east of New Guinea, comprises 20%–25% of the planet's plant and animal species. This high biodiversity results from its complex geological and environmental history (Woodruff 2010; Lohman et al. 2011; Parnell 2013).

The disjunction of the Malesian and continental Asian flora is remarkable and located near the Kra Isthmus, which separates the south of Thailand from Malaysia. There, 375 plant genera reach their northern limit and 200 genera their southern limit (van Steenis 1950). This scholar identified another “demarcation knot” between New Guinea and Australia in the Torres Strait, with 644 genera and 340 genera at the southern and northern limits of their distributions respectively. A third break comes north of the Philippines with 265 genera, from a total of 1185 known from the island of Taiwan, that do not occur in the Philippines. Conversely 421 Philippine genera do not occur in the island of Taiwan (van Steenis 1950). The species disjunction of the Kra Isthmus is also valid for birds (Hughes et al. 2003) and mammal species (Woodruff et al. 2009), while the Pleistocene cycles of aridity and sea-level fluctuations of the Torres Strait (Byrne et al. 2008) is still debated (Toon et al. 2017).

The origin of the Malesian mountain flora and the presence of disjunct distributions for some species on high mountains sometimes located more than 2,000 km apart (such as for *Drapetes ericoides* on peaks in New Guinea and also found on Mount Kinabalu in Borneo) is still hard to explain, but the similarities in dry tropical flora between East Java, Flores and Thailand are striking.

Audley-Charles (1987) offers a fascinating interpretation of the geological history of this part of the world. Myanmar, western Thailand, the Malay Peninsula, and Sumatra appear to be fragments of the ancient Australia-New

Guinea block. The separation took place in the Middle Jurassic (160 million BP¹²), followed by a period of isolation in the sea of Tethys. At the end of the Secondary and beginning of the Tertiary, Southeast Asia and Sumatra fragments remained emerged for a long time, later orienting from northwest to southeast, allowing a link between the continent and Australia-New Guinea. Rotation continued with the fragments taking up their current positions, and during the collision of the Australian and Asian plates between 15 and 3 million years ago, new land was created at the same time as the Sunda volcanic arc.

Since the Quaternary (2 million BP), climatic change oscillations and especially the succession of glacial-interglacial cycles have caused significant variations in sea levels in this part of the world (Woodruff et al. 2010). Although these changes are often invoked as a critical biogeographical driver in the region, any model focusing on Pleistocene events alone should not miss out on important vicariance¹³ and dispersal drivers, as rightly pointed out by Lohman et al. (2011) and Wurster and Bird (2014) to explain the distribution of many species.

Not all scholars agree on the maximum rise of the waters during the last interglacial period (from 130,000 to about 115,000 years ago). According to Haile (1971) and Geyh et al. (1979), the rise was only 3–6 m higher than present levels, whereas Tjia (1980) claims a difference of up to 50 m was possible. According to Morley and Flenley (1987), former sea levels during the last interglacial period could have been up to 180–200 m lower than present levels. The current consensus is now more around 120 m lower (Voris 2000). A 100 m drop in sea level in this region would have been enough to decisively influence the history and evolution of flora and fauna (Flenley 1979). Under this hypothesis, the sea would have retreated from all of the South China Sea and the Torres Strait, enabling the migration of many species. However, the Sunda (west Malesia) and Sahul shelves (Australia, New Guinea and East Malesia) were never connected (Hamilton 1979,

Raven 1979). Moreover, the extreme retreat of the sea lasted for a relatively short time, and during the more significant part of the Quaternary, the sea level was probably in the range of 30–80 m lower than today (Voris 2000). Still, the maximum retreat of the sea created a larger continental landmass and changed the position of ocean currents, which doubtless modified the climate. The most important effects were a global reduction in annual rainfall and significantly greater seasonality of climates. Although the extent of the very humid climate zone cannot be accurately estimated, it may have been smaller. Thus botanical species adapted to mesic climates would have had a reduced distribution area, forming what is known nowadays as the Sundaland refugial flora (Cannon et al. 2009). There is palynological evidence of a drier climate on the Malay Peninsula and in the south of Borneo during the Pleistocene (Morley 1982; Morley and Flenley 1987). Such evidence is lacking for Sumatra, for which Stuijts et al. (1988) mentioned cooler but not drier periods. There is abundant evidence to suggest that the Pleistocene refuge theory applies to the Southeast Asian region (Morley 2018).

During the last ice age (15,000 BP), the surface temperature of the sea in the region was only 3–4°C cooler than it is now (Max et al. 2012), which means that, at least in lowlands, temperatures remained relatively high. However, Walker (1982) and van Beek (1982) demonstrated that large glaciers were formed at high altitudes on Sumatra during this era. This suggests that the altitudinal temperature gradient has decreased from -0.8°C per 100 m to the current -0.6°C (Morley and Flenley 1987).

Although pollen analyses from northwest Borneo lowland sites did not show any replacement of humid equatorial forest by deciduous forest during and since the Tertiary in Southeast Asia (Muller 1972; Whitmore 1981), the presence of 'corridors' of savanna, suggested by Ashton (1972), has recently been confirmed (Wurster et al. 2019).

Most palynological studies in the region cover medium-range altitudes (1,000–1,500 m). Maloney's analysis (1980, 1981) covers 18,500 years on Sumatra. Until 16,500 years ago, the Lake Toba plateau was probably covered by a patchwork of subalpine and

12 BP: Before the present

13 Emergence of physical or biotic barriers leading to subsequent genetic isolation.

montane herbaceous vegetation. The oak forest present at this time was maintained until about 12,000 years ago. About 7,500 years ago, *Eugenia* (Myrtaceae) species predominated, although there seems to be no particular reason for this. From this analysis, it can be shown that before the warming, which occurred about 8,000–9,000 years ago, the altitudinal zonation of vegetation was approximately 350–500 m lower than it is now. This tallies with the findings of James (1985) and Whitehead (1985) in West Sumatra. For the same site, Newsome and Flenley (1988) showed that at the end of the Pleistocene, a coniferous-rich forest was growing around the lake, suggesting an 800 m altitudinal lowering of the vegetation.

After analyzing sediments from a small lake, Danau Padang, situated at 950 m altitude, south of Lake Kerinci on Sumatra, Morley (1980, 1982) described a change in floristic composition during the last 10,000 years. A montane forest type (1,800–2,000 m), distinguished by *Dacrycarpus imbricatus* and *Engelhardtia* species, existed 8,600 years ago, but was replaced by a submontane forest dominated by Fagaceae. This suggests that as the climate warmed, montane species took refuge higher up. After this, the vegetation did not change significantly until 4,000 years ago, when Morley mentions the appearance of anthropogenic activities in the Kerinci region.

In line with van Steenis (1958), van Welzen et al. (2011) confirmed a strong partitioning of Malesia into three regions: the western Sunda Shelf (Malay Peninsula, Sumatra and Borneo), central Wallacea (the Philippines, Sulawesi, the Lesser Sunda Islands, the Moluccas and Java), and the eastern Sahul Shelf (New Guinea). The position of Java is still debated because of its dry monsoon climate in its eastern parts, although it shows more wet flora affinity than seasonal (van Welzen and Raes 2011). During glacial maxima, the Sunda and Sahul Shelves became land areas connected with Asia and Australia respectively, whereas sea barriers remained in between, delineating what is known nowadays as the Wallacea region, a transition zone with the Australasian realm covering Australia, New Zealand, Papua and the Solomon Islands.

The Wallace line (Huxley 1868), a zoogeographic frontier that separates Asiatic fauna from marsupial Australasian fauna (between Borneo and Sulawesi and between Bali and Lombok), has less value as a phytogeographic frontier.¹⁴ However, certain groups are mainly centered on the Sunda region (rattans) or the Sahul region (*Nothofagus* and conifers other than *Pinus*). Results for Sulawesi tend to show that this demarcation line is also relevant for other plants, at least between Borneo and Sulawesi (van Balgooy 1987). Other demarcation lines between Papua and the Moluccas (Weber and Lydekker lines) have been drawn to the east of the Wallacea region. Wallacea is also known as a distinct area because it comprises many endemics and drought-tolerant floristic elements (van Welzen et al. 2011).

Australia is a geographic unit, but in terms of biogeography, many of its biotas are more closely related to external areas than to the rest of Australia (Heads 2013). Four areas of particular phytogeographic interest are classically mentioned in the literature: South West Australia, Tasmania, northeastern Queensland, and the transition zone between the tropics and temperate climates, known as the MacPherson–Macleay Overlap (southeastern Queensland to northeastern New South Wales).

In 1860, Hooker recognized the significant biogeographic differences between eastern and western Australian biota. Southwestern Australia is primarily known for its high diversity and endemism. There is also evidence that eastern Australia has been an important migration route for a long time as it was linked with the northern hemisphere through Malaysia. However, the northward migration of Australian elements has been less successful than the southward migration of Malaysian elements (Burbidge 1960).

14 Wallace's Line is a faunal boundary line drawn in 1859 by the British naturalist Alfred Russel Wallace and named by English biologist Thomas Henry Huxley that separates the biogeographical realms of Indomalaya and Australasia, a transitional zone between Asia and Australia named Wallacea.

North of Australia, the abrupt floristic change mentioned by van Steenis (1950) around the Torres Strait remains a challenge because the divide is not located at the Torres Strait itself, but north of it, in the plains of southern New Guinea. The Fly River savanna is the only part of New Guinea that shows strong affinities with the flora of Australia, and it is unclear why Australian flora has not been able to migrate further north.

Besides Australia and New Zealand, Oceania encompasses three distinct regions covering the small islands of the Pacific: Melanesia, Micronesia and Polynesia (see Sayre et al. 2019 for a classification of the ecosystems). Van Balgooy (1971) gave a comprehensive rendering of the Pacific plant distributions. Malesia has long been considered the main source region for the biota of oceanic islands in the tropical South Pacific based on their shared taxa and high species diversity. However, molecular studies have produced compelling support for New Caledonia and Australia as alternative important source areas (Keppel et al. 2009).

2.2 Framework for a finer ecological zoning of the Asia-Pacific forest formations

Many classification systems have been proposed for vegetation studies, referring to either physiognomy structure (Küchler 1949; Dansereau 1957; Webb 1959; Fosberg 1961), biophysical-ecological, mostly bioclimatic (Trochain 1957; Ellenberg and Mueller-Dombois 1967; Holdridge 1967; UNESCO 1973; Metzger et al. 2012), or phenological-eco-floristic characteristics (Legris and Blasco 1979). Notably, not all have been produced for mapping purposes.

At the global level, the UNESCO'S International Classification and Mapping of Vegetation (UNESCO 1979; Legris et al. 1985) provides a comprehensive classification framework to be used in vegetation maps at a small scale or coarse resolution of 1:1,000,000 or smaller. In Europe, a long tradition of vegetation science and phytogeography schools (Gausson 1959, 1967; Zonneveld 1988; Ozenda 1979; Ozenda and Borel 2000),

culminated in the environmental stratification model (Metzger et al. 2005) and the vegetation map of the Pan-European Project (Bohn et al. 2007). Furthermore, the classification of the world formations was revisited by Faber-Langendoen et al. (2016).

In the Asia-Pacific region, the original bioclimatic Champion's system (1936) was later revised for India by Champion and Seth (1968) and applied to tropical continental Asia (Gausson et al. 1961; Legris 1963; Mueller-Dombois 1968; Blasco et al. 1996), while the forest classification of the Malay Archipelago introduced by van Steenis (1958) was modified by Whitmore (1975, 1984). In the Philippines (Whitford 1911; Bedard 1956), Thailand (Loetsch 1957; Anonyme, 1962), Viet Nam (Schmid 1974; Thai Van Trung 1978; Phuong 2007), Cambodia (Rollet 1972) and Malaysia (Symington 1943; Wyatt-Smith 1964; Fox 1978), the primary classifications were physiognomic, whereas in Indonesia, those of van Steenis (1957), Jacobs (1974) and Kartawinata (1975) were primarily ecological. In Australia, the central systems were physiognomic-structural (Webb 1959), latter evolving as structural-environmental (Webb 1968), structural-functional (Gillison 1981), and structural-floristic (Specht and Specht 2002).

These classifications were produced for mapping purposes. The main vegetation maps available for the region are: the collection of maps published at a 1:1,000,000 scale for India, Cambodia, Sri Lanka and Indonesia in the series 'International map of the vegetation and ecological conditions' (Gausson et al. 1961–1976; Legris and Blasco 1971; Laumonier et al. 1983–1987; Pascal et al. 1982), as well as the maps produced by Pajmans (1975, 1976) for PNG, Dobremez (1971–1978) at 1:250,000 for Nepal, Roy et al. (2015) for India, SOFR (2018) for Australia, Newsome (1987) for New Zealand, Miyawaki and Fujiwara (1988) for Japan, Su et al. (2020) and Guo et al. (2018) for China.

This study lays the foundation for a common framework for the Asia-Pacific Forestry Commission to monitor contemporary intact forest and surrounding landscapes, initiating larger-scale datasets and mapping programs to support sustainable landscape management in the region.

2.2.1 Bioclimates

Different vegetation types occur in climates ranging from warm to cold and from non-seasonal to seasonal. More than a century ago, Schimper (1898, 1903) associated temperatures and vegetation types to define a series of what he called ‘formation types’. His tropical rain forests in humid climates with only a short dry season were distinguished from tropical monsoon or seasonal forests established with a long dry season that lasts between three to four consecutive months. His approach, based on characteristics of the vegetation, was followed by the now classic Köppen classification of climates of the world (1936), as well as by the work of Bagnouls and Gaussen (1957), or Walter and Lieth (1960), who combined graphical representations of temperature and precipitation to define climatic diagrams.

This study uses a bioclimatic framework based on the principles developed by the Toulouse School of the ‘Institut de la Carte Internationale de la Végétation (ICIV)¹⁵ and the French Institute in Pondicherry (Gaussen et al. 1967). Bioclimates consider the main climatic parameters, such as rainfall and temperature, but emphasize their regime (rainfall distribution during the year) and interannual variability, and the length, intensity and season of occurrence of the dry periods. Also considered are the extreme values of these factors, resulting in conditions unfavorable to biological activity, such as extreme low or high temperatures, low rainfall, or the length and intensity of the drought period.

Algorithms derived from the MODIS instrument¹⁶ are available to calculate evapotranspiration (ETP) (Running et al. 2012) and the CGIAR-CSI¹⁷ developed the Global Aridity and the Global Potential Evapotranspiration (Global-PET) Database (Zomer et al. 2008). More suitable for agriculture than forestry, these are statistical datasets that do not reflect the ground situation for any particular year or forest. The

local climate data needed for ETP calculation are rarely available, except for large cities where conditions are considerably different from those in the wild.

The empirical definition of the dry season adopted here has the advantage of being based on more readily available local data. Classes are drawn by combining the mean annual rainfall (R), the mean temperature of the coldest month (tm), and the seasonality expressed as the number of dry months (see **Figures 10** and **11**). A month is considered dry when $P \leq 2T$ or when $P \leq 60$ mm.¹⁸ Published regional bioclimatic maps include India, Southeast Asia, Indonesia (Labroue et al. 1965; Fontanel and Chantefort 1978).

Gaussen et al. (1967)’s map of the main climatic regions in India and continental Southeast Asia clearly shows that the wettest conditions only occur in small areas (Sri Lanka, southern part of the Western Ghats, Assam, Gulf of Siam, Annamitic Range). In these areas, the annual rainfall usually exceeds 2,000 mm, and the average length of the dry season does not exceed three consecutive months. These are areas covered with tropical evergreen rain forest formations. With the exception of northwestern India and the Deccan Plateau, which are very dry (7–9 dry months), arid (10–11 dry months) or even desert-like, most areas of India and continental Southeast Asia are humid or moderately dry with a mean annual rainfall over 1,000 mm and a dry season of 3–6 months (Blasco 1996). These conditions are suitable for seasonal forests, which have been very much degraded to overgrazed thickets in India or regularly burned woodlands in Myanmar and Thailand. Climatic zones result from complex seasonal wind systems (southwest monsoon: May to September; northeast monsoon: October to March).

A mountainous archipelago crossed by the equator, the so-called maritime continent (Indonesia, the Philippines, PNG) harbors complex climatic regimes. With thousands of islands of various sizes, very long coastlines, numerous shallow bodies of water, and many narrow straits controlling the global (Pacific to Indian) ocean circulation, interactions

15 Institute for the International Map of the Vegetation

16 Moderate resolution imaging spectroradiometer. See: <https://modis.gsfc.nasa.gov/about/>

17 CGIAR Consortium for Spatial Information (CGIAR-CSI)

18 P: precipitation; T: mean temperature.

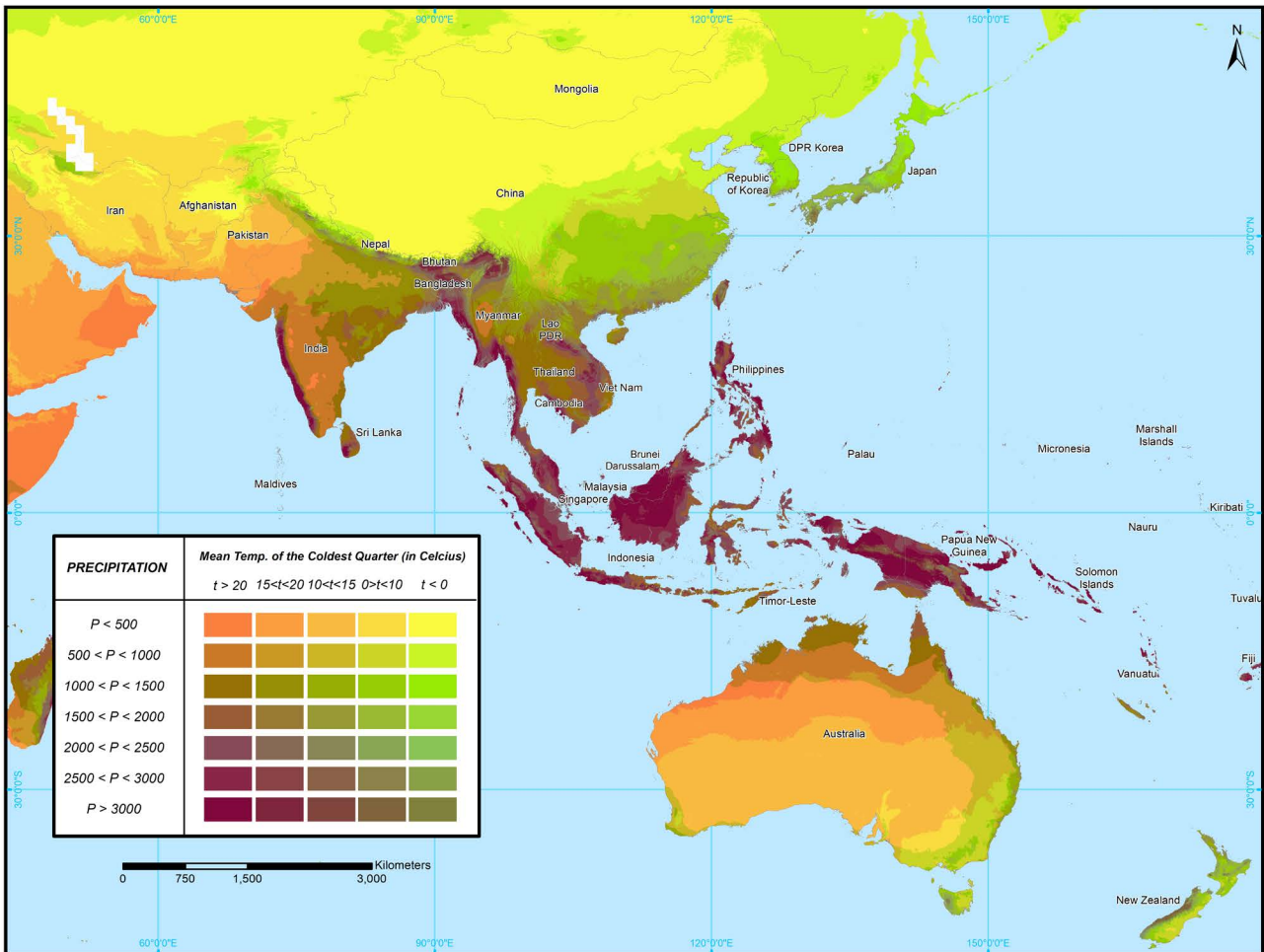


Figure 10 Bioclimates in the Asia-Pacific region, combining mean annual rainfall and mean temperature of the coldest month. Source: Authors

between land and water are at their highest (Yamanaka 2016). This complexity and the high variability of local air circulation and precipitation with diurnal cycles are reflected in the difficulties of modeling climatic variability and climate change, with many uncertainties in the intensity of the decrease or increase in rainfall in some archipelago regions (Kang et al. 2018).

In the southern hemisphere, the Australian continent is predominantly tropical in the north and northeast, subtropical in the east and temperate in the southeast and southwest coastal areas, while the interior has desert-like conditions. The wettest areas are located on the northeast coast, especially in Queensland, with up to 4,000 mm annual precipitation. On the other hand, the entire lowlands are arid, with less than 100 mm annual precipitation in many areas.

Tasmania has a distinct maritime climate with mild summers and cool winters with high precipitation in the eastern mountains (Harlfinger 1993).

The continental islands of the western Pacific tend to be higher and more extended than the basaltic volcanic islands of the central and eastern Pacific. The climate of the Pacific islands is generally tropical, except New Zealand, which has a temperate climate. Temperature varies from an annual average of about 28°C in Kiribati to an annual average of about 15°C on Norfolk Island (Australia), one of the southernmost Pacific Islands. In addition, most of Oceania south of the equator is impacted by near continuous southeast trade winds and frequent tropical cyclones in the South Pacific islands and is considered particularly vulnerable to climate change, particularly the region's low-lying atolls.

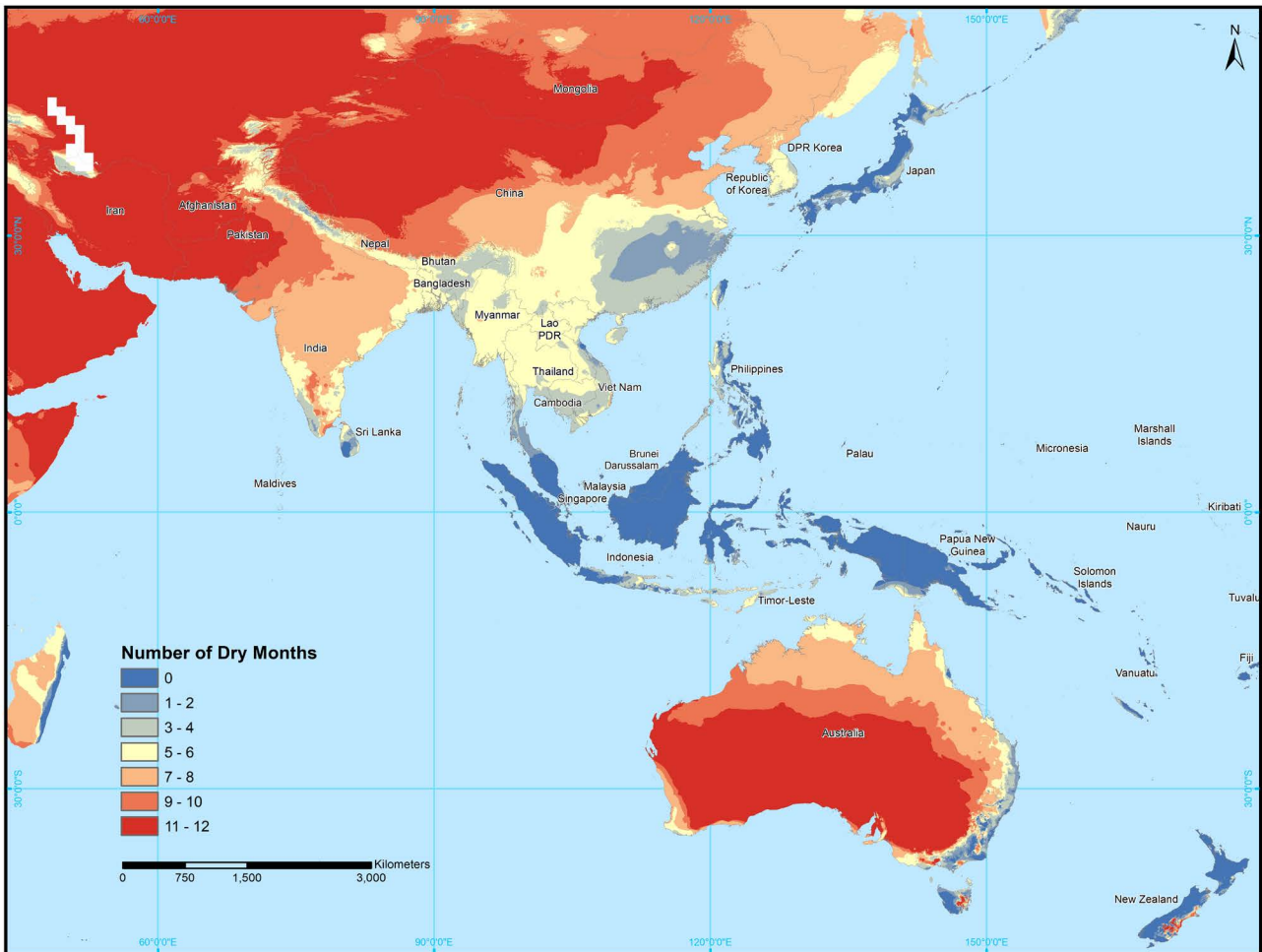


Figure 11 Intensity of the dry season in the Asia Pacific region: annual number of dry months (dry months for precipitation ≤ 60 mm). Source: Authors

2.2.2 Altitudinal zonation

Linked to temperature variation with altitude, the altitudinal zonation observed in the distribution of flora and vegetation types should also be carefully addressed in relation with climate change. An upward shift of 30 m has been already observed for many plants in the Alps (Lenoir et al. 2008), but little is known on this matter for the Asia-Pacific region, although some studies have been carried out focusing on the Himalayas (e.g. Gaire et al. 2014; Hamid et al. 2020; Anderson et al. 2020). Other studies deal with altitudinal zonation in the Asia-Pacific region (e.g. van Steenis 1935, 1972; Symington 1943; Whitmore 1975, 1984; Richards 1996; Ives and Messerli 1989; Ashton 2003).

Amongst critical local studies, were the works of Ediriweera et al. (2008) for Sri Lanka, Martin (1977) for Sarawak, Hynes (1974), Hope et al.

(1976) and Mangen (1986) for New Guinea, Jacobs (1958), Meijer (1961), Oshawa et al. (1985) and Laumonier (1997) for Sumatra, and Meijer (1959) and Yamada (1975–76) for Java. Altitudinally, 800–1,300 m is generally recognized as an important transition zone that differentiates a particular climatic zone where absolute temperature minima become a fundamental limitation for certain animals and plants. This transition from lowland to lower montane forest floristic is gradual (Oshsawa 1991, 1993, 1995; Ashton 2003).

In the tropics, if the average temperature of the coldest month in lowlands is around 26°C, the 15°C isotherm is located at c. 1,800 m because the average temperature gradient decreases approximately 0.6°C to 0.65°C for every 100 m rise in elevation (Dodson and Marks 1997; Barry and Chorley 2010). This value is likely to change because

of climate change. The limit of 15°C, used to distinguish lowlands from montane bioclimates and to delineate montane forests on maps, is empirical but not arbitrary.

The lowering in altitude of the extent of montane forest on isolated massifs (the ‘Massenerhebung’ effect¹⁹) was observed by Richards (1936) in Sarawak and van Steenis (1935), who stated, however, that this phenomenon only occurs on massifs higher than 2,000 m in altitude, otherwise few or no temperate species can be found. Van Steenis (1961) coined the term ‘mountain mass elevation effect’ for this phenomenon instead of ‘Massenerhebung’ and proposed a general zonation for the whole region that distinguishes between two sub-zones, hill and submontane, below what can be considered the real montane zone where the flora displays only temperate elements.

Cloud (‘elfin’) forest is often encountered as low as 600 m in elevation in the small islands of the Pacific but also on coastal middle elevation ranges. For instance, between 1,400 and 1,500 m on the crests of the middle elevation ranges in southwest Sumatra, one passes abruptly from a high forest canopy (35–40 m) of *Altingia excelsa*, *Quercus* and *Eugenia* at 1,200 m into a very low-canopy (5–10 m) elfin forest at 1,500 m on the ridges.

The general scheme proposed by Oshawa et al. (1985) and Oshawa (1990) is relevant for the Asia-Pacific region. Comparing tropical mountains with those in higher latitudes, he noted that climatic conditions concerning forest boundaries in the high peaks in Sumatra were similar to those at the latitudinal limit of warm temperate zones. At the same time, in the Himalayas and Japan, they correspond to cold temperate and subarctic zones respectively.

An analysis of the presence or absence of 1,500 liana and tree species undertaken by Laumonier (1990) enabled the refinement of the general van Steenis (1972) classification. Three important boundaries appeared, situated around 1,800 m, 800 m, and 300 m respectively, and a less well-defined subdivision around 1,300–1,500 m, depending on the orographic situation. This analysis corroborates the findings of Symington (1943) for Peninsular Malaysia and is in line with findings from Kitayama (1992) for Mount Kinabalu in Sabah and Cannon et al. (2007) for the altitudinal zonation of the Sulawesi forests.

2.2.3 Azonal framework, edaphic formations

How exactly does the substratum influence the distribution of vegetation types in a region, and what is the nature of the relationship between vegetation and geology, lithology and soil in plant distribution?

If there is a general agreement on the solid relationship between soils and vegetation for mangroves, freshwater swamps, peatlands, acidic sandy soils and limestone ranges, passionate debates have been held on the subject for the tropical lowlands. For example, botanists working in the Malay Peninsula have argued that there was no apparent relationship between the substratum and the distribution of forest tree species (Poore 1968; Kwan and Whitmore 1970), while other scholars have found convincing evidence of close links between soils and vegetation in Brunei Darussalam and the Malaysian states of Sarawak and Sabah on Borneo (Ashton 1972; Baillie et al. 1987).

For instance in Sumatra, on well-drained lowland soils under the same climatic conditions, Laumonier (1997) pointed out that although the structure of the forests appeared similar, significantly different floristic composition were linked to the geology. On granite bedrock, for instance, there was relative floristic poverty in some families that were better represented on sedimentary rock layer-developed soils. More than 20 different species of Dipterocarps were recorded for the sedimentary derived soils, while the granite-derived soils next to them have less than half this number. The dominant species on granite were *Shorea conica* and *Parashorea lucida*.

19 The Massenerhebung or ‘mountain mass elevation’ effect describes variations in the tree line based on mountain size and location. It refers to physiognomically and sometimes floristically similar vegetation types at higher altitudes on large mountain masses than on small isolated peaks, especially those in or near the sea. It is best known in the tropics and on the small islands of the Pacific where cloud ‘elfin’ dwarf forests occur as low as 600 m above sea level. See: <https://www.briangwilliams.us/tropical-rainforest/the-massenerhebung-effect.html>

The *Hopea* and *Dipterocarpus* genera, which were rare on granite soils, were abundant on sedimentary soils. Laumonier (1997) also pointed out the higher floristic richness of forests on volcanic soils compared with adjacent forests on metamorphic rocks.

Limestone and carbonate soils in general are significant in the region (see maps by Williams and Fong, 2010²⁰), but the karstified landscapes themselves are less well mapped (Clements et al. 2006). The strong relationship between carbonate soil and vegetation type observed in temperate regions is much less apparent in the tropics.

There is also little evidence of direct soil-vegetation relationships in seasonal areas, where many species show great adaptability to soil conditions. The emblematic *Shorea robusta* (sal), for instance, which, together with teak, is one of the most economically valuable trees in India, is distributed throughout the foothills of the Himalayas and in the eastern districts of central India on a wide range of substrates (Blasco et al. 1996).

There are numerous volcanic, metamorphic, granitic, carbonate or sedimentary geological formations in the Asia-Pacific region, which would be interesting to compare in detail for their flora. It would be particularly relevant to carry out this type of study in the framework of a larger scale or higher-resolution ecological mapping regional program.

Another challenge for large-scale ecosystem classification is the lack of large-scale soil maps for the region. For global studies, the FAO-ISRIC soil map²¹ of the world is still a relevant source, but at larger scales (watershed, district), it is necessary to use surrogates like landform or land unit maps or even geological and/or geomorphological data (Laumonier 1997; Theobald et al. 2015).

Wetlands, freshwater and peat swamp areas were first extracted from the ISRIC database (Histosols) and adjusted using the PEATMAP initiative (Xu et al. 2018) and the Indonesian Ministry of Agriculture assessments (Ritung et al. 2019) for Indonesia.

2.2.4 Map of the main forest formations in the Asia-Pacific region

The Asia-Pacific forest formation map reproduced in **Figure 12** is derived from overlaying the 2020 forest cover on a framework using few, widely measured, simple parameters of bioclimatic types occurring in the region (Gausson et al. 1967; Fontanel and Chantefort 1979), supplemented by modern databases such as WorldClim (Hijmans et al. 2005; Fick and Hijmans 2017), the bioclimates of the world (Metzger et al. 2012), the physiographic Shuttle Radar Topography Mission (SRTM) 30 m digital elevation model (DEM), the Harmonized World Soil Database (Fischer et al. 2008), the 1:5,000,000 scale FAO-UNESCO Soil Map of the World (FAO-UNESCO 1981), and the Advanced Land Observing Satellite (ALOS) Landform dataset (Theobald et al. 2015). We cross-checked with the mangrove state data (Giri et al. 2010) and the PEATMAP (Xu et al. 2018) for the wetlands. The selected altitudinal division is based on the criteria mentioned in **Section 2.2.2**. The main formations are listed in table 7 and their specificities are briefly described in the next section.

2.3 The specificity, role and importance of forest and woodland formations in Asia and the Pacific

Within the ecological framework described in the previous section, 30 forest formations of the Asia-Pacific region have been identified, first by a set of bioclimatic parameters, then by physiography, elevation and specific substrate criteria, in line with existing classifications (Whitmore 1984) (see Table 7 and **Figure 12**). For each bioclimatic zone, several edaphic types may exist, such as swamp forest, or karst massifs. Most of these types are sharply bounded. It is also recognized that these forest formations include internal cycles of regeneration after tree fall gap events, encompassing the natural disturbance regime that drives the forest dynamics, including episodic catastrophes such as cyclones or droughts.

20 See: https://www.fos.auckland.ac.nz/our_research/karst/index.html

21 For more information, see the FAO soils portal (<https://www.fao.org/soils-portal/en/>) or the International Soil Reference and Information Centre (ISRIC) website (<https://www.isric.org/>).

Table 7 Main forest formations in the Asia-Pacific region

Formations	Forest Formations and types
1.A.1. Tropical Lowland Humid Forest	Tropical lowland evergreen forest
	Tropical hill evergreen forest
	Tropical submontane evergreen forest
1.A.2. Tropical Montane Humid Forest	Tropical lower montane evergreen forest
	Tropical middle montane evergreen forest
	Tropical upper montane evergreen forest
	Tropical subalpine forest
1.A.4. Tropical Flooded & Swamp	Tropical freshwater swamp forest and woodlands
1.A.5. Tropical Peat swamp	Tropical mixed peat swamp forest
	Tropical peat swamp forest and low pole peat swamp forest
1.A.6. Mangrove	Mangrove
1.A.7 Karst	Tropical karst forest and woodlands
1.A.8. Kerangas	Tropical <i>Kerangas</i> forest and woodlands
1.B.1. Tropical Dry Forest & Woodland	Tropical seasonal evergreen forest and woodlands
	Tropical moist deciduous forest and woodlands
	Tropical dry deciduous forest and woodlands
	Tropical dry evergreen forest and woodlands
	Tropical thorn forest
1.C.1. Subtropical lowland forest	Sub-tropical hill evergreen broadleaved forest
	Sub-tropical submontane evergreen broad-leaved forest
	Sub-tropical submontane needle leaved forest (= warm temperate)
	Sub-tropical dry evergreen
	Sub-tropical karst
1.D.1. Temperate Forest & woodland	Warm temperate deciduous broad leaved
	Cool temperate deciduous broad-leaved
	Cold temperate mixed evergreen coniferous-deciduous broad-leaved
	Cold temperate deciduous coniferous forest
1.D.2. Temperate Flooded & Swamp Forest	Temperate swamp forest and woodlands
1.E.1. Boreal Forest & Woodland	Boreal deciduous coniferous forest (<i>Larix</i>)
1.E.2. Boreal Flooded & Swamp Forest	Boreal swamp forest and woodlands

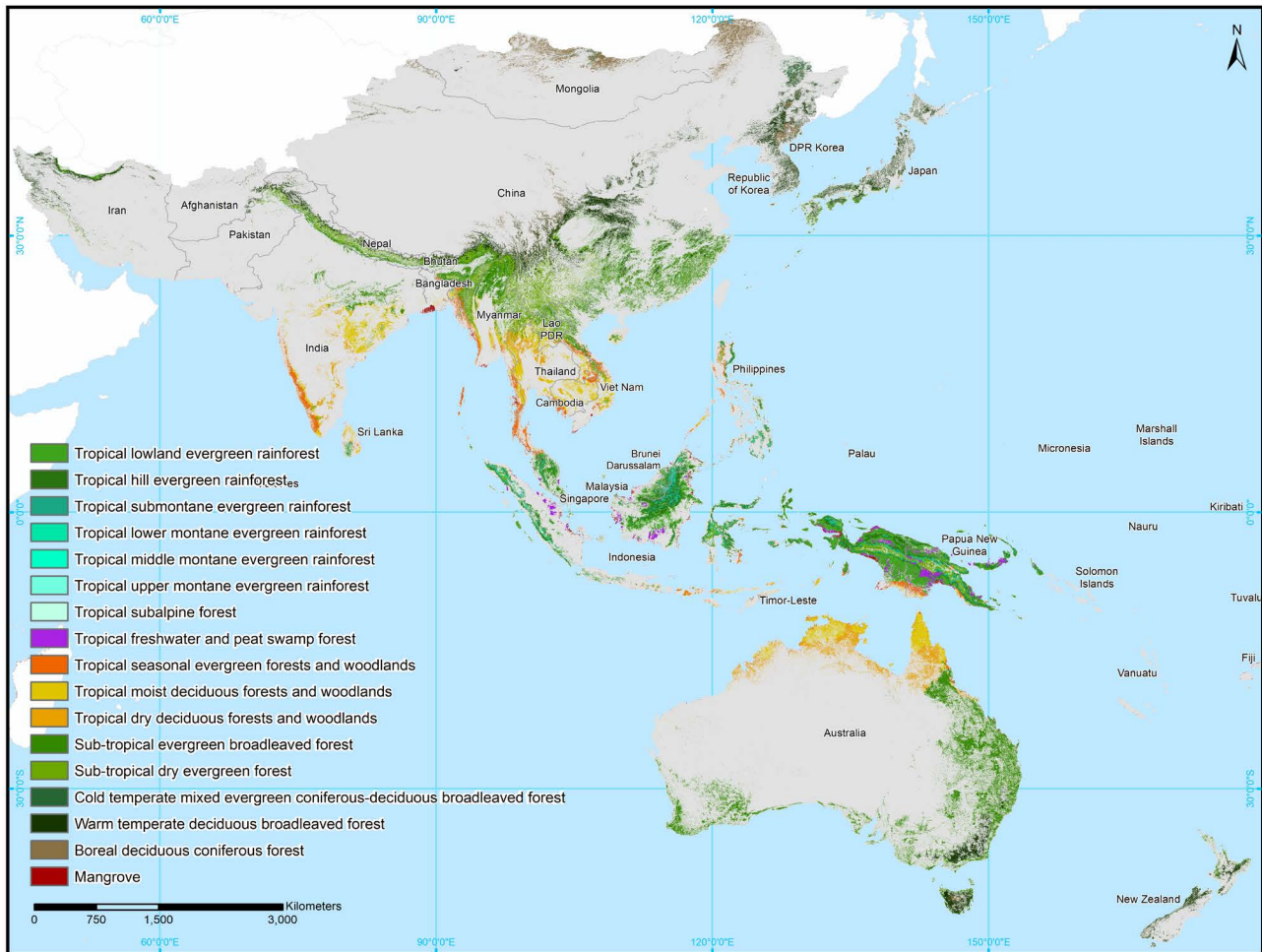


Figure 12 Main forest formations in the Asia-Pacific region. Source: Authors

As with other forests in the world, Asia-Pacific forests provide multiple ecosystem services for food security, livelihoods and sustainable development, including serving as a cradle and reservoir for biodiversity, pollination processes, soil erosion control, clean water provision, water cycle regulation, carbon sequestration and climate regulation, multiple contributions to food security and nutrition, social values, and cultural heritage. The region is known for representing three centers of origin of important food and medicinal species (Chinese, Indian and Malaysian), such as many wild fruits including wild mango, banana, rambutan, mangosteen, spice trees of the Indo-Malayan, Pistachio nuts from the woodlands of Afghanistan and wild apples from Kazakhstan, macadamia nuts from Australia, kiwi and goji berries from China, and many more.

The approach taken in this section is to review and build upon existing knowledge on the forest formations of the Asia-Pacific region, to

elucidate their special characteristics, and to provide basic information to encourage further research into the eco-floristic patterns inherent to each forest type. The main formations and their specificities are briefly reviewed below and knowledge gaps identified.

2.3.1 Humid forest formations on well-drained substrate

2.3.1.1 Tropical lowland evergreen and semi-evergreen forests (< 300 m)

Tropical lowland evergreen and semi-evergreen rain forest formations have been grouped into the same class in order to avoid subtle and often subjective phenological distinctions. They are the most luxuriant of all forests, with the most complex structure. They are dominant in western Malaysia (Sunda shelf, Borneo, Peninsular Malaysia, Sumatra), where the basic knowledge on their ecology originates from studies from the 1930s to the 1980s, with

findings summarized in the classic textbooks of Richards (1952, reedit. 1996), Whitmore (1984) and more recently Corlett (2014), Ashton and Thorogood (2014) and Bruenig (2016).

They are known as “mixed dipterocarp forests (MDF)” due to the dominance of the *Dipterocarpaceae* family, with the large majority of dipterocarps²² occurring under humid climate regimes, with over 2,000 mm of rainfall per year. They are the tallest of all broadleaved tropical rain forests,²³ harbor the highest aboveground biomass and have the highest mean net primary production of any terrestrial ecosystem. They are also the most species-rich, biologically diverse of all ecosystems, a place only being challenged by tropical reef ecosystems. Besides the dominance of trees, big lianas are fairly common, epiphytes occasional to frequent, and bryophytes often abundant. Undergrowth is generally dense, although herbaceous ground vegetation is mostly sparse. Frequent buttresses, cauliflory or ramiflory and a majority of entire mesophyllous leaves best characterize this forest type.

Richards (1952) first observed small-scale habitat variation within rain forests. It is now widely acknowledged that there are indeed large variations within and between rain forests even on short distances. Clear forest communities have been described, allegedly determined by a variety of factors such as historical biogeography, disturbance (fire, wind, and human impacts), topography, elevation, climate, geology and soil (Whitmore 1984; Laumonier 1997; Slik et al. 2011). A characteristic of the tropical rain forest floristic composition is a large number of species represented by only few individuals. Species associations are much less easy to determine when compared to the monotypic or few mixed species stands of higher latitudes.

