Food and Agriculture
Organization of the
United Nations

# FRA 2020 Remote Sensing Survey

ISSN 0258-6150

FAO
FORESTRY
PAPER

186

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 2022

Required citation:
FAO. 2022. *FRA 2020 Remote Sensing Survey*. FAO Forestry Paper No. 186. Rome. https://doi.org/10.4060/cb9970en



ISBN ISBN 978-92-5-136147-4

ISSN 0258-6150 [print]
ISSN 2706-8773 [online]



**Cover photograph:** The Amazon forest has become a visual symbol for Earth's ecological reserves but there is much more to humankind's ecological footprint, from the oceans and fishing to urban infrastructure and agriculture. ©ESA/NASA–T. Pesquet

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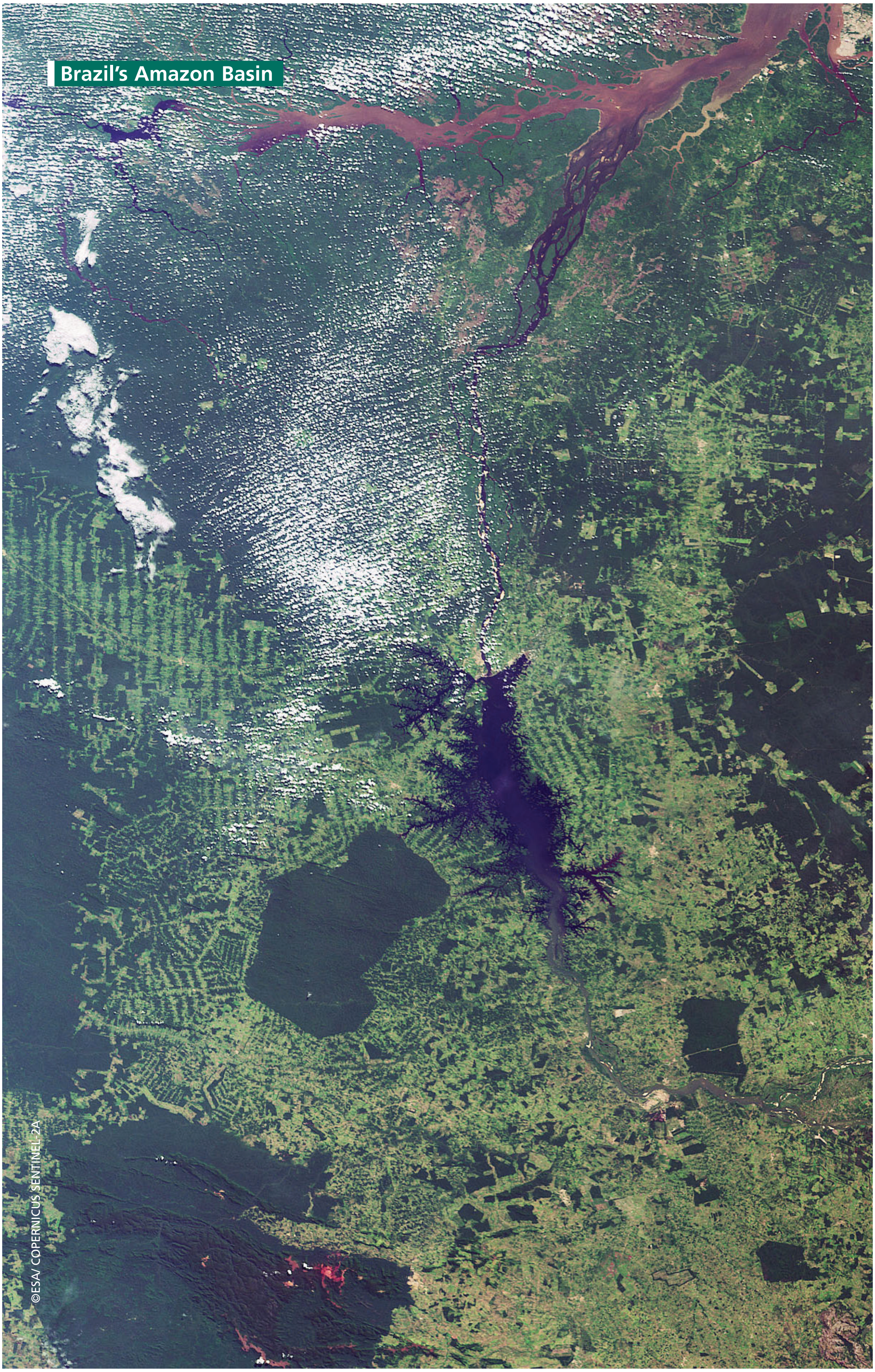

Brazil's Amazon Basin
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# Foreword

The Food and Agriculture Organization of the United Nations (FAO) published the results of the first Global Forest Resources Assessment (FRA) in 1948. Since then, the Organization has conducted periodic assessments, the latest of which was published in 2020. With its long history, official status and unique scope, FRA is now the most comprehensive and authoritative source of information on global forest resources, together with their management and uses.

FRAs are based on national statistics compiled by a global network of officially nominated National Correspondents. The process therefore relies on national capacities to monitor and report on forests. While there is evidence that the forest monitoring capacity in countries has increased significantly during the past decade, many countries, especially in Africa, Asia and Oceania, still lack consistent national time series data for some of the key forest attributes.

To fill this gap and support countries' efforts to use remote sensing and modern digital tools for forest monitoring, FAO Forestry division conducted a global remote sensing survey as part of the Global Forest Resources Assessment (FRA) 2020 programme. In order to ensure greater efficacy and impact, the survey design was based on the lessons learned from the previous four FRA remote sensing surveys and implemented in a participatory manner.

Through a collaborative effort involving more than 800 national experts from 126 countries, FAO and its Members produced a unique dataset, which has enabled a thorough analysis to be conducted of forest area dynamics at the global, regional and ecozone level.

I invite you to use this publication and the results presented here as an additional source of information that will support the transformation of our world towards a more sustainable future.

**Tiina Vähänen**
Deputy Director,
Forestry Division,
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the United Nations

# Acknowledgements

The Remote Sensing Survey (RSS) of the Global Forest Resources Assessment (FRA) 2020 is the result of a collective effort by the FAO Forestry Division, FAO member countries, institutional and resource partners, and many individuals. More than 800 people were directly involved in the FRA 2020 RSS process. They include FRA national correspondents, their alternates and collaborators, who participated in the training on RSS methodology and image interpretation, and collected the data.

The RSS methodology was developed by FAO in close collaboration with the Joint Research Center of the European Commission.

The samples were interpreted using the open source cloud-based Collect Earth platform, which was jointly developed by SERVIR, a joint venture between the National Aeronautics and Space Administration of the United States of America and the United States Agency for International Development, and FAO in partnership with SilvaCarbon (an interagency cooperation programme of the Government of the United States of America), the University of San Francisco's Spatial Informatics Group, the United States Forest Service and Google. The survey was implemented under the overall direction of Anssi Pekkarinen and coordinated by Adolfo Kindgard. The FAO core team also included Valeria Contessa, Erica Lupi, Chiara Patriarca, Mohamed Agamy, Anne Branthomme, Pedro Pablo Vivar and Alexandra Zmachynskaya.

The analysis of the results was conducted by Adolfo Kindgard, Pedro Pablo Vivar and Javier Gallego. The report was drafted by Adolfo Kindgard, Valeria Contessa, Chiara Patriarca, Erica Lupi, Javier Gallego, Javier De Lamo Rodriguez, Anne Branthomme and Anssi Pekkarinen.

The text compiled in Box 2 was provided by Francesco Nicola Tubiello, FAO Statistics Division

The report was edited by Clare Pedrick and Alexander Chepstow Lusty, design and layout by Roberto Cenciarelli, graphs support by Lucia De Canio.

The FRA 2020 RSS process was supported by Giordana Conti, Marisalee Palermo, Daniela Mercuri and Esther Phillips. Several regional and national FAO offices supported organization of the RSS capacity development events.

The FRA 2020 RSS was implemented with financial support from the European Union and the Government of Norway.

FAO is grateful to all countries and territories, institutions and individuals who made FRA 2020 RSS possible.

# Acronyms and abbreviations

| | |
|---|---|
| **AFOLU** | Agriculture, Forestry and other land Use |
| **CBD** | Convention on Biological Diversity |
| **CITES** | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| **CEO** | Collect Earth Online |
| **ESA** | European Space Agency |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FNF** | forest/non-forest |
| **FRA** | Global Forest Resources Assessment |
| **GEE** | Google Earth Engine |
| **GEZ** | Global Ecological Zone |
| **ha** | hectare |
| **IPBES** | Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **JRC** | Joint Research Centre of the European Commission |
| **LU** | land use |
| **LUC** | land-use change |
| **LULC** | land use/land cover |
| **Mha** | million hectares |
| **MODIS** | Moderate Resolution Imaging Spectroradiometer |
| **NRF** | naturally regenerating forest |
| **OWL** | Other Wooded Land |
| **REDD+** | Reduction of Emissions from Deforestation and Forest Degradation |
| **RSS** | Remote Sensing Survey |
| **SAR** | synthetic aperture radar |
| **UNCCD** | United Nations Convention to Combat Desertification |
| **UNEP** | United Nations Environment Programme |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNCTAD** | United Nations Conference on Trade and Development |
| **VHR** | very high resolution |

# Executive summary

The FRA 2020 Remote Sensing Survey presents a clear and detailed picture of changes in forest-related land use and land cover area at global and regional levels for the periods 2000–2010 and 2010–2018, as well as information on the drivers of forest losses and the most threatened forest ecological zones.

In some respects, the results to emerge from this complex global analysis of forest resources are encouraging. The FRA 2020 Remote Sensing Survey reveals a slowdown in the trend of global deforestation, together with a slight increase in global annual forest area gain. The world's forest area covered 3.97 billion hectares (ha) in 2018 – accounting for 30.8 percent of global land area. Annual deforestation declined by around 29 percent during the 2010–2018 period, compared with the first decade of 2000 (from 11 million ha per year (Mha/year) to 7.8 Mha/year). Net forest area losses more than halved between the first and second periods studied, decreasing from 6.8 Mha/year in 2000–2010 to 3.1 Mha/year in 2010–2018.

However, the findings confirm that there is no room for complacency, with high deforestation rates recorded in South America, followed by Africa and Asia. Overall, agricultural expansion is responsible for almost 90 percent of deforestation worldwide. Cropland expansion is the main driver, causing almost 50 percent of global deforestation, followed by livestock grazing, which accounts for 38.5 percent. During the period 2000–2018, the expansion of oil palm cultivation alone caused 7 percent of all deforestation worldwide.

Monitoring the world's forest resources through periodic assessments has been a core activity for the Food and Agricultural Organization of the United Nations (FAO), ever since its foundation. Conducted in cooperation with member countries, the collection, analysis and dissemination of information on the world's forest resources through the Global Forest Resources Assessment (FRA) has become a regular appointment in the international forestry sector, presenting a comprehensive view of the world's forests and the ways in which they are changing.

Since 1990, FAO FRA Remote Sensing Surveys have served as a complement to the country-based FRA reporting process. The fifth FAO FRA Remote Sensing Survey, conducted in collaboration with the Joint Research Centre of the European Commission (JRC), started in 2018.

This study, which took three years to complete, involved the visual interpretation of satellite images from more than 400 000 sample sites worldwide, using Collect Earth Online, an image analysis platform for land monitoring jointly developed by FAO and partners.

Another defining feature of the FRA 2020 Remote Sensing Survey, whose findings are presented here, was a strong participatory approach, which has proved critical in assessing land-use changes consistently at the global level. Underpinned by a standard methodology, the process was driven by a network of more than 800 photointerpreters from 126 countries. Their local field knowledge has been supplemented by expertise in data collection and satellite image interpretation, acquired during 34 national and regional capacity-building workshops organized by FAO. Despite limitations caused by COVID-19, the workshops enabled participants with limited knowledge of remote sensing to interpret satellite imagery and collect data consistently throughout the world.

The results presented here will be valuable in supporting the development of sound policies, practices and investments that affect forests and forestry. Specifically, they will help to improve the estimates of greenhouse gas emissions from the Agriculture, Forestry and other land Use (AFOLU) sector and track progress towards forest conservation and restoration goals. By providing information on where and why deforestation and forest area expansion are occurring – including at biome and ecoregion level – this assessment will contribute to a better understanding of which forest ecosystems are the most threatened and the effectiveness, or otherwise, of area-based forest conservation measures currently in place.


Amazon River
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# 1 Introduction

A growing understanding of the strong relationship between the two main global environmental shifts – climate change and biodiversity loss – and their consequences for human livelihoods and well-being has placed the world's forests at the heart of international environmental agendas.

Indeed, forests play a crucial role in climate change, both as sinks and sources of carbon emissions, and the degradation and loss of forests is a significant source of greenhouse gas emissions (IPCC, 2019). However, at the same time, forests contribute to a large proportion of the global terrestrial carbon sink (Jia *et al.*, 2019), which each year is estimated to remove from the atmosphere about one-third of the carbon dioxide emitted by fossil fuel combustion (Friedlingstein *et al.*, 2020).