Whitmore (1984) has extensively discussed these habitat variations in the MDF. He stressed that variations could be observed within a forest, linked to small-scale topography and geology. One example of differentiation is riparian (riverside) forests, which have a number of

associated forest sub-communities. Corner (1978) and Laumonier (1997) have thoroughly described the natural plant succession observed as one travels upstream from an estuary. Outside the reach of tide influence, there are communities of tree species characteristic of riversides, e.g., the *rapak* formation of *Lagerstroemia* and *Alstonia*, followed higher upstream by the *empran* formation (lowland alluvial) forest type on raised levees, with *Eusideroxylon zwageri* (Lauraceae) often encountered in that environment. This last species is known for producing very hard and durable wood and is very valuable for local construction. Carbon-14 dating has shown that it can live up to 1,000 years. It also has a very slow growth rate, averaging 0.06 cm per year, which is much slower than the growth rate generally observed or estimated for dipterocarps (Kurokawa et al. 2003). It often develops in pure stands and has very high regenerative capacity. It is unfortunately under very high threat of disappearance despite being protected from commercial logging in Indonesia.

Research at the landscape level in the MDF of Sumatra confirmed such high diversity and variations in habitat and species distribution. The lowland and hill dipterocarp rain forests were structurally similar throughout the island, but there were large dissimilarities in tree species composition between, for example, the southwestern and northeastern parts. In the eastern part of the Sumatran plains and piedmonts, there are large floristic variations that cannot be explained by climatic criteria. Very distinct dipterocarp species associations seem confined to very low elevations below 150 m, while others further delineate what can be defined as lower and upper hill dipterocarp forests. On soil over granite rocks, the tree density is lower than on the sediments. The density of trees and lianas, the abundance of epiphytes and the canopy cover are different on slopes, ridges and valley bottoms (Laumonier 1997; Laumonier et al. 2010). There is a very high ecological heterogeneity within dipterocarp rain forest habitats, and the distribution of species and its determinism need to be better understood for conservation and forest landscape management. Since there are no obvious large structural differences, floristic criteria and knowledge of flora are crucial in detecting these variations.

22 More than 400 species (Ashton 1982).

23 A *Shorea faguetiana* tree, measured in 2018 in Sabah, reached a 100 m height.

There are few examples of forests dominated by a single dipterocarp species. One such monotypic stand type is that formed by *Shorea albida* on peat soil (Whitmore 1984). It occurs in Brunei Darussalam, Kalimantan and the Malaysian states of Sarawak on Borneo, but logging has reduced its area considerably, and it is now on the global list of threatened tree species. In Sumatra, *Dryobalanops oblongifolia* is reported forming islets in the middle of swamp forests (Laumonier 1997). There are examples of tree species that become dominant in certain topographic locations, such as the very large *Shorea curtisii* in Malaysia growing on excessively drained and often nutrient-poor ridges, or the majestic *Shorea platyclados* stands of the submontane zone in Sumatra. Some distinct forest types have practically disappeared today due to intensive logging and conversion to agriculture. One example is the former seasonal forest of southeastern Lampung in Sumatra. Another is the stands of *Dryobalanops aromatica*, which used to be dominant on lowland sedimentary rocks in East Malaysia.

Examples of large-scale heterogeneity in forest composition have been described for Borneo and Sumatra. The lowland dipterocarp forests of Borneo can be divided into five regions based on their tree species composition. The factors determining this division are considered to be mainly geographic distance and mean annual rainfall (Slik et al. 2003). In the Sumatra lowlands, Laumonier (1990) describes 10 floristic sectors related to geomorphology, climate and dispersal barriers. Using species distribution modelling (SDM), Raes (2009) identified 11 floristic regions on Borneo, more than the six to eight previously recognized (Whitmore 1984; Wikramanayake et al. 2002).

The Western Ghats in India represent the western boundary of the range of the Malaysian tropical evergreen rain forest, with a species richness per hectare of 65 species, compared with the 250–300 species per ha on Sumatra or Borneo. The dipterocarps are still present with *Dipterocarpus indicus* dominant in the canopy and as emergent trees. Lower storeys were also represented by few dominant species, *Drypetes longifolia* in the lower storey, *Reinwardtiodendron*

anamallayanum in the middle storey, and *Poeciloneuron indicum* in the upper storey (Ayyappan and Parthasarathy 1999). Other variations of the MDF, with subsequent losses in biodiversity, are seen when entering harsher environments (swamps and colder temperatures at higher elevations).

As they contain the most valuable timbers, the MDF have been largely exploited in the Asia-Pacific region through logging operations and, except in very harsh terrain, have experienced large-scale deforestation and conversion to agricultural land use. However, their dynamics, tree species population distribution and ecological functioning remain insufficiently known, with very few experiments and data on productivity, litterfall, water or geochemical cycles. This poses challenges on restoration initiatives. MDF are on the verge of extinction despite supporting the highest biodiversity (taxonomic, functional and phylogenetic diversity), hence promoting the functionality of ecosystems (e.g. primary production, decomposition, nutrient cycling, and trophic interactions) and consequently supporting a broad range of ecosystem services (e.g. food production, climate regulation, pest control, pollination and numerous others) (Mori et al. 2017).

Unique variations of lowland (hill and mountain) tropical forests are those encountered on the small Pacific islands, brilliantly described by Mueller-Dombois and Fosberg (1998) in their magisterial work on the vegetation of that part of the world, where conservation is particularly challenging (Brodie et al. 2013). Lowland tropical rain forests were once extensive on the large islands of Melanesia but scantily represented on the smaller oceanic islands, situated further east, principally in valley bottoms and on narrow coastal strips. This forest has been mostly eliminated or highly altered by humans (Moorhead 2011). Tree canopy species diversity generally decreases with increasing island isolation. At favorable sites, this rain forest extends up onto the lower slopes on the larger islands on windward rainy exposures, where it changes with increasing elevation to a low-stature, shrub- and epiphyte-rich montane rain forest. This vegetation is predominant on moist hilltops and mountain slopes in many tropical islands (Mueller-Dombois and Fosberg 1998).

2.3.1.2 Tropical hill evergreen and semi-evergreen rain forests (300–800 m)

Hill forests are physiognomically and structurally similar to their lowland equivalents, with often higher above-ground biomass, especially on ridges, where impressive tree specimens are often encountered. They remain very dense, with an average canopy height of between 35 m and 40 m and emergent trees reaching 50–60 m. In western Malaysia, this forest type is still categorized as ‘mixed dipterocarp forests’ since the dominance of this family is still very high (50% abundance and 60% dominance for tree diameters above 30 cm). Diversity also remains very high. Their differentiation from lowland forests (Wyatt-Smith 1963; Symington 1943) has been challenged by Whitmore (1984), who does not consider any altitude-based division to be justified below 1,000 m. A shared flora indeed exists for this range of altitude.

Nevertheless, many studies showed significant floristic variations around 300 m to 500 m above sea level. Therefore, from a forestry, agricultural management or conservation point of view, it appears crucial not to consider only a single forest type ranging from 0 to 1,000 m elevation. Some lower elevation species (<300 m) are no longer present or have become very rare, while others, rare in the lowlands, become more abundant uphill.

Richards (1936), in a study on MDF in Sarawak, already noted that species composition could vary significantly over short distances, such as between ridges, without any apparent relation to soil conditions or other factors. It has been pointed out that topography, along with the soil types, moisture regimes, and geological formations, are the main factors shaping species distribution (Whitmore 1984). In trying to explain such patchiness in species distribution, passionate debates occurred over whether topography or soil was the main determining factor.



Photo 1 The most emblematic forests of humid SE Asia, the lowland mixed dipterocarp forests are the tallest of all broad leaved tropical rain forests, harbour the highest above-ground biomass and have the highest mean net primary production of any terrestrial ecosystem. They are also the most species-rich, biologically diverse of all ecosystems. They are on the verge of extinction (© Yves Laumonier).

For some, while certain species can be used as indicators of specific soil conditions, too many appeared to have widespread distribution (Van Steenis 1958; Poore 1964; Williams and Webb 1969). Several studies support this. For instance, forest ecologists working on the Malay Peninsula have argued that there is no clear relationship between the substrate and the distribution of forest species (Poore 1968; Kwan and Whitmore 1970). Many authors maintained that pedological factors in dense rain forests do not affect the production of leaf litter, structure, or biomass (Tanner 1980; Jordan and Herrera 1981; Leigh and Windsor 1982; Proctor et al. 1983a, 1983b). In Peninsular Malaysia, Kwan and Whitmore (1970) found no relationship between the distribution of species and three types of contrasting soil. They concluded that dispersion and reproduction strategies should be more important in explaining the differences, an opinion also shared by Poore (1968). The same conclusion was reached by Newbery et al. (1996), who found no relation between species composition and soil chemistry while studying understorey species in lowland forests in Sarawak. These authors found no relation between species composition and soil chemistry. Instead, they suggested that the main factor was topography, the gradient from lower slopes to ridges, and the underlying cause might be water availability. The results of Bar-Hen and Laumonier (1998) in the Sumatran hill forests confirmed such findings. In a 50-ha study plot in Pasoh Forest Reserve in Peninsular Malaysia, 60% of tree species were generalists, i.e., they were found in all parts of the plot, and 40% were habitat specialists occurring only in specific soil or topography. From this 40%, 17% were found only in riparian sites, and the same proportion was confined to upland areas (upper slopes and ridges). Only 4% were restricted to one soil type, in this case alluvial soils, and less than 1% was confined to granitic lithology (Okuda et al. 2003).

For others, the importance of soil factors is primordial. From a study covering 105 plots in northwestern Borneo, Potts et al. (2002) concluded that abiotic factors were a more important determinant of tree community variation than usually acknowledged. They

found that soil types could essentially predict the communities. However, this relationship seemed to depend on the richness of the soil. Predictions were more complicated to make on nutrient-rich than on nutrient-poor sites. Other researchers in Borneo (Brunei Darussalam and the Malaysian states of Sarawak and Sabah), found close links between soils and vegetation or between geology and vegetation (Ashton 1972, 1982; Baillie et al. 1987). Austin et al. (1972) confirmed the conclusions of Ashton (1964), who mentioned that species distribution in the dipterocarp forest of Brunei Darussalam was controlled by soil characteristics, although no dipterocarp species were found endemic to ultramafic rocks or limestone (Ashton 1988).

Ashton (1978) later concluded that the variability of tree species composition in northwestern Borneo seemed to be related to soil factors only when the phosphorus content was low. According to his observations for the old-growth phase of the rain forest, there are highly niche-specific tree species, and species richness is highest on relatively infertile soils. This was confirmed by the exceptionally high biodiversity encountered in a 6 ha plot on impoverished soil in Sumatra, where more than 300 species with a diameter of 10 cm and greater were found in one ha according to Laumonier (1997). Ashton (1978, 1982) and Baillie et al. (1987) concluded that there is an edaphic influence on the distribution of certain species and emphasized the importance of the magnesium content of the soil.

Ashton and Hall (1992) considered distinct guilds of tree species even on the level of plots sized about 0.5 ha. Dipterocarp species have relatively narrow niches in terms of soil fertility, and their distribution is mainly correlated with phosphorous and magnesium levels.

Another study in Sarawak using ordination to look for associations in tree species composition showed significant correlations with soil factors for alluvial forests and *kerangas* forests but not for dipterocarp forests and forests over limestone (Newbery and Proctor 1984). Newbery and Proctor (1984) found associations between some soil

parameters and vegetation for the alluvial and heath forest types in Sarawak, but less clear for the lowland dipterocarp forest. In Ketambe in northern Sumatra, van Schaik and Mirmanto (1985) compared fluvial terraces of different ages and fertility. They confirmed the frequent empirical observation that very tall dense forests could be found on impoverished soils. They suggested that changes in soil fertility could be responsible for spatial variations observed in the structure, diversity, and production of leaf litter in these particular forest types.

Lithology appeared to be a determining factor on Sumatra. The dominant dipterocarps in the eastern Sumatran metamorphic hills were *Shorea hopeifolia*, *S. gibbosa*, and *S. bracteolata*, *S. ovata*, *Hopea auriculata* and *H. beccariana*. Other canopy species included *Parashorea lucida* and *P. aptera*, which were much more abundant than in the lowlands. In addition, *Whitfordiodendron atropurpurea* (Fabaceae), *Magnolia elegans* (Magnoliaceae), and *Artocarpus anisophyllus* (Moraceae) indicated a hillside habitat. In contrast on volcanic-derived soils, dipterocarps were less abundant but remained co-dominant with Fagaceae and Burseraceae. *Shorea platyclados* appeared as low as 500 m. However, the most abundant and dominant species was mostly *Hopea beccariana*, which becomes the main component of the canopy, reaching impressive sizes on the ridges. These giants were accompanied by *Shorea ovalis* ssp. *sericea*, *S. ovata*, *Quercus argentata* and *Santiria laevigata*. Dipterocarps were poorly represented on steep slopes, and emergent trees were mainly Anacardiaceae such as *Dracontomelon costatum*, Fagaceae, *Quercus argentata*, and Sapindaceae, *Pometia pinnata*, Meliaceae *Dysoxylum acutangulum*, Sterculiaceae, *Pterospermum javanicum*, Simaroubaceae, *Irvingia malayana*, and many species of strangling figs. The canopy was lower, between 25 m and 30 m.

In the Semangkok forest reserve in Peninsular Malaysia, a distinctive tree community was found on the ridges, positively associated with the palm *Eugeissona tristis* and negatively with the bamboo *Gigantochloa scortechinii* (Niiyama et al. 1999). There was

apparent aggregation²⁴ for most of the 30 tree species investigated, with only two showing a random distribution.

Other studies indicate a link between soil nutrients, primarily N and P, and tree species composition in dipterocarp forests. Many of these studies have been performed as field inventories with soil sampling. Experiments with nutrient additions have also been conducted in connection to enrichment planting in secondary forests. For example, Palmiotto et al. (2004) conducted field experiments with seedlings of six tree species. For four of the species, they found clear responses of the seedlings to local soil conditions. They conclude that their results strongly support the hypothesis that soil variation contributes to the spatial variation in tree species distribution.

Eucalyptus deglupta, the only rain forest eucalypt known to occur in the wild in the northern hemisphere, is found at that elevation zone in the Philippines, New Guinea, Sulawesi and the Moluccas (Seram Island also in the lowlands).

2.3.1.3 Tropical and sub-tropical montane rain forest formations

Sub-montane (800–1,300 m)

The forests of the sub-montane zone, a transition zone between lowland and montane flora, are often just as majestic as those lower down. It is still possible to distinguish three or four tree height strata situated at an average of 35–45 m, 20–30 m, 15–20 m, and 5–10 m until an altitude of approximately 1,400–1,500 m. Emergent trees approaching heights of 50 m are still frequently encountered. Many species still have large buttresses. Lianas, hemi-epiphytic and epiphytic figs are also abundant. The leaves are mostly mesophyllous, with higher proportion of compound leaf families (Burseraceae, Meliaceae, Sapindaceae, Fabaceae).

²⁴ Most species of the rainforest show an aggregated distribution pattern, while those with random distributions are less common. Rare species tend also to be more aggregated than common species. All of these characteristics make it challenging to elaborate sampling protocols.

From a floristic standpoint, these sub-montane forests are traditionally characterized by the dominance of Fagaceae, Moraceae and Myrtaceae, families that are also well represented in the lowlands but that are favored here by the absence of Dipterocarps.

Large *Agathis borneensis* are only found in the Kerinci region of Sumatra, often in association with natural populations of *Pinus merkusii*. The most characteristic species elsewhere are *Shorea platyclados* (up to 1,200 m), *Altingia excelsa*, *Quercus*

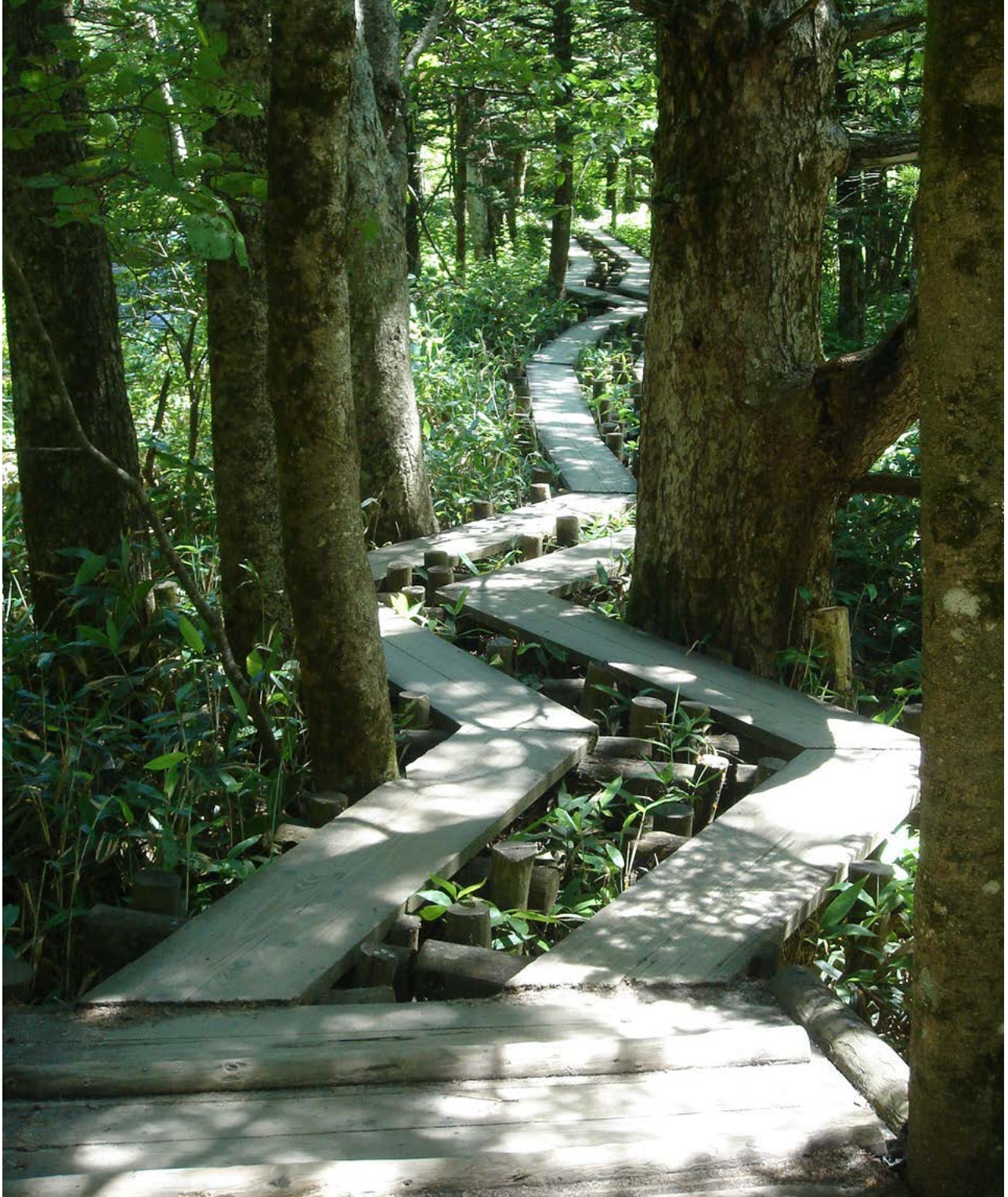


Photo 2 Protected montane forest in the Chūbu-Sangaku National Park in the Hida Mountains range in Kamikōchi, Japan (© Vincent Gitz).

oidocarpa, *Neesia altissima*, *Podocarpus imbricatus*, *P. neriifolius*, *P. wallichianus*. *Lithocarpus hystrix*, *Parkia singularis*, *Santiria laevigata*, *Toona sinensis*, *Sarcosperma paniculatum*, *Drypetes minahassae*, and numerous species of strangling figs (*Ficus* cf. *binnendykii*, *F. disticha*, *F. elastica*).

In the central Himalayas, the tree species of this transition zone have a large altitudinal amplitude distribution, but statistically, the number of temperate genera increases above 1,500 m.

Lower montane (1,300–1,800 m)

From a bioclimatic point of view, montane rain forests are found where the mean temperature of the coldest month is below 15° C, while the absolute minimum may fall below freezing point for a few days. Rainfall is usually high (2,000–4,000 mm or more) and the dry season is short (one or two dry months). Montane rain forests are extremely vulnerable to climate change and fires. The highest peaks of Indonesia, New Guinea, Malaysia and the Himalayas are above the tree line. Finally, the boundary between lowland and montane forests should be drawn at different elevations to allow for the aforementioned Massenerhebung effect. In the Himalayas, New Guinea and Indonesia, the 1,800 m contour is chosen, while for smaller massifs, notably the small islands of Oceania, extremely vulnerable cloud forest can develop as low as 600–800 m above sea level (Loope and Giambelluca 1998). They are mostly broad-leaved, but conifers are also present.

In northeastern India (Assam hills), Myanmar and Thailand, northern Laos and northern Viet Nam, as well as Indonesia, an altitude of about 1,200–1,300 m is generally accepted as the lower limit of lower montane forests (1,300–1,800m). From a floristic point of view, there are marked differences from one mountain to another.

Coniferous forests are practically unknown in western Malesia, South India and Sri Lanka. The only gymnosperm tree known from the Western Ghats is *Podocarpus wallichianus*. In Viet Nam, Lao PDR and Burma,

conifers, Fagaceae (*Quercus*, *Lithocarpus*, *Castanopsis*), Juglandaceae, Lauraceae, and Magnoliaceae are common. In South India and Sri Lanka, Elaeocarpaceae, Lauraceae and Myrtaceae play a conspicuous role. *Pinus kesiya* is common from Assam (northeastern India) to the Vietnamese mountains, through Myanmar, Thailand and Lao PDR. In southern Viet Nam, *Pinus kesiya*, *P. dalatensis* and *P. krempfii* are noteworthy.

The approximate extents of the wild populations of *Pinus merkusii* (For Sumatra, see: Cooling 1968; Laumonier et al. 1997. For Luzon and Mindoro, see: Critchfield and Little 1966), and of *P. kesiya* (Myanmar, northern Thailand and Cambodia: van Zonneveld et al. 2009; Luzon and Mindoro: Turnbull et al. 1980) are of considerable interest as seed sources for plantation forestry. Sumatra is remarkable as the only place where *Pinus* extends south of the equator (Kerinci).

Other very important stands are those of *Araucaria cunninghamii* and *A. hunsteinii* in PNG (Gray 1973) and adjacent islands. Another preeminently important conifer genus, *Agathis*, has been mapped for New Guinea (Whitmore 1977) and Borneo, mostly as scattered individuals and small pockets.

In the central Himalayas, average annual precipitation is greater than 1,500 mm. Characteristic species are *Schima wallichii*, *Castanopsis indica* and *Acer oblongum* in the most humid places, changing to associations of *Pinus roxburghii*, *Schima wallichii*, *Helicia nilagirica*, *Myrica esculenta* at mesophilous sites, and becoming pure stands of *Pinus roxburghii* in drier areas, such as on rocky outcrops.

Upper montane (1,800–2,500 m)

Upper montane forests all have distinctive physiognomy and structure characteristics. They are often referred to as 'cloud forests' because of the persistence of cloud cover at those elevations. The cloud layer is relatively constant at these altitudes with abundant bryophytes. At an altitude of 2,300 m on Mount Kerinci, Sumatra, as is the case on Mount Pangrango in West Java, the canopy, located 15–25 m above the ground, is very

open, with small crowns shaped by the prevailing winds. Gaps represent up to 60% of the plot surface area. Bryophytes cover all individual trees and the branches are often covered in *Usnea*. One of the rare species to still reach 1 m in diameter for a total height of 20 m in Sumatra is *Symingtonia populnea*. Only *Manglietia calophylla* and *Symplocos* sometimes reach this size. Other noteworthy species in the canopy include *Vernonia arborea*, *Acronodia punctata*, *Lithocarpus suffruticosus*, *L. oreophilus*, *Quercus* cf. *steenii* and *Glochidion lutescens*, many *Symplocos* spp, *S. cochinchinensis* var. *sessilifolia*, *Acronodia punctata*, *Castanopsis argentea*, *Polyosma integrifolia*, *P. ilicifolia*, *Neolitsea cassiaefolia*, and *Ficus ribes*. A belt of *Pandanus* is often encountered. Ericaceae (*Vaccinium*, *Rhododendron*) and epiphytic *Schefflera* become more abundant (Laumonier 1997).

Tropical sub-alpine (2,500–3,000 m) and alpine (>3,000 m) forests

Higher up, the forest canopy becomes lower, about 10–15 m high. Trees are twisted and moss-covered with small microphyllous crowns. Stem density is very high, and most species are multi-stemmed. In Sumatra, the open canopy is mostly dominated by *Symplocos cochinchinensis* var. *sessilifolia*, *Ilex pleiobrachiata*, *Myrsine*, *Ardisia* and many Ericaceae, *Vaccinium*.

At 3,000 m, all that remains is a very dense low forest 3–6 m high, dominated by Ericaceae, *Rhododendron retusum*, *Vaccinium miquelii*, *Gaultheria nummularioides*, Symplocaceae *Symplocos cochinchinensis*.

At an altitude of 2,800 m on Mount Talamau, West Sumatra, there is a plateau of *Lycopodium* (*L. cernuum*, *L. clavatum*, *L. complanatum*), Cyperaceae (*Gahnia javanica*) and sparsely growing shrubs (*Vaccinium*, *Rhododendron*, *Gaultheria*, *Sorbus granulosa*) before reaching the summit. At the same elevation, the mossy forest around the small lake on Mount Singgalang, West Sumatra, is particularly beautiful, with large *Leptospermum javanicum* trees to 10 m high.

The same elevation zone in the Himalayas is dominated by the evergreen oak *Quercus lamellosa* from Nepal to northern Thailand and the Chinese province of Guangxi. Depending on the orographic situation and level of humidity, three types can be distinguished: the most humid sites with large *Quercus lamellosa* up to 40 m high, often in association with *Castanopsis hystrix*, *Lithocarpus spicata*, and many Lauraceae such as *Lindsea neersiana* L. *heterophylla* L. *assamica*, and *L. pulcherrima*; the less humid (mesophilous) sites, where the previous type is replaced by the more open *Quercus lanata* forest, a species also occurring from India eastern Uttarakhand to the Indochina peninsula (Viet Nam, Myanmar, northern Thailand), and southwestern China (Guangxi, Tibet, Yunnan). This forest type is the most degraded by humans, with an upper limit of cultivation of 2,000–2,300 m, and the systematic use of fire favoring the development of grasses (*Themeda*, *Cymbopogon*, *Apluda*, etc.) (Dobremez 1973).

Due to volcanic activity, vegetation disappears above 3,400 m on Sumatra (Mount Kerinci), while on Borneo (Mount Kinabalu) or on peaks in Papua (Hope 2014), the tree line is between 3,600–4,000 m. In the eastern Himalayas, the tree line is at an average altitude of 3,700 m. *Juniperus tibetica* holds the record of the tree species found at the highest altitude, up to 4,900 m above sea level, in southeastern Tibet (Miehe et al. 2007), but 400 m lower in the western Himalayas (Pakistan, Kashmir). The dominant genera up to the treeline in the eastern Himalaya are *Juniperus*, *Abies*, *Rhododendron*, and *Betula* (Singh et al. 2020).

2.3.1.4 Temperate and boreal mountain forest formations

These formations are often referred to as broad-leaved, needle leaved or mixed in the literature. The upper montane forest in the central Himalayas (2,500–3,000 m) is characterized by stands of the evergreen oak *Quercus semecarpifolia*, 20–30 m tall, up to 2 m diameter at breast height (DBH) or more. The atmospheric humidity is very high and epiphytes, including pteridophytes and mosses, are abundant. *Quercus semecarpifolia* can even be found at the treeline, which lies at up to 3,700 m. It grows often in association with

Tsuga dumosa, *Ilex dipyrrena*, *I. fragilis*, *Acer campbellii*. Above 3,000 m, *Abies spectabilis* becomes dominant, associated with *Tsuga dumosa*, *Acer caudatum*, *A. caesium* and *A. pectinatum*.

In the extreme climatic conditions of Mongolia and northeastern China²⁵ lies the only Eurasian boreal forest of *Larix gmelinii*, sometimes mixed with *Betula platyphylla*. Further south,²⁶ the formation is gradually replaced by a 'northern' temperate evergreen coniferous and deciduous broad-leaved mixed forest with *Pinus korainensis*, *Abies*, *Picea*, *Taxus* and *Acer spp.*, grading to a southern temperate mixed evergreen coniferous–broad-leaved forest with *Abies halophylla* and conspicuous increase in warm temperate elements,²⁷ before becoming a temperate deciduous broad-leaved forest characterized by oak *Quercus acutissima*, *Q. aliena*, *Q. dentata*, *Populus* and *Ulmus* (Qian et al. 2003).

2.3.2 Seasonal forest formations

Where there is a marked annual dry season, tropical rain forests are replaced by seasonal forests, which are sometimes referred to as monsoon forests. They are found at the fringes of humid areas, especially in Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam in the northern hemisphere, in east Indonesia and part of Australia in the southern hemisphere. Compared to tropical rain forests, they are structurally less complex and floristically less rich. Many species are deciduous.²⁸

In the Indo-Malesian and Pacific regions, they have been reported in India (Pascal 1988),

25 With: mean temperatures of the coldest month reaching -28°C to -52°C; a short summer with temperatures in the range of 15°C–20°C; up to 100 frost days per year; and precipitation ranging from 360 mm to 500 mm.

26 With precipitation in the range of 500–1,000 mm, mean temperatures of 0°C–5.5°C, and mean temperatures in the coldest month ranging from -16°C to -25°C.

27 At altitudes of 500–600 m, mean temperatures between 4°C and 6°C, and precipitation of 500 mm to 800 mm.

28 i.e. shedding their leaves in the dry season.

Bangladesh (Zaman et al. 2011), continental Southeast Asia (Bunyavejchewin et al. 2011; Marod et al. 1999), the Australian Northern Territories (Bowman et al. 1991; Russell-Smith 1991; Webb 1959) and some islands of the Pacific (Gillespie and Jaffré 2003; Pau et al. 2009). They have been described as “moist deciduous forest” by Schimper (1898), Champion (1936), Burt-Davy (1938) and Champion and Seth (1968), while, in Indonesia, they have been under-studied (Laumonier and Nasi 2018; Meijer-Drees 1951; Metzner 1977; Cowie 2006), but the definitions of seasonal forests remain quite arbitrary (Leigh 1999). The term ‘monsoon forest’ is used as a convenient term in the Indo-Malesian and Pacific regions for those forests where water is periodically limiting to plants (Whitmore 1984), e.g. when the vegetation experiences a long dry season followed by a season of heavy rainfall, but this term has been considered rather ambiguous (Russell-Smith 1991).

Standardized structural and floristic classifications of these forests are difficult because of the high variability of the intensity of the dry season, the characteristics of the soils, especially related to water retention, and the local micro-climate linked to landforms.

Besides the seasonal evergreen type, drier forests in the southeastern islands of Indonesia are quite similar structurally (but not floristically) to those described as “semi-evergreen forests” (Beard 1944) or “semi-evergreen and deciduous vine thickets” (Baur 1968; Webb 1959; White and Bruce 1986), but the term “moist deciduous forest” is preferred here since it is often difficult to define “semi-evergreen”.

Most parts of continental Asia located at low elevation were once naturally covered by seasonal forests. In northern Thailand, Lao PDR, Myanmar and the Ganges lowlands, where the temperature of the coldest month lies between 15°C and 25 °C with a rainfall of about 1,500 mm distributed over six months, moist and dry deciduous forests constitute the climax vegetation. The actual leafless period varies between species and, for a given species, from one place to another. On average, deciduous forests are leafless for at least eight weeks in February and March in India.

In the very driest parts of southern New Guinea and also in part of the Palu valley of Sulawesi, there were once patches of natural tree savanna (Whitmore 1984). Seasonal forests are easily degraded by humans to tree or grassland savannas. In southwest New Guinea and on the Gulf of Papua around Port Moresby, a mosaic of seasonal forests, tree savanna and grasslands can still be found, often dominated by *Eucalyptus* and *Corymbia* (e.g. *C. papuana*, *E. alba*, *E. brassiana*, *E. pellita*, *E. tereticornis*) and *Acacia* (*A. crassicaarpa*, *A. leptocarpa*, *A. mangium*, *A. peregrina*, and *A. simsii*). Parts are seasonally flooded, such as the extensive *Melaleuca-Acacia auriculiformis* savannas. The mosaic of dryland and swamp forests is too complex to be mapped at a small scale.

2.3.2.1 Seasonal evergreen forests

The *Sal* (*Shorea robusta*) forests of the Ganges lowlands and northeastern India are remarkable, representing one of the few gregarious species stand in South Asia from the foothills of the Himalaya to as far as Myanmar in the east. The canopy is closed at 30–35 m with some emergent *Sal* up to 45 m.

Seasonal evergreen forest communities contain a variety of important plant species. Well-known are the teak forests (*Tectona grandis*) of India, Myanmar, Thailand and Lao PDR. There are commercially important timbers, teak and gmelina, but also fruit trees including carambola (*Averrhoa carambola*), bael tree (*Aegle marmelos*), mango (*Mangifera indica*) and the introduced tamarind (*Tamarindus indica*).

In the lowlands of the Terai region in Nepal, *Shorea robusta* is associated to *Salmalia malabarica* and *Adina cordifolia* are dominant, while in other areas, *Terminalia* species are also conspicuous. The stratification of the vegetation is very well-defined, with a dense canopy at 30 m, a lower and sparser stratum between 10 m and 20 m, pole trees (5–7 m), and shrubs (1–3 m). Higher up in the hill zone, the landscape is also very much cultivated with few patches of *Sal* forest left, with *Castanopsis indica*, *Bauhinia purpurea*, *Oroxylum indicum*, *Holmskioldia sanguinea*. In the Siwalik ranges

the gentle slopes are covered with *Sal* forests with *Lagerstroemia parviflora*, *Anogeissus latifolius*, *Adina cordifolia* or *Terminalia* spp. (*T. tomentosa*, *T. belerica*, *T. myriocarpa*), while on rocky outcrops only the *Sal* becomes monodominant (Dobremez 1973).

Some seasonal evergreen forests are found in eastern Indonesia and Australia (Laumonier and Nasi 2018; Bowman et al. 1991; Russell-Smith 1991; Webb 1959). In the Tanimbar Archipelago, they are dominated by *Intsia bijuga*, *Manilkara kanosiensis*, *Pometia pinnata*, *Canarium* spp., and *Chisocheton* spp.

2.3.2.2 Moist deciduous forests and woodlands

The occurrence of teak and pines mixed with dipterocarps or Fabaceae lead to so-called 'mixed deciduous forest and woodlands' (Blasco 1983; Champion and Seth 1968; Maurand 1965; Meher-Homji 1977; Rollet 1953, 1972; Schnell 1970; Seth and Kaul 1978; Werner 1993; Rundel 1999).

The canopy of the moist deciduous forest is typically closed and high, often reaching 30 m or more. The understory is relatively open with bamboo clusters often present. Characteristic of the mixed deciduous forest is the dominance of the Fabaceae (*Xylia kerrii*, *Azelia xylocarpa*, *Pterocarpus macrocarpus*, and *Dalbergia* spp.), Lythraceae (*Lagerstroemia* spp.), Combretaceae (*Terminalia* spp.) and Rubiaceae families, together with a relatively low occurrence or absence of Dipterocarpaceae (Rundel 2009).

The Eastern Ghats, a chain of ancient, low hill ranges along the east coast of India, support a diverse array of tropical forests having great conservation value. Much of the Deccan peninsula has dry deciduous forests and secondary scrubland, but the Eastern Ghats also host many remnant patches of evergreen, semi-evergreen and moist deciduous forests (Rawat 1997). Two species of *Shorea* (*Shorea talura* and *S. tumbaggaia*), red sanders (*Pterocarpus santalinus*), and some other associations (*Terminalia* – *Anogeissus* – *Chloroxylon*; *Hardwickia* – *Chloroxylon*; and *Albizia amara* – *Memecylon*) are unique to these ranges (Legris and Meher-Homji 1982; Nayar et al. 1984).

In the same climatic zone, some *Pinus* stands exist in Thailand, Burma, North Laos, Viet Nam. Most of the moist deciduous forests and woodlands have been considerably affected by anthropogenic factors and were probably once evergreen or semi-evergreen forests. Today most of their constituent tree species are resistant to fire. It is noteworthy to mention that all the genera mentioned above for the Mekong area, and even some species are also found in the eastern part of Indonesia, implying migration of plants beyond the Wallace line.

2.3.2.3 Dry deciduous forests and woodlands

Dry deciduous dipterocarp woodlands are typical of tropical continental Asia, especially in Viet Nam, Lao PDR, Cambodia and Thailand. A third of the forest cover in Thailand are woodlands (canopy cover varying from 10% to 40%). The repeated actions of fires and the pronounced dry season (annual precipitations (P) of 1,000–2,000 mm; four to six dry months) are certainly determining factors, but the exact role of soils needs further research. These woodlands are mainly found on acid lithosols and podzolic soils which exhibit similarities across different sites such as a low water-holding capacity²⁹ and a low fertility status (Blasco 1983).

These conditions determine a quite stable and open woody community with a few characteristic *Dipterocarpus* species (*D. intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Pentacme siamensis*, *Shorea obtusa*), a common *Cycas* (*C. siamensis*) and a dwarf bamboo (*Arundinaria falcata*) in the undergrowth. In Thailand, some of these woodlands include teak (*Tectona grandis*) and two pine species: *Pinus merkusii*, generally between 400 m and 1,200 m above sea level, and *P. kesiya* usually above 1,000 m (Werner 1993). Their distribution is closely related to human interference and fires.

Very little is left from the seasonal forests of southeastern Indonesia. Remarkable are the rather untouched forests of the Yamdena Island in the Tanimbar archipelago (Maluku province, Indonesia) representing three distinct

types of seasonal forests (Laumonier and Nasi 2018).

2.3.3 Edaphic formations

2.3.3.1 Peat swamp forest

Tropical peat swamp forests are mainly found in southeastern Asia, notably eastern Sumatra, along the coasts of Peninsular Malaysia, and in Borneo. They are ombrophilous tropical peats, derived only from precipitation, very acidic and extremely poor in nutrients.

They have been thoroughly studied over the past decades (e.g. Anderson 1963; Ashton and Gunatilleke 1987; Cooling 1968; Mani 1974; Maurand 1965, Meher-Homji 1967; Phengkklai et al. 1989; Rosayro 1974; Vidal 1979, 1989; Werner and Balasubramaniam 1992; Whitmore 1989; Siefferman 1992; Laumonier 1997). They have gained even more traction in the last 20 years because of their advocated crucial hydrological function and high carbon storage, which is released in the atmosphere when they are converted to agriculture (Page et al. 2002, 2011; Miettinen et al. 2012).

The low-lying peat swamps along the valleys described in Sarawak (Anderson 1964), or those of central Borneo, which have developed on the podzols of terraces or badly drained plateaus (Brünig 1974 for the Malaysian state of Sarawak and Brunei Darussalam; Sieffermann 1988 for Kalimantan) are different from peat formations that developed in submerged basins of topographical origin, along the same lines as those described by Morley (1981) in South Kalimantan, which arose through the colonization of swamp grasslands, and ‘floating islands’ such as those found in the wetlands (*Lebak*) areas near Palembang (Driessen and Soepraptohardjo 1977).

Organic accumulations due to vegetation debris caused dome-shaped peat deposits to form, due to a faster rate of decomposition around the periphery where the medium has a higher mineral content. Polak (1933) mentions peat depths of up to 15 m at Jambi or Riau, although the average maximum depth does not exceed 7–8 m (Cameron et al. 1987). Peat depths of at least 10 m have also been recorded in Borneo (Anda et al. 2021).

29 They become extremely dry soon after the rains.



Photo 3 Most wetlands and periodically inundated freshwater swamp forests have been converted to agriculture. In low lying basins, organic accumulations due to vegetation debris have caused dome-shaped peat deposits to form. The huge ombrophilous peatlands of Southeast Asia have gained much traction in the last 20 years because of their advocated crucial hydrological function and high carbon storage, which is released in the atmosphere when they are converted to agriculture (© Yves Laumonier).

Peaty soils are usually defined as soils with at least 65% organic matter within a 50-cm-thick layer (Driessen and Rochimah 1977). Their exact surface area has long been debated, with the last agreement for the region synthesized by the PEATMAP initiative (Xu et al. 2018) giving figures of 148,331 km², 22,398 km² and 136,963 km² for Indonesia, Malaysia and China respectively.

Traditionally, the Malay populations of the Malacca Straits gathered timber from these forests (mainly the *balam*, *Palaquium* species and other Sapotaceae). They also harvested the latex (‘pararubber’) and the fruit from the *suntai* (*Palaquium burckii*, *P. Walsurifolium*), from which they extracted an edible oil. Peat forests comprise a large number of species, some of which are attractive to loggers,

such as the *balam* already mentioned, the *ramin* (*Gonystylus bancanus*) and several dipterocarps (three species of *Shorea*, one species of *Anisoptera*). Where the peat is less than 1 m thick, many perennial crops can be cultivated (Driessen and Sudewo 1977). It is thus very important to be able to map peat thickness. This is a technological challenge for remote sensing, and such maps are still debated. The latest published findings on the matter are given for Indonesia in Anda et al. (2021).

The tropical peat swamps occupy regions near the equator where average yearly rainfall is always high (1,500–2,000 mm per year) and relatively well distributed over the year. This distribution influences evapotranspiration and is therefore important

in explaining the presence of peat swamps. Dry periods may nevertheless occur, although they are not repeated every year.

Irreversible changes can occur in the colloidal structure of peat after excessive drainage. The matrix shrinks, the water retention capacity decreases and, in extreme cases, the terrain subsides (Chambers and Sobur 1979). The peat becomes hydrophobic, and the forests it supports rapidly die. They also become extremely sensitive to fire.

These peats are extremely acidic with pH levels of 3 to 4.5, and high humic and fulvic acid content. Suhardjo and Wijaya-Adi (1977) measured pH values ranging from 3.5 to 4.2 in the Kampar region (Riau province, Indonesia). These authors also confirmed that the phosphorus and potassium content were very low. Nitrogen is abundant in the form of nitrogenous organic compounds, which are not easily freed into the environment, nor therefore available to plants. A significant drop in phosphorus, potassium, calcium and magnesium levels is observed as one approaches the center of the peat dome, i.e. as the peat depth increases.

The water exuded by these peat formations is black and rich in phenolic compounds, which can be toxic to animals (Janzen 1974), though not to plants according to Whitmore (1984).

The flora genuinely specific to peat swamps is fairly limited. Anderson (1963, 1964) was the first researcher to observe the way vegetation varies according to peat depth and described a forest type zonation for Sarawak comprising up to five zones distinguished by structural and floristic criteria. It is very important to map this zonation for any management plan. Usually, a distinction between fresh water swamp forest (peat depth below 0.5 m) and peat swamp forest is relatively straightforward in remote sensing analysis, even at Landsat resolution. Several types can also be identified corresponding to differences in peat depth.

Mixed peat swamp forests on shallow peat layer (0.5–2 m)

The structure of these forests is similar to that of the drained lowland forests, with emerging

trees attaining heights of 45 m to 50 m and the canopy often situated in the range of 30 m to 35 m above the ground. In Sumatra, the emergent tree species are *Shorea uliginosa*, *S. teijsmanniana* (Dipterocarpaceae), *Dyera lowii* (Apocynaceae), while the canopy includes *Tetramerista glabra* (Tetrameristaceae), *Camptosperma coriaceum* (Anacardiaceae), *Mezzettia leptopoda*, *Xylopia fusca* (Annonaceae), *Durio carinatus* (Bombacaceae) and *Santiria laevigata* f. *glabrifolia* (Burseraceae).

Formations on moderately thick peat layers (2–5 m)

Forest physiognomy changes drastically, and the canopy height diminishes rapidly as one penetrates further inland, diameters tend towards homogeneity, and the stem density is higher. From the floristic standpoint, the extreme abundance of *Calophyllum sundaicum* is an excellent indication of this zone boundary, where floristic diversity also diminishes notably.

Formations on deep peat layer (5–8 m) and low pole forests on very deep peat layers (over 8 m)

Further inland, towards the center of the dome (peat depth of 5–8 m), a few emergent trees with small crowns are still encountered, mainly *Palaquium burckii* and *P. ridleyi*, *Tetramerista glabra*, *Combretocarpus rotundatus*, or *Gluta aptera*. The floristic composition of the next zone is almost identical except that the emergent trees disappear. The relatively uniform canopy at a height of 20 meters can be easily distinguished on satellite images.

The 'pole' forests in Sumatra are dominated by *Shorea teijsmanniana* and *Calophyllum sundaicum*. There, the very dense forest (10,000 stems per ha) has an even canopy located at a height of 6–8 m. Floristic diversity remains higher than in Borneo with *Timonius flavescens*, *Antidesma* sp., *Tristaniopsis obovata*, *Ilex cymosa*, *Aglaiia ignea*. It is different from the peatlands of central Kalimantan, where besides the pole forest, a tall forest has been observed at the top of the dome in the Sebanggau forest (Husson et al. 2018).

1.1.1.1 Freshwater and seasonal swamp forest formations (peat depth below 0.5 m or no peat)

Freshwater swamp forests are common in Malaysia, Indonesia and PNG (Corner 1978; Pajmans 1975; Whitmore 1984; Bruenig 1991; Laumonier 1997). In continental Asia, they occur mainly in Cambodia on the Tonle Sap. Other freshwater swamps recorded by Champion and Seth (1968) on the west coast of India and by Phengklai et al. (1989) in Thailand, are rather small areas. These types are most extensive in PNG and occur under both humid and seasonal tropical climates. The vegetation map of PNG (Pajmans 1975) records various types of such permanent and seasonal swamp forests, woodlands and grasslands. In Indonesian Papua, they are often classified as peat swamps although the peat layer is shallow and the forests do not resemble at all the peat formations of west Malesia. Many seasonal swamp forests have been converted to agriculture.

2.3.3.2 Mangroves

Mangrove forests, or tidal forests, are primarily determined by very specific soil conditions (Gleysols), combined with regular flooding by sea water and regular input of fresh water leading to unique brackish environment. Globally, they represent only 0.7% of the world's tropical forested area but are highly threatened by the effects of climate change, sea level rise and increasing pressure from human population growth in coastal regions (Bhomia et al. 2016). Mangroves in the Indo-Pacific region are among the most carbon-rich forests in the tropics (Donato et al. 2011), but most of them are threatened by conversion for aquaculture, shrimp ponds, or infrastructure (Kanniah et al. 2015; Fauzi et al. 2019; Kanniah et al. 2021) and under high risk of extinction (Polidoro et al. 2015). Under proper management, their sustainability as forests could be secured (Danhof 1946; Murdiyarso et al. 2021). Since 2000, Myanmar has been losing mangrove forest cover at an alarming rate of 14,619 ha per year (2.2% per year), predominantly in Rakhine and Ayeyarwady (Estoque et al. 2018).

Indonesia remains by far the largest mangrove-holding nation, containing between 26% and 29% of the global mangrove inventory with a deforestation rate of between 0.26% and 0.66% per year between 2000 and 2012 (Hamilton and Casey 2016). The mangroves of the Ganges delta, known as the Sundarbans, comprise the largest contiguous mangrove area in the world, covering parts of India and Bangladesh, while important mangrove areas are also found in Myanmar, the Mekong delta, in many Malaysian coasts, in the Musi River delta on Sumatra, the Kapuas River delta on Borneo, and Bintuni Bay in West Papua in Indonesia, as well as in the Philippines, PNG and Australia.

Like for the swamp forest, a zonation of mangrove communities develops. When the coastline is straight and watered by short perpendicular rivers, zonation is parallel to the coastline. Generally, the coast is colonized by *Avicennia alba*, followed by *Rhizophora apiculata* sometimes combined with *Sonneratia alba*. Further inland, tree species communities are dominated by *Rhizophora apiculata*, *Bruguiera gymnorrhiza* and *B. parviflora* develop. Deeper into the forest, communities of *Bruguiera* mixed with *Nypa fruticans* are encountered, finally giving way to the species which announce the end of the mangrove such as *Heritiera littoralis*, *Ficus microcarpa* and *Oncosperma tigillarum*. This is the pattern most frequently encountered on many coastlines, well described by Soekardjo and Kartawinata (1979) and Soekardjo and Yamada (1984).

Delta type zonation is a more complex model as the network of small creeks, islands and channels gives rise to a wide range of variations in the texture of the substratum, flooding intensity and salinity. On Sumatra, zonation corresponds with the classic pattern described by Watson (1928) and Van Steenis (1958). A fine example of this model can be found at the Sembilang river mouth in South Sumatra. Two distinct environments are revealed on satellite imagery, enabling to distinguish between communities dominated by *Rhizophora apiculata* and *Sonneratia alba* from those dominated by *Bruguiera*.



Photo 4 Mangroves in the Indo-Pacific region are among the most carbon-rich tropical forests, but are also under high risk of extinction. They are highly threatened by the effects of climate change, sea level rise and increasing pressure from human population growth in coastal regions (© Yves Laumonier).

2.3.3.3 Back mangroves

The back mangrove forest is the ecotone corresponding to the upper limit of the tidal influence. These forest formations have been described by Wyatt-Smith (1963) in Peninsular Malaysia, and Laumonier (1997) for Sumatra. Back mangroves, clearly differentiated on satellite images, have a specific flora which differs from that of mangroves. Back mangroves most widely known characteristic species is the stemless palm *Nypa fruticans*, which often forms pure stands alongside and up the rivers. It may also be observed delineating circular areas inland of the mangrove or colonizing brackish swamps formed on former lagoons trapped by sand spits colonized by *Casuarina equisetifolia*. Other characteristic species are *Brownlowia argentata*, *Heritiera littoralis*, *Intsia bijuga*, *Cerbera odollam*, *Excoecaria agallocha*, *Ficus*

retusa and *Ardisia humilis*. *Sonneratia caseolaris* is sometimes found very far upstream from the river mouth.

In other situations, this back mangrove is represented by a very characteristic narrow strip (10–100 m) that very clearly announces the beginning of the fresh water swamp forest. This formation, often dominated by the Nibung palm (*Oncosperma tigillarum*), is clearly visible on satellite imagery. In such places, hillocks are formed by the action of tunneling crayfish (*Thalassina anomala*), and are often colonized by the fern *Acrostichum aureum*.

Coastal *Melaleuca* woodlands are found in back mangrove areas in southern Viet Nam in the Mekong delta (Perera 1975; Spate and Learmonth 1967), and around the *lebak* swamps in Indonesia's South Sumatra (Laumonier 1997), as well as in South Kalimantan.

2.3.3.4 *Kerangas* and *Kerapah*

Kerangas forests³⁰ are developed on white sandy soils, while *Kerapah* forests are their waterlogged counterparts. They have been extensively described for Borneo (Richard 1936; Brünig 1974; Whitmore 1984; Kartawinata 1978; Riswan, 1987) and for the Indonesian islands of Bangka and Belitung (van Steenis 1935). There are no reports from the Philippines, Moluccas, Lesser Sunda Islands or PNG. In Peninsular Malaysia, only tiny patches remained on the east coast, the rest being degraded to a mosaic of open grassland, woodland and shrubs known as '*padang*' vegetation. MacKinnon (1982) assessed *Kerangas* forest locations on Kalimantan. This study has been amended by Laumonier et al. (2020) and Pribadi et al. (2020). Natural *Kerangas* forests are tall, dense and biodiversity-rich. Two types should also be distinguished, the *Kerangas* forest bordering the fresh water swamps, evolving into what is called '*Kerapah*' when they are waterlogged, and the *Kerangas* forest establishing in the sandstone hills (Brunei Darussalam, the Indonesian provinces of West and Central Kalimantan and the Malaysian state of Sarawak on Borneo).

2.3.3.5 Limestone formations

Karst and cockpit limestone are most extensive in South China karst, spreading across the Chinese provinces of Guangxi, Guizhou, and Yunnan, New Guinea and the Moluccas (Seram island), where they are found at all elevations.³¹ In PNG, there are also extensive rather undissected limestone plateaus. Raised coralline limestone is very widespread in southwestern New Britain and

widespread through the Lesser Sunda Islands, Moluccas, Tanimbar and Kai archipelagos.

Limestone outcrops are also spread throughout Southeast Asia, and steep limestone hills ('karsts') are a prominent landscape feature in southern Thailand, northern Viet Nam, western Peninsular Malaysia, central and northwestern Sumatra, Sarawak and East Kalimantan. They mainly occur at low elevations (Whitmore 1984), except in the Moluccas (Indonesia) and Papua, where they occupy very large areas at high elevation. Although their total area is quite small, they harbor unique very fragile ecosystems (Clements et al. 2006). They have been mapped by Laumonier et al (1987) for Sumatra, by Sunartadirdja and Lehmann (1960) for southwestern Sulawesi, and by Longman and Brownless (1980) for Palawan (the Philippines).

Their high rate of endemism, plus the natural beauty of the scenery, make them a priority for conservation, but most karst mountain ranges are located outside legally protected areas. The main threat affecting limestone formations is their use as quarries for the cement industry. Moreover, they are also very vulnerable to fires, with irreplaceable loss of forests and soils (Proctor 1995).

Although some of the most unusual vegetation types and plant species are found on these limestone formations (Kiew and Rahman 2021), the plant species associations they host are poorly known, often due to the difficulty of accessing cliffs. Dipterocarpaceae was reported only as the ninth most common family in limestone sites in Sabah (Kiew 1990, 2001), potentially because they were subjected to heavy logging in some places (Whitmore 1998). Nevertheless, it seems clear that the vegetation varies largely between sites and that, in some places, dipterocarps are almost absent while in others they dominate the canopy (Laumonier 1997; Proctor 1995).

Karst mountains have a wide variety of habitats depending on the slope, soil thickness, the nature of the limestone itself, especially its purity, and also the duration of the erosion processes. In table-like, plateaus

30 *Kerangas* are often referred to as 'heath forests'. As noted by Brünig (1996), the term 'heath forest' is quite unfortunate. First used by Winkler (1914) to describe low 'sub-xerophyllous' vegetation on raised beaches in South Kalimantan that reminded him of the heath vegetation of Europe, *Kerangas* are actually physiognomically, structurally, floristically and ecologically wholly different from temperate heath vegetation.

31 See, for instance, the U.S. pilot and operational navigation charts (1:1 million), and the geomorphological maps (1:1 million) by Löffler and Woodward (1974) for Papua New Guinea.

landforms, five morphological units are often distinguished: the bottom of slopes with a 30° to 45° gradient, slopes steeper than 45° beyond the cliffs, crests and crevassed pinnacles, cliffs and “mesa” type summits.

On Sumatra, the structure of forests on the lower slopes at around 500 m in altitude is similar to those found at the same altitude on non-karst hills. The canopy seldom exceeds 25–30 m height, but occasional emergent trees can reach 50–55 m above

the ground. These trees are mainly *Parashorea lucida*, *Pometia pinnata* and a number of hemi-epiphytic figs. The canopy itself, dominated by these same species, is further occupied by many Meliaceae species (*Aglaiia oligocarpa*, *A. argentea*, *A. ganggo*, *Dysoxylum macrocarpum*), Ebenaceae (*Diospyros toposoides*, *D. apiculate*), Anacardiaceae (*Dracontomelon dao*). One can still encounter dipterocarps such as *Vatica* spp, *Shorea ovalis*, *Hopea dryobalanoides* and *H. pachycarpa*.



Photo 5 Limestone outcrops are spread throughout Southeast Asia. They harbor unique very fragile ecosystems. Their high rate of endemism, plus the natural beauty of the scenery, make them a priority for conservation, but most karst mountain ranges are located outside legally protected areas. The main threat affecting limestone formations is their use as quarries for the cement industry and fire (© Yves Laumonier).

On very steep slopes (circa 55°), at an altitude of 800 m on Sumatra, *Shorea platyclados* can still be found well developed, albeit rarely, mixed among others with *Schima wallichii* and other Theaceae. However, on ridges, mesas and karst towers, sharp rocky outcrops are dominant and only larger crevasses retain enough humus to support tree growth. The forest diminishes considerably in size, with a very high density of pole trees with few isolated emergent trees. The floristic diversity diminishes brutally and dipterocarps are absent.

Soils are generally shallow on summits and pinnacles. They are dark reddish-brown and finely textured with a granular structure. Water percolates through them very quickly, which may cause a water deficit even during short dry periods of very humid climate.

2.3.3.6 Formations on ultramafic rocks

One of the clearest examples of the complex links between geology and plants is the varied communities that occur on the ultramafic ('serpentine', 'ultrabasic') rocks (Proctor 2003; Brady et al. 2005). The soils derived from such rocks are very poor in nutrients with a high magnesium to -calcium (Mg / Ca) ratio and high concentrations of chromium, cobalt and nickel (Richards 1996). In Southeast Asia, ultramafic rocks are found in many areas including Sulawesi, the Philippines, and Borneo, and there is a range of different vegetation types associated with them due to a combination of factors like soil chemistry, fire and drought. One of the most beautiful examples is the vegetation on Mount Bloomfield on Palawan in the Philippines, with very distinct vegetation types that differ clearly from the surrounding vegetation at the same elevation (Proctor 1995). Tall, evergreen rain forests rarely occur on these rock-formations, and low trees, shrub and even grassy vegetation prevail instead. In the Malaysian state of Sabah, in the area near Mount Kinabalu, there are ultramafic rock outcrops that, at least in some parts, host tall dipterocarp forests (Proctor 2003). They are also found in New Caledonia linked to the very high level of plant endemism and speciation (Isnard et al. 2016), and outcrops occur as well in the south of Santa Isabel (and adjacent San Jorge) and southern Choiseul in the Solomon Islands (Lee 1969).

2.4 Conclusion

After a brief reminder of the biogeographical settings of the Asia-Pacific region emphasizing complex patterns of species distribution, **Chapter 2** proposed a framework that could be used by the Asia-Pacific Forestry Commission (APFC) for a future eco-floristic vegetation mapping program, with a review of the main forest formations and types characteristics.

As pointed out in **Section 2.3**, forests entail very distinct tree species composition even under very similar climatic and edaphic conditions. Knowledge of species distribution and population dynamics is crucial to local forest landscape conservation and management at the provincial or district levels. Unfortunately, the geographical range of so many plant species, above all in the tropical zone, is still poorly known. New initiatives, such as species-specific vulnerability maps combining information on species distributions, threat exposure and sensitivity are now being developed for Asia (see Fremout et al. 2020 for the method; Gaisberger et al. 2020). Overall, 74% of the most important areas for the conservation of 63 socio-economically important tree species in Indonesia and Malaysia fall outside PAs, with species severely threatened across 47% of their native ranges, while the most imminent threats were overexploitation and habitat conversion, surpassing climate change impact (Gaisberger et al. 2021). Still, many species ranges are non-congruent, there are few sharp floristic boundaries, and most data available is only on presence-absence, while there is a need for data on long-term tree population dynamics. According to Whitmore (1973), "the variation of frequency of occurrence shows how misleading qualitative impressions of species distribution can be, and how important it is that ecological analyses of the rain forest are not based solely on presence or absence". Unfortunately, this statement still remains valid nowadays. It is easier to identify few characteristic species for temperate or seasonal forest formations, but it is much more complex for tropical rain forests. This complexity is reflected in the lack of rigor of some existing classifications alternating structural and floristic criteria in the same framework.

Species-based prioritization, focusing on species that require a large forest area will indirectly protect many others (Cardillo and Meijaard 2012; Suarez-Rubio et al. 2013). This is why this study suggests that large-scale (high resolution) ecological vegetation mapping and related socio-ecological surveys (flora diversity, functional biodiversity, ecosystem functioning, water, soil and indigenous knowledge), integrating altitudinal zonation, edaphic conditions and vegetation, and including floristic information, should become a standard for the region and be applied in each Asia-Pacific country. Such use of eco-floristic-based classification, supported by multivariate analyses of floristics, structural and ecological covariates, will allow the long-term monitoring of populations of species, including conspicuous endemic or endangered species or genera, focusing not only on their occurrence but also on potential indicator species populations to monitor forest health. It appears crucial, as an additional level of classification, to subdivide bioclimatic or edaphic types.

Such a protocol would be initiated at sub-national scale (provincial or district levels) to monitor rather large areas, analyzing larger landscapes, then zooming into some specific areas with higher-resolution satellite data, eventually complemented by drone surveys (Wich and Koh 2018; Nowak et al. 2019). It should be settled in line with existing need assessments for the Hindu Kush Himalaya and Mekong regions (Saah et al. 2019a).

New satellite remote sensing platforms, big data and cloud computing will lead to increasingly easy data acquisition and analysis of vegetation in the future. Very high-resolution satellite sensors (e.g. WorldView-3/-4, TerraSAR-X) already provide potential valuable data for vegetation mapping, but their cost is still prohibitive. LiDAR,³² both terrestrial and airborne, is a technology that is becoming increasingly used in the region to analyze the terrain, forest structure, height and density of stands

and habitats within the forest. LiDAR pulses are affected by weather conditions such as dense fog, smoke, or rain. Unlike LiDAR, radar technology is not affected by adverse weather conditions and hence has been extensively used in remote sensing to assess forest cover in the humid tropics, where cloud cover is a recurrent challenge for optical remote sensing. Although the resolution of images returned by radar may be of lower quality as compared to that returned by LiDAR, it is often used in conjunction with optical remote sensing, especially to study forest degradation (Mitchell et al. 2017; Crowson et al. 2018). For now, the Sentinel satellites series of the European Commission's Copernicus program, with its free data, a temporal acquisition of five days at the equator, and multi-sensor potential combination of multispectral, thermal, and C-band data, offer one of the best solutions in terms of cost/benefit ratio (Le Traon et al. 2019).

The methodology can easily follow standards and protocols mentioned in the IPCC Good Practice Guidance (Penman et al. 2000) and use tools from the OpenForis platform, such as SEPAL (FAO 2021) and Collect Earth (Saah et al. 2019b). Wall-to-wall on-screen visual interpretation of the vegetation made by interpreters who know the field will remain crucial when establishing such large- to very large-scale ecological mapping. At the same time, it will be necessary to organize capacity building and knowledge management at the national level to ensure wide ownership of outputs. Such large-scale ecological mapping will incur costs and require a longer expected average time for ground truthing linked to detailed ecological studies, as well as longer times for data analysis. However, once the baseline data set and maps are available, monitoring every two to four years will become much easier.

While there is still a considerable lack of knowledge today on species distribution and ecosystem functioning, it remains that forests in the Asia-Pacific region are under increasing social and environmental pressures from various threats that need to be addressed without delay. These threats are documented in the next chapter.

32 LiDAR stands for "Light Detection and Ranging". It uses light in the form of a pulsed laser to measure distances

3 Increasing pressures and threats on primary forests: assessing risks

Like in many other parts of the world, natural landscapes and forests in the Asia-Pacific region are under increasing pressure from various threats rooted in environmental, socio-economic and political drivers. This chapter considers the remaining primary forests within a broader landscape perspective. It analyzes the dynamics at stake and the threats to forests within the surrounding landscape matrix (forest patch configuration and composition, planted forests, agricultural land, mining or industrial sites, infrastructures or human settlements) that directly or indirectly impact forest status and trends.

Satchi et al. (2021) recently assessed the vulnerability of humid tropical forests to multiple threats. A similar approach has been made for the western Himalayas (Thakur et al. 2021). Various disciplines have developed their own conceptual models of vulnerability. In his analytical review, Füssel (2007) presented the different approaches and definitions of vulnerability. This chapter follows the ecological approach of Metzger et al. (2005), who assessed the vulnerability of ecosystems to global change using ecosystem services, threats and a time frame. This concept is applied in performing vulnerability (or risk) mapping for two of the main threats in the region, namely deforestation and fires.

Besides changes in forest cover and fragmentation, which are covered in **Chapter 1**, this chapter looks at the increasing pressures and threats faced by forest ecosystems and driven by population growth, migration and conflict, globalization and economic growth, urbanization and infrastructure development, agriculture and planted forest expansion. These threats are

not new (see Yasmi et al. 2017 for the Greater Mekong Subregion), but they are increasingly exacerbated by climate change, pollution and the emergence of infectious diseases in what is perceived as a novel era with new disturbance regimes (Leverkus et al. 2021). Not all of these threats can be mapped, and many are context- or scale-specific. Direct drivers of deforestation include conversion to agriculture, infrastructure expansion and mining, while underlying drivers include a range of political, cultural and socio-economic factors, such as unsound policies, weak governance and poor law enforcement, a lack of investment and financial resources, population growth, migration, and conflict.³³ A brief review of the main biophysical (direct), social and political (underlying) drivers of threats affecting the region is given below, with a model of fire risks and a model forecasting the state of the primary forest in 2050 assessed.

3.1 Biophysical drivers

3.1.1 Climate change

Climate change induces a vicious circle, weakening the resilience and adaptive capacities of remaining forests, leading to a further increase in forest degradation, which causes further changes in the climate. Rapidly accelerating climate change is anticipated for the second half of the century and beyond and is projected to have major implications for biodiversity, ecosystems, farming systems, and PAs. Building upon the Fifth and Sixth

³³ FAO submission to the UNFCCC Secretariat on issues identified in decision 1/CP. 16, paragraph 72 and appendix II, in answer to the invitation of paragraph 5 of draft conclusions UNFCCC/SBSTA/2011/L.25

IPCC Assessment Reports³⁴ as well as relevant literature, this section addresses the impacts of climate change on forests of the region.

Global warming gradually affects forest ecosystems. Climate change will likely increase the intensity and frequency of forest fires, typhoons, floods, droughts, species invasion, pests and disease outbreaks. Due to global warming, climatic zones are shifting poleward and upward in mountainous regions. This climatic shift might occur faster than the migration speed of many plant or animal species and threaten some specific ecosystems such as mountain forests.

How climate change will affect the El Niño-Southern Oscillation (ENSO), one of the world's dominant weather-makers, has been the subject of recent collaborative research (McPhaden et al. 2020). ENSO is instrumental to the understanding of future climate evolution in the Pacific, which has a major influence on precipitation and drought, and thus on fire risk in Indonesia.

Climate projections predict temperature increases in the Asia-Pacific region in the range of 0.5–2°C by 2030 and up to 3°C by 2070. Under the high and very high emissions scenarios outlined in the latest IPCC report (IPCC 2021), global heating is predicted to reach 3.6°C and 4.4°C above pre-industrial levels respectively by the end of the century. Even in the intermediate scenario, global warming of 2°C is extremely likely to be exceeded (IPCC 2021). Temperatures are likely to warm more quickly in the arid areas of northern Pakistan and India and western China. In Central and South-Central Asia, projected temperature changes are noticeable across the region, with a general warming trend seen moving north across the steppes of Central Asia and mountain tops warming. Mean annual

temperatures are projected to increase from an average of 2.4°C to 3.2°C in Central Asia (Zomer et al. 2015a).

A regional climate model for Southeast Asia indicates a projected warming up to 3 °C depending on locations and seasons, with more significant warming at night than daytime for all seasons (Chotamonsak et al., 2011). For East Asia, the annual mean surface air temperature was predicted to increase by 1.8°C and precipitation decrease by 0.2 mm/day for 2030–2049, although the intensity and occurrence of heavy precipitation events will increase over the Korean Peninsula (Lee et al., (2013).

The annual mean temperature is also projected to rise in the Pacific when compared to the 1981–2000 period (1990 baseline level): Annual mean temperatures would increase for all countries in the region, with the 2070 levels consistently higher than the 2050 levels (ADB 2013). Warming is projected to exceed 2.3°C by 2050 relative to the pre-industrial era. PNG, Solomon Islands, Timor-Leste and Vanuatu are expected to experience temperature increases of more than 2.5°C on average by 2070, with some areas of these countries experiencing an increase of nearly 3°C in the same period relative to 1990 levels (ADB 2013). A recent critical analysis and review of the models published over the past five decades found that these models were highly accurate in predicting subsequent global mean surface temperature (GMST) changes (Hausfather et al. 2020).

Furthermore, climate change is likely to further alter the availability of water resources. In the driest areas of Mongolia and northern China, the frequency of drier years significantly impacts the water deficit and related insect and fire threats. Models project increases in rainfall throughout much of the region, including greater rainfall during the summer monsoon period in South and Southeast Asia. However, rainfall is projected to decline during the winter monsoon, which suggests increased aridity (Preston et al. 2006). More intense tropical cyclones and ocean warming are other potential consequences of climate change (Hijioka et al. 2014).

34 In particular, the contribution of Working Group (WG) II, part A sectoral aspects and part B regional aspects, chapters 24, 25 and 29 (IPCC 2014a, 2014b), and IPCC 2021. Climate Change 2021: The Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report.

Although many model uncertainties remain, the global sea level in the region is expected to rise by approximately 3–16 cm by 2030 and up to 50 cm by 2070 (Preston et al. 2006). Central estimates of the long-term mean sea level rise in Singapore by 2100 were projected to be 0.52 m and 0.74 m under RCP4.5 and RCP8.5³⁵ scenarios respectively (Cannaby et al. 2016). This global sea level rise, in conjunction with regional sea level variability, will affect all coastal areas of the Asia-Pacific region, putting many mangroves at risk and submerging low-lying atolls. Large low-lying agricultural plains and coastal Asian cities such as Jakarta and Bangkok will also be badly affected, with flood risk even underestimated. Kulp and Strauss (2018) developed a new DEM model (COASTDEM) focusing specially on coastal areas, which allows much more precise modeling of the sea level rise. Indeed, recent coastal land LiDAR measurements reveal the greatest sea level rise vulnerability in the tropics, especially in Asia (Hooijer and Vernimmen 2021), with millions of people affected.

The outcomes of climate change on biodiversity and ecosystem services are likely to differ between forest types and geographical areas. Due to the low resolution of most climate change models, it is difficult to predict actual levels and locations of future changes in biodiversity, and the indiscriminate use of climate envelope methods irrespective of species sensitivity to climate may be misleading and in need of revision (Beale et al. 2008).

Research on the impact of climate change on forest ecosystems has so far focused mainly on mangroves (Ward et al. 2011), including their resilience capacity (Krauss et al. 2013), or mountain forests of the Himalayas (Zhao et al. 2011; Corlett and Westcott 2013; Gaire et al. 2014; Hamid et al. 2020) and small islands of the Pacific (Loope and Giambelluca 1998). Zomer et al. (2015b) explored the impacts of projected climate changes on the vegetation of the Asian Highlands, notably along the great arc of the Himalaya, the high-elevation Tibetan

Plateau, with case studies presented from southwestern China, Nepal, Bhutan, and Central Asia, and predicted significant and increasing biophysical and biological perturbation for biodiversity, ecosystems and ecosystem services. Nwee et al. (2020) and Pomoim et al. (2021) assessed the impact of climate change on the forest protected area networks of Myanmar and Thailand. Results from their geospatial modeling and analyses show that large spatial shifts in bioclimatic conditions can be expected across all bioclimatic zones. Potential impacts include an upward shift in the mean elevation of bioclimatic zones in montane regions, expansion of the lower elevation zones into higher elevations, and potential disappearance of habitats with highly specific bioclimatic conditions.

Due to the lack of long-term in situ monitoring experiments, many uncertainties remain regarding the particular impacts of climate change on lowland and hill tropical rain forests (Ostendorf et al. 2001; Vogt et al. 2016) or peat swamp forests (Cole et al. 2015). In association with rising temperatures, changes in rainfall and evapotranspiration will affect photosynthesis and growth (Clark 2004). Major gaps in our current understanding of key issues still exist, including the thermal tolerances and acclimation potential of tropical species and processes (Corlett 2011).

3.1.2 Fires

Forest fires are a well-known threat in the region (Wang et al. 2019). In Mongolia and northern China, wildfires constitute a major factor that determine the spatial and temporal dynamics of forest ecosystems. The highest fire hazard is found in the submontane larch (*Larix sibirica*) and pine (*Pinus sylvestris*) stands growing on seasonally freezing soils, found in the Khentey and Khubsugul foothills (Goldammer and Mutch 2001). In the Himalayan hills and mountains, forest fires can be difficult to control due to the challenges of access by both land and air. In the Western Himalayas, most accidental fires from March to June are due to the accumulation of fire fuel material from chir pine needles (*Pinus roxburghii*) on the forest floor (Suresh Babu et al. 2016; Dar et al. 2017). In Australia, although bushfires are known as a natural phenomenon that contributed

35 RCP stands for representative concentration pathway, a classification of climate scenarios based on the expected level of radiative forcing in 2100 and developed for the IPCC Fifth Assessment Report (IPCC 2013).

significantly to the shaping of the country's forest and vegetation, notably the predominant fire-climax *Eucalyptus* forests, their intensity and higher frequency under climate change will cause significant challenges for people and nature alike. In Indonesia, infamous peatland fires now occur almost every year, with potential catastrophic episodes during El Niño years (Legg and Laumonier 1998; Page et al. 2009).

The MODIS instrument aboard the Terra and Aqua satellites of the USA National Aeronautics and Space Administration (NASA) has been used to scan the Earth's surface to monitor fires on a daily basis for almost 15 years. Since 2012, the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the National Oceanic Atmospheric Administration (NOAA) & NASA Suomi National Polar-orbiting Partnership (SNPP) weather satellite has contributed to this effort by producing higher-resolution images of the Earth's surface. While MODIS had a 1,000 m resolution per pixel, VIIRS has a 375 m resolution per pixel. This higher resolution enables VIIRS to detect smaller fires and more precisely delineate fire perimeters. VIIRS is a well-suited tool for monitoring fire activity that enables scientists and firefighters to more accurately model and predict shifts in fire behavior. VIIRS also allows the estimation of GHG emissions released into the atmosphere as a result of a fire.

Fire risks were assessed for three areas with frequent forest fires: Indonesia, Australia and the Himalayas using the random forest regression algorithm (**Box 5**).

The results (**Figures 13 to 15**) showed that the most influential variable in all regions was the distance from previously burned areas. In countries with large proportions of burned areas, fires can be categorized into anthropogenic (human-caused) fires or (natural) seasonal wildfires. In regions with mainly anthropogenic fires, such as Nepal, Indonesia, Malaysia, Cambodia, Myanmar, Thailand, and Viet Nam, distance from deforestation was also an important variable, linked to agricultural practices such as swidden agriculture (land clearing through burning) and land opening for large industrial plantations. It was also reinforced by variables

Box 5 Method to separate fire degraded forests from intact forests

The Random Forest Regression model has been successfully applied to assess fires probability (Milanović et al. 2021; Oliveira et al. 2012) and to identify the most significant determining factors (Guo et al. 2016; Ma et al. 2020). A regression tree is built by recursively partitioning the sample into more homogenous groups. Once a tree has been built, the response for any observation can be predicted by following the path from the root node down to the appropriate terminal node of the tree, based on the observed values for the splitting variable. The predicted response is the final value taken from the average of each terminal node of each decision tree (Grömping 2009).

We used MODIS MCD64A1 burned area monthly products (Giglio et al. 2016) and accumulated it to get maps of burned areas for 2000–2010 and 2011–2020. We choose filtered burned areas with a confidence level greater than or equal to 80%. Predictor variables used include SRTM terrain model (Hennig et al. 2001), WorldClim climatology data (Fick and Hijmans 2017), distance from roads (OpenStreetMap), distance from human settlements (Pesaresi and Freire 2016), distance from previous burned areas (burned areas in 2000–2010 for calibration, burned areas in 2011–2020 for prediction), distance from previous deforestation, and peatland area (Xu et al. 2018). We ran the fire probability and prediction model and identified important driving factors for each country. The random forest regression model was performed using R software packages 'raster' (Hijmans 2021), 'randomForest' (Liaw and Wiener 2020), 'usdm' (Naimi et al. 2014), and 'Boruta' (Kursa & Rudnicki 2010).

such as distance from road and distance from human settlements (lower accessibility to forest). Meanwhile, in regions with mostly seasonal wildfires like Australia, climatology variables appeared more determinant than topographic or anthropogenic disturbance variables. The importance of tropical peatland fires, which account for the most devastating air pollution and health-related problems for the population of Southeast Asia, remains striking (see **Table 8**).

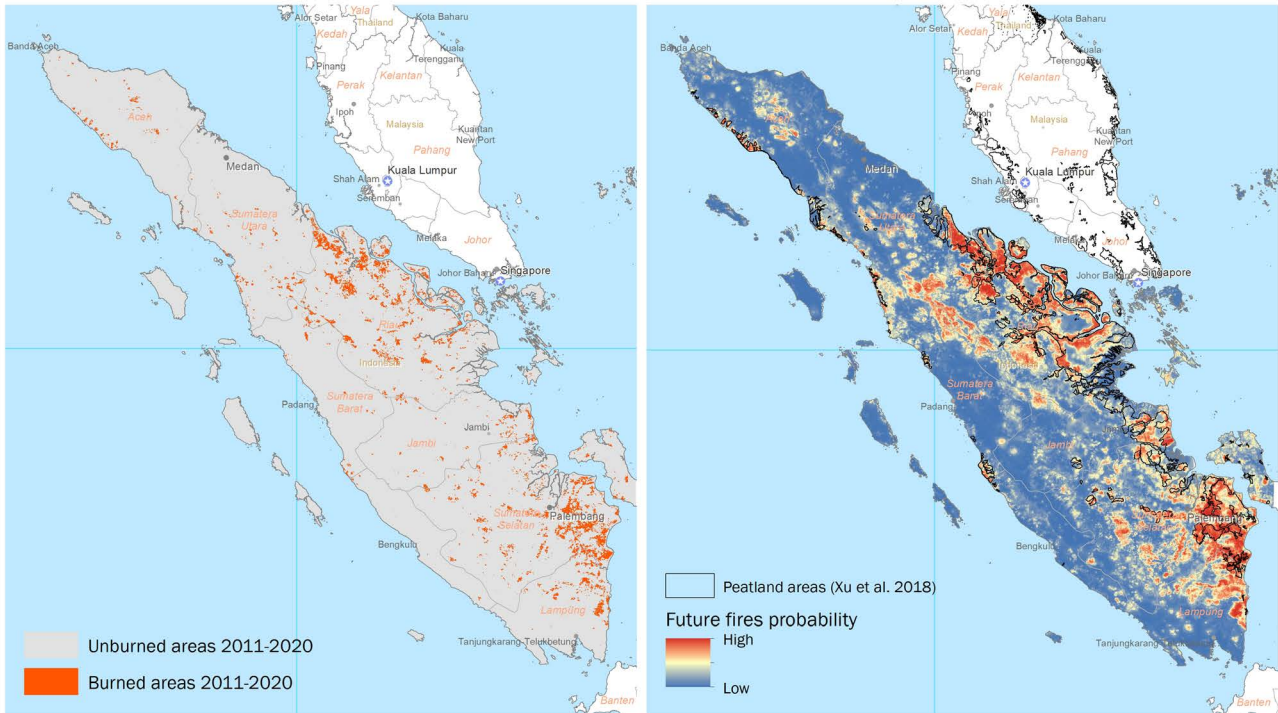


Figure 13 MODIS MCD64A1 burned areas 2011-2020 (left), and fire risk probability in Sumatra, Indonesia (right). Source: Authors

Table 8 Burned areas in the tropical peatlands of the region during 2001-2010 and 2011-2020 periods, based on MODIS MCD64A1 burned areas product. The Indonesian part of Borneo is at very high risk of fire occurrence.

Region	Peatland area (Xu et al. 2018) in 1000 hectares	Percent of burned area in peatlands 2000–2010	Percent of burned area in peatlands 2011–2020	Percent of peatland area with high risk ($p \geq 0.9$) of future fire
Indonesian Borneo	4,959	12.5%	12.9%	18.1%
Malaysian Borneo	1,524	7.3%	5.2%	2%
Sumatra, Indonesia	6,433	9.8%	10.4%	5.3%
Malaysia Peninsula	749,699	4%	5.3%	2.2%
West Papua, Indonesia	3,693	1.6%	2.2%	4.4%

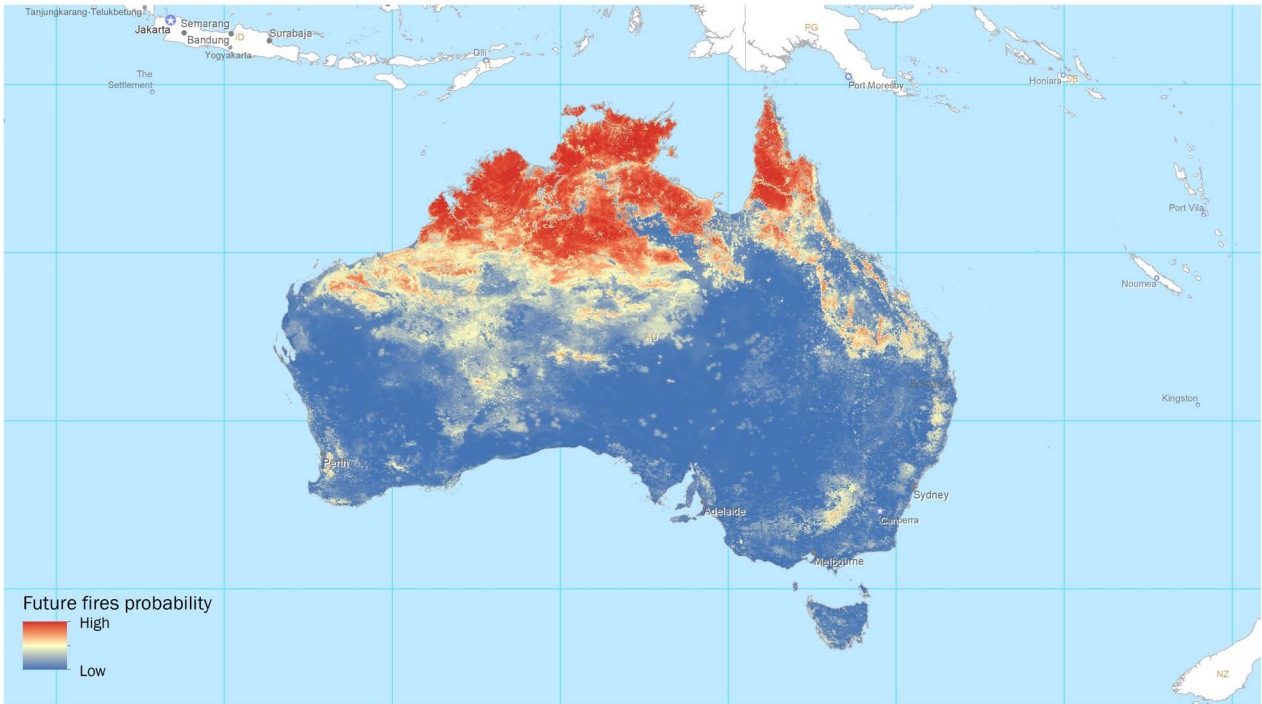


Figure 14 Fire risk probability in Australia. Source: Authors

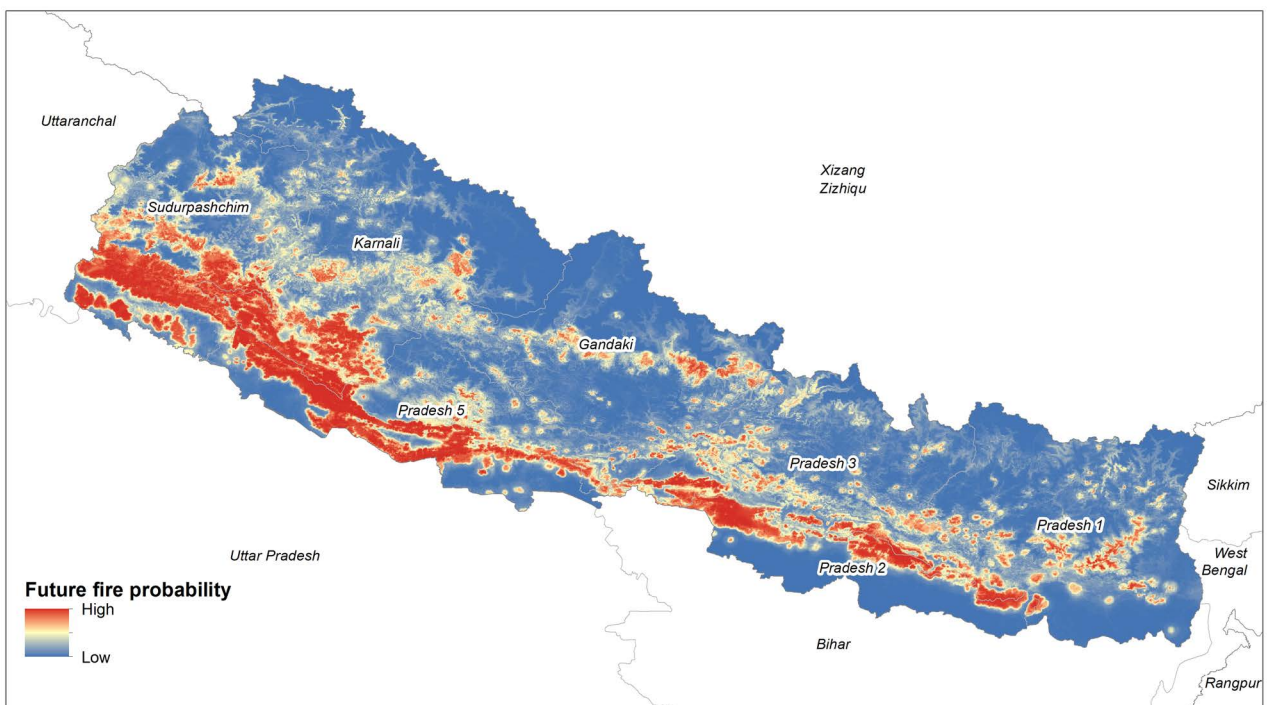


Figure 15 Fire risk probability in Nepal. Source: Authors

3.1.3 Invasive species

The number of invasive alien species (IAS)³⁶ is rising across the Asia-Pacific region. Most of these species, especially tree species, are introduced for economic reasons or for forest rehabilitation purposes. The Asia-Pacific Forest Invasive Species Network (APFISN) was established as a response to the challenges posed by IAS to the sustainable management of forests. Almost all ecosystems are affected and invasive insect pests are often associated with introduced tree species. In the region, some ill-conceived programs of reforestation have often promoted IAS that can affect regeneration of primary ecosystems (Chazdon and Brancalion 2019; Seddon et al. 2019; Seddon et al. 2020). The invasion of the European woodwasp (*Sirex noctilio*) appeared to be promoted by fungal infections in the Mongolian pine trees (*Pinus sylvestris*) of northern China (Wang et al. 2021). In Australia, old-growth forests have been affected by outbreaks of both invasive grasses and animal species.