In addition to their role in mitigating climate change, forests are critically important for the conservation of terrestrial biodiversity. They provide habitats for almost 80 percent of all amphibian species, 75 percent of all birds and more than 68 percent of all mammal species, as well as many other plant, fungi and invertebrate species (FAO and UNEP, 2020). Along tropical coasts, mangrove forests provide unique breeding grounds and nursery sites for many species of fish and shellfish (FAO, 2007; Hutchison, Spalding and zu Ermgassen, 2014). In addition, forests harbour high levels of genetic diversity, representing an intergenerational resource of immense social, economic and environmental importance (FAO, 2014a).

Forests also contribute to human well-being, food security and nutrition, and to local livelihoods, by providing social, economic and environmental services, such as the regulation of hydrological flows, clean water supply, soil protection and the provision of a wide range of food and raw materials (FAO and UNEP, 2020). In addition, they play a critical role in regulating local and regional climate regimes (IPCC, 2019; Leite-Filho *et al.*, 2021) and in providing key habitats for a wide variety of crop pollinators (Krishnan *et al.*, 2020).

Many multilateral agreements, targets and goals have recognized the importance of forests to sustainable development. The 2030 Sustainable Development Agenda acknowledged the crucial role that forestry and its community play in transforming the world and achieving the Sustainable Development Goals (Gregersen, El-Lakany and Frechette, 2020).[1]

All three of the Rio Conventions – the Convention on Biological Diversity (CBD),[2] the United Nations Convention to Combat Desertification (UNCCD)[3] and the United Nations Framework Convention on Climate Change (UNFCCC)[4] – recognize the importance of forests in meeting their respective objectives and the potential that forests offer in aligning actions to meet targets across the conventions through the implementation of nature-based solutions (UNFCCC, CBD and UNCCD, 2012). Underscoring the essential role of forests and trees in bolstering livelihoods, providing clean air and water, conserving biodiversity and responding to climate change, *The State of the World's Forests 2018* (FAO, 2018a) highlights the profound interlinkages that exist between forests and many other goals and targets of the 2030 Agenda. Moreover, the United Nations Decade on Ecosystem Restoration, which started in 2021 and aims to halt and reverse the destruction and degradation of the planet's ecosystems, includes forest ecosystems in its overarching goals.[5]

[1] www.un.org/sustainabledevelopment/development-agenda
[2] www.cbd.int/convention
[3] www.unccd.int/convention/about-convention
[4] https://unfccc.int
[5] www.decadeonrestoration.org

Other relevant international instruments, agreements and conventions related to forests are described in Table 1.

**Table 1. List of other international instruments relevant to the conservation and sustainable use of forests**

| International instruments/agreements/conventions | Relevance to forests |
|---|---|
| United Nations Decade on Ecosystem Restoration 2021–2030 (UN General Assembly, 2019)6 | Aims to prevent, halt and reverse the degradation of ecosystems, such as forests. |
| United Nations Strategic Plan for Forests 2017–2030 (UN, 2017a) | Includes six forest-related global forest goals and 26 associated targets to be met by 2030. |
| International Tropical Timber Agreement (UNCTAD, 2006) | Aims to ensure that exported tropical timber and timber products from species that are not listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are from sustainable sources. |
| Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (CBD, 2011) | The use and exchange of forest genetic resources is regulated by this protocol. |
| Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources (FAO, 2014b) | Identifies 27 strategic priorities for action to sustainably manage forest genetic resources. |
| Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1983) | Includes many tree- and forest-dependent species in its appendices, exerting different levels of control on their international trade. |
| Ramsar Convention (UNESCO, 1971) | Includes designations for forest ecosystems such as mangroves and peatland forests. |
| New York Declaration on Forests (UN, 2017b) | Calls for action to halt global forest loss and comprises ten goals related to the protection and restoration of forests. |
| International Plant Protection Convention (FAO, 2011) | Aims to secure coordinated, effective action to prevent and control the introduction and spread of pests of plants and plant products. |
| Convention on the Conservation of Migratory Species of Wild Animals (UNEP, 1979) | Provides a global platform for the conservation and sustainable use of migratory animals and their habitats, including forests. |

*Source*: Compiled by authors from sources listed in the table.

Monitoring progress towards these global goals and targets requires accurate assessments of the status and trends of the world's forests over time. However, measuring global forest resources, as well as their use, management and changes, is more complicated than it may seem.

Since its founding, FAO has regularly collected, analysed and disseminated information on the status of and trends in the world's forest resources through the Global Forest Resources Assessment (FRA), at intervals of five to ten years. The latest of these assessments, published in 2020 (*Global Forest Resources Assessment 2020*), examined the status and trends in more than 60 forest-related variables for the period 1990–2020 (FAO, 2020b).

Since 2005, FRAs have been based on data provided by a well-established network of national correspondents appointed by country governments (FAO, 2018b). As with any country-driven process, the quality of FRA depends on the capacity of countries to provide reliable estimates of their forest resources. However, while there have been

[6] www.decadeonrestoration.org

significant advances in forest resource assessment, some countries still lack the capacity to conduct periodic assessments and provide reliable data for FRA, which can result in varying levels of data timeliness and accuracy across countries. Although the coverage (by country) of data on deforestation, afforestation and natural forest area expansion in FRA 2020 is good and the quality is higher than in the previous assessments (Nesha *et al*., 2021), there is still considerable room for improvement, as relatively few countries and territories have reliable data on, for example, forest area trends for the last 30-year period (FAO, 2020b).

While FRA remains the only official and the most comprehensive global reporting process on forest resources, their management and uses, other valuable sources of data exist to support global forest monitoring. One example is the widely used Global Forest Change product (Hansen *et al.*, 2013), which provides spatially explicit datasets of annual tree cover loss and gain since the year 2000, based on remotely sensed data. In contrast to the FRA and other international reporting processes, such as the UNFCCC, which focus on land use, this product interprets forest change from a land cover (tree cover) perspective (i.e. the biophysical properties of a land surface). Therefore, it does not distinguish forests from other tree-covered areas, such as oil palm plantations, fruit orchards, trees in other agricultural production systems and urban settings. Furthermore, the Global Forest Change product considers all kinds of tree-cover losses in an equal manner and does not separate temporary tree-cover loss resulting from tree harvesting or other reasons, from the removal of trees for permanent land-use change (Hansen *et al.,* 2014). The product's other limitations relate to the challenges associated with estimating forest land-use extent from tree-cover data and inconsistencies in the data series due to algorithm adjustments and variations in the quality of satellite imagery used (University of Maryland, 2020).