Islands (including forest fragment 'islands') are particularly sensitive to IAS. The notorious invasion of the island of Guam by the brown tree snake in the 1950s led to the destruction of most mammal and bird populations (Mortensen et al. 2008). In highly-populated Java, national parks are affected, although alien plants appear to remain confined to trails in dense forest habitats (Padmanaba 2007).

Forest degradation and fragmentation increase the capacity of alien species to invade (Simberloff et al. 2002), and highly diverse ecosystems such as tropical rain forests appear to be more resilient than their temperate counterparts (Balvanera et al. 2006). A number of examples of introduced trees invading temperate forest ecosystems have been documented (Richardson 1998; Paine 2006), but rain forests, especially on the small islands of the Pacific, are not

spared, as shown by examples such as the invasion of Hawaiian forests by two non-native tree species: *Fraxinus uhdei* and *Morella faya* (Asner et al. 2008). The African tulip tree (*Spathodea campanulata*) is another prominent invasive species capable of transforming native forests into near monocultures and making forestry and agriculture very difficult in PNG, Fiji and other Pacific Islands. In Queensland (Australia), it is known to be toxic to Australian native stingless bees. It has now been spotted in Sri Lanka. Another example is the Ecuador laurel or salmwood (*Cordia alliodora*), which was introduced as a forestry tree to Vanuatu in the 1970s and has since become dominant. It is considered a serious pest in locations where it has been planted (see Vanuatu's NBSAP 2018–2030³⁷).

IAS are addressed in all the national biodiversity strategies and action plans (NBSAPs) in the Asia-Pacific region, and most countries have identified IAS as a major threat to their biodiversity. Several countries such as New Zealand have also expressed concern that climate change can cause IAS to become more widespread.

3.2 Socioeconomic drivers

3.2.1 Population and economic growth

According to the UN medium-variant projection, the world's population is expected to grow from 7.7 billion in 2019 to 8.5 billion in 2030 (a 10% increase) and 9.7 billion in 2050 (a 26% increase). In the meantime, the population of the Asia-Pacific region³⁸ is expected to grow, albeit at a slower pace, from 4.3 billion in 2019 to 4.6 billion in 2030 (a 7.5% increase) and 4.9 in 2050 (a 13% increase). The population of Eastern and South-Eastern Asia is projected to peak at 2.4 billion around 2038, while the population of Central and South Asia could peak later,

36 An "invasive species" is a species that is non-native (or alien) to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Iannone et al., 2021)

37 See: <https://www.cbd.int/doc/world/vu/vu-nbsap-v2-en.pdf>

38 The figures given here embrace the UNDESA regions of: Oceania (incl. Australia / NZ), Southern Asia, Eastern and South Eastern Asia, and corresponds broadly to the geographical scope of this study.

around 2065, at just under 2.6 billion people. The population in Oceania is expected to continue to grow until the end of the century (UNDESA 2019).

An important rural-urban migration is observed in many countries, leading to ageing and feminization in rural areas. This could have positive implications for forests as pressure is reduced. Moreover, the remittance of wages from migrant workers could also impact land use, forest cover and conditions. However, in many cases, conflict and disasters are leading to migration and displacement (see, for instance, **Box 4.7** about refugees and forest degradation in APFSOS III). Outmigration can also facilitate land grabbing by big companies.

Population growth and economic growth, particularly in middle-income and developing countries, are driving a considerable increase in demand for material products. The recent OECD global material resources outlook to 2060 predicts a considerable increase in the consumption of all material resources (OECD 2019). Globally, the use of material resource grew from 27 billion tonnes (Gt) to 89 Gt per year between 1970 and 2017. The OECD outlook foresees that in the absence of new policies, it could reach 167 Gt in 2060. This growth is reflected in all major categories of materials. It will bring significant environmental consequences affecting many economies and societies. The consumption of biomass resources is expected to increase from 22 Gt in 2017 to 37 Gt by 2060. Within that category, wood demand is expected to grow faster, driven by industrial activities and construction, and fuelwood even more. All of these increases in material resource use are particularly pronounced in Asia, driven by economic growth, first in the BRICS,³⁹ then in other developing countries. Changing lifestyles and changing consumption patterns, including increasing consumption of animal products, are driving an increase in food and feed demand, fostering agriculture expansion, accelerating deforestation and increasing the pressure on remaining forests.

3.2.2 Infrastructure development, urban sprawl and mining sector expansion

Infrastructure development, urban sprawl and expansion lead to forest fragmentation and degradation in still forested landscapes. In Indonesia, for instance, the plan to move the capital city to central Kalimantan will have major impacts on remnant forest ecosystems of the selected site. Although increased urbanization, which draws populations from rural areas should have a positive effect on forests, it leads often to the aging of the remaining rural population, leaving rural areas more prone to land-grabbing by big companies in search of land for agricultural expansion.

One of the greatest threats to forests, especially primary forests, are road and railway construction and expansion. Roads in the Asia-Pacific region, including illegal or unofficial roads, have a major impact on forest loss. Since the work of Barber et al. (2014) on the Amazon, many other studies have confirmed that deforestation is much higher near roads and rivers (see Alamgir et al. 2019; Soan et al. 2019; Laurance 2019 for the impact on planned roads in the heart of Borneo and a highway megaproject in the heart of New Guinea's rain forest). The expansion of railways (e.g. for China's Belt and Road Initiative) is also having a major negative impact on forests, especially in Cambodia, Lao PDR, Myanmar, and Viet Nam. Conversely, a lack of accessibility can become a conservation issue, limiting, for instance, fire control capacities. We use the OpenStreetMap dataset⁴⁰ to assess the level of this threat against our forest maps.

In many Southeast Asian and Hindu Kush Himalayan countries, large-scale hydropower projects and solar energy plants are consuming substantial forest areas (ICIMOD 2015). Concerns have been expressed over the long-term economic viability and ecological costs of such projects where the alteration of flow regimes will affect downstream ecosystems (Bandyopadhyay et al. 2016). One of the reasons behind the decline in dry-season flows and consequent

39 i.e. Brazil, Russia, India, China and South Africa.

40 OpenStreetMap. See: <https://www.openstreetmap.org>

water conflict between Bangladesh and India is the construction of as many as 25 hydropower projects in the Indian states of Sikkim and West Bengal.⁴¹

In addition, mining operations play a direct role in forest landscape destruction in many Asia-Pacific countries, including on the small islands of the Pacific. Given the burgeoning demand for minerals such as copper, gold, nickel, cobalt and bauxite often found in intact forest landscapes and PAs, it is crucial that the mining sector's forest impacts are better understood and addressed (Bradley 2020). Besides large corporate operations, artisanal and small-scale gold mining have considerable impacts on the environment and health of local communities. While understanding the risk, many smallholder miners are not interested in the slow and low returns of smallholder agriculture and are even less attracted by the low pay, conflicts, and poor labor conditions in the expanding plantations taking over Indonesian landscapes.⁴² In 2016, artisanal and small-scale gold mining in Indonesia produced USD 5 billion of gold a year, accounting for about 7% of total gold production. There were as many as 300,000 artisanal gold miners working at 1,000 informal sites across the country.⁴³

In addition, urbanization, mining or industrial activities can generate soil, water and air pollution in forest ecosystems. In some areas, forest landscapes have become dumping sites for garbage and wastewater. A review assessing global issues on waste management showed how several sources of pollution are affecting the environment, population health, and sustainable development in developing countries (Ferronato and Torretta 2019).

3.2.3 Logging

Asia-Pacific forests have been extensively logged. At least half of the NBSAPs in the region cite logging as a threat to biodiversity. Although it is recognized that most of the fauna of the region can persist in logged-over forests (Meijaard et al. 2005; Wilcove et al. 2013; Gaveau et al. 2013), most logging operations have been unsustainable, especially in the tropics (Edwards et al. 2014). Illegal logging by concessionaires harvesting outside the approved harvesting blocks, or not respecting species or size classes, or by organized gangs that enter forests where other parties hold concessions, or by individuals or groups from local communities that harvest trees for their own use or local sale without any form of permit or license, have been a rampant issue in the Asia-Pacific (Mir and Fraser 2003; Smith et al. 2003) and is still a widespread and major threat nowadays. Illegal timber trade in the Asia-Pacific region was estimated to be worth USD 11 billion a year in 2018, equivalent to about 30% of the total regional trade in wood products. Illicit logging in the region remains widespread, the major regional producers being Indonesia, Malaysia, Lao PDR, Myanmar, Cambodia, PNG and the Solomon Islands.⁴⁴

While land tenure in PNG is a unique case (Armitage et al. 1998; Brown et al. 1990; Mandawali 2021), with most land managed under customary rules, over-logging and illegal logging remain major threats, especially since the country's GDP depends heavily upon logging. Over the last decade, PNG has become the world's largest exporter of tropical timber. A crackdown by the government came in mid-2021 after reports exposed massive tax evasion by logging companies.

Furthermore, the establishment of logging road networks contributes significantly to fragmentation and access for immigrant settlers, hunters and illegal loggers. Once depleted, logged-over forests are invariably converted to plantation crops, often by the same company that had previously operated timber extraction.

41 Ghosh N. 19 May 2017. Sharing Teesta's a murky business. *The Hindu Business Line*. See: <https://www.thehindubusinessline.com/opinion/sharing-teestas-a-murky-business/article9707179.ece>

42 See: <https://www.newmandala.org/the-gold-farmers/>

43 See: <https://www.asiapacific.ca/blog/artisanal-and-small-scale-gold-mining-sector-problems-and>

44 See: https://globalinitiative.net/analysis/tainted_timber/

3.2.4 Agriculture expansion

The eradication of hunger remains a global challenge and agriculture has expanded to meet the demand of a burgeoning population expected to exceed 9 billion by 2050.⁴⁵ Agriculture, including both smallholder farmers and large corporate plantations, is the planet's largest form of land use, covering almost 40% of the Earth's land surface⁴⁶, and agriculture expansion remains a major threat to Asia-Pacific forests.

Swidden agriculture is an ancestral land use system widely practiced across the Asia-Pacific region. Trends show that this traditional practice is declining as farmers are now shifting towards more intensive farming systems, or alternatively, abandoning agricultural farming altogether as a result of policy, market and farmer preferences dynamics (de Jong et al. 2001; Potter and Badcock 2006; Padoch et al. 2007; Cramb et al. 2009; Rerkasem et al. 2009; van Vliet et al. 2012). Yet in other areas, farmers are still maintaining the swidden system (Nielsen et al. 2006) but often making changes from the original practice, notably shortening the fallow length (Schmidt-Vogt et al. 2009, Huijun et al. 2002, Padoch and Pinedo-Vasquez 2010).

The pros and cons of such a system on society and environment have been largely documented for almost a century and are still debated (Mertz 2009; Dressler et al. 2017; Li et al. 2014). Burning activities associated with swidden agriculture have been criticized for eroding biodiversity and ecological functioning of the land. Several countries have blamed the practice for causing deforestation, which has led to its ban in several Southeast Asian countries. Negative perceptions, mainly from agricultural departments in the 1990s, stem from the idea that this system did not significantly improve the economic condition of poor upland communities but caused environmental degradation (Brady 1996; Kerkhoff and Sharma 2006). On the contrary, many researchers depicted swidden agriculture

as an ideal way of farming in the tropics while conserving the environment and biodiversity (Russell 1988; Cramb 1989; Finegan and Nasi 2004; Mertz et al. 2009; Teegalapalli and Datta 2016), arguing that the ban is based on limited and narrow research that does not take into account the diversity and complexity of swidden agricultural systems, a deeply cultural and traditional practice that has been adapted and shaped by local communities.

With increasing population densities, short-cycle shifting cultivation replacing traditional long-cycle swidden agriculture is now threatening even more remote areas of higher elevation since most accessible areas are already cultivated. Shifting cultivation, with a shortened fallow period, is a major threat to forest ecosystems in almost all countries (Henley 2011; Lal 2015).

Above all, large-scale commercial agriculture remains a major threat to Asia-Pacific forests, with agricultural commodity tree crops (oil palm, rubber, coffee, cocoa, spice trees) and tree plantations for the pulp and paper timber industry as the main players. In Southeast Asia as a whole, 73% of deforestation is commodity-driven (permanent farming and – to a much smaller extent – mining), 19% is due to logging and 8% due to shifting agriculture. In Cambodia, companies grow rubber, sugar and pulpwood on large economic land concessions granted by the government. As well as causing deforestation, such activities have also displaced rural communities (EPRS 2020). In Indonesia and Malaysia, oil palm expansion (large enterprises and smallholders) has caused forest and biodiversity loss and habitat fragmentation, CO₂ emissions from land use change, intense soil erosion during the immature phase of tree crops, water pollution from fertilizer application, as well as complex social impacts on local communities (Hartemink 2006; Obidzinsky et al. 2012; Savilaakso et al. 2013; Jelsma et al. 2017; Rulli et al. 2019), sometimes even spreading into PAs, or on unsuitable soils, such as on peatlands, which are prone to regular flooded episodes in the future (Sumarga et al. 2016). While large private enterprises are responsible for the bulk of environmental impacts, the smallholder oil palm sector exhibits higher annual rates of expansion (Lee et al. 2013).

45 See: <https://population.un.org/wpp/>

46 See FAOSTAT: <https://www.fao.org/faostat/en/#data/RL> (accessed on 2 March 2022).

3.2.5 Loss of traditional knowledge and wisdom

Much of the region's high biodiversity is located in the territories of Indigenous Peoples. Youth outmigration from rural areas is affecting the transmission of traditional knowledge, which is often critical for sustainable forest landscape management. The loss of traditional knowledge is an important threat facing primary forests. Cultural and religious dimensions once had an important role in forest conservation, the sacred character of a forest being often a sufficient protection in itself. However, this is changing in many areas due to economic development, outmigration and the loss of traditional wisdom (Kotru et al. 2020; Pingault et al. 2021a).

Since the IPCC's Fifth Assessment Report, the need to tap into Indigenous knowledge when adapting to climate change has been put forward (Galloway McLean et al. 2012), albeit with limited progress in terms of policy change (Ford et al. 2016). While widely advocated (IPBES 2019; ICCA Consortium 2021), it remains a struggle to integrate Indigenous knowledge into policy. The traditional knowledge and rights of local communities are critical to addressing the crisis of biodiversity loss. Dawson et al. (2021), in their research with Indigenous Peoples in Peru, Kenya, India and China, showed that Indigenous values and worldviews promote balance with nature and social equity, but these values face multiple threats. Deforestation and degradation are lower in Indigenous Lands than in non-protected areas across the tropics, broadly performing comparably to PAs (Sze et al. 2021). During the COVID-19 pandemic, Indigenous mountain communities from Peru to Kenya to Tajikistan, Bhutan and PNG were able to ensure the food security and health of their communities thanks to their localized, biodiverse, circular food systems founded on ancestral knowledge and cultural values.⁴⁷

In many Asia-Pacific countries, traditional knowledge of local communities and Indigenous Peoples is recognized as

very important for the conservation of primary forests (Raymond et al. 2010). The empowerment of local people, secured customary forest tenure, inclusive management and integration of scientific knowledge with local wisdoms through participatory action research are some success factors identified for healthy forest landscape management in Southeast Asia (Suksai et al. 2020; Markphol et al. 2021).

3.2.6 Land grabbing, land tenure conflicts and war

Tensions and conflicts over natural resources (land, forest, and water), land tenure and use rights, can lead to armed conflicts and even war, which in turn impact biodiversity and forest ecosystems (HLPE 2011). Because many remaining forests are situated along international borders, their conservation requires international cooperation. The transfer of land is a major threat, especially land grabbing by major players such as mining, oil palm, rubber estate companies (Rulli et al. 2013; Suhardiman et al. 2015; Semedi and Bakker 2014), and Indigenous Peoples are often misled by plantation companies (Huesca 2016).

Conflicting land uses and mandates, the incoherence of policies across sectors (environment, agriculture, economic development) and across scales (at national, sub-national and local levels), corruption, weak governance and weak law enforcement, in particular regarding land access and tenure rights, are also detrimental to primary forests. In the Philippines, for example, primary or natural forests can be classified under two legal land classifications: timberlands and national parks; management regimes may differ based on the land tenure rights issued for the purpose. Conflicts may arise if customary and official tenure rights overlap and land tenure decisions focus only on the official land status rather than institutions collaborating with each other in the overlapping areas where forests are located.⁴⁸ Other critical governance issues in the region include the misalignment of national regulations on forest protection and timber concessions. The main concern expressed by forest

47 See: <https://www.iied.org/indigenous-food-systems-prove-highly-resilient-during-covid-19>

48 Consultation – Primary Forests: Governance tools for conservation and sustainable forest management.

stakeholders participating in the preparation of APFSOS III was that resource degradation would be exacerbated by a weakening of governance, with increased corruption or the failure of the rule of law (FAO, 2019).

3.2.7 Lack of capacity, policy and regulatory framework

Many countries still lack the needed technology to map the areas to be protected and the capacity needed to better manage their forest landscapes, including multi-stakeholder land use planning. Inappropriate policy and regulatory frameworks have been identified by the NBSAPs of many Asia-Pacific countries as constraints to the good governance of biodiversity conservation, including for forest resources and PAs. Some policy and regulatory frameworks are outdated, while others conflict with each other. Others yet need to be better supported by enforcement rules, regulations and authority. Nepal's NBSAP 2014–2020⁴⁹ cites poor governance and unclear administrative jurisdictions as some of the factors identified as underlying threats to forests. More specifically, weak enforcement of the law and regulatory mechanisms is considered one of the main underlying factors behind deforestation and forest degradation and is related to conflicting sectoral policies, poor coordination, and inadequate capacity of forestry sector institutions. A number of NBSAPs have taken specific actions relating to governance in PAs, such as Malaysia's NBSAP entitled "National Policy on Biological Diversity 2016-2025".⁵⁰ Action 6.4, "improve the effectiveness of PA management", includes reviewing existing legislation governing PAs to ensure effective management and promoting partnerships and co-management with Indigenous Peoples and local communities to safeguard and monitor PAs, among other sub-actions.

In some countries, there is still an excessive focus on timber production rather than looking at forests in their entirety, especially

in PNG and the Solomon Islands. While many ministries of forestry pursue a management approach that ensures equal emphasis on forest production and forest protection/conservation, many governments do not feel compelled to fund PA management from their own domestic financial resources since donors are often keen to support it.⁵¹ Another challenge is a lack of synergy between different ministries involved in forest landscape management. For example, in Thailand, while no conflict of instruments, rules or norms has been identified, there is a big gap in coordination to implement these instruments.⁵² There is a need to build synergies across sectors, including agriculture, water management and land use planning. A more integrated landscape approach should be adopted (see **Chapter 4**).

3.3 Projecting the evolution of primary forests of the Asia Pacific, looking for priority areas for conservation

Using results from **Chapters 1** and **2**, as well as a selection of determinant drivers of threats, future deforestation risks and a forecast of the situation in 2050 have been modeled to identify priorities for actions in managing primary forest landscapes. Deforestation probability models based on machine learning are generally run using a logistic regression approach (Vieilledent et al. 2013; Pujiono et al. 2019; Gaveau et al. 2021), the Random Forest algorithm with a probability output (Cushman et al. 2017), or other machine learning algorithms such as cellular automata (Fuller et al. 2011; Sharma et al. 2019; Voight et al. 2019).

The "forestatrisk" Python package (Vieilledent 2021) was used to model the spatial probability of deforestation risk and predict probable forest cover in the region in 2050. The workflow of the procedure is briefly described in **Box 6** and **Figure 15**, and mapping results are illustrated in **Figures 17** to **19**.

49 See: <https://www.cbd.int/doc/world/np/np-nbsap-v2-en.pdf>

50 See: <https://www.cbd.int/doc/world/my/my-nbsap-v2-en.pdf>

51 Consultation – Primary Forests: Governance tools for conservation and sustainable forest management.

52 *Ibid.*

Box 6 Workflow of the forest at risk model in assessing probabilities of deforestation.

The *forestatrisk* package uses georeferenced raster files by blocks of data, making calculation fast and efficient and enabling to cover large geographic areas with high spatial resolutions. This package uses an intrinsic conditional autoregressive (iCAR) binomial logistic regression function, a logistic regression model that includes aspects of randomness (spatial autocorrelation) and uses Bayes’ theorem as an estimator. Spatial randomness is one of the advantages of this package as it can strengthen the model through residual spatial variability mapping, which may not be represented by the explanatory factors used. The model for forecasting future forest cover, illustrated in **Figure 16**, uses the deforestation maps of **Chapter 1** and drivers of threat such as distance to roads, distance to settlements, distance to deforestation (2000–2010 and 2010–2020) and distance to forest edge, weighted by altitude and slope.

Road networks are one of the main factors leading to deforestation and forest degradation (Poor et al. 2019; Barber et al. 2014; Newman et al. 2014). The distance to roads and distance to settlements were calculated using the OpenStreetMap (OSM) dataset,¹ devoid of the foot path class, and the Global Human Settlement Layer (Pesaresi et al. 2015), with a distance buffer of 100 m. Altitude and slope were derived from the SRTM dataset (Farr et al. 2007). The DEM spatial resolution of 30×30 m was converted to 100×100 m. Slope and altitude can, for instance, influence the risk of deforestation, affecting plantation companies’ choice of site development, but not necessarily local swidden farmers.

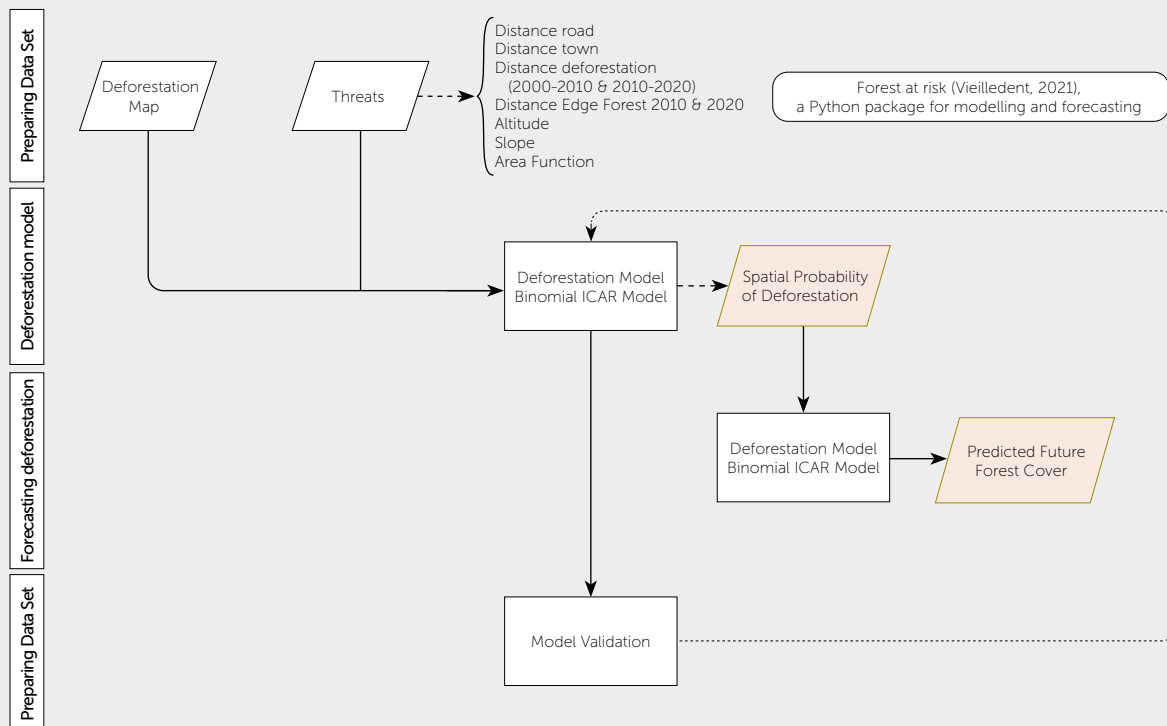


Figure 16 Forest at risk model workflow. Source: Authors

1 See: <https://www.openstreetmap.org/#map=5/-2.546/118.016>

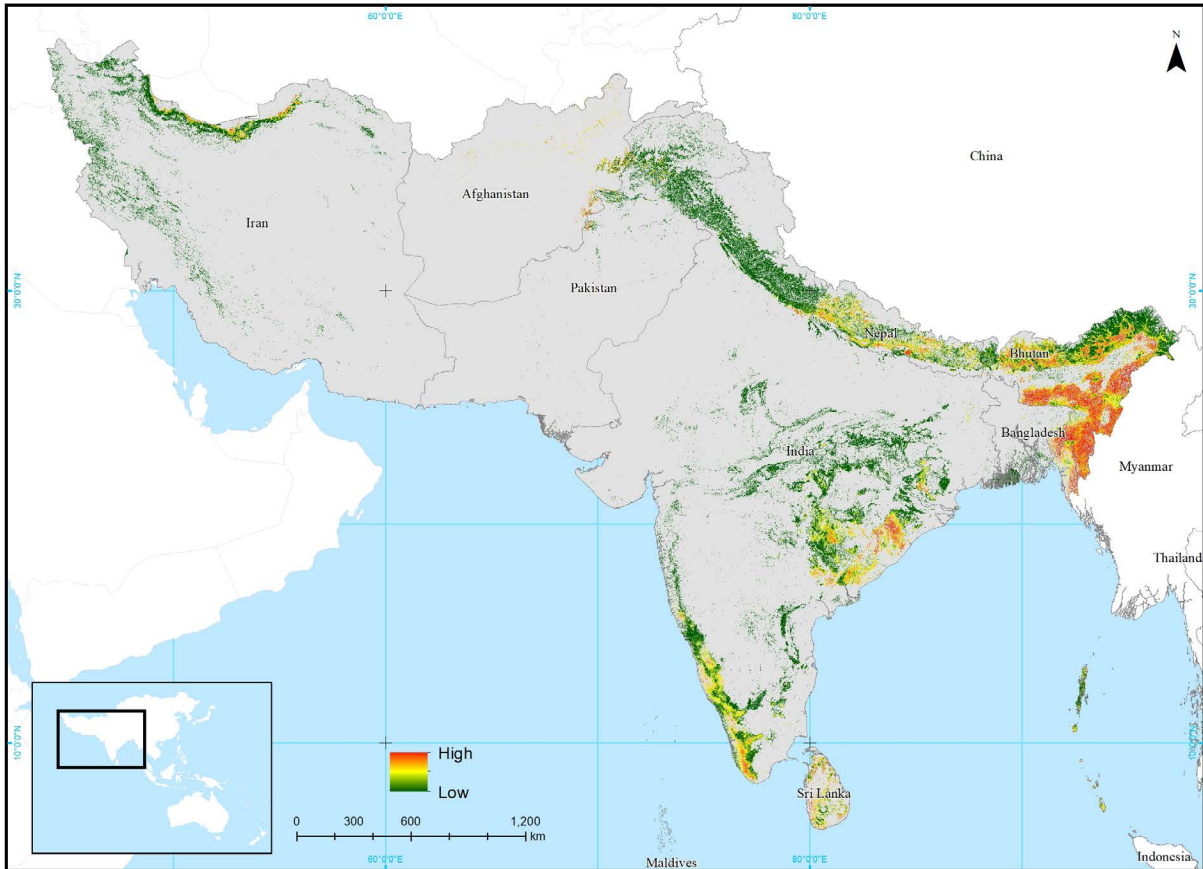


Figure 17a Probability of deforestation risk for 2050 in South Asia. Source: Authors

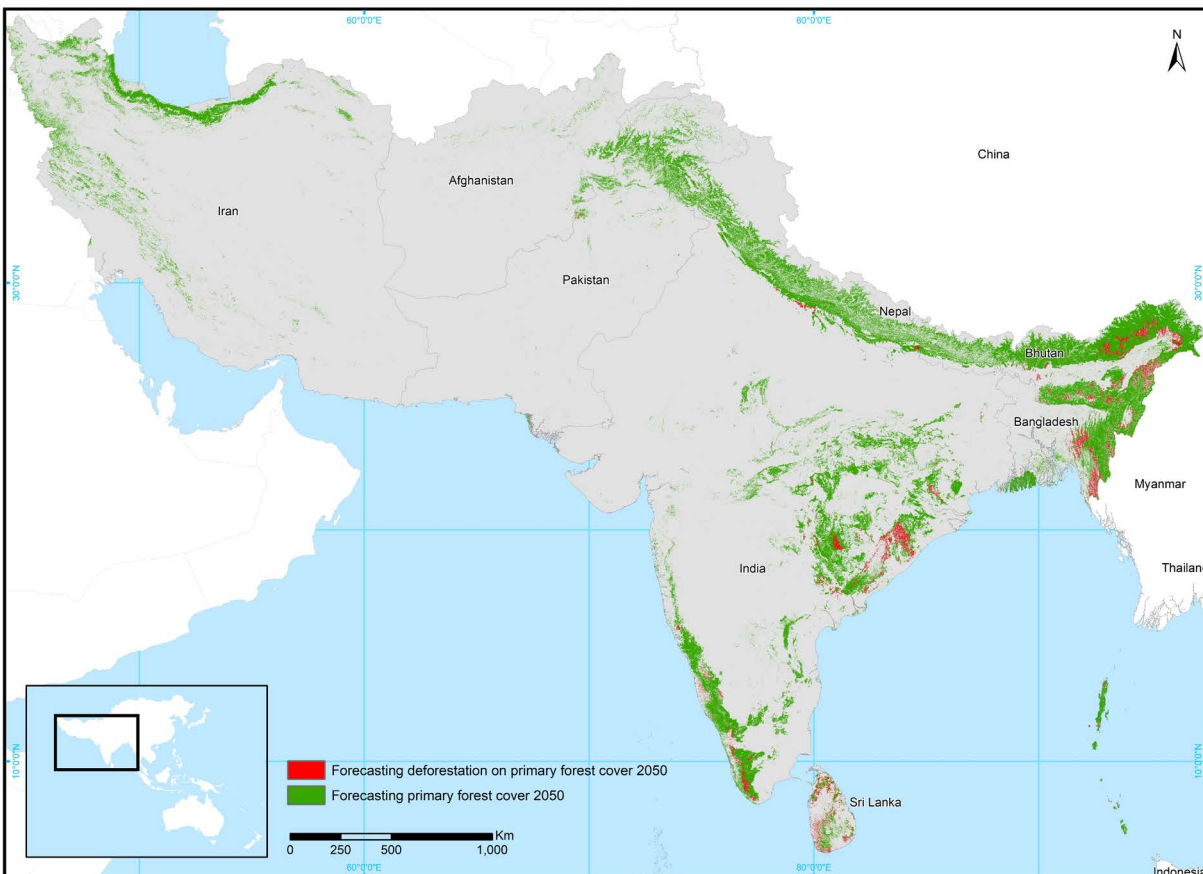


Figure 17b Forecasting primary forest cover in 2050 in South Asia. Source: Authors

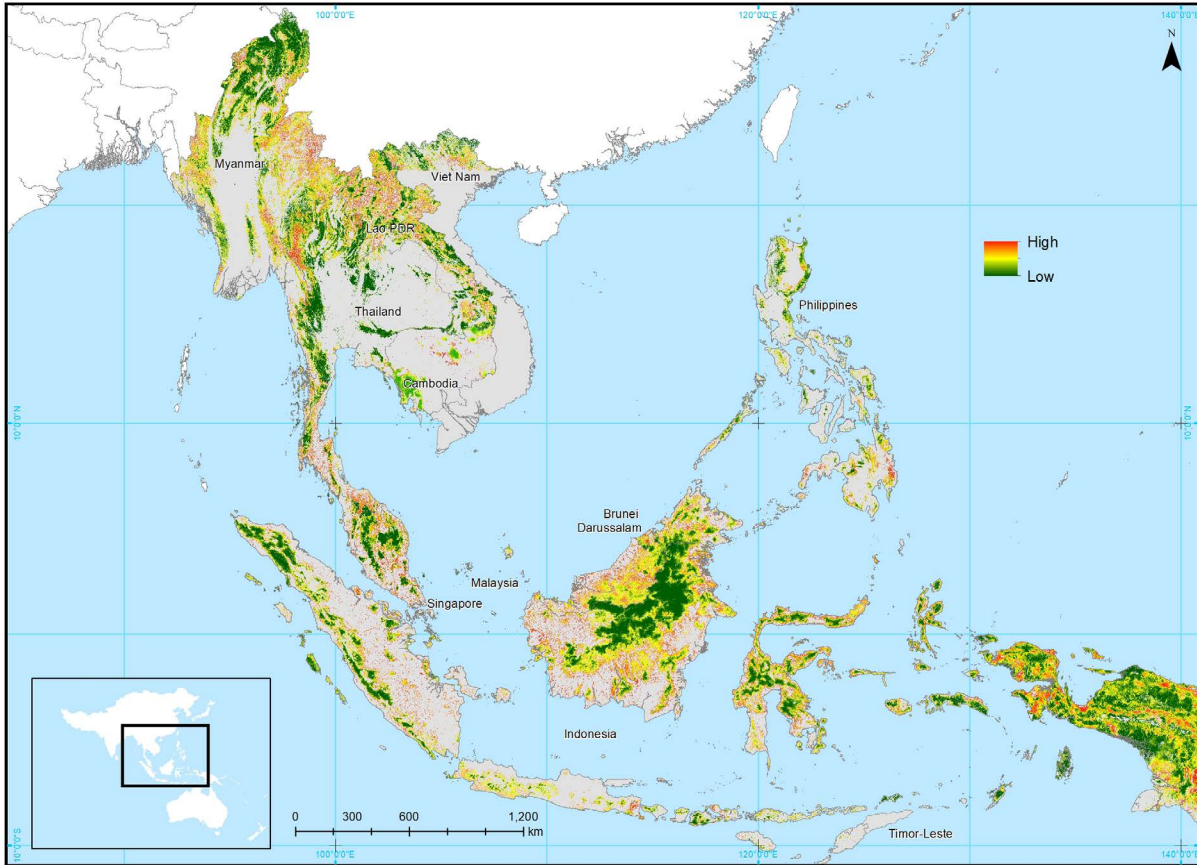


Figure 18a Probability of deforestation risk for 2050 in Southeast Asia. Source: Authors

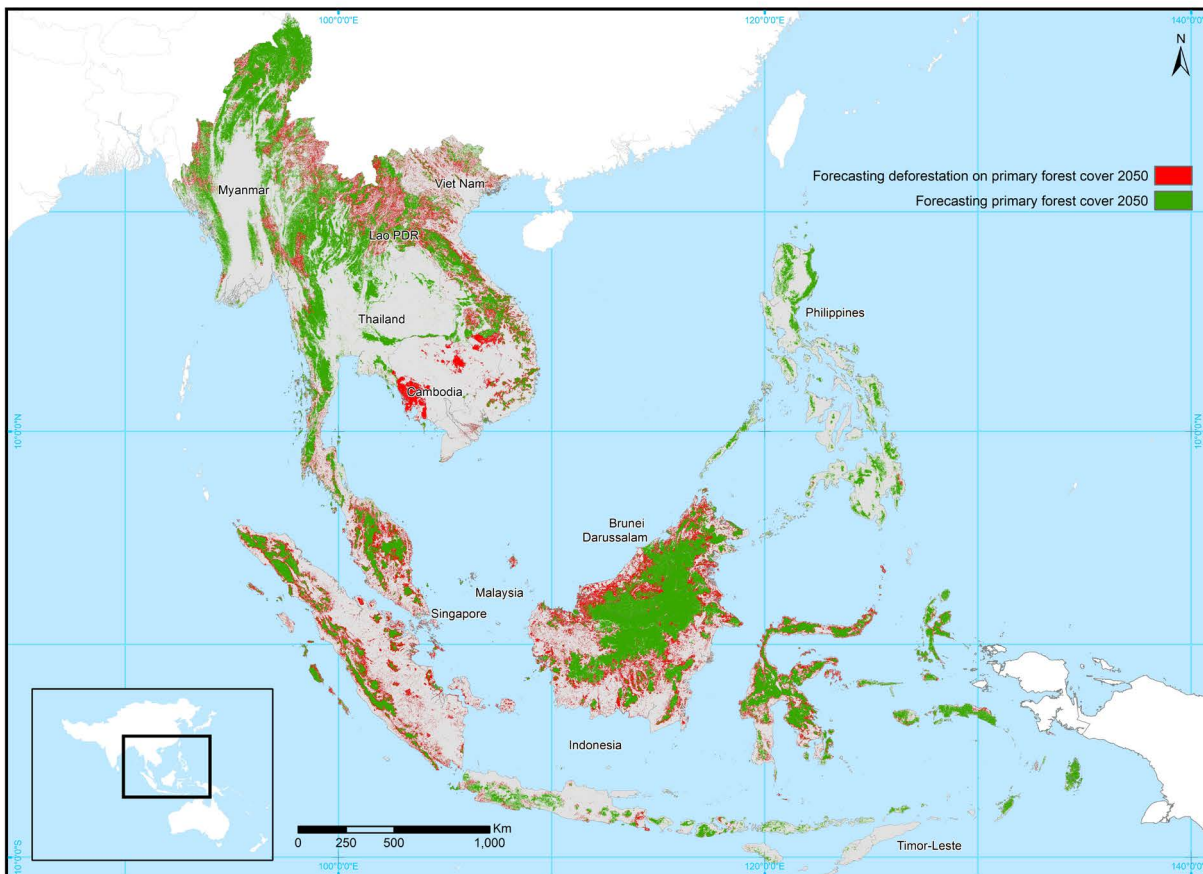


Figure 18b Forecasting primary forest cover in 2050 in Southeast Asia. Source: Authors

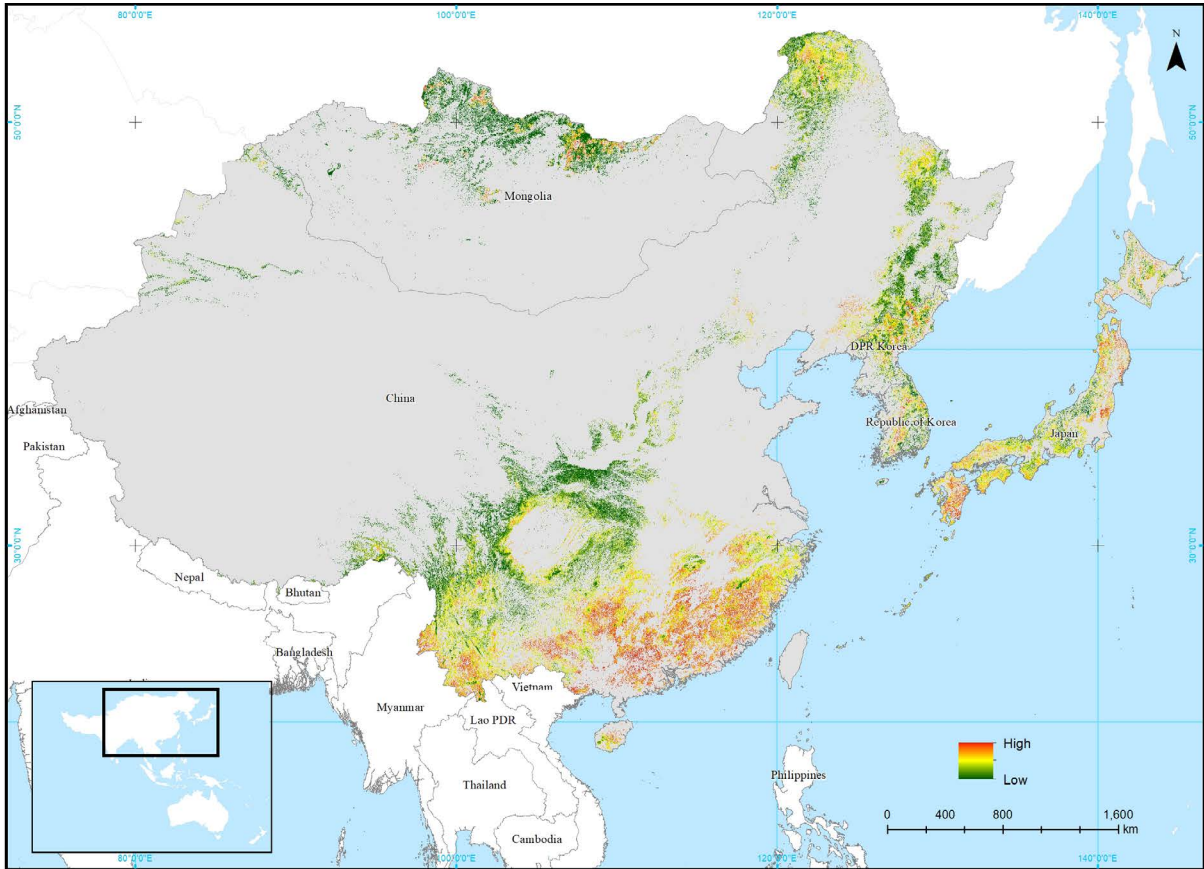


Figure 19a Probability of deforestation risk for 2050 in East Asia. Source: Authors

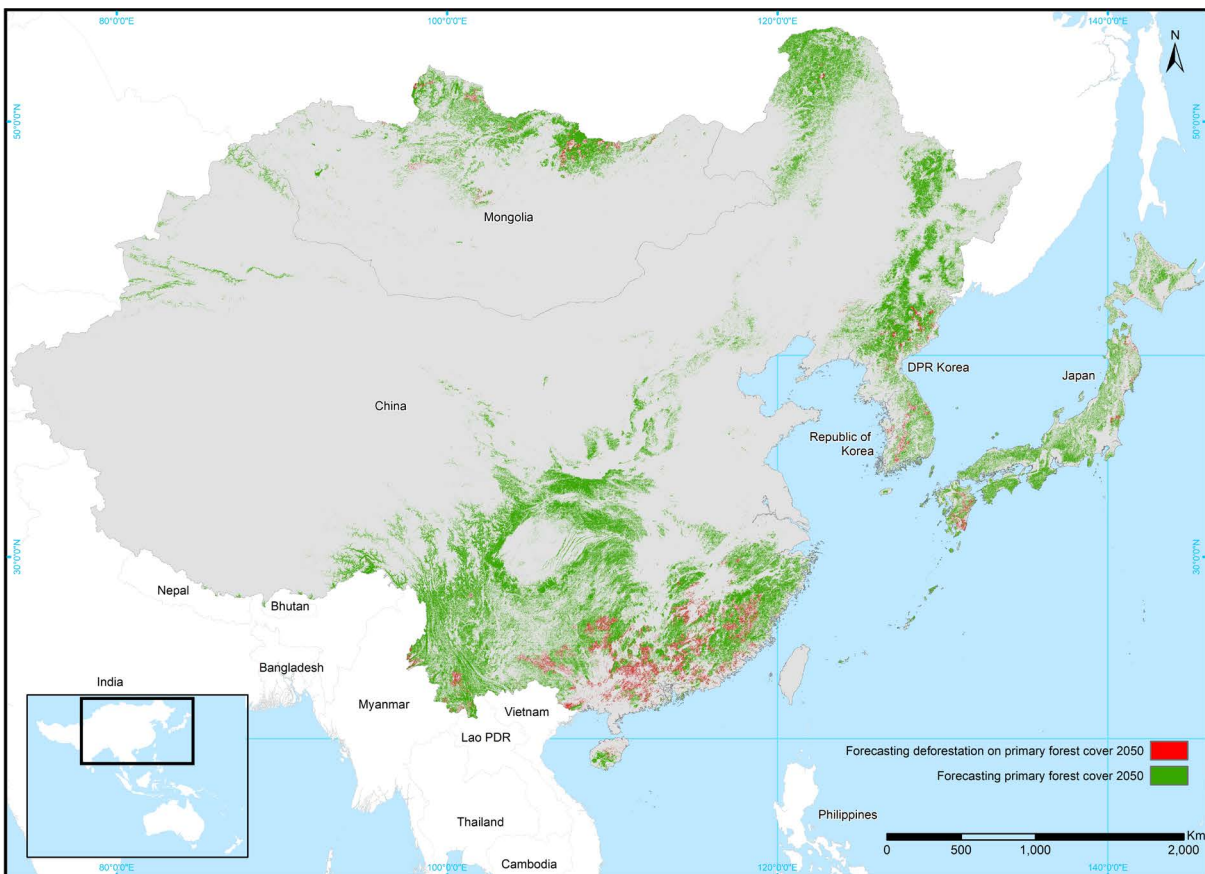


Figure 19b Forecasting primary forest cover in 2050 in East Asia. Source: Authors