As a result, these differences in definitions (land use vs. land cover) and methods produce dissimilar estimates of global deforestation trends between the two approaches (Jia *et al*., 2019).

BOX 1

**Land use versus land cover**

Land use is defined by the arrangements, activities and inputs that people undertake in a certain land cover type. By contrast, land cover is just the observed biophysical cover of the Earth's surface. The land use and land cover of an area can differ or match. For example, the land use might differ in two areas with high tree cover, where one area is a natural forest and the other is a city park.

FRA interprets the status and trends of forests from a land-use perspective (that is, the activities by which humans use land), under which an area can be temporarily devoid of tree cover and remain forest. However, this perspective explicitly excludes tree stands in agricultural production systems and urban areas

*Source*: FAO. 2020a. Terms and definitions. FRA 2020. Rome. www.fao.org/3/I8661EN/i8661en.pdf

Complementing the information collected through the country reporting process, the FRA Remote Sensing Surveys (RSS) aim to generate independent, robust and consistent estimates of forest area and its changes over time at global, regional and biome levels, which are compatible with the FAO definition of forest (FAO, 2020a). In addition, the surveys work to strengthen countries' capacities to use remote sensing for forest monitoring.

In 2018, FRA, in collaboration with the Joint Research Centre (JRC) of the European Commission and inputs from an international group of experts, began working on the fifth FAO FRA Remote Sensing Survey. This survey builds on the work of previous Remote Sensing Surveys, while incorporating recent technological developments and placing a strong emphasis on integrating local field knowledge.

The data collection process of this survey spanned about 3 years and involved 34 national and regional capacity-building and data collection workshops convened by FAO in collaboration with partner organizations. A network of more than 800 photointerpreters from 126 countries was trained in satellite imagery interpretation and collected data from more than 400 000 sample sites worldwide through visual assessment of cloud-free satellite images using Collect Earth Online (Saah *et al*., 2019).

This report presents estimates of changes in land use and land cover area at global, regional and biome levels for the periods 2000–2010 and 2010–2018. In addition, with the information on the land-use transitions in the periods under study, the survey has been able to characterize the drivers of forest losses and identify the most threatened forest ecozones. These findings are useful for many different purposes, including improving the accuracy of estimates of greenhouse gas emissions from the AFOLU sector (Smith *et al*., 2014), assessing the effectiveness of area-based forest conservation measures, tracking progress towards forest conservation and restoration goals, and more.

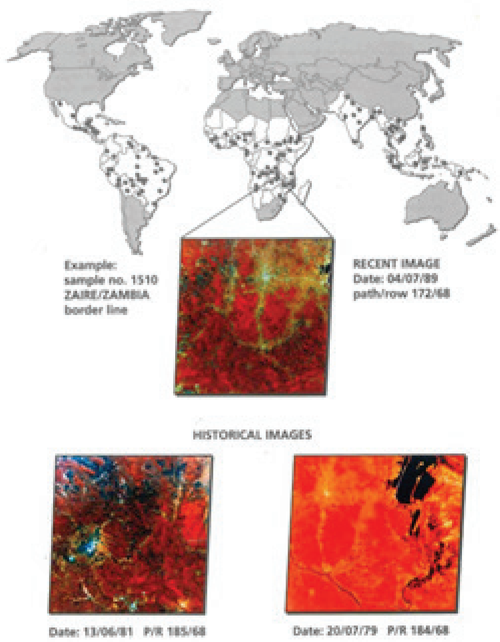
The participatory and collaborative nature of the assessment has been a key factor in overcoming current limitations in order to assess land-use changes consistently at the global level.

# 2 Previous remote sensing surveys

## 2.1 FRA 1990 AND 2000 PAN-TROPICAL REMOTE SENSING SURVEYS

The first large-scale FRA Remote Sensing Survey was implemented as part of FRA 1990. It focused on all the tropical regions, called in the 1990 and 2000 assessments 'pan-tropical', and relied on 117 sampling units that covered about 10 percent of the total tropical surveyed area (see Figure 1). For each sampling unit, multi-temporal Landsat satellite images were used to determine forest and land cover changes from 1980 to 1990. The survey produced estimates of forest area and forest area change at the regional, ecological and pan-tropical level.

**Figure 1. Pan-tropical Remote Sensing Survey design**




*Source*: FAO. 1996. Forest Resources Assessment 1990. Survey of tropical forest cover and study of change process. Forestry Paper No. 130. Rome.

The FRA 2000 pan-tropical Remote Sensing Survey built on the FRA 1990 survey and complemented the sampling units with more recent Landsat satellite images to assess forest and land cover changes for both the periods 1980 to 1990 and 1990 to 2000, as well as assessing the trend of forest area changes.

## 2.2 FRA 2010 GLOBAL REMOTE SENSING SURVEY

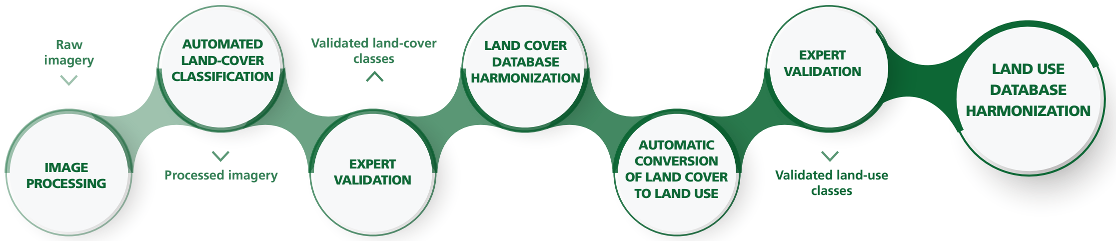
The FRA 2010 RSS was the first global survey on forest land-use change, including deforestation, afforestation and the natural expansion of forests (FAO and JRC, 2012).

The assessment used a sample-based approach, applying a systematic sampling design based on each longitude and latitude intersection, with a reduced intensity above 60 degrees north due to the curvature of the Earth.

The whole land surface of the Earth was covered with about 13 500 sampling units, of which some 9 000 fell outside deserts and areas with permanent ice. Each sampling unit was a 10 km × 10 km square tile, providing a sampling intensity of about 1 percent of the global land surface.

For each sample plot, Landsat satellite images dating from 1990, 2000 and 2005 were segmented and classified using an automated, supervised approach, where national experts participated in the final validation.

**Figure 2. Generalized flowchart of the FRA 2010 Remote Sensing Survey processing chain**




*Source*: Adapted from FAO and JRC. 2012. Global forest land-use change 1990–2005, by E.J. Lindquist *et al.* FAO Forestry Paper No. 169. Rome.

Nearly 7 million segments inside the sampling units were analysed at each time interval to enable the detection of forest area, forest gains and forest losses that were 5 ha or greater in size.

In 2013, as part of the FRA 2015 assessment, updated forest land-use and change rates (losses and gains) were calculated at the global, regional and ecological zone scales for 1990, 2000 and 2010.

## 2.3 GLOBAL DRYLANDS ASSESSMENT 2017

The Global Drylands Assessment 2017 used a stratified systematic sampling design of 45 strata following regional division by aridity zones (UNEP-WCMC, 2007; Bastin *et al.*, 2017; FAO, 2019). In total, 213 782 sample plots measuring 70 m$^2$ were established across the world (see Figure 3). For each sample plot, data on 77 variables describing the sample site were collected through visual interpretation of various satellite images (Landsat 7, Landsat 8, Moderate Resolution Imaging Spectroradiometer (MODIS) and very high resolution (VHR) images available through Google Earth). The variables were selected to describe land cover, land use, land-use change and other significant land dynamics (such as tree coverage, trees outside forest, disturbances) for the reference period 2000–2015.

**Figure 3. Global Drylands Assessment 2017 stratified systematic sampling design**

*Source*: Developed from Bastin *et al.*, 2017. The extent of forest in dryland biomes. Science, 356(6338): 635–638.

More than 200 photointerpreters with knowledge of the land and land uses in specific regions participated in the interpretation. The analysis was conducted during a series of regional workshops organized in collaboration with partner universities, research institutes, governments and non-governmental organizations worldwide. Data were analysed using the Open Foris Collect Earth (CE) tool[7], an open-source software developed by FAO.

[7] https://openforis.org/tools/collect-earth/


Fairbanks, Alaska
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# 3 Methods and materials

The FRA 2020 Remote Sensing Survey – the fifth such survey to have been conducted – built on the lessons learned from the past surveys, with a strong emphasis on increasing the statistical precision and reliability of the forest change estimates. To achieve this objective, the survey was implemented with a specific focus on: (a) the integration of local expertise in the process; (b) the development and application of easy-to-use tools and methods for image interpretation; (c) a strong capacity development programme to ensure consistency in the interpretation and results worldwide; and (d) quality assurance and quality control protocol implemented in real time.

Compared with FRA 2010 Remote Sensing Survey, the FRA 2020 Remote Sensing Survey adopted a simplified methodology and the data collection was performed using a user-friendly tool, Open Foris Collect Earth Online (CEO),[8] which facilitated the involvement of a wide network of local photointerpreters without the need for a high level of remote sensing expertise.

Compared with the Global Drylands Assessment 2017 (Bastin *et al*., 2017), which focused on assessing the land status and did not have an efficient sampling approach to estimate land-use changes – since such changes are rare events and occur only on a small fraction of the land – the sampling design for the FRA 2020 Remote Sensing Survey was developed to produce more precise statistics on forest and land-use change by adopting an ad hoc stratified random sampling design following (as baseline strata) the Global Forest Change product (Hansen *et al*., 2013).

## 3.1 DATA COLLECTION

### 3.1.1 Sampling design

The main objective of the sampling design was to derive robust estimates, particularly for the changes in forest area at regional and global levels.

The sampling frame of the FRA 2020 RSS was based on a tessellation of the Earth's surface (see Figure 4) into equal area hexagons (39.62 ha each), originating from a discrete global grid of equally-sized hexagons. An additional assessment was carried out for a 1-ha square centroid in each hexagon to collect more detailed information on land use and tree cover, land-use change and related drivers.

The tessellation of the Earth produced more than $1.2*10^9$ hexagons, out of which approximately 335 million fall on land and constituted our sampling frame.

To reduce the uncertainty of forest area change estimates we used **stratified random sampling**.

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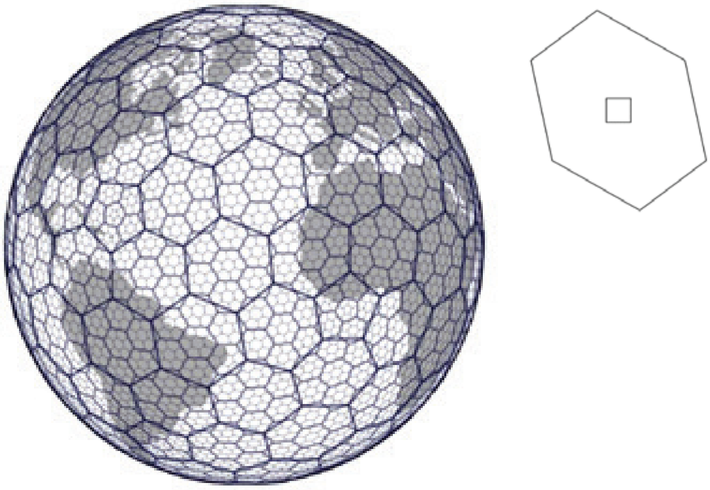
[8] https://openforis.org/tools/collect-earth-online

**Figure 4. Hexagonal tessellation of the Earth, based on a truncated icosahedron and single hexagon plot with 1 hectare square centroid**



*Source*: Sahr, K. 2019. Central place indexing: Hierarchical linear indexing systems for mixed-aperture hexagonal discrete global grid systems. Cartographica: The International Journal for Geographic Information and Geovisualization, 54(1): 16–29.

The hexagons were stratified to 80 strata, using a combination of the 20 Global Ecological Zones (GEZ) and four strata of tree cover change from the Global Forest Change product (FAO, 2010; Hansen *et al*., 2013). These four strata consisted of:

- **big changes:** > 40 percent of pixels in the hexagon with changes;
- **small changes:** between 5 percent and 40 percent of pixels in the hexagon with changes;
- **no changes in tree-covered areas (no change forest):** < 5 percent of pixels with changes and > 10 percent tree cover; and
- **no changes outside tree-covered areas (no change non-forest):** < 5 percent of pixels with changes and < 10 percent tree cover.