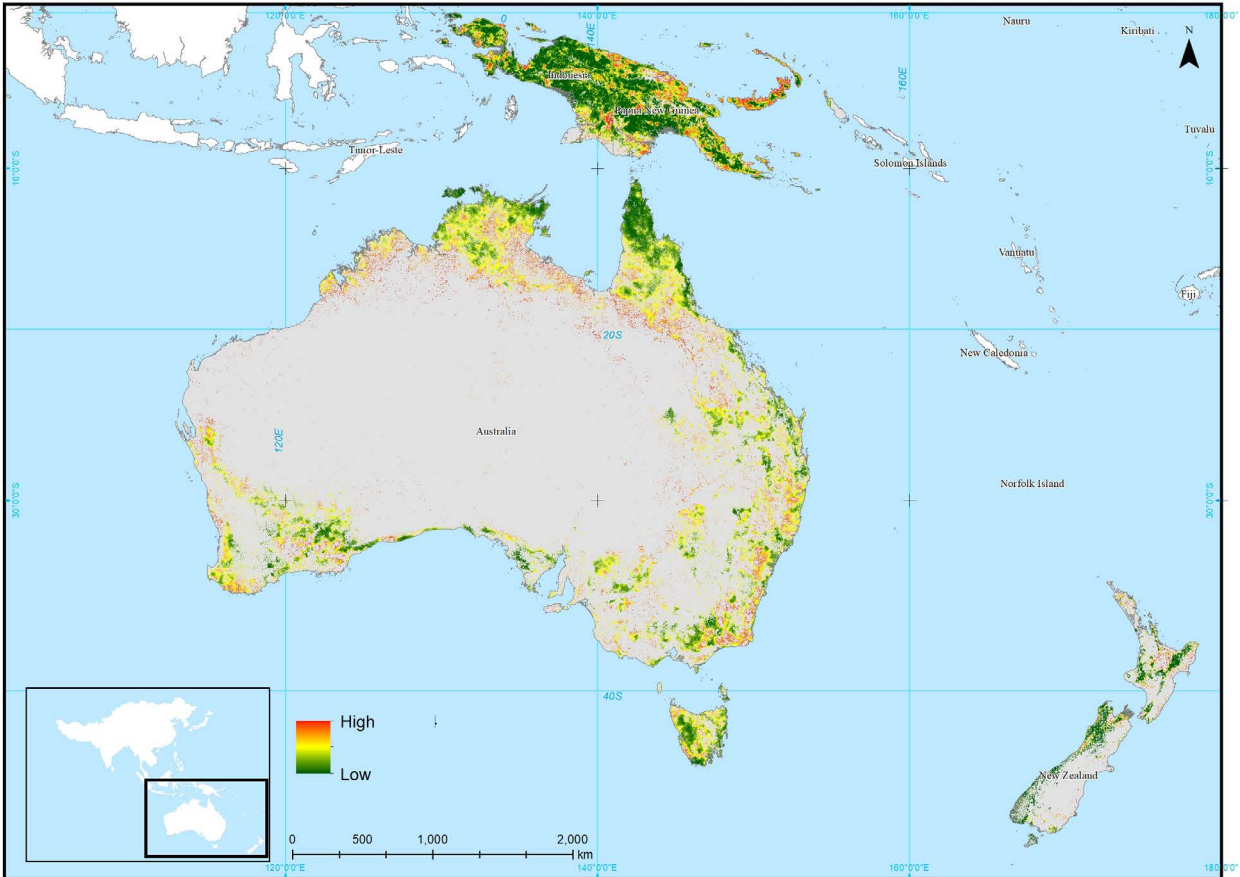


Figure 20a Probability of deforestation risk for 2050 in Oceania. Source: Authors

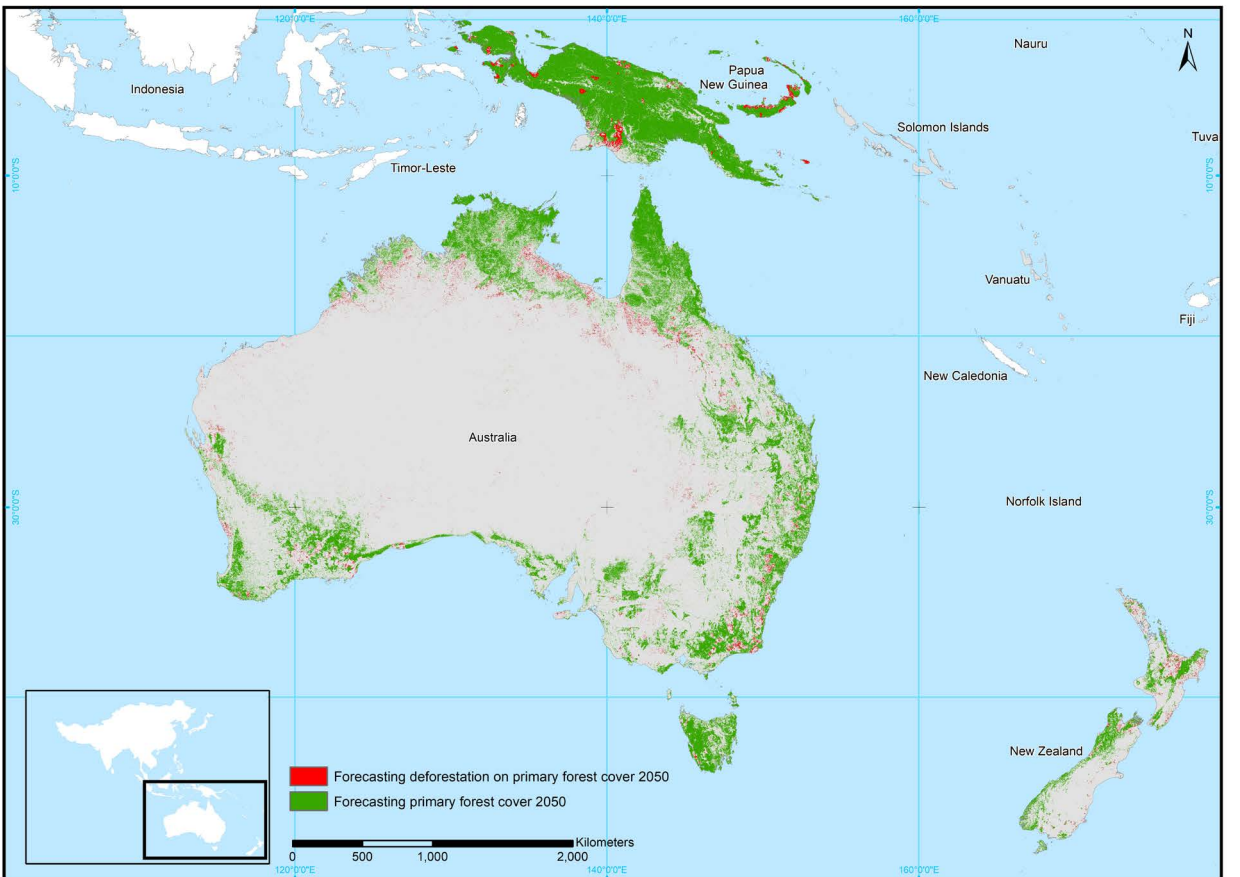


Figure 20b Forecasting primary forest cover in 2050 in Oceania. Source: Authors

The *forestatrisk* model emphasizes that most new deforestation will happen where recent deforestation occurred. The forests closest to areas of former deforestation are at greatest risk of further deforestation, and the peak probability of deforestation is at low elevation (100–200 m). In the Asia-Pacific region, the altitudinal limit to growing oil palm and many other commercial commodities (with the exception of tea) lies at 1,000 m above sea level. The model shows as well that the risk of deforestation is also higher on gentle slopes as steeper slopes pose technical challenges for companies. The model also highlights risks emanating from existing population concentrations and roads. However, the limitation is that there is no way to predict how the transportation network, planned roads and new railroads will look in 2050.

In India, the regions at the highest deforestation risks are the Western and Eastern Ghats, and above all, the northeastern districts of Arunachal Pradesh, with the most drastic loss prediction for Meghalaya, Nagaland, Assam, Tripura, Manipur, Mizoram, where forests will have practically disappeared by 2050. High-elevation regions of the Himalayas are also at high risk, except for Bhutan. In Bangladesh, Chittagong province has the highest risk of deforestation. The landscapes of northern Mongolia and China will also be much affected.

In Southeast Asia, the highest deforestation risk is predicted for Myanmar and Lao PDR at the border with China. In Myanmar, Chin district to the west and Shan district at the Chinese border and the northeastern border region with Thailand will see significant losses in forest. In Cambodia, the Khao Kong forest landscape is the only resilient region. All of Lao PDR and the north of Viet Nam are also much affected, as is southwest Yunnan in China. In Indonesia, the highest risk is for Borneo, Sulawesi, and Papua islands. By 2050, the lowland forests of Sumatra will have disappeared, and the landscapes will look like those of Java today. On Java, Bali, and the small islands of Nusa Tenggara Timur, the risk of deforestation is lower since most lowland forests have already disappeared.

Looking at forest types, Southeast Asian mangroves still appear to face high threats of destruction. However, numerous efforts have been made through rehabilitation programs in many countries. As already spotted out by Giri et al. (2015) and Richards and Friess (2016), the main causes of mangrove deforestation in South East Asia remain conversion to other land uses (aquaculture, rice agriculture in Myanmar, oil palm expansion in Malesia and Indonesia), but also overharvesting, pollution, a decline in freshwater availability, flooding, a reduction in silt deposition, coastal erosion, and disturbances from tropical cyclones and tsunamis. The most affected areas are the Ayeyarwady delta in Myanmar and Bintuni Bay in West Papua, but many smaller areas are not properly addressed at the scale we worked with.

Tropical freshwater swamp forests (periodically inundated), which are very suitable for agriculture development, have practically disappeared from Southeast Asia. Patches can be found in central Cambodia around Ton Le Sap Lake and the Lower Mekong area. Extensive freshwater swamp forests (often wrongly classified as peat swamp) still exist in the Papua province of Indonesia and in PNG.

Extensive deforestation, drainage, and conversion to plantations have also damaged most peat swamp forests in Indonesia and Malaysia. Both countries' policies are based on the narrative of oil palm and other major monoculture commodities as drivers of prosperity and development. However, primary tropical peat swamp forests represent a unique wetland ecosystem of distinctive hydrology supporting unique biodiversity and globally significant soil carbon storages. Nonetheless, they are now very fragmented and at a high risk of fires. This ecosystem is complicated to restore once the original hydrological process has been damaged. Research clearly shows that the debate should be focused not on how to sustainably develop drainage-based plantations but on whether sustainable conversion to drainage-based systems is possible at all (Evers et al. 2017). Few peatlands fall within existing legally protected areas.

While much attention has been given to peat swamps for their enormous carbon stock and CO₂ emission when drained, it has overshadowed the fact that lowland *terra firma* rain forests fade away in silence. As predicted since the beginning of this century (Laumonier 1997, Jepson et al. 2001), the tropical lowland rain forests of Southeast Asia, the unique lowland dipterocarp forest type representing the biodiversity richest terrestrial ecosystem, have almost disappeared in Sumatra and Peninsular Malaysia. A similar bleak future is predicted for Borneo, as shown by trends in Sarawak.

Seasonal, moist and dry deciduous forests are poorly represented, mostly in small patches. Sparsely wooded tropical and subtropical woodlands have been much more affected by human influence than denser forest biomes because of earlier human settlements, agriculture, the clearing of land for pastures, and the intensive use of fire for hunting and to improve grassland productivity.

Temperate broadleaved and mixed forests are also depleted and fragmented because of high population density and a long history of agricultural development. Boreal forests are not spared, even in very remote areas.

A last emphasis should be made on the particular cases of small Pacific islands, which will experience a particularly bleak future. This is the only part of the Asia-Pacific region where the impacts of climate change are occurring faster than the impacts of land use changes.

3.4 Conclusion

The findings of the previous three chapters highlight the need to assess and monitor intact forests in the Asia-Pacific region under large scale inventories and mapping programs and consider their diversity if the various pressures they experience are to be addressed effectively. Theoretically, PAs will not be affected by deforestation and in many cases are considered the only place harboring pristine, primary forest. Not only have PAs been blamed for the displacement of local communities in many cases, but

their effectiveness for conservation has long been debated (Andam et al. 2008; Gaveau et al. 2012; Geldmann et al. 2019) and is very much context-dependent. For instance, if it is recognized in general that PAs have not worked optimally to reduce the effects of deforestation in Indonesia (Brun et al. 2015), they have at least slowed down the process while sometimes only displacing deforestation elsewhere. Although it has been acknowledged in many situations that they represent the last fortresses against conversion to agriculture, they rarely cover all ecosystem types as they are often confined to mountain zones. Although cost-effective solutions have been proposed to expand PA systems, such as in southwestern China (Yang et al., 2019), it would be unrealistic to set up PAs everywhere for prominent logistics and budgetary reasons. Alternatives for the co-management of primary forest and surrounding landscapes should be developed. Priority areas for conservation do not always have to be in PAs: the ecological value and socio-ecological context of the broader landscape also need to be considered. The areas identified as intact forest in the present study represent landscapes where other effective area-based conservation measures (OECMs) can contribute to ecologically representative and well-connected conservation systems integrated within wider landscapes (IUCN 2019).

Since primary forest cover cannot be ultimately reduced to protected forest areas, ways to proactively manage intact forest landscapes must be developed. To achieve this, regional cooperation mechanisms and joint research networks should be created to specifically address and understand the ecological dynamics of primary forests and create practical evidence to manage their surrounding landscapes on a sustainable basis. An integrated landscape approach is advocated to that end (Sayer et al. 2013; Reed et al. 2019), involving all relevant stakeholders in the process, including country experts and other key players such as multilateral and bilateral organizations, the private sector and non-governmental organizations, but also and foremost Indigenous Peoples and local communities through community-based monitoring programs.

Resources for conservation of primary forest outside PAs are limited, so they must be used wisely to deliver the greatest possible biodiversity gain, and this cannot go without Indigenous knowledge. A new UN report concludes that deforestation rates are significantly lower in areas where Indigenous Peoples live and bear responsibility for their forests (FAO and FILAC 2021). Safeguarding and strengthening the rights of Indigenous Peoples is thus vital to preserving forests and biodiversity and fighting climate change (Dymond et al. 2007). Indigenous communities are the guardians of forest health and biodiversity (Sheil et al. 2015).

Methods have been developed to assess the value of the biodiversity of a region's indigenous forest to help prioritize conservation resources without the need for detailed biodiversity information (Dymond et al. 2007; Lambert and Mark-Shadbolt 2021). At the local level (watershed, Indigenous territory), improvements to low-altitude

remote sensing using unmanned aerial vehicles (UAVs) allow the development of basic protocols for large-scale landscape and vegetation mapping linked with guidelines for participatory mapping, while also recording folk classifications, perceptions on landscape, ecosystem services and how biodiversity and forest is perceived.

There is a need for transformative change to stop further biodiversity loss. Integrated landscape approaches provide a multistakeholder perspective to facilitate such transformative change by embedding conservation, the sustainable use of biodiversity, ecosystem services and landscape governance as a prerequisite for wellbeing and development in all sectors of society (Shi et al. 2020; Meijer et al. 2021; Brockhaus et al. 2021; Reed et al. 2021; Ros-Tonen et al. 2021).

The next chapter presents governance tools that can contribute to the preservation of intact forests both within and outside PAs.

4 Governance instruments for primary forest conservation in the Asia-Pacific region

One important takeaway from **Chapter 1** is that important areas of intact forests exist beyond what is reported by countries to the FRA on the extent of primary forests. These intact forests are faced with the main threats of deforestation, forest degradation and fragmentation, but a large proportion are not covered by PA networks. In addition to the option of considering these areas for PA status, it is important to consider forest protection using an integrated landscape approach, hence the importance of establishing degraded forest areas as buffer zones to protect intact forests against further degradation, and creating ecological networks and corridors to ensure connectivity between areas of fragmented forest. Following upon this, **Chapter 2** considers the considerable diversity of forests in the Asia-Pacific region. While there is a lack of knowledge about eco-floristic variation within each forest type, species distribution, population dynamics and the status of many important tree species, especially in the tropical zone, it becomes clear that all different forest types need to be protected. **Chapter 3** considers the major threats and drivers of threats to the intactness of forests in the region. It identifies two main categories of threats: climate change and human activities, both inside and outside the forest; forest fires being both generally driven by human activities and aggravated by climate change. Vulnerability to the impacts of climate change is itself often increased by human activities as most studies agree that healthier, non-degraded and less fragmented forests are in a better position to adapt (FAO 2016). Having said that, the most serious and immediate threats to primary forests come from socioeconomic drivers including agricultural expansion, infrastructure development and logging. Primary forest conservation therefore

depends on how human activities are managed, both inside and outside the forest.

PAs are often seen by many actors as the primary mechanism to ensure the protection of forests. What is clear from previous chapters is that PAs cannot be the only mechanism to ensure protection of primary forests against deforestation, degradation and fragmentation. One reason is that not all primary forests are currently covered by national parks and other conservation areas. PAs do not cover all types of forests, and they are often established in areas where threats (e.g. competing demands on land) are in fact lower. Many intact forests are not protected by PAs and are in fact used for various activities. While it may be possible in some places to increase the extent of PAs, other mechanisms may need to be deployed for these forests. A second reason is that PAs by themselves are often insufficient to protect the area where they are established.

For all of these reasons, a range of mechanisms and tools need to be mobilized in addition to and in support of PAs, such as creating buffer zones, to increase the protective role of areas around primary forests and consider the entire landscape matrix for integrated management. Decisions relative to the designation of PAs, the management and effective implementation of the protected status, and the sustainable management of forests that are not protected all depend on governance, including forestry institutions and governance but also interactions and relations to other sectors. These can provide incentives to various actors (including national governments, local authorities, the private sector, farmers, Indigenous Peoples and local communities) to effectively conserve primary forests.

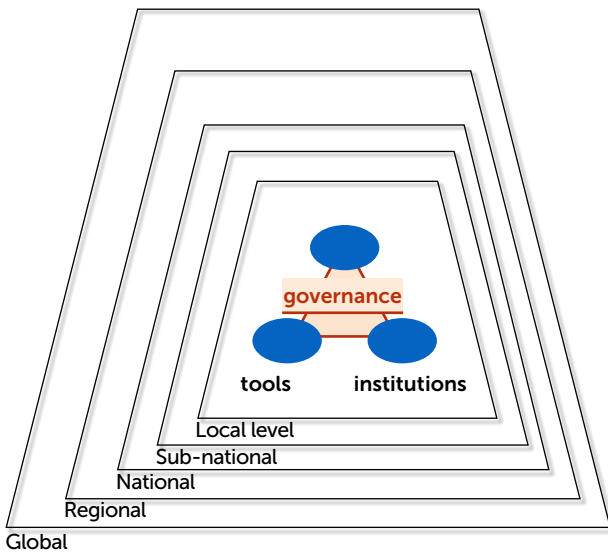


Figure 21 Schematic representation of the constituting elements of the enabling environment across scales. Source: Authors

Chapter 4 examines the range of actors, and governance at international, regional, national and local levels. **Chapter 5** will examine how different mechanisms and tools can be used to address a diversity of threats and situations, illustrated with examples.

An enabling environment to protect primary forests depends upon actors, institutions and tools at various levels. Proper governance mechanisms are needed between and across these levels (**Figure 21**). This chapter presents an overview of forest governance in the region, covering: the main actors and institutions, salient tools and instruments from international and regional to national and local scales, and associated challenges and opportunities for governance.

4.1 Actors and institutions: an overview

The governance of forests is both shaped and influenced by a range of actors and institutions operating at different scales, from local to national, regional and international levels, the actions of each group influencing the actions of others. State actors and institutions include national governments, state authorities, and intergovernmental organizations. Non-state actors include the private sector (e.g. firms

and industry associations), non-governmental organizations (NGOs), civil society organizations (CSOs), and academia (Sotirov et al. 2020). Forestry management regimes include: co-management regimes, community forestry, smallholder forestry, largeholder forestry, or companies granted concessions on state lands (FAO 2019b). In the Asia-Pacific region, the interplay and power dynamics between these actors have historically contributed to a decrease in primary forest cover. Examples of issues related to the range of actors and their roles in forestry governance include power dynamics between the public and private sector but also the need to reinforce coordination and coherence between local, national, regional and international decisions and actions.

The dynamics at play among actors determine, for example, if a certain area is designated as protected or if a certain forest is sustainably managed. In particular, the conservation and sustainable management of a forest depends on the stewardship role of an actor or group of actors, because it is the steward of the forest that will protect it from external threats, monitor fires and invasive alien species, or alert public authorities of encroachment or degradation perpetrated by external actors. However, to assume such a role, local actors need to have a specific interest to do so, usually drawing benefits (ecosystem services and goods) from the forest. Hence their interest generally depends on their use rights.

At the local level, the main actors are the Indigenous Peoples and local communities (IPLCs) who live in and around, use, and manage forests. IPLCs depend on forests for their livelihoods as well as for cultural and spiritual values. Their range of ability to conserve or manage forest resources is, however, dictated in large part by the influence of state (e.g. through national-level legislation) and non-state actors (e.g. the logging industry), particularly as regards tenure and access rights. National tenure regimes are established by national legal frameworks. However, these do not always consider or have not formalized the rights (e.g. customary tenure) of IPLCs to use forest resources for their livelihoods (as opposed

to logging or purely conservation uses). The rights of IPLCs can be compromised by private sector actors, as happened in PNG, where special agricultural business leases were given to investors for an area of 5 million hectares in customary land under community ownership for the cultivation of oil palm and other industrial crops, often under the pretext of agroforestry (APFSOS III: FAO 2019). This is why social safeguards are an important aspect of commercial enterprise activity, as highlighted in the *Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security* (VGGTs: FAO 2012). IPLCs also manage forests through programmes that have been developed to increase local participation, formalize land tenure and access rights, support livelihoods, enhance the role of non-wood forest products, and acknowledge the importance of Indigenous knowledge, as well as the cultural and spiritual dimensions of forests. Some examples include collective forestry, community forestry and joint forest management (APFSOS III: FAO 2019). The participation of IPLCs is a key element of forestry governance.

At the national level, forest governance lies with legal frameworks adopted and decisions taken by the national government and its different line ministries. These include not just forestry but also ministries in charge of, for example, trade, economy, planning, sustainable development, agriculture and environment (including climate change and biodiversity). Governments, for instance, establish PAs and develop and implement regulatory frameworks. They also interact with the private sector, such as through legislation governing timber concessions. At regional and international levels, national governments participate in the negotiation processes that are in place for the development of conventions, guidelines, targets, initiatives, etc. Decisions taken at these levels influence governance issues at the national level as these decisions would then need to be reflected in national legal and strategic frameworks (including national climate change plans or national sustainable development strategies).

National policies, laws, rules and decisions must be enforced all the way to the local level as well as between the different actors. This means that governance structures are not enough to enable the different actors to adhere to and be accountable for national decisions. The decision-making process must be evidence-based, inclusive and relevant to local populations. In the Greater Mekong Subregion, while supportive policies, legislation and institutional frameworks are in place to enable forest governance, there are still numerous challenges in terms of implementation, enforcement, and compliance (Gritten et al. 2019).

Actors in the private sector range from small and medium enterprises to large companies; their different objectives and scale of activity can have variable impacts on forest conservation and management. Small and medium enterprises may have different priorities and interests from large logging companies, as well as different incentives for sustainable timber extraction. Many small and medium-sized forest enterprises operate informally because of challenges associated with operating in the formal system, such as rigid rules and regulations and high transaction costs (APFSOS III: FAO 2021). The imbalances of power and capacities between these actors is another issue. Concessions given for logging can range from small (a few hectares) to larger areas (over 100,000 hectares), and for periods ranging from one to 100 years (Chan 2017). This can create conflicts with local communities over the right to land, as well as reduce opportunities for sustainable forest management (SFM) because of the security of tenure of the logging concession (Chan 2017). The private sector, however, can have a role to play in positive outcomes for forest conservation and management, through zero-deforestation commitments, commitments addressing commodity-driven deforestation, or investments related to lowering carbon emissions.

Environmental NGOs and other CSOs⁵³ play a role in forest governance by contributing to national policy and decision-making processes

53 CSOs are not-for-profit, voluntary entities formed by people in the social sphere that are separate from the state and the market. CSOs represent a wide range of interests and ties and can include community-based organizations as well as non-governmental organizations (NGOs).

at all levels, as well as to local-level forest management. For example, CSOs in the Asia-Pacific region have been involved in land use planning processes and community rights issues by standing up for civil society participation and community land rights recognition (Chakib 2014). They are also involved in national and sub-national forest governance, such as through community forest management (Gritten et al. 2014). In India, CSOs are major actors in implementing the Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (Act No. 2 of 2007)⁵⁴, which recognizes community forest rights, and educating communities about their rights by providing mediation, facilitation, and direction roles.⁵⁵ Like CSOs, environmental NGOs are involved in forest governance by supporting the environmental and social aspects of forest conservation, management and governance. They also provide support to local communities in implementing forest management arrangements, as well as monitoring and assessing the status of forest conservation and management. Both CSOs and environmental NGOs are involved in policy discussions at the national level and also participate in discussions at transnational, regional and international levels, contributing to improve participation, equity, transparency and accountability that are part of good governance.

Academia and research are another category of actors that influences the discourse of primary forest conservation. The science generated by academia and research provides evidence for conservation and management decisions taken at local, national, regional and international levels, which then influence policy decisions and can contribute to the development of strategies for forest conservation and management (e.g. through community forestry). In addition to research, academia is involved in forest

assessments, monitoring, and evaluation. This knowledge is transmitted to policymakers and other relevant stakeholders, including the private sector; it is also applied to on-ground actions such as SFM.

4.2 International and regional agreements, instruments and processes

There are no international agreements that apply solely to primary forests. Rather, international agreements and instruments that address the conservation of primary forests are either embedded in those relating to the forestry sector or are of a more global nature. In the latter case, these address forestry as an element for achieving sustainable development or other environment-related objectives and goals such as the SDGs and multilateral environmental agreements. While not all agreements or instruments are legally binding, they provide the framework for international governance processes and mechanisms, which guide the implementation of common global goals and national commitments at all levels of governance.

4.2.1 Global sustainable development and environmental goals

Adopted by all UN member states in 2015, the 2030 Agenda for Sustainable Development (UN 2015) encompasses 17 SDGs with 169 associated targets. Importantly, these goals are integrated, meaning that they recognize that action in one area will affect outcomes in others. In the case of forestry, this mirrors what happens at, for example, the national level, where a market policy (e.g. timber concessions) can impact conservation objectives. The SDG that specifically addresses forest conservation is SDG 15 (life on land), which aims to “protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.”

The 2030 Agenda is consistent with other existing international commitments, including the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets, developed

54 <https://tribal.nic.in/fra.aspx>; <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC077867>

55 ATREE. Role of Civil Society Organizations in enabling sustainable and equitable Community Forest Resource management in Maharashtra. See: <https://www.atree.org/projects/role-civil-society-organizations-enabling-sustainable-and-equitable-community-forest>

under the aegis of the UN Convention on Biological Diversity (CBD). These two instruments are mutually supportive and reinforcing. Since its entry into force in 1993, the legally binding CBD addresses the conservation and sustainable use of biodiversity, including forests and forest PAs. The Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets (five goals, 20 targets) are an overarching framework on biodiversity for the biodiversity-related conventions, the entire UN system and all other partners engaged in biodiversity management and policy development. The CBD, the Strategic Plan and its Biodiversity Targets set the framework for countries to set their own biodiversity strategy and action plan. These include their own targets and are prepared in the context of national circumstances (including national legal and policy frameworks, planning, accounting, etc.) to contribute to global biodiversity goals and objectives agreed through the CBD. Implications for governance are that at the national level, NBSAPs should consider and be aligned with legally binding international agreements such as the CBD or the UN Framework Convention on Climate Change (UNFCCC), regional agreements and instruments, voluntary agreements and instruments, and the range of relevant sectoral national legislation and policies.

Specific to forest biodiversity, under the CBD, the Expanded Programme of Work on Forest Biological Diversity was adopted at the sixth meeting of the Conference of the Parties (COP) in 2002 (CBD COP Decision VI/22⁵⁶). Its implementation is the responsibility of the Parties to the Convention. This program of work consists of three program elements, 12 goals, 27 objectives and 130 activities. Program element 2 (“institutional and socio-economic enabling environment”) has three goals. The first and second goals⁵⁷ are particularly relevant to governance issues and their impact on primary forest conservation.

56 See: <https://www.cbd.int/decision/cop/?id=7196>

57 Respectively: “Enhance the institutional enabling environment” and “Address socio-economic failures and distortions that lead to decisions that result in loss of forest biological diversity”.

Reflecting increasingly recognized linkages between conventions, international organizations and partnerships, the CBD also called for greater integration of the key environmental Conventions – the CBD, UNFCCC, UN Convention to Combat Desertification (UNCCD) – and other international instruments, and gave new emphasis to the importance of primary forests when it noted the “exceptional importance of primary forest for biodiversity conservation” and “the urgent necessity to avoid major fragmentation, damage to and loss of, primary forests of the planet...” (CBD COP Decision 14/30).⁵⁸

The Paris Agreement⁵⁹ was adopted in 2015 under the UNFCCC to: limit global warming well below 2°C by reducing GHG emissions; provide a framework for transparency, accountability, and the achievement of more ambitious targets; and mobilize support for climate change mitigation and adaptation in developing nations. The Paris Agreement is a legally-binding treaty whose implementation is achieved through countries’ voluntary actions, as per their Nationally Determined Contributions (NDCs). REDD+, a climate change mitigation mechanism developed by Parties to the UNFCCC, supports countries’ efforts to reduce emissions from deforestation and forest degradation (REDD+), support the conservation and sustainable management of forests, enhance forest carbon stocks, and ultimately contribute to achieving the Paris Agreement.

4.2.2 Global forestry instruments and initiatives

There are no comprehensive, legally binding global instruments (such as treaties) focusing only on forests. In 2007, the UN non-legally binding Instrument on All Types of Forests (UNFF, which was established in 2000), and adopted by the UN General Assembly. In December 2015, this instrument was renamed to become the UN Forest Instrument, still

58 See: <https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-30-en.pdf>

59 See: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

non-legally binding, and saw its objectives expanded to include SFM. It is also in line with the SDGs. The UN Strategic Plan for Forests 2030 (UNSPF) was presented in January 2017, at a special session of the UNFF. It was adopted by states and subsequently by the UN Economic and Social Council, and then the UN General Assembly, in the context of the SDGs in April of that same year. Building upon the four global objectives on forests included in the UN Forest Instrument, the UNSPF provides a global framework for action at all levels to sustainably manage all types of forests and trees outside forests, as well as to halt deforestation and forest degradation. Also voluntary, the UNSPF outlines six Global Forest Goals (GFGs) and 26 targets to be reached by 2030 (UNDESA 2019). The GFGs and their related targets are intended to “stimulate and provide a framework for voluntary actions, contributions and enhanced cooperation by countries and international, regional, subregional and non-governmental partners and stakeholders”. GFG 5 and its four targets are of specific relevance to governance in the forest sector.

Countries, organizations and private entities work to restore degraded and deforested lands by supporting forest landscape restoration (FLR). This has implications for primary forest conservation, as one of the intentions behind FLR is to reduce the pressure on primary forests. The Bonn Challenge,⁶⁰ launched in 2011, is a global effort to restore 150 million ha of degraded and deforested land by 2020. This goal was surpassed in 2017.⁶¹ This effort was later extended to 350 million ha restored by 2030 with the adoption of the **New York Declaration on Forests (NYDF)**⁶² during the 2014 UN Climate Summit. Since 2014, **over 200 governments, multinational companies, groups representing Indigenous communities, and non-governmental organizations have endorsed the NYDF.** The NYDF is a non-legally binding political declaration which includes a voluntary Action Agenda. It is an example of a transnational

public-private partnership involving both state and non-state actors. It aims to combine goals developed and adopted under other global agreements, including the SDGs, the Paris Agreement on Climate Change, Aichi Targets of the Global Biodiversity Strategic Plan, the 2011 Bonn Challenge, REDD+, climate and forest financing pledges, and corporate supply chain commitments. Linkages to these global processes provide the context for an integrated approach to protecting and restoring forests, transforming supply chains, and improving forest governance.

4.2.3 International trade

Globalization has had negative impacts on the forest sectors of forest-rich countries with weak forest governance. Many of these countries opened up their economies to allow the rapid exploitation of their forest resources, but this was not matched with efforts to strengthen forest governance. A consequence has been unsustainable and often illegal forest exploitation (APFSOS III: FAO 2019). Trade agreements and certification schemes are two avenues used to combat overexploitation and deforestation and decrease pressures on primary forests.

Over 900 species of commercially valuable trees are listed in the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a multilateral treaty to protect endangered plants and animals that entered into force on 1 July 1975 and currently gathers 183 parties. Its aim is to ensure that the international trade of wild plant and animal species does not threaten their survival. Among its objectives, the program aims to improve and strengthen forest governance. Through financial support mainly from the European Union (EU), the CITES Tree Species Programme⁶³ provides direct financial assistance to countries for taking conservation and management measures to ensure that their trade in timber, bark, extracts and other products from CITES-listed tree species is sustainable, legal and traceable.

60 See: <https://www.bonnchallenge.org/>

61 See: <https://www.bonnchallenge.org/about>

62 See: <https://www.nydfglobalplatform.org/declaration/>

63 See: <https://cites-tsp.org>

International timber trade is linked to forest protection, governed through regulatory frameworks, and involves state and non-state actors. Resulting from concerns over the legality of EU timber imports (Giurca et al. 2013), the EU Forest Law Enforcement, Governance and Trade Action Plan (FLEGT) was introduced in 2003 to exclude illegally sourced timber and timber products from the European market.⁶⁴ An independent evaluation of the EU-FLEGT Action Plan was undertaken in 2016. Its main conclusions were that the Action Plan “continues to: (i) be a relevant response to the challenge of illegal logging; (ii) be effective in terms of raising awareness; (iii) contribute to forest governance globally; and (iv) help reduce demand for illegal timber in the EU” (EC 2019).

Two key components of the Action Plan are the EU Timber Regulation (EUTR) on the demand side and Voluntary Partnership Agreements (VPAs) on the supply side. Working with partner countries to improve forest governance and capacity building is a key element of the Action Plan. The EUTR prohibits operators from placing illegally harvested timber and timber products on the EU market. Operators who do place timber and timber products on the EU market are obliged to carry out due diligence so that the risk of importing illegally harvested timber is minimized (EC 2019). VPAs are entered into voluntarily but, once entered, become legally binding trade agreements between the EU and timber-exporting countries outside the EU.⁶⁵ A challenge is that VPA countries often need to adjust their regulatory frameworks. In some countries, if existing regulatory frameworks are enforced, there is a risk of harming small and micro-enterprises in the formal sector and smallholders in the informal sector. The EU-FLEGT Facility is addressing these issues through assessments and pilot interventions in Thailand, Viet Nam, Lao PDR and Myanmar.⁶⁶ Other countries outside the EU have passed legislation combating timber illegal trade. Most notable are the 2008

US Legal Timber Protection Act,⁶⁷ the 2012 Australian Illegal Logging Prohibition Act,⁶⁸ and Japan’s Clean Wood Act,⁶⁹ which began implementation in 2017.

The International Tropical Timber Organization (ITTO) is an intergovernmental organization which has six major focus areas: (i) SFM; (ii) economics, statistics and markets; (iii) sustainable forest industries; (iv) climate change mitigation and adaptation; (v) capacity building; and (vi) contribution to the SDGs. Within the focus area of SFM, the ITTO works in the area of forest law enforcement, governance and trade. Ten Asia-Pacific countries are producer members: Cambodia, Fiji, India, Indonesia, Malaysia, Myanmar, PNG, the Philippines, Thailand and Vanuatu. Operating under the aegis of the ITTO, the International Tropical Timber Agreement⁷⁰ was adopted in 2006. Originally planned to expire on 7 December 2021, the International Tropical Timber Council decided to extend the Agreement until 6 December 2026.⁷¹ The objectives of the Agreement are to promote the expansion and diversification of international trade in tropical timber from sustainably managed and legally harvested forests and to promote the sustainable management of tropical timber producing forests.

Voluntary forest certification is also used to discourage the sale of illegally or unsustainably harvested timber and non-timber products (see **Section 5.2.2**). It is a market mechanism for “forest monitoring, tracing and labeling timber, wood and pulp products and non-timber forest products, where the quality of forest management is judged against a series

64 See: <https://www.atibt.org/en/p/100/legality-of-the-timber-trade-and-forest-governance>

65 See: <https://www.flegtlicence.org/vpa-countries>

66 See: <https://www.euflegt.efi.int/smes-mekong>

67 See: <https://www.congress.gov/congressional-report/110th-congress/house-report/882>

68 See: <https://www.legislation.gov.au/Details/C2018C00027>

69 See: <https://www.rinya.maff.go.jp/j/riyou/goho/english/attach/pdf/english-index-3.pdf>; and <https://www.rinya.maff.go.jp/j/riyou/goho/english/english-index.html>

70 See: https://www.itto.int/direct/topics/topics_pdf_download/topics_id=3363&no=1&disp=inline

71 See: <https://treaties.un.org/doc/Publication/CN/2021/CN.384.2021-Eng.pdf>

of agreed standards”.⁷² Forest certification also addresses a range of economic, social, environmental and technical aspects of forest management, including the well-being of workers and communities.⁷³ Forest managers may apply for forest certification for different reasons, such as to earn higher prices for their products, improve their public image, achieve social and environmental goals, or even maintain and increase access to some markets for which certification is essential.

4.2.4 Regional initiatives and institutions

Regional and sub-regional institutions and initiatives provide a bridge between international policies and national actions. In the area of primary forest conservation, this is crucial because many issues related to primary forest conservation, including SFM, are transboundary in nature. For example, regional and sub-regional bodies and processes are encouraged to build and strengthen synergies between the global UNSPF 2030 (UNDESA 2019) and their policies and programmes, including in the context of their contributions to the implementation of the SDGs. A number of institutions and initiatives that support primary forest conservation are established in Asia and the Pacific. They include the APFC at regional level, and the Association of South East Asia Nations (ASEAN), the Mekong River Commission (MRC), the Pacific Community, or the South Asian Association for Regional Cooperation (SAARC) at the sub-regional level.

Composed of 34 countries,⁷⁴ the APFC is one of six FAO Regional Forestry Commissions.

72 WWF. Forest Certification. See: https://wwf.panda.org/discover/our_focus/forests_practice/forest_sector_transformation_updated/forest_certification/

73 FAO. Sustainable Forest Management Toolbox. See: <http://www.fao.org/sustainable-forest-management/toolbox/modules/forest-certification/further-learning/en/?type=111>

74 Australia, Bangladesh, Bhutan, Cambodia, China, the Democratic People's Republic of Korea, Fiji, France, India, Indonesia, Japan, Kiribati, Republic of Korea, Lao PDR, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Papua New Guinea, the Philippines, the Russian Federation, Samoa, the Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Tonga, Tuvalu, the United States of America, Vanuatu, Viet Nam, and the United Kingdom (observer status). See: <https://www.fao.org/asiapacific/apfc/en/>

It focuses mainly on the following areas of work: (i) improvements in forest management for multiple benefits; (ii) policy, economics and institutions; and (iii) the involvement of people in forestry. Through its working group on SFM, the APFC developed the ‘Code of practice for forestry harvesting in Asia-Pacific’ (FAO 1999b), which has served as a model for the formulation of national codes in 14 countries.

Regional networks and organizations like the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) and the Asian Forest Cooperation Organization (AFoCO) invest in capacity building and knowledge sharing to support the rehabilitation of degraded lands. Officially launched in 2008, the proposal to establish APFNet was adopted by the APFC. Together with FAO, APFNet developed the Asia-Pacific Regional Strategy and Action Plan for Forest Landscape Restoration to 2030 (FAO and APFNet 2018). Composed of 16 member countries⁷⁵ AFoCO is a treaty-based intergovernmental organization that promotes cooperation towards achieving the SDGs and regional and global forestry objectives. It works to rehabilitate degraded forest land and prevent deforestation and forest degradation.

FLR has been gaining traction in recent years in the Asia-Pacific region. The Asia-Pacific Economic Cooperation (APEC) adopted a goal of increasing forest cover in the region by at least 20 million ha by 2020. According to a report published in October 2021 (APEC 2021), this objective has been reached and exceeded, forest cover in the region having increased by 27.9 million hectares between 2007 and 2020. The Asia-Pacific Regional Strategy and Action Plan on Forest and Landscape Restoration to 2030 (FAO and APFNet 2018) aims at “promoting and accelerating forest and landscape restoration to enhance ecological functioning and human well-being in degraded and deforested landscapes of the Asia-Pacific region”, including through: resource mobilization,

75 Thirteen Parties (Bhutan, Brunei Darussalam, Cambodia, Indonesia, Kazakhstan, Lao PDR, Mongolia, Myanmar, Philippines, Republic of Korea, Thailand, Timor-Leste, and Viet Nam), and three Observers (Kyrgyzstan, Malaysia, and Singapore).

strengthened stakeholder engagement and scientific basis; and enhanced learning, collaboration and coordination on FLR across the region.

Other regional initiatives whose work is relevant to forest conservation are the Asia-Pacific Forest Invasive Species Network (APFISN) and the **Regional Model Forest Network—Asia (RMFN-Asia)**. **APFISN** is a cooperative alliance of the 34 AFPC member countries. It focuses on inter-country cooperation that helps detect, prevent, monitor, eradicate and/or control forest invasive species in the Asia-Pacific region. Originally established as an informal network in 2000, the **RMFN-Asia** is an initiative of the International Model Forest Network (IMFN), working on sustainable forest and landscape management, and other features and activities important for lives and livelihoods. The network has eight Model Forests⁷⁶ across China, India, Indonesia, Japan, the Philippines and Thailand, with two others under development in Viet Nam and Cambodia. In April 2020, **RMFN-Asia** launched its Regional Model Forest Network-Asia Strategic Plan 2020–2024. **The plan identifies poverty alleviation, livelihoods and food security, forest restoration and biodiversity conservation, water security, landscape governance, climate change and gender equity and equality as priority focal areas.**

The Strategic Plan of Action for ASEAN Cooperation on Forestry (2016–2025) addresses five major strategic areas of work, including SFM; trade facilitation, economic integration and market access; forestry sector resilience and role in climate change; institutional strengthening and human resources; and strengthening ASEAN’s joint approaches on regional and international issues affecting the forestry sector (ASEAN 2016). Forest law enforcement and governance (FLEG) is an important issue in ASEAN countries. In September 2001, the first regional Ministerial Conference on FLEG took

place in Bali, Indonesia and adopted the Bali Declaration to combat illegal logging. ASEAN is also involved in forest management and FLR issues. It represents regional member country positions and common views in international fora.

The MRC is an intergovernmental organization for regional dialogue and cooperation in the Lower Mekong River Basin, comprising Cambodia, Lao PDR, Thailand and Viet Nam. A major document of the MRC is its Basin Development Strategy (BDS), which aims, among other objectives, to maintain the ecological function of the Mekong River Basin, including forested watersheds. The SAARC addresses issues related to cross-border timber trade and to illegal timber trade in the SAARC area. SPC’s Forests and Trees Programme aims to ensure the sustainable management of the subregion’s scarce and diminishing forest and tree resources.

Lastly, the role of international and regional environmental NGOs, donors, and other financing institutions need to be recognized as actors that play significant roles in supporting the conservation of primary forests. These include the World Wildlife Fund for Nature (WWF), IUCN, The Nature Conservancy (TNC), Conservation International (CI), The Center for People and Forests (RECOFTC), and global, regional and bilateral donors, such as the Global Environment Facility (GEF), the Green Climate Fund (GCF), the World Bank (WB) and the Asian Development Bank (ADB).

4.3 National rules and instruments

The design and implementation of national rules and instruments are key to primary forest conservation. Frameworks related to forests and forest governance are essential, but so too are policies and rules related to the activities that constitute the biggest threats for forest conservation. Agriculture, mining and infrastructure development need to be coherent with the objective of primary forest conservation.

Governments are Parties to global intergovernmental fora, such as the SDGs, the CBD, the UNFF or the UNFCCC, where they

⁷⁶ As defined by the international model forests network, a model forest is a voluntary governance framework for the sustainable management of forests, natural resources and the larger landscapes that surround them. See: <https://imfn.net/model-forest/>

negotiate and ultimately make decisions on global issues. Examples of country commitments to these global fora include NDCs and National Adaptation Plans (NAPs) under the UNFCCC and NBSAPs under the CBD. NBSAPs typically consider forest conservation, while NDCs consider forest rehabilitation and reforestation as a climate change mitigation and adaptation tool. Some NDCs also include commitments to reducing deforestation and land use change. Of the 41 NBSAPs of the Asia-Pacific region countries, 14 specifically refer to the term “primary forest”, one refers to “primary vegetation” and one refers to “mature forests”. Other terms used in NBSAPs include “natural”, “intact”, “primeval”, “pristine”, “virgin”, “indigenous”, “native”, “indigenous” and “mature”. For example, in the Republic of Korea where no legal definition for primary forest exists, the proxy term “virgin forest” is used. Virgin forests are recognized as environmentally significant areas for conservation under the Forest Protection Act (2019) and the Natural Environment Conservation Act (2019).⁷⁷

The conservation of these forest habitats is usually addressed through PA targets. National governments are also members of regional and sub-regional fora, prioritizing and strategizing regionally-relevant decisions on issues that impact forest conservation and management. They implement the commitments and decisions made in global, regional and sub-regional bodies. Finally, governments are responsible for different aspects of good governance at the national and local levels, such as: formalizing tenure and access rights; managing PAs; establishing and enforcing laws and regulations in areas such as logging; and providing legal and market-based incentives. They are also responsible for ensuring and coordinating the enforcement and oversight of these rights, regulations and incentives.

4.3.1 Instruments combating agricultural expansion into forest areas

Various instruments can be mobilized to avoid the encroachment of agriculture into forested areas. Most of them generally depend on other line ministries than those responsible for biodiversity conservation and for forestry.

A first key instrument is land use planning, a process that regulates the different uses of land, and across different sectors. It can declare areas to be kept as permanent forests, meaning that they cannot be converted to other land uses and more broadly orient the development of economic activities to facilitate a landscape approach to primary forest conservation. Therefore, planning from national to sub-national levels can contribute to the safeguarding of primary forests. In the Philippines, for example, forest land use planning is integrated in municipal comprehensive land use planning, which itself is a “**rational** approach of allocating **available** land resources as **equitably** as possible among **competing** user groups and for **different** functions **consistent** with the development plan of the area...” (Philippines Republic Act 7279, Section 3)⁷⁸. Land use planning, particularly at sub-national levels, can support integrated landscape approaches. It can be supported by tools that can show ecosystem services generated by different scenarios of land use, such as *Land Use Planning for Environmental Services (LUMENS)*. *LUMENS* is a framework accompanied by a publicly available software that allows inclusivity, integration and informed land use planning within a landscape, and has been used in Indonesia, Viet Nam and Papua New Guinea. Another example is the use of scenarios of land use to determine ecological redline areas (ERAs) in Shanghai using ES, biodiversity and ecologically fragile hotspots, landscape structure, and stakeholder opinions to help policymakers select a land use plan for 2040 to inform Shanghai’s Urban Plan (2016–2040) (Bai et al. 2018).

77 See reply to 2021 questionnaire on governance sent to forestry experts in selected Asia-Pacific countries.

78 See: <https://enptinio.com/clup-philippines-questions/#what-is-a-comprehensive-land-use-plan>

Governments are responsible for fixing the rules for granting concessions for logging or other land use on land owned by the state. In doing so and in delivering individual concessions, they need to consider potential impacts of these concessions on primary forests, as well as on local populations in the area. The granting of concessions should respect land use planning and orientations and can be done with conditions, on a case-by-case basis, such as integrating sustainable forest management practices, or taking a participatory concession management approach.⁷⁹ Economic land concessions (ELCs) are long-term leases granted to concessionaires, allowing them to clear land to develop industrial-scale agriculture. ELCs can be granted for a range of activities spanning from large-scale plantations to cattle rearing. However, in Cambodia, ELCs have caused land disputes between concessionaire companies and local residents and have been the source of land conflicts, including land grabs, forced evictions, and natural resource exploitation. According to the EastAsiaForum, ELCs were even granted in more than 270,000 ha of protected forest areas.⁸⁰ The government issued a suspension on new ELCs in 2012, but criticism remains – for example, the suspension does not resolve the issue of land tenure, Indigenous communal land titles, and forested areas were not included.⁸¹

From the perspective of importing countries, the European Commission has taken steps. The Commission recognizes that the expansion of agricultural land is one of the leading drivers of deforestation and forest degradation. As a relevant consumer of commodities associated with deforestation and forest degradation, it put forward an initiative to minimize the consumption of products coming from supply chains associated with deforestation or forest degradation, promote the consumption of ‘deforestation-free’ products and reduce the EU’s impact on global deforestation and

forest degradation.⁸² In November 2021, the European Commission proposed a regulation to minimize EU-driven deforestation and forest degradation.⁸³

Finally, national policies for agricultural development or intensification, which are expected to increase revenue from agricultural land, are likely to drive deforestation. To avoid this, they should contain safeguards for forest protection. There is a need to link instruments for agricultural development with instruments for forest protection. Here, for example, the establishment of OECMs is relevant as a landscape-level instrument; environmental and social impact assessments can generate accountability of the agriculture sector towards forest protection.

4.3.2 Regulations combating overharvesting, illegal logging and illegal trade

One of the major problems for primary forest conservation in the Asia-Pacific region is the overharvesting of wood. Mechanisms combating wood overharvesting are of particular relevance for Asia-Pacific governments. The range of institutions and mechanisms that can be mobilized include concessions (private sector and forest land owners); monitoring and enforcement of laws (including logging bans); rules governing logging and conservation areas; managing forests jointly with local communities and Indigenous Peoples; and adjusting legal mechanisms formalizing tenure and forest user rights.

While logging in natural forests in the Asia-Pacific region is declining in many countries (e.g. Cambodia, Indonesia, Malaysia, PNG), it remains the dominant wood production system (APFSOS III: FAO 2019). In many countries, governance failures regarding the regulation of logging concessions given to private companies have resulted in widespread unsustainable logging (APFSOS III: FAO 2019). One way for national

79 See: <https://www.fao.org/3/I9487EN/i9487en.pdf>

80 See: <https://www.eastasiaforum.org/2016/06/29/cambodias-devastating-economic-land-concessions/>

81 See: <https://opendevdevelopmentcambodia.net/topics/concessions/#ref-73837-62>

82 See: https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_5919

83 See: https://ec.europa.eu/environment/publications/proposal-regulation-deforestation-free-products_en

governments to regulate the overharvesting of wood is to impose logging bans. For instance, logging bans were imposed after natural disasters such as flooding (e.g. Thailand's ban imposed in 1989 and China's ban in 1998). These bans have had mixed results, rarely fully achieving the intended forest conservation goals and, in some cases, resulting in significant unintended negative socio-economic consequences, such as job losses and reduced government revenues (e.g. in Sri Lanka, because of the closure of sawmills and timber sales depots) (FAO 2001). In other instances, weak management controls of the bans caused legal logging to be replaced by illegal logging (e.g. in the Philippines). Illegal logging remains a challenging issue, including in SAARC countries, where illegal cross-border timber trade occurs within communities and by organized groups.⁸⁴ Another consequence of logging bans was that countries with limited alternative domestic sources of wood began to import timber from abroad, often from countries with weaker environmental regulations. Hence, given their potentially significant unintended impacts, it is important to undertake a careful analysis and establish an effective governance framework before implementing such logging bans (Durst et al. 2001; APFSOS III: FAO 2019).

Wood importing countries are increasingly concerned about the sourcing of timber and, more specifically, whether timber is obtained through illegal logging. Where illegal timber imports are prohibited or criminalized, due-diligence requirements are imposed on operators placing wood products on the market. To address this, countries in the Asia-Pacific region use legal incentives, or voluntary market-based instruments such as certification schemes, VPAs or other voluntary standards (see **Sections 4.2.3** and **5.2.2**). CSOs and environmental NGOs can also play a role: for example, both CSOs and environmental NGOs have a formal role as independent observers of the timber legality assurance system in Indonesia,

lending credibility to the voluntary partnership agreement timber legality assurance system and eventual FLEGT licensing (EU FLEG Facility 2017).

4.3.3 Legal incentives and market-based instruments

Legal incentives such as taxes, subsidies, or fiscal transfers have been used for promoting forest conservation. India initiated the world's first ecological fiscal transfer mechanism: India's Finance Commission, which determines the criteria for allocating central tax revenues to states based on measurable criteria, expanded the criteria to include forest areas. Therefore, states that conserved forests received a higher share of resource allocation, incentivizing sustainable management, including afforestation and reforestation (APFSOS III: FAO 2019). Other types of incentives include payments for ecosystem services (PES). Viet Nam developed a national PES scheme in which upland communities are given incentives by hydropower plants and some municipal water and ecotourism companies to protect forests to ensure a clean water supply for power generation, domestic or industrial uses.⁸⁵ PES are intended not only for water but also for other ecosystem services such as biodiversity conservation and carbon sequestration.

Viet Nam has built upon its experience with PES to develop its Carbon for Forest Ecosystems Services program, whereby the country's largest carbon emitters would pay forest communities and landowners to protect and expand forests.⁸⁶ PES schemes are being explored in other countries in Asia as well. Recently, a project was conducted to generate scientific knowledge on the design of effective PES schemes in PNG, the Philippines and Thailand (Kawasaki et al. 2020). The study identified a few areas of information (namely: ecosystems values, community awareness, policies and laws,

⁸⁴ EU FLEGT Facility. 2017. Briefing Cross-border timber trade in the SAARC area. See: <https://www.euflegt.efi.int/publications/cross-border-timber-trade-in-the-saarc-area>

⁸⁵ See: <https://www.climatelinks.org/blog/vietnams-payment-forest-environmental-services-safeguarding-resources-and-improving-lives>

⁸⁶ See: <https://news.mongabay.com/2020/03/vietnams-new-conservation-plan-prioritizes-trees-and-people-emissions-not-so-much/>

and capacity) as essential for building a good governance not only of forest resources, but also of the PES process itself. PES schemes require careful consideration before being developed and implemented, especially with regards to ecological, institutional, and cultural preconditions, including tenure clarity and security among ecosystem service providers (Prokofieva 2016).

4.3.4 Land tenure and access rights

In the Asia-Pacific region, a strong impetus for tenure reform has come not only from domestic sources but also from international processes such as REDD+, the EU-FLEGT initiative, and the VGGTs. The VGGTs (FAO 2012), a guiding framework for addressing tenure issues, were endorsed in 2012 by the UN Committee on World Food Security, to promote secure tenure rights and equitable access to land, fisheries and forests with respect to all forms of tenure, be they public, private, communal, Indigenous, customary or informal (FAO 2019b). The VGGTs also note that governance is closely linked to the issue of access, which is in turn defined and regulated through tenure systems that may be based on written policies and laws, as well as on unwritten customs and practices (FAO 2012). The VGGTs also address the role of non-state actors, calling upon businesses to act with due diligence where human rights and the legitimate tenure rights of others are concerned, and thus to address and implement social safeguards as appropriate. Due diligence is extended to transnational corporations, including enterprises owned or controlled by states, or receiving substantial support and service from state agencies (FAO 2012). Clear and secure tenure rights are a necessary condition to ensure participation in processes towards and commitment to primary forest conservation. They can also be seen as a precondition for communities SFM efforts but also for investors to commit funds in forest-related activities such as forest restoration.

In the forest sector, and in particular for forest conservation and management, the issue of land tenure is crucial, especially as it applies to local communities and has broad implications with regards to equity, rights,

participation in decision making, and resource management. Forest tenure is considered a bundle of five rights for the use of forestland: access, withdrawal, management, exclusion and alienation rights,⁸⁷ and strengthening these rights for given stakeholders is part of tenure reform (APFSOS III: FAO 2019). **Figure 22** shows the indicators for forest tenure, as extracted from the Governance of Forests Toolkit prepared under the Governance of Forests Initiative.⁸⁸ It describes and provides an overview of actors, rules and practices as they apply to the principles of good governance.

The recognition of land tenure by governments is an essential basis for the governance of forest resources as a clear allocation of rights will influence the clear ownership of responsibilities. In a regional assessment of three pillars of forest governance for the Greater Mekong Subregion, tenure (under pillar 3) was given a low score – 2.2 out of 5 (RECOFTC 2018). In India, community forest resource (CFR) rights are recognized under the Forest Rights Act, transferring collective rights and responsibilities to forest-dwelling communities for sustainable use of their customary forests (Gupta et al. 2020). Despite positive examples of tenure reform, the reform is not always implemented to its full potential. In the Philippines, bundles of rights were transferred to local communities to promote the access, use and control of forest resources. However, tenure reform focused mainly on improving forest cover without necessarily generating sustainable livelihood opportunities (Pulhin et al. 2018). Uncertain tenure among customary groups is also a cause for conflict, such as over timber or, in the case of land grabbing, for the production of agricultural commodities (APFSOS III: FAO 2019). The distribution of forest ownership is also an important element in forest legislation

87 Access: the right to enter the forest. Withdrawal: the right to obtain products from the forest (including harvesting timber, non-timber forest products and woodfuel). Management: the right to regulate internal use and transform the forest resource, such as through silvicultural treatments. Exclusion: the right to determine who has access to the forest. Alienation: the right to sell or lease management or exclusion rights and use them as collateral.

88 See: <https://www.wri.org/publication/governance-forests-initiative-indicator-framework-version-1>

		GOVERNANCE COMPONENTS		
		Actors	Rules	Practice
PRINCIPLES OF GOOD GOVERNANCE	Transparency	Land & Forest Agencies 1. Capacity to administer and monitor forest tenure 2. Capacity to negotiate and design forest contracts	Legal Framework for Forest Tenure 6. Recognition community and indigenous tenure rights 7. Legal support and protection of forest tenure 8. Transparent rules for selling and allocating public forests 9. Clear responsibilities and authority for forest tenure administration Law and Policy Processes 10. Coordination of tenure laws/policies with forest management objectives	Forest Tenure Administration 11. Transparent and accessible land tenure administration services 12. Transparent and accessible administration of permits and licenses 13. Competitive processes for awarding major forest contracts 14. Comprehensive design of forest contracts Forest Tenure Monitoring 15. Comprehensive and accurate information 16. Public access to information Community Forest Tenure 17. Recognition and resolution of community forest tenure claims 18. Participatory community mapping Dispute Resolution 19. Accessible and effective dispute resolution
	Accountability			
	Participation	Dispute Resolution Mechanisms 3. Capacity to resolve forest tenure disputes		
	Coordination	Civil Society 4. Capacity to engage on forest tenure issues 5. Representation of indigenous and community groups		
	Capacity			

Figure 22 Forest tenure indicators. Source: Governance of Forests Initiative (2009).

as the formal owner of the forest determines who manages and controls the forest. In most Asian countries, the majority of natural forests are owned by the government, whereas in the Pacific, forests are mostly held by customary owners.⁸⁹ In some countries, the collective and private or individual ownership of forest lands is increasingly being guaranteed by legislation (FAO 2010). Collective forest tenure reforms are recognized as vehicles for moving towards SFM as well as towards other environmental and sustainable development goals, even if their potential can still be developed (Aggarwal et al. 2021).

The NBSAPs of a number of Asia-Pacific countries specifically recognize the importance of tenure and rights of IPLCs and forest dwellers for biodiversity conservation and management objectives and include actions to address this. In Cambodia, the NBSAP⁹⁰ aims to “develop and implement a comprehensive national plan for the management of the forest estate, including (...) protection of resource tenure rights and practices of local communities and

Box 6 Sustainable forest management through customary landowners’ empowerment

Despite the fact that close to 90% of all land in Fiji is customarily owned, the leasing of land and management of forests have been centralized within government since before independence. This strategy has proven to be relatively unsuccessful, with landowners still very much ‘spectators’ on the development of their land and forests with few improvements to their socio-economic status despite the damage done to their natural environments. Customary landowners must be empowered to manage their own land and forests to achieve the required objectives as they know the value of their natural resources and are the ones who will ensure their protection/conservation for their present benefit as well as that of future generations. As a start, institutions like the Ministry of Forestry need to re-orient themselves to better focus on supporting customary landowners in this regard.

Source: Reply to 2021 questionnaire on governance sent to forestry experts in selected Asia-Pacific countries.

⁸⁹ In the Asia-Pacific region, public ownership accounts for 87% of forests in South Asia, 91% in Southeast Asia, 58% in East Asia and 57% in Oceania. Local communities in Pacific Island countries own 97% of forests on average (FRA 2015).

⁹⁰ See: <https://www.cbd.int/doc/world/kh/kh-nbsap-v2-en.pdf>

indigenous ethnic minorities.” (Strategic Objective 2.2). Malaysia’s NBSAP aims to “develop policy and legal instruments that

empower IPLCs to be effective custodians of biodiversity” (Action 2.1). Increasingly, formal tenure rights are being given to IPLCs, most notably in Thailand, Viet Nam and China. Despite this, IPLCs still face insecure rights to their land, for a number of reasons such as the absence of evidence for formalizing claims (APFSOS III: FAO 2019). Yet the role of Indigenous Peoples in forest conservation and management is important, and it is therefore crucial to recognize customary collective and individual rights of Indigenous Peoples to communal lands and natural resources. Many countries have included SFM in their forest policies or set targets for areas of forest land under community-based forestry (CBF). However, achieving these targets has been impaired by a number of factors, including the ability of communities to obtain tenure certificates for their forests (APFSOS III: FAO 2019).

4.3.5 Translating global objectives into national commitments, strategies and action plans

Linking national commitments to global processes and translating them into national action needs to be highlighted as a relevant mechanism for primary forest conservation as it can both strengthen national engagement and help attract international support.

4.3.5.1 National Biodiversity Strategies and Action Plans (NBSAPs)

NBSAPs are the main policy instrument for setting biodiversity conservation targets and implementing the CBD at the national level.⁹¹ The NBSAPs are a planning process addressing threats to national biodiversity. They can be considered a link between international policy frameworks and national policies, legislation and regulations. Sectoral national legislation can be influenced by NBSAPs, while existing legislation can be used to support the implementation of

NBSAP actions. Bearing in mind national-level circumstances (political and institutional arrangements), NBSAPs should be prepared through consultation processes involving a range of stakeholders from line ministries (e.g. environment, forestry, land use planning, finance, etc.), environmental NGOs, CSOs, academia, community groups and the private sector. The Solomon Islands’ NBSAP⁹² explicitly states that: “from a mandate perspective, the NBSAP is built from the provisions provided by the existing environmental laws and policies”. Most NBSAPs contain a description of the values of biodiversity and ecosystem services in the country; an analysis of the causes and consequences of biodiversity loss; an overview of national constitutional, legal and institutional frameworks; implementation plans; and an institutional monitoring and reporting mechanism (CBD 2011). In addition to these, two ‘core’ elements of the national biodiversity strategy are the principles, priorities and targets; and the national action plan. The principles, priorities and targets are the ‘high-level’ elements of the strategy that provide the framework for the NBSAP as a whole and include the long-term vision, the main goals or priority areas, and national targets in line with the Aichi Biodiversity Targets. The National Action Plan provides further details and sets out national actions to achieve the strategy, with milestones. These two elements define intended actions for primary forest conservation, including ‘direct’ actions such as the establishment of PAs for forest biodiversity conservation, as well as other actions addressing drivers of biodiversity loss (e.g. as applicable to countries: poor or weak governance, insecure IPLCs tenure and use rights, or unsustainable logging).

Thirty-six out of 41 countries have explicitly addressed, to some degree, governance as an issue for biodiversity conservation in their NBSAPs. Inappropriate policy and regulatory frameworks (some outdated, and some conflicting with each other), weak law enforcement, and weak institutional capacity were also identified as impediments. Nepal’s NBSAP 2014–2020,⁹³ for example, specifically

91 Of the 49 Countries and Territories included in the scope of this document, 41 have elaborated NBSAPs. These have been considered in a rapid analysis of the most recent NBSAPs based on the use of keywords including: “governance”; “tenure”; “rights”; “logging”; and “certification”.

92 See: <https://www.cbd.int/doc/world/sb/sb-nbsap-v2-en.pdf>

93 See: <https://www.cbd.int/doc/world/np/np-nbsap-v2-en.pdf>

highlights poor governance and weak enforcement of law and regulatory mechanisms as major factors behind deforestation, forest degradation and biodiversity loss. It also cites the poor integration and harmonization of policies and laws as a factor. It targets the development and implementation of criteria and indicators of SFM.⁹⁴ The Philippines' NBSAP 2015–2028⁹⁵ recognizes governance issues as a contributing factor to biodiversity loss, citing a lack of enforcement and political will. For the Solomon Islands, from a regulatory point of view, the enforcement of environmental rules is undermined by the discontinuity of rules within and between levels of governance – at national and provincial levels – and by the multiplicity of customary rules at local level (Solomon Islands' NBSAP 2016–2020⁹⁶). Other NBSAPs address governance specifically in their action plans. For example, Bhutan's NBSAP 2014⁹⁷ aims to “strengthen good governance for sustainable management of forests” (Strategy 7.2). Vanuatu's NBSAP⁹⁸ aims to improve information management and monitoring conservation area management effectiveness and practice (Focus Area CA2). It seeks to establish, for each priority conservation area (CA), “opportunities for mutually beneficial co-management arrangements, which takes into account and builds upon good governance practices where they exist” (Action CA2.5). It is meant to “apply, as appropriate, a diversity of governance arrangements that include recognition of Indigenous and Community Conserved Areas (ICCAs) through national legislation or other effective means of formal inclusion in the national systems” (Action CA2.8).

As previously mentioned, establishing PAs is the most widely used mechanism to conserve primary forests. Through NBSAPs, national governments commit to establishing PA systems (Aichi Biodiversity Target 11) to meet both international and national biodiversity conservation objectives and targets. Some

countries also consider the enabling environment needed for effective PAs. Brunei Darussalam's NBSAP⁹⁹ called for “adequate and permanent reserved forest and marine areas categorized as protected sites for wild flora and fauna protection and conservation in the country” but also called for strengthening governance to make PA objectives effective – specifically, that the agencies concerned have “adequate legal provisions and administrative and technical regulatory procedures.”

4.3.5.2 Nationally Determined Contributions (NDCs)

NDCs within the framework of the UN Framework Convention on Climate Change (UNFCCC) can offer major opportunities to the forestry sector. FAO conducted regional synthesis of the NDCs in Asia and in the Pacific from an agriculture, forestry and fisheries perspective (Crumpler et al. 2020a, 2020b). In both Asia and the Pacific, more than 80 percent of the countries include mitigation commitments on forests in their NDCs, mainly: reducing deforestation and degradation; promoting SFM; and reducing forest fires. In both Asia and the Pacific, more than 80 percent of countries that have an adaptation component in their NDCs include measures related to forests, including reducing deforestation and degradation, monitoring forest health, improving ecological connectivity, restoring ecosystems and species, controlling invasive species, and preventing forest fires. Nepal, for example, commits to decrease deforestation with quantified targets. There are also commitments to enhance coastal resilience and explore carbon sequestration in mangrove plantations (Timor-Leste), and to reduce forest fires (Indonesia).

NDCs are high-level documents with principles and commitments. Other important documents are National Adaptation Plans (NAPs) that all developing countries (and many others) are preparing and implementing. NAPs assess vulnerabilities and risks and identify adaptation measures to address them on the medium- and long-term. They can also include more precise measures.

94 Action AI under its 5.4.2 Management of Forest Biodiversity Outside PA Strategy.

95 See: <https://www.cbd.int/doc/world/ph/ph-nbsap-v3-en.pdf>

96 See: <https://www.cbd.int/doc/world/sb/sb-nbsap-v2-en.pdf>

97 See: <https://www.cbd.int/doc/world/bt/bt-nbsap-v4-en.pdf>

98 See: <https://www.cbd.int/doc/world/vu/vu-nbsap-v2-en.pdf>

99 Submitted to the CBD in 2015.

Examples of adaptation measures taken from NAPs and from the adaptation component of NDCs, include: monitoring the impacts of climate change on biodiversity with local communities (NAP of Sri Lanka¹⁰⁰); forest fire watch and prevention (NAPs of Fiji¹⁰¹ and Sri Lanka); and the protection, restoration and sustainable management of mangroves and coastal forests (NAPs of Fiji, Kiribati¹⁰² and Sri Lanka; NDCs of India¹⁰³ and Viet Nam¹⁰⁴). The plans can include measures to both adapt the forests and to increase their contribution to the adaptation of other sectors (Meybeck et al. 2020).

4.4 Forest conservation at the local level

International and regional agreements, together with national policies, rules and instruments, frame and orient governance mechanisms at the local level. National policies can make SFM a priority, establish a framework for decisions on logging, concessions and agricultural expansion, or define the roles of different actors at different levels in governing forest resources through institutional reform. National legislation can establish rights over the ownership and management of forest resources. At the local level, governments can improve forest governance, including through supporting participatory forest management schemes, strengthening policies and legislation, improving tenure regimes, and ultimately making governance more effective, efficient, transparent, accountable, equitable and participatory.

100 See: <https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/National%20Adaptation%20Plan%20of%20Sri%20Lanka.pdf>

101 See: https://www4.unfccc.int/sites/NAPC/Documents/Parties/National%20Adaptation%20Plan_Fiji.pdf

102 See: <https://www4.unfccc.int/sites/NAPC/Documents/Parties/Kiribati-Joint-Implementation-Plan-for-Climate-Change-and-Disaster-Risk-Management-2019-2028.pdf>

103 See: <https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf>

104 See: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/Viet%20Nam_NDC_2020_Eng.pdf

4.4.1 Community engagement

According to FAO,¹⁰⁵ participatory approaches and tools in the forestry sector have been predominantly adapted and developed within the context of CBF.¹⁰⁶ CBF encompasses both collaborative forest management regimes where forestry is practiced on land that has some form of formal communal tenure and requires collective action, and smallholder forestry on land that is generally privately owned (FAO 2016). It refers to the management of forest lands and forest resources by or with local people, individually or in groups, and for commercial or non-commercial purposes. CBF covers a range of activities including Indigenous management of sacred sites of cultural importance, smallholder forestry schemes, small-scale forest-based enterprises, company-community partnerships, and decentralized and devolved forest management.¹⁰⁷ CBF aims to conserve forests while contributing to the economic development and livelihoods of local communities.

CBF covers a range of situations in which communities have different degrees of control and rights over forest management, including aspects such as monitoring the resource itself, or monitoring crime (e.g. in Cambodia and the Philippines). In Indonesia, weak forest governance practices regarding logging are addressed by allowing for independent monitoring by local communities through the independent monitoring mechanism within the policy framework of the timber

105 See: <http://www.fao.org/forestry/participatory/90732/en/>

106 CBF is an umbrella term covering a spectrum of regimes, including: participatory conservation (e.g. community PA management in Cambodia, joint PA management in Thailand, or village conservation in Indonesia); joint forest management (e.g. in India); community forestry (both limited and full devolution) (e.g. community forestry and leasehold forestry in Nepal; private ownership (FAO 2016); and social forestry, such as Indonesia's Perhutanan Sosial (social forestry) program.

107 See: <http://www.fao.org/forestry/participatory/90729/en/>

legality verification system.¹⁰⁸ Finally, while not strictly related to forests, the importance of community-based monitoring can be seen in Malaysia's NBSAP Action 2.1, which aims to "strengthen and support community-based biodiversity monitoring and patrolling such as the Honorary Wildlife Wardens and the Honorary Rangers programs". Through its participatory approach, CBF empowers people with a direct stake in forest resources to be part of all decision-making aspects of forest management, including policy formulation processes.¹⁰⁹ IPLCs can play a significant role in SFM because they have both the local skills and expertise with regards to the management of forest concession areas. They can contribute to well-managed forest concessions, which can in turn potentially have positive social, economic and environmental benefits, such as creating employment, maintaining ecosystem services, generating foreign exchange, and earning government revenue (van Hensbergen 2018). In the Asia-Pacific region, IPLCs are increasingly participating to forest management schemes. In China, Nepal, India, the Philippines and Viet Nam, the involvement of local communities in forest management has increased significantly since the 1990s. In Nepal, CBF management modalities include community forestry, leasehold forestry, buffer zone community forests, protected forests and religious forests. These were substantially expanded since the early 2000s. As of 2017, these CBF modalities covered over 38% of the national forest area (Pathak et al. 2017). Forest user groups in Nepal¹¹⁰ are formally organized as per the Forest Act 1993; since the enactment of the Act, the government has gradually transferred parcels of national forest, particularly in the mid-hills, to local communities based on an agreed forest

management plan between the District Forest Office and local forest user groups (Dahal et al. 2008).¹¹¹

Despite challenges and limitations, many countries in the Asia-Pacific region, and particularly in Southeast Asia, have set targets for areas of forestland under CBF. In Bhutan and Mongolia, CBF programs have been enacted more recently. Strong tenure rights are associated with effective CBF outcomes. In Asia, most forests are legally under state control and CBF regimes generally involve some form of devolution of responsibility for forest management. In the Pacific, customary landownership, including forest ownership, is both widespread and legally recognized (FAO 2016). In Australia, the rights of Indigenous Peoples to own and manage land, including forest land, is increasingly recognized, and in 2013, 34% of the national forest estate was under some form of Indigenous CBF regime (FAO 2016).

It is crucial to actively involve local people in the conservation and management of forest resources, as IPLCs living within or adjacent to forests directly derive benefits from forest resources but often also hold valuable knowledge on forest conservation and management. As such, IPLCs can have an effective role in forest conservation (e.g. in PAs), management (e.g. the management of forest concession areas; SFM), and monitoring (e.g. for illegal logging; see **Box 7**). A number of NBSAPs address this. In Myanmar, the NBSAP¹¹² states that the recognition of customary tenure and traditional systems of governance is fundamental to the promotion of traditional practices that benefit conservation and encourage the sustainable use of resources. In the Philippines, protected area management boards are formal bodies comprising diverse membership and perspectives that are legally authorized to consider protected area issues and make decisions on management.

108 Fight Illegal Logging, Indigenous and Local Communities Conduct Monitor Logging in 4 Provinces in Indonesia. See: <https://pplh-mangkubumi.or.id/en/2020/10/20/fight-illegal-logging-indigenous-and-local-communities-conduct-monitor-logging-in-4-provinces-in-indonesia/>

109 *Ibid.*

110 Interestingly, Community Forest User Groups in Nepal were found to be the most effective institution to provide immediate support to disaster affected communities (Gentle, 2020).

111 See: https://www.cifor.org/publications/pdf_files/events/documentations/yogyakarta/papers/chapter%205%20dahal.pdf

112 See: <https://www.cbd.int/doc/world/mm/mm-nbsap-v2-en.pdf>

Box 7 Local government and illegal logging

In the Philippines, following floods due to Typhoon Ulysses, the Department of the Interior and Local Government (DILG) directed local government units (LGUs) and the Philippine National Police (PNP) to implement a crackdown on illegal logging also by reactivating their local anti-illegal logging task forces in coordination with the Provincial and Community Environment and Natural Resources Offices of the Department of the Environment and Natural Resources (DENR). All LGUs were also reminded that under the DENR Memorandum Circular 2011, all municipal/city mayors, through their respective *barangay* captains,¹ are to conduct upland monitoring “to ensure that no illegal logging, kaingin (slash-and-burn farming) and other forms of forest destruction” are taking place within their jurisdictions. They were ordered to report to their regional task forces (RTFs), “through the Provincial Governor and/or the DILG Regional Director,” incidents of forests destruction especially slash and burn farming (kaingin) and illegal logging activities.

Source: <https://dilg.gov.ph/news/DILG-to-LGUs-PNP-Crackdown-on-illegal-logging-expedite-planting-of-trees/NC-2020-1390>

1 i.e. the highest elected official in a *barangay*, which is the smallest administrative division in the Philippines.

4.4.2 Community rights

There are several common features to forest governance in community-based forestry (CBF) schemes. Tenure security is essential for communities to address and be accountable for forest management. As a result, government policies on CBF must be supported by laws on tenure and rights. These laws must be implemented and enforced to give equitable and fair ownership of and access to land and forest resources, as well as to the benefits they generate. According to APFSOS III (FAO 2019), “those countries that have made most progress in the past two decades are those that have advanced institutional reforms, especially related to tenure, and increased the area of forest available for community forestry and forestry on private lands”. In Thailand, orders are being developed to accompany the May 2019 Community Forestry Act. These include guidelines on registering as a community and developing a management plan. Myanmar is developing guidelines for social forestry, and Lao PDR is planning to build the capacity of villages to develop forest management plans (RECOFTC 2020a).

Institutional reform can play a major role in CBF as participatory forestry mechanisms have different requirements from institutional requirements for timber extraction and logging concessions. Here, the role of

government institutions shifts from serving as main ‘deciders’ to more facilitating and regulatory roles in supporting inclusive and participatory approaches. Actors involved in CBF can include community institutions, non-governmental organizations, or the private sector. Community institutions can include forest user groups, farmer unions and cooperatives. Non-governmental organizations have a role in supporting communities, including providing technical support, as well as helping bring community priorities, needs and objectives to the attention of governments. For example, the Rights and Resources Initiative’s Strategic Response Mechanism in Indonesia helped empower communities in the Bukit Betabuh Forest Reserve to create social forestry enterprises that would allow them to retain the rights to their lands and to economically benefit from the forest resources. The Yayasan Hutanriau (Riau Forest Foundation) helped these communities respond to the illegal expansion of palm oil plantations and illegal logging on their customary lands.¹¹³ In Indonesia, the government granting of a social forestry license provides access to financial institutions. More often, though, financial institutions do not consider social forestry licenses sufficient for them to

113 See: <https://www.peoplenotpoaching.org/using-social-forestry-stop-illegal-logging-and-benefit-local-communities>

disburse loans because of the limited time frame associated with tenure (e.g. in Myanmar and Cambodia). Nevertheless, recently revised laws in Myanmar and Lao PDR lay the foundations for using social forestry as a mechanism for community-based enterprises (RECOFTC 2020b).

Some issues can hinder the full potential of CBF. For instance, in Pakistan, joint forest management has been recently introduced, and local communities are recognized as key stakeholders in forest conservation and management. However, while their rights, privileges and obligations are clear, their role is less so (APFSOS III: FAO 2019). Land acquisitions can also impact CBF regimes as there can be potential overlap between land under forest concessions and land under local community management. This is the case in many parts of Asia, where the area of land allocated to large-scale timber concessions is larger than the forest land under community ownership or administration. (van Hensbergen 2018).

4.4.3 Conflicts

Conflicts are a major issue in local level governance. Conflicts have arisen over land tenure (e.g. customary rights vs. state-owned forests), between IPLCs and conservation agencies (e.g. around the creation of PAs), and between communities and logging concessionaires. Conflicts can also arise over boundaries between community forests and other types of forests, between neighboring community forests, and within communities over benefit-sharing arrangements among community members (APFSOS III: FAO 2019). Encouraging IPLC participation in forest conservation and management is gaining traction as a possible way to prevent, manage and solve conflicts. Despite efforts to divest ownership, rights and related benefits to communities, elite capture has been reported in many cases, leading to dissatisfaction and resentment among other community members. At the local level, land tenure and community participation are particularly sensitive issues with regards to forest concessions (e.g. ELCs in Cambodia). In many countries, forest governance does

not consider the customary rights of forest-dependent people and, in doing so, opens the space for concession allocations to have significant impacts on the rights of local communities, potentially leading to conflicts (van Hensbergen 2018). Moreover, uncertainty about tenure rights can dissuade concession holders from making the investments required to achieve SFM (*ibid.*). In the Indonesian province of Riau, a conflict is ongoing between local communities and companies holding industrial plantation forest concession rights. Prihatin and Wicaksono (2020) showed that this is a result of economic disparities (e.g. income earned by migrant workers as opposed to income for local communities) and of the tenure conflict between customary forests and production forests.

Despite the frequency of forest-related conflicts, many countries lack effective mechanisms for conflict resolution. Clear demarcation of boundaries can help with this. Cambodia's NBSAP¹¹⁴ recognizes that, with regards to forest areas, there is a lack of clear demarcations, classifications and registration, which "distorts the interpretation of land tenure and user rights, both of which are essential elements in management planning and conflict prevention and resolution." The One Map geoportal initiative in Indonesia is an example where the government uses technology to reconcile conflicting land rights claims through land mapping and managing land ownership information (FAO 2016). Communities can also play a role in monitoring potential conflicts (**Box 8**).

114 See: <https://www.cbd.int/doc/world/kh/kh-nbsap-v2-en.pdf>

Box 8 Citizens and science – two case studies.

In Indonesia, law enforcement on deforestation often relies on field reports from civil society organizations (CSOs) and the public. The use of near-real-time satellite data by HAKA – a grassroots non-profit organization addressing deforestation monitoring in the Indonesian Leuser Ecosystem – allows this approach to be conducted more efficiently. To improve the capability of law enforcement officials, HAKA GIS staff trained police officers and staff members of several forest management units, the conservation unit, and the national park management unit with the financial and technical support of the World Resources Institute (WRI)'s Global Forest Watch (GFW). As a result of HAKA's training program and intensive communication with government officials, GFW and its derivative products have been adopted by the local government and the forest management units as part of their forest monitoring systems. Evidence-based reports from the civil society are acknowledged and accepted for further action by the government agencies in the Leuser Ecosystem. To complement these efforts, HAKA has also conducted other types of training targeting different stakeholders, such as raising awareness for local women and citizen journalism training for local communities. For example, as a result of HAKA intervention, there was a crackdown on illegal gold mining and marijuana plantations in the forest zone by the police, and GFW's fire hotspot data was used as a key reference to support the firefighting efforts of the government and local people.

Launched by a group of young environmental professionals in response to the lack of consolidated maps of forest areas in Malaysia, and limited access to such information, Hutanwatch is an open data website that promotes forest transparency in Malaysia. Free and open access to information has created a level playing field for all individuals and organizations working in the field on forest monitoring, advocacy and stewardship in Malaysia. Using Hutanwatch, any interested party can investigate forest cover change, check whether tree loss occurs within or outside forest reserve boundaries, identify potentially illicit forest activities and encourage additional courses of action, such as by informing Hutanwatch, journalists, local representatives, CSOs or enforcement agencies. The information is transmitted to and validated by Hutanwatch, and then uploaded to Hutanwatch's news page,¹ where the public can read and add further information on incidents.

Source: Bahar and Wicaksono (2021)

1 See: <https://www.hutanwatch.com/news>

5 Mechanisms and tools for primary forest conservation

Primary forests conservation objectives are tied to ecological priorities including biodiversity, ecosystem services and climate change. The main threats to primary forests are deforestation, degradation and fragmentation (see **Chapters 1 and 2**), and these are influenced by complex socioeconomic and biophysical drivers, many of which are pressures from outside forest areas (see **Chapter 3**).

This last chapter describes how selected governance tools and mechanisms (see **Chapter 4**) most widely used in the Asia-Pacific region can be mobilized, in addition with or in relation to legally protected areas, to address different drivers of threats. It builds upon the information gathered from the questionnaire on governance sent to forestry experts in selected Asia-Pacific countries; from the discussions held during the 23–25 March 2021 online expert workshop on primary forest conservation (Pingault et al. 2021a); from an initial rapid analysis of various NBSAPs of Asia-Pacific countries; and from youth contributions to the Asia-Pacific roadmap on innovative forest technologies (Pingault et al. 2021c).

5.1 Protected areas

The most widely used mechanism for conserving primary forests is designating them as PAs (Leberger et al. 2020). Although most intact forests are located outside of PAs, as mentioned in **Chapter 1**, much of the area of primary forest cover is located within PAs according to national reporting. More specifically, the 2020 Global Forest Resources Assessment (FRA) noted that many countries reported their primary forest area by using the area of forest in national parks and their conservation areas as proxies. It should be

noted that while registration as PA slows down deforestation, it does not always stop it entirely. PAs must be complemented by other mechanisms.

The International Union for Conservation of Nature (IUCN) defines PAs as “clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.”¹¹⁵ The six IUCN categories for PA management (**Table 9**) have been adopted by the UN system,¹¹⁶ and while the application of the IUCN PA categories is voluntary, most countries use them (Dudley 2008).

From 1990 to 2015, the extent of forests designated for biodiversity conservation in the Asia-Pacific region increased from 12.4% of the forest area to 16.5% (FAO 2015). The period of most rapid expansion of the PA network was from 1990 to 2000, but since then, the expansion of forest area under PAs slowed down (APFSOS III: FAO 2019). According to the most recent data from the world database on PAs (WDPA: UNEP-WCMC 2021), there are 35,474 PAs in the Asia-Pacific region. Of these, terrestrial PAs cover 15.38% of the total area; the vast majority (46%) are IUCN Category IV, followed by Category III (19%). National parks (Category II) account for only 4%, whereas Category I PAs – strictly conserved – account for 10% (UNEP-WCMC 2021). Having said that, when in a PA, primary forests typically fall under Category I, as their

¹¹⁵ See: <https://www.iucn.org/theme/protected-areas/about>

¹¹⁶ e.g. the UN List of Protected Areas, the Convention on Biological Diversity Programme of Work on Protected Areas, and the World Database on Protected Areas.