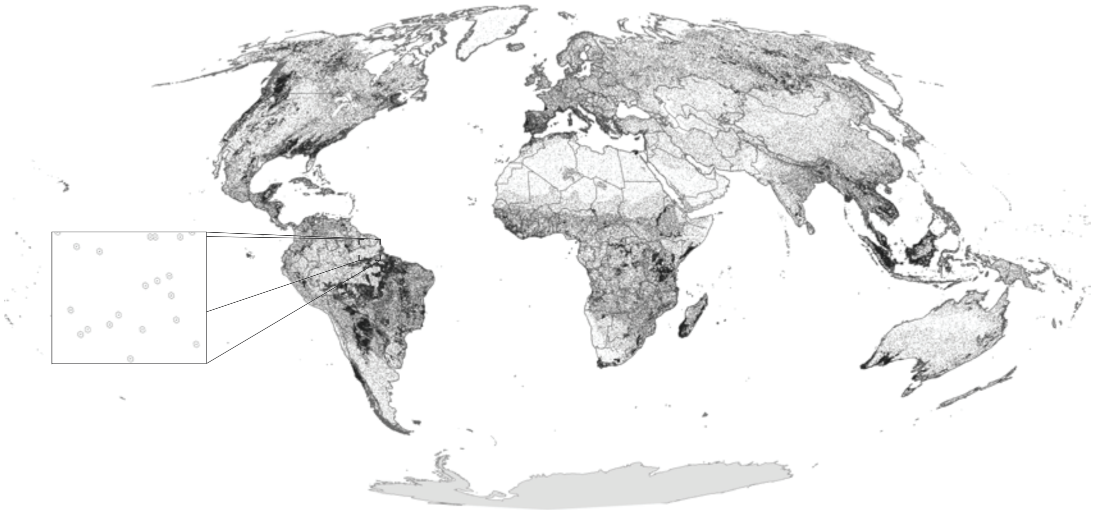
Following the work of Hansen *et al*. (2013), we have chosen to refer to the above-mentioned four strata interchangeably as Hansen strata. The targeted total number of samples was approximately 400 000, with a sample intensity of 0.03 percent. After defining the strata, the sample allocation was carried out in four stages:

1. Allocating 50 percent to the two 'no changes' Hansen strata and 50 percent to the two 'changes' strata.
2. The sample in the 'no changes' strata is equally divided between 'no change forest' and 'no change non- forest', i.e. 100 000 units to each stratum.
3. The sample in the 'changes' strata is divided between 'big changes' (140 000 units) and 'small changes' (60 000 units).
4. The sample allocated to each of the four Hansen strata is distributed among the global ecological zones (GEZ) proportionally to the number of hexagons.

The final number of samples for each 80 strata was calculated using proportional sampling and the samples to be assessed where chosen randomly.

The final distribution of the Remote Sensing Survey samples is shown in Figure 5. The sample distribution pattern reflects land cover change dynamics in different areas. For example, in the central part of Chile, the high concentration of samples is related to forest management and plantation cycles, while in the north of Paraguay it is related more to deforestation and land-use changes than land cover changes.

**Figure 5. FRA 2020 Remote Sensing Survey global distribution of samples**



*Notes*: The darker areas show a higher density of samples than the lighter areas.
Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
*Source*: UN. 2020. MapoftheWorld [online]. [Cited 1 January 2021].un.org/geospatial/file/3420/download?token=bZe9T8I91b), modified by the authors.

### 3.1.2 Image interpretation

The assessment was carried out using visual interpretation and Open Foris Collect Earth Online (CEO) (Saah *et al*., 2019).

CEO is a custom-built, free, open-source and user-friendly software that enables the visualization and interpretation of satellite imagery in a cloud-based environment. It was developed collaboratively by NASA SERVIR (a joint venture between the National Aeronautics and Space Administration of the United States of America and the United States Agency for International Development that partners with leading geospatial organizations in Asia, Africa, and Latin America)[9] and FAO in partnership with SilvaCarbon (an interagency cooperation programme of the Government of the United States of America), the University of San Francisco's Spatial Informatics Group, the United States Forest Service and Google. The full functionality of Collect Earth Online is implemented in the cloud, with no need for desktop installation. The software's codebase is shared through FAO's Open Foris initiative.

The analysis was conducted using Landsat and Sentinel images as main data sources. Best available Landsat 5 or Landsat 7 data were used for years 2000 and 2010, and best available Landsat 8 and Sentinel-2 for 2018. VHR images from Bing Maps, DigitalGlobe and MapBox were also available as additional data to support the analysis. In addition, CEO has the option to visualize each plot as a Keyhole Markup Language file on Google Earth.

9 www.nasa.gov/mission_pages/servir/overview.html

### 3.1.3 Survey form

The users analysed the samples using an interactive CEO survey form divided into two main parts:

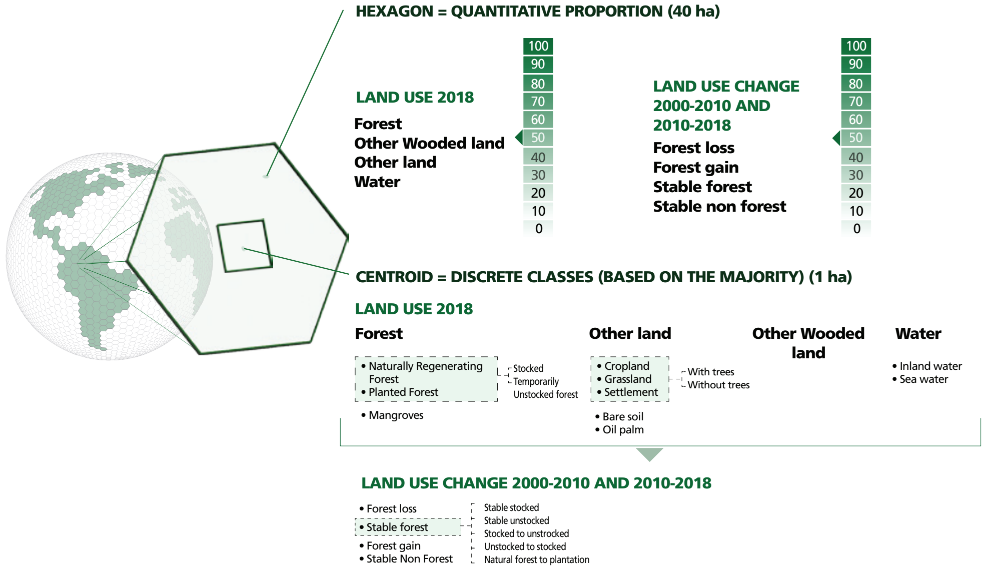
**I. Centroid**

The first part of the survey form focuses on the categorical classification of the hexagon's centroid into defined variables for each land-use class (FAO, 2020a) and subclass for 2018 (IPCC, 2006), as well as land-use change classes for the given time intervals (2000–2010 and 2010–2018). The land-use and land-use change classes were assigned according to the majority (i.e. if more than half of the centroid is covered by forest, it will be classified as Forest). Moreover, the presence of trees was also recorded for the other land subcategory, in order to extract the percentage and hectares of other land with tree cover from the results (see Figure 6).