Table 9 IUCN PA categories

IUCN Category	Description
Ia. Strict nature reserve	Strictly protected areas set aside to protect biodiversity and also possibly geological and geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such PAs can serve as indispensable reference areas for scientific research and monitoring.
Ib. Wilderness area	Usually, large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
II. National Park	Large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.
III. Natural monuments or feature	To protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small PAs and often have high visitor value.
IV. Habitat/species management area	Protecting particular species or habitats and management reflects this priority. Many PAs of Category IV will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
V. Protected landscape/seascape	Where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value; and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
VI. PA with sustainable use of natural resources	To conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Source: (Dudley 2008)

main characteristic is that they are largely undisturbed. Globally, existing PAs cover 37% of tropical primary forest and 25% of intact forest landscapes.¹¹⁷

In Japan, the PA system has evolved over time, backed by science and expertise, to address updated conservation and conservation management priorities (**Box 9**). Japan's 7.58 million hectares of national forests, both primeval and planted, are administered and managed by the Forestry Agency of Japan. Parts of national forests that are particularly important for biodiversity, such as primeval forests and habitats for rare wildlife, are designated as 'protected forests' (661 sites

designated as of April 2020, covering 13% of national forests). Japan has also established a system of 'green corridors', monitored and assessed by the Committee for Administration of Protected Forests (24 green corridors designated as of April 2020, covering 8% of national forests). Originally established in 1915, many protected forests have since been designated as natural parks or natural monuments. In 1989, the system of protected forests was modified to include the concept of 'zone category', which was adopted as a tool for protection and administration to popularize the zoning idea of PAs (Ujihashi and Fujiwara 2021).

Leberger et al. (2020) showed that, globally, forest loss was lower within PA boundaries and that higher protection categories (I-III) are more effective at preventing forest loss

117 See: <https://research.wri.org/gfr/forest-designation-indicators/protected-forests>

Box 9 The evolution of Japan's protected areas.

Japan's Expert Council on the Protected Forest System and Other Initiatives was established in June 2014 to review and resolve issues concerning the designation of protected forests and challenges to address for protection and administration, among other issues. The protected forest system was revised in September 2015 based on a report provided by the Expert Council and considering the growing interest of people in biodiversity and the accumulation of scientific knowledge built up through research. As part of this revision, several new zone categories and biodiversity conservation methodologies, such as "restoration," were designated to support simpler and more efficient administration. Thus, the former seven categories were condensed to three more concise and effective categories: (i) "forest ecosystem reserve," primeval natural forests representative of climates or forest zones observed in Japan – corresponding to IUCN Category Ib; (ii) "biocenosis protected forest," for forests with an endemic biological community; and (iii) "rare population protected forest," for forests providing habitat to rare wildlife. The "forest ecosystem reserve" is also recognized as a mechanism working to preserve the value of Japan's World Natural Heritage sites and UNESCO Biosphere Reserves. Almost the entire land area of the World Natural Heritage sites in Japan (Shiretoko, Shirakami-Sanchi, Ogasawara Islands and Yakushima) has been designated as protected forest. Lastly, the scheme for the administration of protected forests has been made more efficient by consolidating several existing committees into the Committee for Administration of Protected Forests, a unified organization set up for each regional forest office, with subcommittees created when needed. This governance system has led to greater effectiveness and efficiency in protected forest monitoring by allowing different intervals to be set between surveys depending on the specific conditions of each forest.

Source: Ujihashi and Fujiwara 2021

than lower categories (IV-VI). There are aspects to consider in order to ensure PAs are well established and governed. Firstly, PAs need to be assigned management categories, and IUCN provides guidance for this. Applying management categories is a process involving: (i) identifying management objectives; (ii) assessing if the site meets the IUCN definition of a PA; (iii) if so, documenting the characteristics – legal status, management objectives etc. – and justification for PA status; (iv) using this information to propose a management category for the PA; (v) ideally, carrying out a consultation process to agree on the proposed category; and (vi) government making the final decision on the category (Dudley 2008; Stolton et al. 2013).

IUCN has developed a series of guidelines for countries to consult for the process of establishing and managing PAs ("IUCN WCPA Best Practice Protected Areas Guidelines Series"¹¹⁸). These include the 2020 **guidelines for conserving connectivity through**

ecological networks and corridors; the 2013 guidelines for applying protected area management categories, including best practice guidance on recognizing protected areas and assigning management categories and governance types; and the 2013 **governance of protected areas**.

5.1.1 Management authority and governance

Management authority and responsibility for PAs also need to be considered. IUCN defines different governance types that describe the different types of management authority and responsibility that can exist for PAs but do not necessarily relate to ownership: (i) public governance (by national government or sub-national administration or agency); (ii) shared governance; (iii) private governance; and (iv) governance by IPLCs. (Dudley 2008; Borrini-Feyerabend et al. 2013; Stolton et al. 2013). The main governance type found in the Asia-Pacific region is sub-national ministry or agency (39.1%), followed by federal or national ministry or agency (25.6%). Collaborative governance accounts for 2.8% of PAs, governance by Indigenous Peoples accounts

118 See: <https://www.iucn.org/theme/protected-areas/resources/iucn-wcpa-best-practice-guidelines-protected-area-managers-series>

for just 0.9%, and lastly, forests governed by local communities only 0.2% (UNEP-WCMC 2021). IUCN has explored a set of broad principles for the good governance of PAs, including legitimacy and voice, direction, performance, accountability, fairness and rights (IUCN 2016).

Management objectives for the different IUCN PA categories can be developed and assigned without considering the different IUCN governance types defined above. However, considering governance types together with management category can be important for comparisons of PAs and their effectiveness in future databases (Dudley 2008; Stolton et al. 2013).

Establishing, managing and monitoring PAs involves numerous different actors, including academia, IPLCs, governments or other owners of forest land, sub-national government entities (e.g. at the provincial or district level), PA agencies, non-governmental organizations, and private sector partners. In Myanmar, only the ‘management by government’ IUCN governance category is recognized by the Protection of Wildlife and Protected Areas Rules (2002). Myanmar’s NBSAP (2015–2020)¹¹⁹ addresses PA effectiveness (**Box 10**). It acknowledges that the adoption of management models that recognize sustainable use, and co-management and community management, are essential for establishing ecologically representative, effectively and equitably managed PA systems. To this effect, Myanmar’s NBSAP calls for expanding IUCN governance categories to include co-management and community conserved areas, and has a specific target (Target 11.2) that “IUCN governance categories and management categories are recognized in policy and practice”. This includes ICCAs, while not undermining existing governance structures and customary management that promote sustainable use. Consultation plays an important role in the PA process, including defining PA and buffer zone boundaries. The use of free, prior and informed consent by and for communities is highlighted.

¹¹⁹ See: <https://www.cbd.int/doc/world/mm/mm-nbsap-v2-en.pdf>

Box 10 PA governance in biodiversity policy – examples

Some countries specifically address PA governance in their NBSAPs. Lao PDR’s NBSAP (2016–2025)¹ states that PA governance “is hampered by the fact that most are not yet delineated on the ground and only six have management plans.” Malaysia’s NBSAP (2016–2025)² aims to improve the effectiveness of PA management by establishing “a framework for the National PA system, including developing appropriate methods, standards, criteria and indicators for evaluating the effectiveness of PA management and governance, taking into account the IUCN-World Commission on Protected Areas (WCPA) Framework for evaluating management effectiveness” (Action 6.4). The Philippines’ NBSAP (2015–2028)³ notes that while its National Integrated Protected Areas System “has clearly articulated the policy framework for the establishment of PAs, the emergence of other governance types has also reinforced the arguments for developing a national PA system plan, to take account of other modes of area-based conservation efforts.”

1 <https://www.cbd.int/doc/world/la/la-nbsap-v2-en.pdf>

2 <https://www.cbd.int/doc/world/my/my-nbsap-v2-en.pdf>

3 <https://www.cbd.int/doc/world/ph/ph-nbsap-v3-en.pdf>

IPLCs are sometimes evicted from their ancestral lands once national parks are created (e.g. Kaeng Krachan National Park in Thailand), or their livelihoods can be endangered because of restricted access to forest resources. Conflicts exist because of the lack of recognition of the role of local and indigenous communities in protecting forests and landscapes (APFSOS III: FAO 2019). In Pakistan, “local communities will be empowered and their capacity developed so they can act as custodians of PAs and landscapes.”¹²⁰ In Tonga, while the land tenure system for the protection of priority areas for conservation objectives is centralized, the NBSAP¹²¹ states that “the involvement of local communities that are directly impacting areas of high conservation

¹²⁰ See: <https://www.cbd.int/doc/world/pk/pk-nbsap-v2-en.pdf>

¹²¹ See: <https://www.cbd.int/doc/world/to/to-nbsap-01-en.pdf>

value should be encouraged and, where appropriate, incorporated into protected area management.” Malaysia’s NBSAP¹²² recognizes that cooperation with local and Indigenous communities is needed for successful habitat and species conservation and calls for the development of community conserved areas (CCAs) as an integral part of the national PA network (Action 6.3). The *tagal sungai* and *tagal hutan* systems in Sabah and the *tagang* system and community forests in Sarawak are examples. Through the Community Conservation Resilience Initiative, the Global Forest Coalition is working with five villages in Sabah which were selected because they reflect the diverse land use practices of each community. For example, practicing *tavol* in Alutok (in the Tenom district) prohibits hunting and resource gathering in specific forest areas during specific time periods so that resources are not depleted and conflict and competition within the community are avoided. In Mengkawago, Sabah, the Sungai Rumanau community documents traditional knowledge of wild honey collection, harvests that honey sustainably, and protects the surrounding forest area, providing broader environmental benefits.¹²³

The IUCN green list of protected and conserved areas (IUCN-WCPA 2017) provides the first global standard of best practice for area-based conservation. The overarching objective of the program is to “increase and recognize the number of effectively managed and equitably governed protected and conserved areas, to deliver conservation outcomes.”¹²⁴ In the Asia-Pacific region, the following countries are participating in the IUCN green list program: Australia, Bhutan, China, Korea, Lao PDR, Malaysia, PNG, Solomon Islands and Viet Nam.

5.1.2 Enforcement

Despite an increase in the coverage of PAs, the enforcement of PA conservation rules is not always ensured, as in the case of

rubber plantations that have expanded into PAs in northeastern India, Yunnan province in China, or most of the Mekong River basin. In Cambodia, Lohani et al. (2020) stated that while PAs had lower rates of forest loss than non-PAs, cumulative forest loss in PAs was still high (around 20% from 1993 to 2017), suggesting that PA enforcement continues to be an issue. Enforcement is important not only to ensure that national legislation is correctly and fairly implemented, but also to ensure the accountability of all actors involved in its implementation. If PA rules were correctly enforced, large areas of protected natural forests should be excluded from production. However, this is not always the case on the ground. From 2005 to 2010, 60% of the expansion of rubber plantations in continental Southeast Asia occurred in PAs, as was also the case in India, China and in the Mekong River Basin (APFSOS III: FAO 2019). In some countries, and despite existing policies and laws designed to protect biodiversity, PAs are opened up for the cultivation of commercial crops, mining, infrastructure and urban development (APFSOS III: FAO 2019; Lohani et al. 2020).

Another challenge is ensuring the participation and empowerment of IPLCs in PA creation and management. Viet Nam, for instance, highlighted the need to provide more incentives for IPLCs to become more involved in natural forest governance and management (APFSOS III: FAO 2019). PA management is sometimes undermined by the exclusion of populations whose livelihoods depend on forest resources. This has in some instances led to conflicts between IPLCs and conservation entities such as national park officials. Furthermore, as seen in Viet Nam, overlaps between customary and official tenure rights in many PAs have encouraged illegal logging and affected land use by local communities.¹²⁵

Another issue with regards to PAs is linked to the designation of primary forest land as

122 See: <https://www.cbd.int/doc/world/my/my-nbsap-v2-en.pdf>

123 See: <https://globalforestcoalition.org/community-conservation-malaysia/>

124 See: <https://www.protectedplanet.net/en/thematic-areas/green-list>

125 See: <https://www.recoftc.org/projects/v4mf/stories/forest-governance-reforms-needed-region-forum-told;> and <https://www.recoftc.org/special-report/communities-improve-landscapes-southeast-asia/unlocking-potential-social-forestry-southeast-asia>

“protected” – more specifically, this is related to what is considered as primary forest, and how it is monitored. At the global level, the IUCN’s Global Programme and Secretariat’s Forest Conservation Programme advocate for distinguishing “primary forests and intact forest landscapes” from other forest areas and giving them priority within the international community (IUCN 2020).

5.1.3 Aligned legislative frameworks

National policies and laws on forestry can sometimes be misaligned with other national sectoral policies and legislations (FAO 2010). This can create murkiness for enforcement, accountability, monitoring, reporting, and the definition of rights, to name a few. In other cases, such as for forest management, policy implementation is weak, and updated and relevant legislation is needed (FAO 2010). For example, although SFM has been adopted as a guiding principle in the forest policy of many Asia-Pacific countries, not all countries have revised their forest policies and legislation in recent years (FAO 2010).

There can also be cases of misaligned or conflicting priorities. For instance, the Republic of Korea reported that protection of primary forests often conflicts with interests of municipal authorities who wish to develop the region and obtain high returns on investments. The most recent dispute regards Mount Gariwang region. This region, designated in 2006 as Forest Genetic Resources Protection Zone, had been selected among the few plausible sites meeting the required international standards to build an alpine race course for the 2018 Pyeongchang Winter Olympics Games. After the Olympics, there were long and contentious discussions to reach final consent on a forest restoration plan. Recently, the government was able to draw a compromise in coordination with relevant ministries and municipal offices to implement the restoration of the region while maintaining in operation the slope’s cable cars only during the preparatory periods for the restoration, but not beyond 2024.¹²⁶

¹²⁶ Reply to 2021 questionnaire on governance sent to forestry experts in selected Asia-Pacific countries.

5.1.4 Effectiveness

PAs are established to achieve a variety of objectives, and their strictness level and locations can be driven by motivations other than preventing land clearing or deforestation. For example, PAs targeting areas of biodiversity conservation may be located in low-threat areas (Shah et al. 2021). The habitat integrity – and therefore also effectiveness – of a PA depends on different factors, including its level of protection (e.g. IUCN category) or isolation from human activities (Leberger et al. 2020). In a number of countries, PAs are located in high-elevation or otherwise remote areas that have less human activity and therefore are de facto ‘better protected’ due to their location. In the Greater Mekong Subregion for example, PAs are mostly located in forested uplands where there is less human intervention; most other forested areas are affected by human activities, which frequently overlap with PAs.¹²⁷ Singh et al. (2021) studied the effectiveness of PAs in Thailand and noted that PAs located in highland areas (above 750 m) are well-protected,¹²⁸ whereas those at lower altitude, where human and agricultural pressures are higher, are less well-protected. In the Hindu Kush Himalayas, the transboundary Kangchenjunga Landscape Conservation and Development Initiative (KLCDI), which spans Bhutan, India and Nepal, emphasizes the landscape approach, and encompasses 19 protected areas.¹²⁹

An important aspect for using PAs as a governance mechanism for primary forest conservation is to check how effective the PAs actually are. Shah et al. (2021) found that countries with lower agricultural activity, higher economic growth and better governance are most strongly associated with greater country-level PA effectiveness. They also found that while stricter IUCN-PA categories are often associated with greater levels of avoided deforestation, the differences in their effectiveness are not always large and can be a result of other factors. Thus, more evidence is needed to guide policymakers in their

¹²⁷ GMS Forest Policy Brief 03 on Forest Biodiversity Conservation. See: <http://www.fao.org/3/at935e/at935e.pdf>

¹²⁸ 66% of Thailand’s PAs are situated above 1,000 m.

¹²⁹ See: <https://www.icimod.org/initiative/about-klcdi/>

choice of PA management categories, such as understanding whether a PA is effective because of its location or because of its management.

A number of methodologies have been developed to assess the effectiveness of PAs, such as the Management Effectiveness Tracking Tool (METT). Protected area management effectiveness (PAME) evaluations are “the assessment of how well PAs are being managed – primarily the extent to which management is protecting values and achieving goals and objectives” (Hockings et al. 2006). Three main ‘themes’ are reflected: (i) PA design issues relating to both individual sites and protected area systems; (ii) adequacy and appropriateness of management systems and processes; and (iii) delivery of protected area objectives including conservation of values.¹³⁰ Most PAME methodologies are based on the IUCN WCPA framework for PAME, which includes six key elements: context, planning, inputs, process, outputs and outcomes (UNEP-WCMC 2017). Ongoing PAME assessment efforts have been consolidated into the Global Database on Protected Area Management Effectiveness (GD-PAME).¹³¹

India, for instance, has recently released its management effectiveness evaluation (MEE) of national parks and wildlife sanctuaries and institutionalized its MEE process (Mohan et al. 2020). At a dedicated event, Shri Prakash Javadekar, India’s Minister for Environment, Forest and Climate Change, announced that from 2021 onwards, annual rankings and awards would be introduced for the top 10 national parks, the top five coastal and marine parks and the top five zoos in the country.¹³²

Hence, although PAs are the most widely used mechanism to conserve primary forests, their sole ‘designation as PA’ status is not always sufficient. PAs need to be supported by other measures including: (i)

the enforcement of laws and regulations governing the protection of the forest;¹³³ (ii) incentives or compensation measures for the various actors to respect the PA status; (iii) the establishment and management of buffer zones around PAs and ecological corridors linking fragmented forest areas/PAs; and (iv) the management of intact forests outside PAs. A more integrated landscape approach needs to be adopted.

5.2 Complementary approaches for the protection of primary forests

5.2.1 Connectivity

Wide-ranging species need to be able to move over large areas, and connectivity will be essential to maintain genetic diversity and enable populations to migrate in response to climate change (Senior et al. <https://paperpile.com/c/ZoXdeA/ljNh> 2019).

Ecological connectivity is important for a number of reasons including species flow, adaptation to climate change and the provision of ecosystem services, and Aichi Biodiversity Target 11 calls for establishing “well-connected systems of PAs and other effective area-based conservation measures.” The OECM clause was a last-minute addition to Aichi Biodiversity Target 11 to acknowledge the contribution that many areas not legally designated as PAs can contribute to effective conservation (Laffoley et al. 2017). Forest fragmentation is a challenge for maintaining ecological connectivity between PAs and OECMs. It is therefore essential to ensure connectivity between PAs and OECMs, as opposed to increasing the size of a few isolated PAs and OECMs, for the effective conservation and management of biodiversity (Hilty et al. 2020). This can be achieved through the establishment of ecological networks, which are made up of a system of core habitats (PAs, OECMs and other intact natural areas) that are connected by ecological corridors (Hilty et al. 2020).

¹³⁰ See: <https://www.cbd.int/protected-old/PAME.shtml>

¹³¹ Available at: <https://www.protectedplanet.net>

¹³² Press Information Bureau. 11 January 2021. Ministry of Environment, Forest and Climate Change, Government of India. See: <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1687688>

¹³³ Here a lack of financial capacity can be an issue; necessary funds should be available for law enforcement officers or park rangers.

Under the IUCN’s World Commission on Protected Areas (WCPA), a Task Force was established in 2015 to provide guidance on OECMs in terrestrial, freshwater and marine habitats. Among its activities, the Task Force developed a Rapid Assessment Screening Tool to assess if an area could be further scrutinized for accounting as OECM by questioning the area’s management, status and objectives (IUCN WCPA 2018a). Building on the work of the Task Force, a decision on PAs and OECMs was adopted by CBD COP14 in 2018 (CBD/COP/14/8¹³⁴). OECMs are defined by the CBD as “a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values.” In essence, by considering OECMs in conservation policy, it is recognized that there are sites outside of formal protected area networks that also benefit biodiversity and ecosystems in important ways (Alves-Pinto et al. 2021). COP Decision 14/8 also established four groups of criteria for OECM identification: (i) the area is not currently recognized as a protected area; (ii) the area is governed and managed; (iii) it achieves sustained and effective contribution to in situ conservation of biodiversity; and (iv) it supports associated ecosystem functions and services and cultural, spiritual, socio-economic and other locally relevant values.¹³⁵

OECMs were also recognized by the Fourth UN Environment Assembly in March 2019 in its resolution on “Innovation on biodiversity and land degradation” (UNEP/EA.4/Res10¹³⁶).

Examples of types of forest management that may qualify as OECMs include (IUCN-WCPA 2018b; Laffoley et al. 2017):

- Indigenous and community-managed reserves, which meet the IUCN PA

definition, but are not reported as national PAs.

- Wildlife conservancies adjacent to national parks or PAs.
- Hunting reserves that maintain natural habitats and other flora and fauna as well as viable populations of hunted and non-hunted native species.
- Privately managed areas with primary conservation objectives and demonstrated effectiveness that are not reported as PAs in national reports.
- Areas of active habitat restoration to restore degraded ecosystems of high value for biodiversity and ecosystem services, e.g. restored coastal wetlands and mangroves.
- Some permanently set-aside areas of forest, such as old-growth, primary, or other high-biodiversity value forests, which are protected from threats.

The above suggests that, in principle, SFM could be compatible with the OECM definition, hence OECMs offer a new opportunity to recognize positive biodiversity effects of at least some forms of SFM implementation (S. Wertz-Kanounnikoff, FAO, personal communication).

In some countries, buffer zones have been established to insulate areas where biodiversity conservation is the primary objective from potentially damaging external influences, particularly from those caused by inappropriate forms of land use (Bennett and Mulongoy 2006). The management of production forests can be used to enhance the quality of PAs, where these forests serve as buffer zones around parks and reserves or provide connectivity at the landscape scale. In this respect, it is important to consider forest types so that plans provide connectivity between patches of a particular forest type, as well as between different types of forest. Global restoration targets offer a huge opportunity to design optimal landscapes and large-scale configuration of forests to meet multiple objectives, including biodiversity conservation. For example, restored forests can be located in and around PAs to enhance

134 See: <https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf>

135 See: *Ibid.*

136 See: <https://www.informea.org/sites/default/files/decisions/UNEP-EA.4-Res.10-en.pdf>

PA quality, provide buffer zones, and improve connectivity, effectively expanding the habitat area available to wildlife. Alternatively, they can be located in watershed areas to enhance watershed services. They can be used to improve the quality, size and connectivity of remaining forest patches in agricultural landscapes. When situated around natural forest patches, plantations can reduce edge effects by providing a ‘soft edge’ and thereby increasing the area of quality habitat within the natural forest patches. If there is a high edge to area ratio, this can substantially increase their effective size and therefore biodiversity value. In addition, by providing a forest canopy, plantations can facilitate the dispersal of understory species that avoid open areas, thereby increasing connectivity. Plantations may also serve to reduce pressure on natural forests if they provide alternative supply of fuelwood and timber, particularly if they are located close to the source of demand (e.g. an urban area).

In 2020, the IUCN published their *Guidelines for conserving connectivity through ecological networks and corridors*.¹³⁷ Including buffer

zone management in NBSAPs is a way to ensure that buffer zones are included in national policy (**Boxes 11** and **12**). Nepal’s NBSAP (2014–2020),¹³⁸ for example, calls for promoting the concept of biological corridors and connectivity between community-managed forests. The effective management of buffer zones is addressed within Strategy A (improvement in management of PAs and species), in the priority area: “Reviewing and strengthening governance and management of buffer zones. This, among other, includes addressing the issue related to management of community and leasehold forests located inside buffer zones, and improving financial management.”

Establishing and managing buffer zones around PAs, as well as ecological corridors linking fragmented forest areas, involves a range of actors including local communities, but academia plays an important role in identifying these areas. Both academia and public authorities¹³⁹ play a significant role in identifying and planning for the management of intact forests outside PAs by interfacing science and policy.

Box 11 Buffer zones in Myanmar’s NBSAP

In Myanmar, the Protection of Wildlife and Protected Areas Rules established the ability to designate buffer zones within PAs. According to Myanmar’s NBSAP (2015–2020), buffer zones should be established using participatory mapping and community-based natural resource management approaches developed in collaboration with communities living within and around PAs. Co-management, community conservation agreements, and participatory mapping and monitoring can help reduce conflicts between PAs and communities, ensure that livelihood needs are met, and provide a framework for benefit sharing from PA designation.

Action 11.3.4 under Target 11 aims to “implement pilot projects in at least five PAs involving local communities in designating buffer zones and co-management providing incentives for conservation and compensation for restricted access.”

Source: Republic of the Union of Myanmar. National Biodiversity Strategy and Action Plan 2015-2020.

¹³⁸ See: <https://www.cbd.int/doc/world/np/np-nbsap-v2-en.pdf>

¹³⁹ Public authorities include a variety of different line ministries involved, such as forestry, natural resources, environment, land use planning, and water. It also includes different levels of government (e.g. provincial or district level).

¹³⁷ See: <https://portals.iucn.org/library/node/49061>

Box 12 Buffer zones in Nepal

In 2019, Nepal's Forest Research and Training Center (FRTC) conducted a study entitled *An Assessment of Forestry Sector's Contribution to Sustainable Development Goals (SDGs) in the Context of Nepal*, which involved a case study to assess the contributions to the SDGs of the Baghmara buffer zone community forest in Chitwan National Park. Findings included:

- The buffer zone forest is managed through its forest management plan with the technical support of the national park authority.
- Buffer zone user groups have constructed artificial conservation ponds to accumulate water for wild animals with the support of Chitwan National Park.
- Forests in the buffer zone have been managed with appropriate restoration, conservation and management activities designed by respective forest groups considering forest conditions and requirements. Planting in public and private lands is undertaken as part of forest improvement activities.
- Forest quality with per unit tree numbers in the buffer zone area has improved due to several concerted forest activities, including the conservation and protection of wetlands (ponds and lakes) inside core national parks for wild animals. The buffer zone committee and buffer zone forest groups have managed ponds, lakes and rivers for both wild animals and water-based tourism promotion.
- Intensive patrolling is organized, and illegally involved people are arrested. Offenders are penalized based on their involvement in illegal activities identified with the rigorous investigation.

Nepal's PAs are broadly guided by conservation-related policies. The success of the buffer zone concept in conservation has been largely attributed to the involvement of local communities. The flow of revenue to local communities, in accordance with the National Parks and Wildlife Conservation Act 1973, has facilitated poverty alleviation, reduced hunger, improved livelihoods, and encouraged health, education, and infrastructure-related activities in buffer zone communities, which, in turn, has fostered conservation of forest and biodiversity.

Source: Reply to 2021 questionnaire on governance sent to forestry experts in selected Asia-Pacific countries.

5.2.2 Market based tools: concessions, certification and voluntary agreements

Commercial agriculture, plantations for oil palm, rubber and pulp and paper industries, over-logging and illegal logging have been identified as major threats for primary forests in the Asia-Pacific region. Logging concessions are where an owner of forest rights (usually the government) transfers those rights to another party (private sector), and usually for a medium to long-term time frame; the concession holder then typically pays for timber rights on the basis of area covered, volume extracted, or a combination of these. Often, the concession holder is also required to carry out other duties in addition to harvesting timber, such as managing the forest and providing infrastructure and social services for local communities. Many concessions, however, have failed

for a number of reasons, including the lack of skills of the concession holder in forest management, and weak governance that allows for concession holders to disregard contractual terms or the law (van Hensbergen, 2018). Furthermore, in many countries, forest governance does not properly account for the customary rights of forest-dependent people, risking deleterious impacts on the rights of local communities, which can lead to conflicts. Unclear tenure rights deter concession holders from investing in silviculture and SFM. However, working in partnership, concession holders and local rights holders can potentially contribute to the prevention of the illegal settlement and degradation of forest reserves (FAO 2018). Formalizing tenure and user rights is critical for forest governance from a rights perspective but also to avoid conflict, improve the possibility of successful concessions, and encourage private actors to invest in SFM.

Certification schemes and VPAs are some tools used in the Asia-Pacific region to address these issues. **Voluntary bilateral agreements** (most notably the EU FLEGT) are entered into voluntarily but, once entered, become legally binding trade agreements. They are used by some Asia-Pacific countries; the EU FLEGT Facility is currently operating in seven Asia-Pacific countries¹⁴⁰ where countries are either negotiating (Lao PDR – see **Box 13**, Malaysia and Thailand), implementing (Viet Nam) or, in the case of Indonesia, issuing FLEGT licenses for verified legal products it exports to the EU. Myanmar is engaged in dialogue with the EU, while China and the EU are working together through the Bilateral Coordination Mechanism (BCM) on FLEGT.

Certification schemes are used by both private and public entities and exist at global and national levels. Two types of certification schemes can be distinguished: (i) those certifying that specific agricultural commodities are not the result of deforestation of areas of particular interest; and (ii) those certifying that forests are sustainably managed and that forests and tree products are coming from such sustainably managed forests. The first category includes for instance the Roundtable on Sustainable Palm Oil, one of the most widely used certification schemes, which develops and implements global standards for sustainable palm oil (APFSOS III: FAO 2019). Illustrating the second category, the two main global forest certification schemes are the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). Both schemes offer an independent assessment of SFM practices against a series of ecological, economic and social sustainability principles, standards, criteria and indicators of performance, and guarantee consumers that the products they buy are issued from sustainably managed forests (Gutierrez Garzon et al. 2020). The approaches used by each scheme differ, however. Producers must be certified by accredited certifiers to be allowed to use the FSC logo on their products. These certifiers are responsible for auditing forest operations, assessing compliance with FSC standards (developed at a national or subnational levels), and issuing

Box 13 Voluntary Partnership Agreement (VPA) – EU and Lao PDR

To establish a system to verify the legality of timber and timber products harvested and exported by Lao PDR, the EU and Lao PDR held four joint expert meetings (JEM) on a voluntary partnership agreement (VPA) on Forest Law Enforcement, Governance and Trade (FLEGT). At the fourth JEM from 9–11 September 2020, five timber legality definitions were reviewed; progress was made by Lao PDR on defining the legality of timber from conversion areas, plantations, village use forests, land belonging to individuals, legal entities and organizations, confiscated timber and imported timber. It was noted by both sides that these definitions are living documents to be reviewed depending on further work on Lao PDR legislation reforms and the timber legality assurance system. Since the third JEM in June 2019, among other key regulations, Lao PDR has promulgated the amended land law, the amended forest law, the decree on promotion of commercial tree plantation, and the decree on environmental impact assessments, hence providing further clarification on what will be considered legal under the VPA between Lao PDR and the EU

Source: EU/Lao PDR Joint Press Release. 28 September 2020. <https://ec.europa.eu/environment/forests/pdf/Joint%20Press%20release%20-%20EU-Laos%20JEM4.%2020200928.%20Final.pdf>

FSC certificates. The PEFC instead endorses national certification systems, which develop their own certification standards and accredit certifiers. This enables forest operations to use the PEFC label on their products. The Thai national forest certification system, for example, was endorsed by PEFC in 2019.

Accessing certification schemes can prove difficult for communities and smallholders because of the cost and complexity of the required procedures. They may also face difficulties supplying the amounts of timber required by markets, or commercial restrictions placed by governments. The certification of community-based forest management therefore often requires significant amounts of financial and technical support.

¹⁴⁰ China, Indonesia, Lao PDR, Myanmar, Malaysia, Thailand and Viet Nam.

5.2.3 Monitoring of changes and threats

The monitoring of changes and threats is key to primary forest conservation. Monitoring is the first step for the management of risks such as fires and pests and diseases. There is also the urgent need to improve the monitoring of changes in ecosystems that might be caused by climate change. Monitoring also contributes to good governance by providing up-to-date, transparent and accessible information on the status and use of primary forests, as well as other environmental data and map trends over time. This information can be used for planning, forest management, law enforcement, the prevention of illegal activities and illegal trade of forest products, and reporting on biodiversity targets, to name a few practical applications.

Monitoring activities involves a range of institutions and actors including governments, law enforcement officials such as forest rangers, universities, CSOs, citizen science groups and communities of practice, and IPLCs.

Innovative technologies hold considerable potential to improve forest monitoring (Roshetko et al. 2022). For instance, open access data systems such as Google Earth Engine (GEE) can be used for mapping land use. The information generated can help enforce forest protection laws. GEE-generated information can also assist organizations managing certification schemes in excluding companies that drive deforestation or source material from PAs (Sarzynski et al. 2021). The Spatial Monitoring and Reporting Tool (SMART) is an open source tool that supports and facilitates patrolling and law enforcement in forests and other biodiversity hotspots. It collects, stores, communicates and analyzes data collected by forest law enforcers on illegal activities, wildlife, patrol routes, and management actions and can also be used to evaluate the performance of forest rangers (Gabriel and Ravindran 2021). Consumer-grade unmanned aerial vehicles (UAVs or drones) and imaging technologies can be used to support inventory activities, assess initial degradation levels, develop restoration plans, and monitor restoration progresses. Forest Watcher is a mobile application used in Nepal that helps collect critical baseline data about forest status and strengthens community participation in forest conservation (Lama et al. 2021).

5.2.4 Financial capacity

A lack of financial capacity is a constraint for the conservation of primary forests as it has implications for conservation actions including law enforcement, forest management both within and outside PAs, monitoring logging concessions, responding to direct external threats (e.g. fires), and even paying the salaries of staff in forest departments. This was noted by several experts who responded to the questionnaire. In the Philippines, there is a lack of resources to protect primary forests, even in areas designated as sacred sites. Protection and local government units were unable to respond to the forest fire that occurred in Bud Bongao, a sacred mountain in the UNESCO World Heritage site Tawi-Tawi Island because they were unable to bring enough water to the site (Pingault et al. 2021a). In Viet Nam, law enforcement and financial investment for natural forest conservation are still considered insufficient (Pingault et al. 2021a). In the Republic of Korea, 'forest conservation zones', including 'forest genetic resources protection zones', are designated by the Minister of the Korea Forest Service, city mayors, or by the provincial governors based on recommendations of the National Institute of Forest Science. However, because the designation of new forest conservation zones entails the allocation of additional resources for management, regional forest offices or the heads of the state forest offices sometimes feel the burden of PA expansion. The Philippines is currently implementing the Biodiversity Finance Initiative (Biofin) Project to fill the financing gap for the conservation and sustainable use of biological diversity by identifying, accessing, combining, and sequencing sources of funding (Philippines NBSAP 2016). In Lao PDR, the Strategic Plan on Governance for 2011–2020 calls for upscaling successful innovations in governance such as the allocation of district development funds.

Three main types of investments are needed for SFM, forest conservation or restoration and avoided deforestation and forest degradation: (i) investments to create enabling conditions; (ii) investments for on-the-ground activities; and (iii) investments to ensure policy coherence (FAO 2021). Some of the main actors in financing forest conservation are the public sector (governments), multilateral donors (e.g. the Global Environment

Facility) and the private sector. Key aspects for conservation finance success include ensuring clear tenure rights, the participation of local communities, and fair and equitable benefit sharing (FAO 2021).

Financial resources are also needed to support PA management and managers. IUCN published their *Guidelines for Financing Protected Areas in East Asia* in 2001 and *Financing Protected Area – Guidelines for Protected Area Managers* in 2000. In December 2007, representatives from six Conservation Trust Funds in the Asia-Pacific region formed the Asia-Pacific Conservation Trust Fund Network (APNET). One of its areas of work is financing through its PA finance working group. More broadly, the Conservation Finance Alliance (CFA) is a **global and collaborative network** of volunteer members whose mission is to promote sustainable financing for biodiversity conservation worldwide. In 2020, the CFA proposed a taxonomy of conservation finance mechanisms and strategies under which all known mechanisms can be categorized: return-based investments; economic instruments; grants and other transfers; business and markets; public financial management; risk management; and financial efficiency (Meyers et al. 2020). This taxonomy aims to clarify the definition and role of conservation finance to demonstrate the importance of its mechanisms and strategies for addressing the underlying causes of nature loss and contribute to increasing sustainable funding flows to nature conservation.

Finally, adequate financial resources and innovative financial tools to connect big funds to small projects have been identified as a critical condition for sustainable management of landscapes, allowing the effective conservation of primary forests (Pingault et al. 2021a).

5.3 Combining tools, means and scales for primary forest conservation.

Effectively conserving primary forests requires a combination of technical interventions; not only establishing PAs, but also: establishing them in the right place; enforcing their status; managing the whole landscape of which they

are part to enhance ecological connectivity; monitoring changes and threats; and managing risks such as fire, pests or diseases. This requires the engagement and coordinated action of a wide range of stakeholders across sectors and scales with appropriate planification and support, involving multiple levels of governance (**Figure 21**).

As shown in **Chapter 3**, many of the threats to conservation are found outside the forestry sector. It is thus important to consider ways to reduce these external threats and influence all actors that have an impact on forests.

A key group is the range of public actors and institutions, including national governments, state authorities and intergovernmental organizations. At the national level, institutions and organizations relevant to forest governance vary by country. In some countries, forestry is separated from conservation, whereas in others, they are in the same ministry but are separated at the level of implementation. Forest governance is also linked with broader land use governance discourses, such as those on agriculture, or mining. The private sector is another group of actors who are also important drivers of deforestation as they primarily exploit forest resources for timber extraction and transnational trade. They also are a source of innovation and of funds that can be redirected towards conservation. The private sector can also steer the movement towards sustainability through methods such as corporate social responsibility, certification, and voluntary standards. IPLCs including community forestry and smallholders also play a crucial role. These three categories of actors are essential and their interests must be well understood, but other actors are also important because they inform, influence the debates and also act. These include environmental non-governmental organizations (NGOs) and other civil society organizations (CSOs), academia and research.

There are numerous mechanisms, tools and instruments by which governance can promote SFM. They can be organized by level, from the international level with global goals, forest instruments and initiatives, and transnational trade mechanisms, to regional and sub-regional levels, including transboundary cooperation. However, most mechanisms are national,

including logging concessions and logging bans, legal incentives and market-based instruments, fiscal transfer mechanisms, payments for ecosystem services, land tenure rules, rules for the establishment and management of PAs, and the alignment of national policies and legislation, as well as measures to ensure coherence between all these policies. Finally, local implementation is critical, including to ensure effective engagement of local communities including through community-based forestry (CBF), ensure tenure security, implement institutional reform, facilitate relations between actors, prevent and manage conflicts.

There is a range of global objectives to which countries have subscribed, and these may also engage private actors to a degree. A key question is how these objectives, which are separated at the strategic level, can come together in implementation.

All commitments at the global level create opportunities for local actors to make their voices heard. Governments are committed to delivering results. From this perspective, forests can become a means through which to achieve objectives. This creates opportunities for the forestry sector and those actors depending on it. They can show the contributions they can make to global objectives, the contribution they can make to the objectives of a government or a private actor and claim support to do so - whether compensation or incentive - as well as a better recognition of their role by and through their inclusion in forest governance. For example, because of private sector commitments to achieve net zero deforestation or as part of corporate social responsibility, enterprises may now have an interest in contributing to the conservation of primary forests. Global goals, the publicity around them, the interest of consumers, and the concern of importing countries create an interest for exporting countries and for the private sector to reduce deforestation, and conserve primary forests. The question is: how can this be transformed into an incentive for local actors in the form of better governance, institutions and rules, as well as by specific incentives? This is essential to achieving efficient primary forest conservation. Taking the example of

international trade, there can be an interest to protect primary forests because of the concerns of importing countries and of consumers. Another example are NDCs and NAPs: non-forest sectors that benefit from forestry adaptation can provide support (such as financial) to forest restoration and conservation. Mangroves are very emblematic in this respect as they are presented as a way to protect cities or rice fields from sea-level rise, which could incentivize cities to provide financial support for their restoration and conservation. As they reduce costs in other sectors, providing them with benefits, these other sectors could be invited to contribute to their restoration and conservation.

There is thus a range of opportunities to strengthen conservation and create appropriate measures for effective primary forest conservation. However, most of the aforementioned commitments are geared towards the conservation of forests in general and are very rarely targeted specifically at primary forests. This may be a point on which to work and make proposals. There are clear biodiversity objectives for the conservation of primary forests but with limited funding options and poor articulation of linkages to other sectors. On the other hand, the climate change mechanisms available are economy-wide, facilitating cross-sectoral approaches, and have significant funding, but they tend to be blind to biodiversity: a forest is of interest only because it sequesters carbon. An important question is thus how to prioritize forests that are more important to primary forest conservation in forest conservation objectives for climate action. A second key question is how to engage local communities to participate in the protection of their forests if they cannot benefit directly from them. As such, there may be trade-offs between purely protecting areas of forest and allowing some forms of interactions that create an interest in their protection in the long run as part of SFM.

5.4 Conclusion

In the Asia-Pacific region, governance to address drivers of deforestation and forest degradation suffers from a number of factors, including: the absence of sound policies,

conflicting policies, a lack of enforcement, a lack of financial support and illegal activities (EC 2019). Other critical governance issues in the region include tenure and use rights, access to forest resources, conflict management and resolution, the equitable participation of IPLCs in decision making processes, and the misalignment of national regulations on forest protection and timber concessions. In the context of the preparation of APFSOS III (FAO 2019), a survey of forest stakeholders was conducted, asking what they considered major disruptions in the region until 2030. The most significant concern expressed was that a weak governance, with increased corruption or a failure of the rule of law, could exacerbate resource degradation (APFSOS III: FAO 2019).

Addressing these weaknesses in governance requires coherent intention, planning and action at a range of levels and by a range of actors. In the forestry sector, governance involves social and economic systems that affect how people interact with forests. This includes institutions, laws, policies, traditional norms and culture, forms of land tenure, and markets (Cowling et al. 2014). In responding to the questionnaire on governance sent to experts from the Asia-Pacific region, some indicated that

mechanisms (e.g. laws, regulations, voluntary standards) are poorly implemented and/or enforced because of a lack of capacity, human resources and funds; the misalignment of existing policies and norms; and/or lack of a country-wide overall land use planning. As a result, even if mechanisms are in place, the enabling environment for their governance may be weak (e.g. illegal logging still occurring in PAs, or tenure rights of local communities not formalized or recognized). As illustrated in this chapter, instruments and mechanisms are available to a range of actors to mobilize institutions and action for primary forest conservation.

A robust enabling environment is needed to conserve primary forests, both directly and indirectly through SFM and landscape approaches around them; hence the effective, efficient, transparent, accountable, equitable and participatory governance of forests is a critical aspect to be addressed. Any discourse on governance should capture the range and complexity of mechanisms and institutions and the actors involved in shaping and implementing them. Efforts to strengthen forest governance in the Asia-Pacific region must include increasing stakeholder participation, market-based approaches, forest-related conflict resolution, and institutional reform.

6 Recommendations and roadmap for primary forest conservation in Asia and the Pacific

This section gathers the main areas of recommendations emerging from this study and from the collective process of elaboration of the roadmap (Pingault et al. 2020, 2021a). Some of these recommendations may not seem new. As has been pointed out during the expert workshop, good solutions to difficult problems are rare and need to be repeated until they are widely adopted. They must be appropriately articulated, combined and adapted for specific contexts. Primary forest conservation requires: (i) an improved knowledge of the different types of forests at finer scales, of their status, trends and functioning, including large-scale ecological mapping and studies on species distribution and species population trends, and the various threats they face, driven by land use, land cover and climate changes; (ii) a compelling narrative, i.e. a shared vision and clear picture of the various values of primary forests and the challenges ahead; (iii) a clear understanding of land tenure and responsibilities; and (iv) efficient mechanisms to connect large funds to small projects. This will allow: (i) the alignment of various sustainable development objectives; (ii) the adoption of cross-sectoral, integrated approaches, particularly at the landscape level, where all of these objectives need to be balanced; (iii) the consolidation and involvement of large coalitions of actors, not only those living close to forests but also distant actors that are somehow connected to forests; and (iv) the harnessing of the potential of innovative technologies to support improved monitoring and reporting, as well as inclusive and participatory governance and decision-making processes.

Overall, the originality of these draft recommendations resides more in the way they are articulated, the key concepts

they push forward, and the means of implementation they promote. They can also contribute to raise awareness on specific points of attention that are already known but need to appear more clearly in the big picture. They are grouped under six broad areas of work.

Recommendation I focuses on the need to improve data collection, monitoring and reporting on forest ecosystems, including primary forests, using all means available (including innovative technologies and the engagement of local actors). This improved and, where possible, real-time monitoring and reporting will contribute to improving knowledge and understanding of forest ecosystems and to better orienting land use planning, management and conservation efforts. It will also contribute to: increased ownership across sectors and actors (your treasure is what you measure); informing and better grounding sound decisions by policymakers and other actors; an improved understanding of and means of addressing climate change impacts; preventing and combating illegal activities (logging, poaching, cross-border trafficking); and identifying, delineating and mapping priority areas for conservation (**Recommendation II**). Based on this comprehensive knowledge, a compelling narrative can be built to raise awareness, strengthen and broaden actors' engagement in primary forest conservation through large multi-stakeholder coalitions (**Recommendation III**). Such cross-sectoral coalitions and dialogues will help enhance policy-coherence across sectors, actors, jurisdictions and scales, especially at the landscape level, where it is particularly needed (**Recommendation IV**), as well as align primary forest conservation with other SDGs, particularly climate action and

protection of biodiversity (**Recommendation V**). Finally, regional and international cooperation can help address transboundary issues and support primary forest conservation through technology transfer, capacity building, and exchange of knowledge and experience between countries and actors (**Recommendation VI**). It can also help forge collaborations in common research areas.

It is difficult, if not impossible, to craft a set of recommendations that are simultaneously broad and comprehensive enough to embrace the huge diversity of primary forests in the Asia-Pacific region and of the threats they face, yet precise and operational enough to lead to concrete action plans in specific contexts.

The set of recommendations below (**Section 6.1**) provide an overall framework to be used within the deployment of the roadmap (**Section 6.2**) and to be adapted by governments and other relevant actors to their own context, priorities and needs.

6.1 Recommendations

I. Explore innovative ways to improve monitoring and reporting on primary forests

1. Support the uptake and upscale of innovative technologies to enable accurate and real-time monitoring and data collection, using consistent methods over large areas, long periods of time, at lower costs [*remote sensing satellite or drone observations in inaccessible areas; acoustic monitoring; etc.*].
2. Support the uptake and upscale of innovative technologies to improve reporting, information sharing and data analysis, and develop near-real time alert systems on forest degradation and associated risks such as fires [*open cloud data platforms integrating various information and datasets collected by different actors*].
3. Support local actors and communities' engagement and participation in monitoring and data collection [*e.g. through citizen science initiatives and crowdsourcing of field data; using digital technologies, such as mobile apps or*

open data platforms] and uptake their observations in decision-making at higher levels.

4. Clarify and harmonize national definitions, criteria, and indicators used to monitor forest status and trends [*On definitions: primary vs. intact, old-growth or natural forests. On criteria: minimal forest fragment size, level of importance, including biological diversity, level of threats, etc.*].
5. Improve transparency and replicability of reporting in line with international processes and guidelines [*e.g. ITTO guidelines, IPCC or IUCN guidelines, FAO Global Forest Resources Assessments guidelines*].
6. Improve monitoring and reporting on tenure status and rights, including on customary and traditional rights.
7. Link such monitoring (including of social impacts) to commodity value chains and to incentives, both to gather data and give value to it.
8. Link the data gathered through reporting to other relevant contextual information, e.g. environmental, socioeconomic, institutional, especially at the country level.

II. Improve the knowledge and understanding of the functioning and dynamics of primary forest ecosystems within broader landscapes to orient land use planning, management and conservation efforts

1. Dedicate increased resources, in each country of the Asia-Pacific region, to improving the knowledge and understanding of forest ecosystems, their ecological diversity, intactness, fragmentation level, species composition, population dynamics and functioning.
2. Integrate the knowledge of local and Indigenous actors; co-produce knowledge with local actors [*e.g., citizen science initiatives at local or national level*].
3. Acknowledge and assess the different values (environmental, economic, social, cultural, religious and existence values) of forest ecosystems and of the ecosystem services they provide, taking into account

- all available knowledge, including local and Indigenous knowledge.
4. Use these assessments to reflect the value of primary forests and of the ecosystem services they provide in integrated systems of environmental and economic accounting, and to better ground conservation policies and landscape management actions.
 5. Use this knowledge to define and identify priority areas for conservation or protection, based on clear criteria, agreed nationally and grounded on sound evidence, and to orient land use planning. *[Criteria such as: minimal forest fragment size; level of importance – including ecological value, cultural value, ecosystems services; and level of threats]*
 6. Translate this knowledge into a compelling narrative and make it available through training and capacity-building to all actors involved in SFM and primary forest conservation or protection, or in activities that impact forest ecosystems, as well as to the broad public
 7. Identify the key knowledge and information gaps that need to be addressed to support land use planning and conservation efforts, including:
 - Large-scale *[minimum of 1:50,000 for all countries; 1:25,000 for small islands]* ecological vegetation mapping including forest types and surrounding agricultural matrix to adapt conservation efforts to the specific circumstances of different landscape and ecosystems;
 - Coordinated studies on fragmentation, composition and configuration of landscapes *[natural forests, remnant forests and other land uses, connectivity issues]*;
 - Better understanding of: tenure regimes; PA status of different areas; primary forest status outside PAs.

III. Build a compelling narrative for primary forest conservation and consolidate new coalitions of actors

1. Build a compelling narrative, highlighting the amazing contributions of forests, and in particular of primary forests, to sustainable development objectives

- (including climate change mitigation and adaptation, protection of biodiversity and poverty reduction).
2. Adopt a cross-cutting perspective and articulate this narrative consistently: over time (integrating short- and long-term), across sectors and actors (identifying synergies and mutual benefits and addressing trade-offs), and across scales (from local to global).
 3. Pay a specific attention to primary forest margins and forest borders as the frontier of conservation and as the thin line where most conflicts are concentrated.
 4. Use this compelling narrative, as well as the related knowledge and information (maps, data, plans), to: improve transparency, raise awareness and encourage buy-in; build large coalitions of actors and strengthen ownership across actors and sectors; gain traction on the political agenda and enable policy coherence; attract funding and deliver true impact.
 5. Encourage and incentivize landowners and private actors (including remote ones) to contribute to primary forest conservation, through regulation, standards and incentives
 6. Strengthen ownership and encourage participation of less powerful actors, including women, youth, IPLCs, in forest governance and decision making processes, and make the forestry sector more attractive to them.
 7. Secure the tenure, access and use rights of IPLCs dependent on primary forests for their subsistence and livelihoods.

IV. Ensure policy coherence across sectors and scales and promote integrated landscape approaches for primary forest conservation

1. Enhance policy coherence over time, as well as between land use policies (forest, agriculture, infrastructures) and other sectoral policies that impact forests (energy, water, mining), at all levels (local, national, regional), and especially at the landscape level where all these policies interact.
2. Organize, as appropriate, dialogues at different scales, between foresters,

conservationists, policymakers and other relevant actors involved in the economic sectors that impact primary forest conservation, and encourage these actors to contribute to primary forest conservation by demonstrating their interest to do it.

3. Elaborate sustainable and integrated landscape management plans and strategies, at local and national levels, that strengthen synergies and address trade-offs across land uses, sectors and actors, and that articulate coherently short- and long-term objectives, challenges and opportunities.
4. Ensure that forests are recognized by themselves, not only as land reserves for agriculture and other sectors, and that sustainable forest management and primary forest conservation objectives are incorporated in broader integrated land use planning and landscape management plans and strategies, at local and national levels.
5. Consider, in integrated land use planning and landscape management plans, not only conservation areas but also the surrounding landscapes, as well as the need to create buffer zones along forest margins and ecological corridors between forest fragments to reduce forest degradation, limit forest fragmentation and restore connectivity.
6. Mobilize sustainable and innovative finance mechanisms [e.g. *green bonds, climate bonds, blended finance, impact finance*] for integrated landscape management that contribute to primary forest conservation.
7. Design appropriate mechanisms to facilitate the flow of financial resources towards local actors on the ground, connecting large funds, including internationally sourced funds, to small projects.

V. Align sustainable land use, climate action and biodiversity objectives for the conservation of primary forests

1. Promote sustainable land use and integrated landscape approaches, integrating the objective of primary forest conservation in the policies

and mechanisms related to climate action and biodiversity conservation and sustainable use.

2. Recognize and advocate for the contribution of primary forests to overall adaptation to climate change and integrate primary forest conservation and management in National Adaptation Plans (NAPs).
3. Take into account, in Nationally Determined Contributions (NDCs), the vulnerability of primary forests, as well as their potential for climate action, both adaptation and mitigation.
4. Recognize, in the design and implementation of the NDCs, the specific biodiversity and conservation values of primary forests, in addition to their carbon sequestration potential.
5. Ensure consistency and maximize the synergies between NDCs and National Biodiversity Strategies and Action Plans (NBSAPs).
6. Consider primary forest conservation objectives in international climate finance mechanisms to orient and prioritize funding.

VI. Strengthen regional and international cooperation for the conservation and management of primary forests

1. Exchange knowledge and lessons learned across countries and categories of actors about defining, identifying and managing primary forests.
2. Transfer technologies, including for mapping and monitoring primary forests and supporting conservation efforts.
3. Track and prevent illegal logging and illegal collection of wood and non-wood forest products in primary forests [*innovative technologies can help for wood species identification and tagging*].
4. Facilitate capacity development through appropriate means at regional level [*e.g. communities of practice, regional platforms*].
5. Facilitate transboundary cooperation for conservation and management of primary forests, in particular for those forests whose importance crosses national borders [*e.g. peace parks*].
6. Promote international cooperation on deforestation-free commodities.

6.2 Rolling out the roadmap for primary forest conservation

This study proposes a practical roadmap to support primary forest conservation in Asia and the Pacific. It comprises the four following steps, as illustrated in **Figure 23**: (i) carrying out an initial assessment, building upon a large scale ecological mapping program, of the current situation of primary forests; (ii) developing a strategy: defining priorities and means of implementation for primary forest conservation and protection; (iii) creating an enabling environment for primary forest conservation and protection; and (iv) acting collectively and individually.

This process could be implemented and articulated at different scales in a coordinated way: at the regional and national levels on the one hand, and at the local level on the other hand, in each specific forest landscape identified as a priority area for conservation.

At the regional level, the APFC, informed by the main findings and recommendations of the present study, could set regional priority areas and priority actions for primary forest conservation. Given the huge diversity of forest formations in the region, and of the threats they face, these regional priorities will have to be adjusted to national circumstances and needs, and each APFC member country could be invited to develop its own national roadmap. This study also contains a wealth of detailed information, relevant

at national or even sub-national levels, that can help governments and other actors in the elaboration of their primary forest conservation strategies, at national and local levels. Member countries could be invited to report regularly to the APFC the progress they have made in the development of their national roadmap, as well as the lessons learned and challenges faced during the elaboration and implementation of this roadmap at national and local levels. The APFC could adjust its regional strategy and plan of action based on the feedback received from countries.

Starting from the priorities identified at national level, the same exercise could be conducted by local authorities in each primary forest massif identified as a priority area for conservation at the national level, in collaboration with all actors concerned at the local level. Local actors should be invited to discuss and build a shared and integrated landscape approach, embracing not only the primary forest area to be conserved but also the surrounding landscape and its dynamics [see recommendation IV.5]. Such an approach should seek to properly articulate legal protection with the other instruments presented in **Chapter 4**, considering local circumstances.

1 Initial assessment of the current situation of primary forests

- Describe the diversity, status and trends of the different primary forest types, building upon available scientific evidence.
- Identify and assess the threats faced by primary forests, as well as their drivers.
- Identify the actors involved or to be involved in primary forest conservation (e.g. public authorities, scientists, private forest companies, CSOs, IPLCs).
- Assess the performance of existing instruments (regulations, standards, economic incentives) in supporting primary forest conservation and identify the gaps and needs.

3 Create an enabling environment for primary forest conservation

- Invest in research and development, extension and capacity-development to improve the knowledge and understanding of forest dynamics and ecosystem functioning within broader landscapes to orient land-use planning management and conservation efforts [II].
- Raise awareness and enhance citizen participation in forest monitoring and primary forest conservation [I.3].
- Elaborate conducive policies and regulations to address/overcome the threats identified above and enhance primary forest conservation.
- Mobilize the resources and develop the infrastructure needed for integrated landscape management that contribute to support primary forest conservation [IV.6] and connect large funds to small projects [IV.7]

2 Develop a strategy: define priorities and means of implementation for primary forest conservation

- Based on the initial assessment, identify priority areas for primary forest conservation, based on criteria including: size, level of importance, or level of threats.
- Define a strategy and priority actions for primary forest conservation, including measures for primary forests outside PAs.
- Define the means of implementation to be deployed (legal protection, other regulations, voluntary standards, economic incentives and governance mechanisms) and adapt their articulation to the given context.

4 Act collectively and individually for primary forest conservation

- Define the roles and responsibilities of the different actors involved, build a compelling narrative and consolidate new coalitions of actors [III]
- Ensure policy coordination across sectors and scales and align sustainable land use, climate action and biodiversity objectives with primary forest conservation [V].
- Promote integrated landscape approaches [IV], embracing not only the primary forest area to be conserved but also forest margins, as well as the surrounding landscape and its dynamics [III.3, IV.5].
- Exchange knowledge and lessons learned across countries, sectors and actors [VI.1] and adapt strategies and action plans accordingly.

Figure 23 Four-step practical way forward for primary forest conservation [Numbers between brackets in this figure refer to the above recommendations]. Source: Authors

7 Conclusion

While the total forest area in Asia and the Pacific has increased over the past decades following reforestation programs in many countries, the primary forest area still continues to decline.

This study aims to provide governments and other actors with all the information that they need to guide their decisions in determining priority areas and means for interventions to conserve primary forests.

The Asia-Pacific region is very large and diverse, making it hard to draw here an exhaustive list of these priority areas. Such a list will ultimately depend on nationally and locally determined priorities, properly informed by the main dimensions that frame the national and local context, and that the different chapters of this paper successively cover: (i) level and trends of preservation and fragmentation of forests; (ii) diversity of vegetation types and ecological diversity of types of primary forests; (iii) diversity of threats and risks to forests; (iv) diversity of governance and policy contexts and means of intervention.

Six areas for recommendations to enhance primary forest conservation in Asia and the Pacific emerged from this study and from the collective process of elaboration of this roadmap: (i) explore innovative ways to improve monitoring and reporting on intact forests; (ii) improve the knowledge and understanding of the functioning and dynamics of primary forest ecosystems within broader landscapes to orient land use planning, management and conservation efforts; (iii) build a compelling narrative for primary forest conservation and consolidate new coalitions of actors; (iv) ensure policy coherence across sectors and scales and

promote integrated landscape approaches for primary forest conservation; (v) align sustainable land use, climate action and biodiversity objectives for the conservation of primary forests; and (vi) strengthen regional and international cooperation for the conservation and management of primary forests.

Some of these recommendations may not seem new. As has been pointed out, spatial planning and environmental governance issues are typical examples of so-called 'wicked problems' that traditional planning methods fail to resolve. Solutions are few and far between and need feedback loop adaptation until they are widely adopted. Overall, the originality of these draft recommendations resides more in the way they are articulated, in the key concepts they push forward, and in the means of implementation they promote. They can also contribute to raising awareness on specific points of attention that are already known but need to appear more clearly in the big picture.

It is difficult, if not impossible, to craft a set of recommendations that are simultaneously broad and comprehensive enough to embrace the huge diversity of primary forests in the Asia-Pacific region and of the threats they face, yet precise and operational enough to lead to concrete action plans in specific contexts. These recommendations need to be appropriately articulated, combined and adapted for specific contexts. As such, beyond the overall framework these recommendations provide, this study also proposes a practical way forward that can help governments and other actors to elaborate their own roadmap, adapted to their own context, priorities and needs. This

process comprises the four following steps: (i) carrying out an initial assessment, building upon a large scale ecological mapping program, of the current situation of primary forests; (ii) developing a strategy: defining priorities and means of implementation for primary forest conservation and protection; (iii) creating an enabling environment for primary forest conservation and protection; and (iv) acting collectively and individually. This process could be implemented and articulated at different scales in a coordinated way: at the regional and national levels on the one hand, and at the local level on the other hand, in each specific forest identified as a priority area for conservation.

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Annexes

Annex 1 Process of development of the study

This study has been developed through an inclusive and participative process that associated 425 key regional experts and decision makers from governments and international organizations, from the private sector and civil society, as well as from academia and research institutions. Young students and young professionals were given a central role in this process as they will be the forest managers of tomorrow.

This process was launched on 30 July 2020, through an online inception workshop that gathered 89 participants from 29 countries (full list of participants in **Annex 2**). This workshop showed the high level of interest and enthusiasm shared by many stakeholders in the region for the study. It was an occasion to: (i) present the regional context and the two aforementioned topics; (ii) present the participative process of development of the roadmaps; (iii) receive feedback on the two corresponding scoping notes circulated as background documents ahead of the workshop; and (iv) launch and organize the technical work on each topic. Pingault et al. (2020) present in greater depth the discussions held and the main results of this inception workshop. Particular thanks to the colleagues who contributed to the preparation of the workshop or accepted to serve as speakers, chairs or rapporteurs during the discussions: Amos Amanubo, Illias Animon, Anne Branthomme, Stephen Elliott, Vincent Gitz, Thomas Hofer, Rodney Keenan, Yves Laumonier, Yanxia Li, Rao Matta, Mike May, Alexandre Meybeck, CTS Nair, Robert Nasi, Marco Piazza, Nathanaël Pingault, Edmund

Leo Rico, James Roshetko, Maria Paula Sarigumba, Vaeno Vigulu, Shengfu Wu, Makino Yamanoshita.

A second technical workshop on primary forest was held from 23–25 March 2021 to take stock of the progress made in the study and pursue more in-depth discussions among experts. This workshop attracted an audience of about 100 people from 28 different countries, including regional experts and decision makers, as well as some students and young people engaged in activities related to the forest sector in the region (full list of participants in **Annex 3**). During this workshop, participants: (i) examined the extent, status and diversity of forest types in the region, as well as the forest typology to be used in the roadmap; (ii) discussed the multitude of threats and increasing pressures faced by different types of primary forests in diverse contexts; (iii) linked threats to forest types to identify priority areas for primary forest conservation; (iv) reviewed the governance mechanisms and measures that can support primary forest conservation at different scales; and (v) worked collectively on broad areas for policy recommendations regarding: classification and mapping of primary forest ecosystems and of the threats they face in the region, and governance strategies and action plans to strengthen and enhance primary forest conservation. The results of this workshop are presented in greater depth in Pingault et al. (2021a). The following colleagues, who actively contributed to the success of this workshop as organizers, speakers, chairs or rapporteurs, deserve particular

thanks: Clarence Gio Almoite, Nadine Azzu, Anne Branthomme, Ricardo Calderon, Federica Coccia, Li Diqiang, Hannes Gaisberger, Edward Game, Vincent Gitz, Thomas Hofer, Riina Jalonen, Kasturi Devi Kanniah, Monika Kiczakajlo, Rajan Kotru, Yves Laumonier, June Mandawali, Nguyen Manh Hiep, Jennica Masigan, Jalesi Mateboto, Rao Matta, Mike May, Alexandre Meybeck, Robert Nasi, Nathanaël Pingault, Ate Poortinga, Lilik Budi Prasetyo, Fabio Ricci, James Roshetko, Ryosuke Ujihashi, Vongvilay Vongkhamsao, Russel Warman and Tetra Yanuariadi. Any errors remaining in the text are the sole responsibility of the authors.

In parallel, a web consultation was conducted through a questionnaire on “Primary forests: Governance tools for conservation and sustainable forest management” sent to regional experts. Contributions were received from experts in nine countries (**Annex 5**).

At the end of the process, an expert online validation workshop was organized from 23–24 November 2021 to present the main findings and key recommendations emerging from this study and discuss the way forward. The workshop attracted a diversified audience of 85 experts from 26 different countries representing all key

stakeholder groups, including international organizations, governments, private sector, civil society, research and academia (full list of participants in **Annex 7**). Its results are presented in detail in Pingault et al. (2021b). During this workshop, participants highlighted the huge potential of innovative technologies to improve forest monitoring and enhance primary forest conservation in Asia and the Pacific. They also called for the adoption of innovative and people-centered approaches for primary forest conservation. During this workshop, the APFC, its member countries and relevant stakeholders were encouraged to roll out the roadmap process proposed in this study. This collective process needs to be properly coordinated and articulated across sectors, actors and scales. The following colleagues, who actively contributed to the success of this workshop as organizers, speakers, chairs or rapporteurs, deserve particular thanks: Keiran Andrusko, Nadine Azzu, Federica Coccia, Lobzang Dorji, Vincent Gitz, Monika Kiczakajlo, Rao Matta, Alexandre Meybeck, Robert Nasi, Nathanaël Pingault, Fabio Ricci, James M. Roshetko and Sheila Wertz-Kanounnikoff.

Annex 2 List of participants to the inception workshop

Table 10 contains basic information on the people registered to the inception workshop, as filled by the participants themselves in the registration form.

Table 10 Participants to the inception workshop

Name, Given name	Gender	Country	Organization
Amanubo Amos	Male	Uganda	International Forestry Students Association (IFSA)
Animon Illias	Male	Thailand	FAO
Baldwin Brian	Male	Italy	Consultant
Barbour Liz	Female	Australia	University of Western Australia
Binti Farazi	Female	Bangladesh	FAO
Bontuyan Philip	Male	Lao PDR	GIZ
Branthomme Anne	Female	France	FAO
Brawner Jeremy T.	Male	USA	University of Florida
Brown	Male	Australia	Forest Research Institute - USC
Bull Lyndall	Female	Italy	FAO
Byambasuren Oyunsanaa	Male	Mongolia	Department of Forest Policy and Coordination, Ministry of Environment and Tourism, Mongolia
Coroza Oliver	Male	Philippines	Center for Conservation Innovations Ph
De Lu	Male	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Durst Patrick	Male	Thailand	Asia Forests
Edirisinghe Nishantha	Male	Sri Lanka	Forest Department
Ei Ei Swe Hlaing	Female	Myanmar	Forest Research Institute
Elliott Stephen	Male	Thailand	Chiang Mai University
Endozo Claudett	Female	Philippines	Department of Environment and Natural Resources-Forest Management Bureau
Evans Melissa	Female	New Zealand	Scion
Faisal Hussain	Male	Maldives	Ministry of Fisheries, Marine Resources and Agriculture
Gan Kee-Seng	Male	Malaysia	Asia Pacific Association of Forestry Research Institutions (APAFRI)
Gerrand Adam	Male	Indonesia	FAO
Gitz Vincent	Male	Indonesia	CIFOR/FTA
Hampton Ross	Male	Australia	Australian Forest Products Association (AFPA)
Hansen Eric	Male	USA	Oregon State University
Herbohn John	Male	Australia	University of the Sunshine Coast
HJ. Abdul Khalim Bin HJ. Abu Samah	Male	Malaysia	Forestry Department Peninsular Malaysia

Name, Given name	Gender	Country	Organization
Hofer Thomas	Male	Thailand	FAO
Inthirath Baisone	Female	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF)
Jadin Jenna	Female	Thailand	RECOFTC - The Center for People and Forests
Jigme Dorji	Male	Bhutan	Department of Forest and Park Services
Johnson Kristofer	Male	Bangladesh	FAO
Joowon Park	Female	Republic of Korea	Asian Forest Cooperation Organization (AFoCO)
Kabigting Ray Thomas	Male	Philippines	Department of Environment and Natural Resources-Forest Management Bureau
Keenan Rodney	Male	Australia	University of Melbourne
Kong Young-Ho	Male	Cambodia	Korea-Mekong Forest Cooperation Center
Kono Marija	Female	Canada	US Forest Service International Programs
Laumonier Yves	Male	Indonesia	Center for International Forestry Research (CIFOR)
Lee Stephanie	Female	Canada	Independent Consultant
Li Yanxia	Female	China	International Bamboo and Rattan Organisation (INBAR)
Mahoney Jesse	Male	Australia	Australian Government Department of Agriculture, Water and the Environment
Mateboto Jalesi	Male	Fiji	Pacific Community (SPC)
Matta Rao	Male	Thailand	FAO
May Mike	Male	Brazil	Suzano/FuturaGene
Meechantra Kallaya	Female	Thailand	FAO
Meybeck Alexandre	Male	Italy	CIFOR/FTA
Nair CTS	Male	India	None - Formerly FAO
Nasi Robert	Male	Indonesia	Center for International Forestry Research (CIFOR)
Nguyen Manh Hiep	Male	Viet Nam	Department of Protected Forest Management
Norbu Chencho	Male	Bhutan	Asian Forest Cooperation Organization (AFoCO)
Norbu Wangdi	Male	Bhutan	Department of Forests and Park Services
Nyi Nyi Kyaw	Male	Myanmar	Forest Department
Ogawa Shun	Male	Japan	Forestry Agency
Page Tony	Male	Australia	University of the Sunshine Coast
Pauig Cathy	Female	Philippines	Department of Environment and Natural Resources-Forest Management Bureau
Payn Tim	Male	New Zealand	Scion
Payuan Edwin	Male	Lao PDR	RECOFTC - The Center for People and Forests

Name, Given name	Gender	Country	Organization
Piazza Marco	Male	Thailand	FAO
Pingault Nathanaël	Male	Italy	CIFOR/FTA
Putz Jack	Male	USA	University of Florida
Quyên Nguyễn	Female	Viet Nam	Asian Disaster Preparedness center
Rico Edmund Leo	Male	Philippines	Center for Conservation Innovations Ph
Rocas Nelissa Maria B.	Female	Philippines	Department of Environment and Natural Resources- Forest Management Bureau
Roshetko James M.	Male	Indonesia	ICRAF, World Agroforestry Centre
Sapkota Lok Mani	Male	Thailand	RECOFTC - The Center for People and Forests
Sarigumba Maria Paula	Female	Philippines	University of Saskatchewan
Shengfu Wu	Male	China	China National Forest Products Industry Association
Silori Chandra	Male	Thailand	RECOFTC - The Center for People and Forests
Sinha Rakesh	Male	India	FAO
Smithies Chris	Male	Lao PDR	Earth Systems
Suntra Hang	Male	Cambodia	Forestry Administration
Tacconi Luca	Male	Australia	The Australian National University
Tandin	Male	Bhutan	Department of Forest and Park Services
Thaung Naing Oo	Male	Myanmar	Forest Department
Ugyen	Male	Bhutan	Jomotsangkha wildlife Sanctuary
Ujihashi Ryosuke	Male	Japan	Forestry Agency
Uzzaman Arfan	Male	Bangladesh	FAO
Vave Uatea	Male	Tuvalu	Department of Agriculture
Vigulu Vaeno	Male	Solomon Islands	Solomon Islands Government
Vongsouthi Kevaly	Female	Lao PDR	Earth Systems
Walter Sven	Male	Italy	FAO
Woodgate	Male	Australia	SmartSat CRC
Xi Luo	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Yamanoshita Makino	Female	Japan	Institute for Global Environmental Strategies
Yasmi Yurdi	Male	Cambodia	International Rice Research Institute (IRRI)
Yong Harry	Male	Malaysia	Forestry Department Peninsular Malaysia
Yutaka Machida	Male	Japan	Forestry Agency
Zahari bin Ibrahim	Male	Malaysia	Forestry Department Peninsular Malaysia
Zhe Kong	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)

Annex 3 List of participants to the primary forest workshop

Table 11 contains basic information on the people registered to the technical workshop on primary forest conservation, as filled by the participants themselves in the registration form.

Table 11 Participants to the primary forest workshop

Family Name	Given Name	Gender	Duty country	Organization
Almoite	Clarence Gio	Male	Philippines	Benguet State University
Azzu	Nadine	Female	Italy	CIFOR/FTA
Bajaj	Megha	Female	Thailand	Asian Institute of Technology
Bounithiphonh	Chaloun	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF)
Branthomme	Anne	Female	italy	FAO
Brawner	Jeremy	Male	United States of America	University of Florida
Byambasuren	Oyunsanaa	Male	Mongolia	Fire Management Resource Center - Central Asia Region, National University of Mongolia
Calderon	Ricardo	Male	Republic of Korea	Asian Forest Cooperation Organization (AFoCO)
Coccia	Federica	Female	Italy	CIFOR/FTA
Diqiang	Li	Female	China	CAF research institute of forest ecology; environment and protection
Dorji	Lobzang	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Dorji	Jigme	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Finke	Anna	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Fujiwara	Junichi	Male	Japan	Forestry Agency
Gaisberger	Hannes	Male	Italy	Alliance of Bioversity International and CIAT
Game	Edward	Male	Australia	The Nature Conservancy
Gan	KeeSeng	Male	Malaysia	Asia Pacific Association of Forestry Research Institutions (APAFRI)
Gerrand	Adam	Male	Indonesia	FAO
Gitz	Vincent	Male	Indonesia	CIFOR/FTA
Hlaing	Yimon	Female	Myanmar	Forest Department
Hofer	Thomas	Male	Thailand	FAO

Family Name	Given Name	Gender	Duty country	Organization
Hussain	Faisal	Male	Maldives	Ministry of Fisheries, Marine Resources and Agriculture
Inoue	Yasuko	Female	Japan	Forestry and Forest Product Research Institute (FFPRI)
Inthirath	Baisone	Female	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF)
Jalonen	Riina	Female	Malaysia	Alliance of Bioversity International and CIAT
Kamran	Shahrukh	Male	Germany	Eberswalde University for Sustainable Development
Kanniah	Kasturi Devi	Female	Malaysia	Universiti Teknologi Malaysia (UTM)
Keenan	Rod	Male	Australia	University of Melbourne
Kettle	Chris	Male	Italy	Alliance of Bioversity and CIAT
Khine Zaw Wynn	-	Male	Myanmar	FAO
Kiczakajlo	Monika	Female	Italy	CIFOR/FTA
Kieft	Johan	Male	Indonesia	UNEP
Kong	Young-ho	Male	Cambodia	Korea-Mekong Forest Cooperation Center
Kono	Marija	Female	Canada	US Forest Service
Kotru	Rajan	Male	India	TRESTLE Management Advisors
Lama	Sony	Female	Nepal	Red Panda Network
Laumonier	Yves	Male	Indonesia	CIRAD/CIFOR
Lowe	Andrew	Male	Australia	University of Adelaide
Luo	Xi	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Maharjan	Sajeen	Male	Nepal	Environment Nepal
Mandawali	June	Female	Papua New Guinea	PNG Forest Research Institute
Masigan	Jennica	Female	Philippines	Center for Conservation Innovation Ph
Mateboto	Jalesi	Male	Fiji	Pacific Community (SPC)
Matta	Rao	Male	Thailand	FAO
May	Mike	Male	Brazil	FuturaGene Suzano
Meybeck	Alexandre	Male	Italy	CIFOR/FTA
Moore	Peter	Male	Italy	FAO
Nair	CTS	Male	India	Independent Consultant

Family Name	Given Name	Gender	Duty country	Organization
Naito	Daisuke	Male	Indonesia/Japan	Center for International Forestry Research (CIFOR)
Nasi	Robert	Male	Indonesia	Center for International Forestry Research (CIFOR)
Negi	Vikram	Male	India	G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora
Nguyen	Manh Hiep	Male	Viet Nam	Viet Nam Administration of Forestry
Nguyen	Quyên	Female	Viet Nam	Asian Disaster Preparedness Center (ADPC)
Norbu	Pasang	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Norbu	Chencho	Male	Bhutan	Independent (Self employed)
Nuanvixay	Bounta	Male	Lao PDR	Earth Systems
Ogawa	Shun	Male	Japan	Forestry Agency
Ojeda	Michelle	Female	Philippines	Department of Environment and Natural Resources (DENR) - Forest Management Bureau
Palomar	Jamila Audrey	Female	Philippines	Center for Conservation Innovations Ph
Park	Joowon	Female	Republic of Korea	Asian Forest Cooperation Organization (AFoCO)
Patriarca	Chiara	Female	Italy	FAO
Pauig	Cathy	Female	Philippines	Department of Environment and Natural Resources (DENR) - Forest Management Bureau
Payn	Tim	Male	New Zealand	Scion
Peng	Peng	Male	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Perez	Nikko Adrian	Male	Philippines	Sangguniang Kabataan Provincial Federation of Cotabato
Phongoudome	Chanhsamone	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF)
Pingault	Nathanael	Male	Italy	CIFOR/FTA
Poopathiyar	Arjunan Elayaraja	Male	India	AALAMARAM
Poortinga	Ate	Male	Thailand	SERVIR-Mekong
Pouli	Tolusina	Male	Samoa	Forestry - Ministry of Natural Resources and Environment

Family Name	Given Name	Gender	Duty country	Organization
Prasetyo	Lilik Budi	Male	Indonesia	IPB University
Rai	Arun	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Rico	Edmund Leo	Male	Philippines	Center for Conservation Innovations Ph
Roshetko	James	Male	Indonesia	ICRAF/FTA
Sapkota	Lok Mani	Male	Thailand	RECOFTC
Saputra	Angga	Male	Indonesia	IPB University
Sarigumba	Maria Paula	Female	Canada	University of Saskatchewan
Sarzynski	Thuan	Male	Viet Nam	Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)
Satkuru	Sheam	Female	Japan	International Tropical Timber Organization (ITTO)
Setiawan	Yudi	Male	Indonesia	IPB University
Sinha	Rakesh	Male	India	FAO
Sobhan	Istiak	Male	Bangladesh	World Bank
Tamang	Sanjaya Raj	Male	Nepal	ForestAction Nepal
Tempheh	KJ	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Tenneson	Karis	Female	United States of America	Spatial Informatics Group
Triraganon	Ronnakorn	Male	ASEAN	RECOFTC
Ugyen	-	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Ujihashi	Ryosuke	Male	Japan	Forestry Agency
Vigulu	Vaeno	Male	Solomon Islands	Ministry of Forestry and Research
Vongkhamsao	Vongvilai	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF)
Warman	Russell	Male	Australia	University of Tasmania
Wijaya	Arief	Male	Indonesia	World Resources Institute (WRI) Indonesia
Woodgate	Peter	Male	Australia	SmartSat CRC
Wu	Shengfu	Male	China	China National Forest Products Industry Association

Family Name	Given Name	Gender	Duty country	Organization
Xin	Alisa	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)
Yanuariadi	Tetra	Male	Japan	International Tropical Timber Organization (ITTO)
Yanxia	Li	Female	China	International Bamboo and Rattan Organisation (INBAR)
Yasmi	Yurdi	Male	Cambodia	International Rice Research Institute (IRRI)
Zangpo	Dawa	Male	Bhutan	Department of Forests and Park Services, Royal Government of Bhutan
Zhang	Shiyi	Female	China	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)

Annex 4 List of participants to the validation workshop

Table 12 contains basic information on the people registered to the expert validation workshop, as filled by the participants themselves in the registration form.

Table 12 Participants to the validation workshop

Name Surname	Gender	Country	Organization
Almoite Clarence Gio	Male	Philippines	Benguet State University
Andrusko Keiran	Male	Australia	Australian Department of Agriculture, Water and the Environment
Arjunan Elayaraja	Male	India	Aalamaram-banyan tree
Azzu Nadine	Female	Italy	CIFOR-ICRAF/FTA
Bajaj Megha	Female	Nepal	Asian Institute of Technology
Bounithiphonh Chaloun	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI)
Branthomme Anne	Female	Italy	FAO
Bull Lyndall	Female	Italy	FAO
Coccia Federica	Female	Italy	CIFOR/FTA
Coroza Oliver	Male	Philippines	Center for Conservation Innovation Ph Inc.
De Lu	Male	China	APFNet
Dorji Lobzang	Male	Bhutan	Department of Forests and Parks Services, Ministry of Agriculture and Forests
Durst Patrick	Male	Thailand	Independent consultant
Esguerra Elise Gabrielle	Female	Philippines	Forest Management Bureau
Faisal Hussain	Male	Maldives	Ministry of Fisheries, Marine Resources and Agriculture
Gabriel Marie Jessica	Female	Philippines	University of the Philippines Los Baños
Game Edward	Male	Australia	The Nature Conservancy
Gan Kee Seng	Male	Malaysia	Asia-Pacific Association of Research Institutions (APAFRI)
Gerrand Adam	Male	Indonesia	FAO
Gitz Vincent	Male	Italy	CIFOR-ICRAF/FTA
Hansen Eric	Male	USA	Oregon State University
Inthirath Baisone	Female	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI)
Ioannou Anna	Female	Thailand	FAO
Jalaluddin Harun	Male	Malaysia	Academy of Science Malaysia (ASM)
Jalonen Riina	Female	Malaysia	Alliance of Bioversity International and CIAT
Johnson Kristofer	Male	United States of America	FAO

Name Surname	Gender	Country	Organization
Kamran Shahrukh	Male	Germany	Eberswalde University for Sustainable Development
Kasturi Devi Kanniah	Female	Malaysia	Universiti Teknologi Malaysia
Keenan Rodney	Male	Australia	University of Melbourne
Kotru Rajan	Male	India	Trestle Management Advisors
Lama Sony	Female	Nepal	Red Panda Network
Laumonier Yves	Male	Indonesia	CIFOR-ICRAF/FTA
Li Yanxia	Female	China	International Bamboo and Rattan Organisation
Louman Bas	Male	Netherlands	Tropenbos International
Machida Yutaka	Male	Japan	Forestry agency
Mackey Brendan	Male	Australia	Griffith University
Maharjan Sajeen	Male	Nepal	Environment Nepal
Mandawali June	Female	Papua New Guinea	Papua New Guinea Forest Research Institute
Masigan Jennica Paula	Female	Philippines	Center for Conservation Innovation Ph Inc.
Mateboto Jalesi	Male	Fiji	Pacific Community (SPC)
Matta Rao	Male	Thailand	FAO
Name Surname	Gender	Country	Organization
May Mike	Male	Spain	FuturaGene Suzano
Meybeck Alexandre	Male	Italy	CIFOR-ICRAF/FTA
Nair C T S	Male	India	Freelance Consultant
Nasi Robert	Male	Indonesia	CIFOR-ICRAF
Negi Vikram	Male	India	Govind Ballabh Pant National Institute of Himalayan Environment
Oyunsanaa Byambasuren	Male	Mongolia	Department of Environment and Forest Engineering, National University of Mongolia
Palomar Jamila Audrey	Female	Philippines	Center for Conservation Innovation
Park Joowon	Female	Republic of Korea	Asian Forest Cooperation Organization
Patriarca Chiara	Female	Italy	FAO
Payn Tim	Male	New Zealand	Scion
Perkin Scott	Male	Thailand	IUCN Asia Regional Office
Pham Thu Thuy	Female	Viet Nam	CIFOR-ICRAF
Phongoudome Chanh Samone	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI)
Piazza Marco	Male	Thailand	FAO
Pin Kar Yong	Male	Malaysia	Asia-Pacific Association of Research Institutions (APAFRI)

Name Surname	Gender	Country	Organization
Pingault Nathanaël	Male	Italy	CIFOR-ICRAF/FTA
Pouli Tolusina	Male	Samoa	Forestry Division, Ministry of Natural Resources and Environment
Prabhu Ravi	Male	India	CIFOR-ICRAF
Rai Arun	Male	Bhutan	FRMD, DoFPS, MoAF
Ramatia Deasy	Female	Indonesia	IPB
Roshetko James M.	Male	Indonesia	CIFOR-ICRAF/FTA
Sapkota Lok	Male	Nepal	RECOFTC
Sarigumba Maria Paula	Female	Philippines	University of Saskatchewan
Sarzynski Thuan	Male	Viet Nam	CIRAD
Satkuru Sheam	Female	Japan	International Tropical Timber Organization
Sihanath Dalaphone	Female	Lao PDR	IFC
Silori Chandra Shekhar	Male	Thailand	RECOFTC
Sobhan Md Istiak	Male	Bangladesh	World Bank
Steel Ashley	Female	Italy	FAO
Tamang Sanjaya Raj	Male	Nepal	ForestAction Nepal
Tempheh KJ	Male	Bhutan	Department of Forests and Parks Services, Ministry of Agriculture and Forests
Tenneson Karis	Female	United States of America	Spatial Informatics Group
Togado Raiza Mae	Female	Philippines	Department of Environment and Natural Resources
Triraganon Ronnakorn	Male	Thailand	RECOFTC
Tshering Ugyen	Male	Bhutan	Department of Forests and Parks Services, Ministry of Agriculture and Forests
Vongvilay Vongkhamsao	Male	Lao PDR	National Agriculture and Forestry Research Institute (NAFRI)
Wertz-Kanounnikoff Sheila	Female	Thailand	FAO
Wijaya Arief	Male	Indonesia	WRI Indonesia
Woodgate Peter	Male	Australia	Esus Pty Ltd
Wu Junqi	Female	China	International Bamboo and Rattan Organisation
Xi Luo	Female	China	APFNet
Yudi Setiawan	Male	Indonesia	Environmental Research Center, IPB University
Zangpo Dawa	Male	Bhutan	Department of Forests and Parks Services, Ministry of Agriculture and Forests
Zhang Shiyi	Female	China	APFNet

Annex 5 Respondents to the survey “Primary forests: Governance tools for conservation and sustainable forest management”

Country	Expert	Affiliation
China	Liao Jing	Program Officer. Department of International Cooperation. National Forestry and Grassland Administration of China.
Bhutan	Karma Jigme Temphe	Chief Forestry Officer. Social Forestry and Extension Division. Department of Forests and Park Services. Thimphu
Fiji	Mr Bulai Sairusi	Former Forestry Advisor for SPC
Republic of Korea	Jin Sunpil and Joowon Park	Vice Executive Director of AFoCO; and Program Officer for Planning & Coordination. Strategy & Outreach Team, Planning & Budget Division. Asian Forest Cooperation Organization. Republic of Korea
Nepal	Bishwa Nath Oli	PhD (Ministry of Forests and Environment)
New Zealand	Anna Tyler	Manager International Standards Organisations. International Policy. Ministry for Primary Industries, New Zealand
Thailand	Ronnakorn Triraganon	Senior Strategic Advisor.
The Philippines	Marcial C. Amaro, Jr., CESO III	Department of Environment and Natural Resources. Forest Management Bureau. Assistant Secretary for Policy, Planning, and Foreign Assisted Projects and Special Projects, and Director, in concurrent capacity
Vanuatu	Godfrey Bome	Department of Forests, Vanuatu

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Primary forests and natural landscapes in Asia and the Pacific are under increasing pressure and threats driven by population growth, migration and conflict, globalization and economic growth, urbanization, mining and infrastructure development, agriculture and planted forest expansion, forest fires and invasive species. Many of these threats are increasingly exacerbated by climate change. To address these threats, FAO and the Center for International Forestry Research (CIFOR), lead center of the CGIAR research programme on Forests, Trees and Agroforestry (FTA), have developed a roadmap for the conservation of primary forests in Asia and the Pacific, building upon state-of-the-art knowledge and extensive consultation of key regional stakeholders. This publication uses a remote-sensing methodology to accurately and consistently identify and delineate the remaining 'intact forests' and 'contiguous intact forests' in the Asia-Pacific region over large areas, over long periods of time, and at reasonable costs. It illustrates the huge diversity of forest formations in Asia and the Pacific and calls for a better understanding of the dynamic at stake in forest ecosystems and surrounding landscapes at finer scale. It proposes a set of recommendations, inviting policymakers and other relevant stakeholders to adopt an integrated landscape perspective and to combine different mechanisms and tools at different scales, including protected areas and other area-based conservation measures, to support effective primary forest conservation.

The CGIAR Research Program on Forests, Trees and Agroforestry (FTA) is the world's largest research for development program to enhance the role of forests, trees and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, ICRAF, INBAR and TBI.

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