**II. Hexagon**

The second part of the survey form focuses on the quantitative estimation of the proportion of the area of the hexagon falling into each main land-use class (Forest, Other Wooded Land, other land and Water) in 2018. Forest gains and losses were recorded for 2000–2010 and 2010–2018. In both classifications, discrete 10 percent classes were used (see Figure 6).

**Figure 6. Workflow of the variables collected during the assessment for both centroid and hexagon**




At both levels (centroid and hexagon), the land-use type was recorded for 2018. Land-use changes for periods 2000–2010 and 2010–2018 were recorded using the following classes:

- Stable forest
- Stable non forest
- Forest loss
- Forest gain

### 3.1.4 Participatory data collection approach

Participatory national and regional workshops were the pillars of the Remote Sensing Survey data collection. The invited experts were nominated through the FRA National Correspondents network[10] by national authorities based on specific technical requirements, which prioritized technical experts familiar with the land-use dynamics and ecology of the study areas analysed.

The experts were trained during the workshops, using standard modules to ensure consistent photointerpretation that applied FRA terms and definitions. The workshops also presented examples of problematic samples and discussing their analyses, thereby reducing the likelihood of interpretation errors.

Moreover, the use of Landsat and Sentinel-2 mosaics in Collect Earth Online as reference data assured consistency within the global samples. In addition, VHR sources were used only if of the same year as the mosaics. No national maps were used to classify the samples, with the exception of Australia and Canada.

To ensure effective participation of the experts in implementing the survey, countries and territories were divided into two groups, according to the number of samples being assessed:

1. Large countries with extensive forest area, such as Brazil, China, Democratic Republic of the Congo, Indonesia, the Russian Federation and the United States of America, received targeted support according to their specific needs. This support consisted of physical or virtual national workshops, hiring additional national consultants to undertake part of the sample interpretation, and remote support from FAO.

2. The smaller countries were invited to physical or online regional workshops where the national experts were trained together in interpretation of the samples. The data collection started during the workshop and was either completed by the national experts during the workshop, or afterwards with remote support from FAO.

## 3.2 DATA ANALYSIS

The data analyses were performed at the global, regional and biome level; the latter were derived from the Global Ecological Zones product (FAO, 2010).

## 3.3 VALIDATION

### 3.3.1 Quality assurance and quality control

The quality assurance and quality control process was divided into two steps:

- the quality assurance during the workshops; and
- quality control after the data collection.

In terms of the first step, during the training workshops, members of the FRA Team checked a random 10 percent of the samples collected by each participant in the beginning of their assessment work, in order to detect systematic errors and ensure that the understanding of the RSS methodology was consistent.

A basic step to assess any survey, or more generally any information data source, is to compare it with other data sources. The disagreement between different sources does not necessarily mean that a particular data source is inferior in quality, but an analysis of the disagreements can reveal specific subsets that may be worth exploring further. For this reason, once data collection had been completed for a country, the FRA Team checked the results obtained against the data reported from the country to the FRA 2020 (FAO, 2020b) and against other land cover/land use estimates available through global maps, such as GlobeLand30–2010[11] and the European Space Agency's

[10] www.fao.org/forest-resources-assessment/background/national-correspondents/en

[11] www.un-spider.org/links-and-resources/data-sources/land-cover-map-globeland-30-ngcc

2009 global land cover map,[12] before performing the quality control step.

If the Remote Sensing Survey estimates were in line with the other products – especially with FRA 2020 (FAO, 2020b) – no further quality control was performed, as the data were presumed to be correct. If not, the second phase of the quality control was performed after the workshop.

In the second phase, the FRA team reviewed approximately 12 percent of the plots for each national photointerpreter, consisting of a random selection of 7 percent of the samples and the remaining 5 percent corresponding to specific error classes. The 12 percent of plots chosen were analysed in Collect Earth Online by FAO and compared with the interpretation of the national photointerpreter.

If obvious errors were found, the national photointerpreters were requested to revisit and correct their plots, and if they were unavailable, FAO or local consultants corrected the inconsistencies instead.

### 3.3.2 Accuracy assessment implementation

The interpretation accuracy assessment was conducted at the end of the FRA 2020 Remote Sensing Survey data collection (FAO, 2020b).

The assessment was done for approximately 3 percent (about 12 000 units) of the global sample sites. Each unit of the supervised sample was photointerpreted by three operators. Operators were assigned to the regions corresponding to their specific expertise.

The analysis suggests that the interpretation error is an important component of the estimation error. Further analysis of the results will be carried out to improve the applied methodology for future assessments.

[12] www.esa.int/ESA_Multimedia/Images/2010/12/ESA_s_2009_global_land_cover_map#.YZIw46-cmKw.link

# 4 Results

This chapter presents the Remote Sensing Survey results on the status of Forest and other land use area in 2018, as well as forest area trends and deforestation drivers for the periods 2000–2010 and 2010–2018. The results are presented at the global, regional and GEZ level.

Note that numbers given in the text, tables and figures in this report may not sum to the totals indicated and percentages may not tally to 100 due to rounding.

## 4.1 FOREST AND OTHER LAND USES IN 2018

**Distribution of global land area by main land uses in 2018**

According to the FRA 2020 Remote Sensing Survey, the world's forest area was 3.97 billion ha in 2018, corresponding to 30.8 percent of the global land area (see Figure 7).

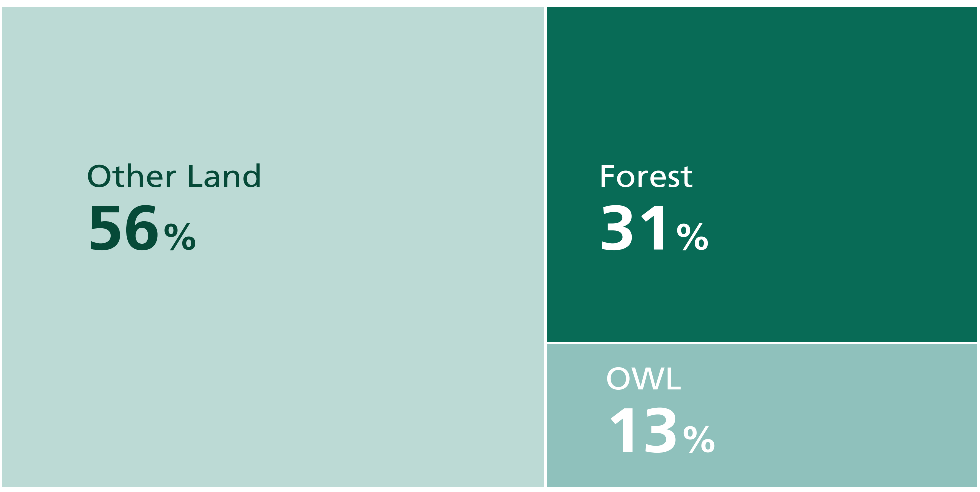
The estimate is slightly lower than the global forest area obtained from country reporting to FAO for the Global Forest Resources Assessment 2020, which was 4.06 billion ha (FAO, 2020b).

Grasslands cover 20.9 percent, Bare Soil 18.0 percent, Croplands 14.8 percent and Settlements 2.2 percent of global land area (see Figure 8 and Table 2). Altogether, these other land subclasses have an area of 7 200 Mha.

The Remote Sensing Survey estimate for total agricultural land area is about 1.3 percent less than official figures reported to FAOSTAT for 2019 (FAO, 2021a) and the estimated share of cropland is approximately 2.8 percent higher than that of FAOSTAT. These differences can result from a number of factors, including differences in the data collection methodology, reporting processes and definitions (see Box 2).

The Remote Sensing Survey estimates the global area of Other Wooded Land at 13.2 percent of the global land area, equivalent to 1 701 Mha (see Table 2). This figure is almost double the area reported by countries to the FRA 2020. One of the reasons for this difference lies in the fact that these areas are challenging to map and measure, and have therefore received less attention in the country-level forest monitoring processes. However, further investigation is needed to better understand the underlying reasons and their impact on the estimates in different regions of the world.

**Figure 7. Distribution of land area by FRA land use classes in 2018**



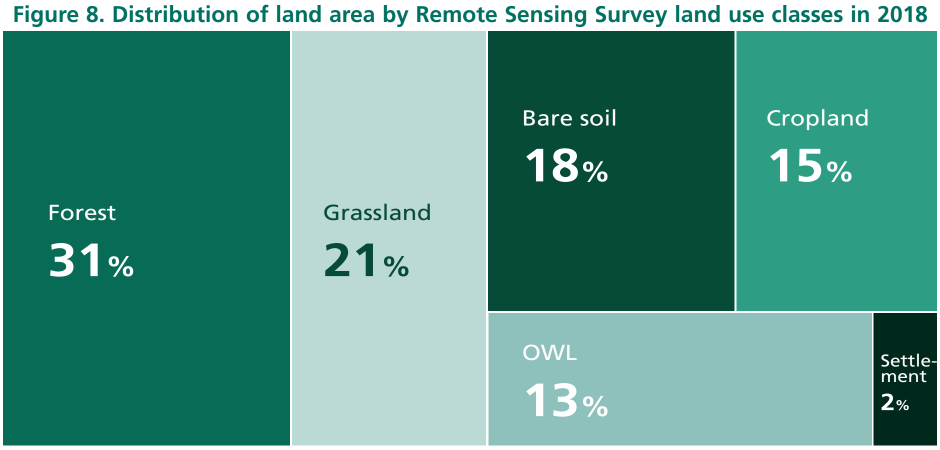
BOX 2

**FAO land use and land cover classifications**

FAO defines standards and classifications for the collection of data and statistics on food and agriculture from its member countries. To this end, FAO is the custodian agency of land use and land cover classifications, which can be found within the FAO Land Use, Irrigation and Agricultural Practices Questionnaire, based on the land use definitions originally developed by FAO for the World Census of Agriculture. This questionnaire encompasses the full matrix of land-use data – covering the entire country area including land and water – while a separate questionnaire managed by the FAO Global Forest Resources Assessment (FRA) focuses exclusively on the collection of forest-related information. The full set of land-use data collected from countries, together with complete classifications, is available at the FAOSTAT Land Use domain. The data specific to forests are collected separately and disseminated, together with additional definitions, via the FRA data portal. With reference to the definitions provided in the FAO Land Use questionnaires, the matrix of a country's land area is subdivided into three mutually exclusive classes: *Agricultural Land*, *Forest (Land),* and *other land*. In turn, *Agricultural Land* is subdivided into *Cropland* and *Land under permanent meadows and pastures* (see FAO Analytical Brief on Land use statistics and indicators). The FRA classes further distinguish a class termed *Other Wooded Land*, which is a subset of *other land* in the fuller FAO land use matrix. These FAO and use classes are used by the UN System of Environmental and Economic Accounting (SEEA). The other international land use classification used by countries is the one developed by the Intergovernmental Panel on Climate Change (IPCC, 2006), which subdivides a country's land matrix into six mutually exclusive land use classes: *Cropland*, *Grassland*, *Forest Land*, *Wetlands*, *Settlements*, *Other*. While the IPCC terminology, for historical and practical reasons reflects land cover terminology from the scientific literature, it is in fact virtually the same as FAO land use classes in relation to *Agricultural Land* and *Forest* – so much so that a nearly one-to-one mapping between IPCC and FAO is provided in the FAO Land Use Questionnaire. Remote sensing-based approaches to determine land use from observable land cover characteristics and their dynamics, such as the one provided in this report through the use of Collect Earth Online, abound in the literature and provide a wide range of results in terms of assessed area extent, typically provided at regional or global level, of the land use class studies. This wide difference in results shows a strong dependence – among the multiple approaches that can be applied (for example, supervised or unsupervised) and the underlying validation data – on the operational set of rules applied to associate land cover to land use. For instance, assessments of the range of estimates of land use, made by using as input available high- and low-resolution land cover maps, indicate world total cropland area ranging between 1 200 and 1 900 million ha, a value that contains cropland estimates made in this report. Conversely, FAOSTAT statistics collected at country level indicate a world total area of cropland of about 1 500 million ha.

*Source*: FAO 2021b. Land statistics. Global, regional and country trends, 1990–2018. FAOSTAT Analytical Brief Series No. 15. FAO, Rome. Available at: https://www.fao.org/food-agriculture-statistics/data-release/data-release-detail/en/c/1370253

**Figure 8. Distribution of land area by Remote Sensing Survey land use classes in 2018**



All the results are presented at regional and FRA subregional level, as well as at GEZ level.

**Table 2. FRA Remote Sensing Survey area estimates (Mha) and +/-95% confidence interval (percent) for land use classes by FAO region and subregion in 2018**

| Region and subregions (Mha) | Forest | ± | Cropland | ± | Grassland | ± | OWL | ± | Settlement | ± | Bare soil | ± | Land area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North America | 736.8 | 1.10% | 232.9 | 3.10% | 381.4 | 5.70% | 336.9 | 4.20% | 63.8 | 6.10% | 333.9 | 7.50% | 2 085.60 |
| Central America | 23.5 | 5.90% | 9.7 | 10.20% | 13.2 | 8.60% | 2 | 33.70% | 1.1 | 34.50% | 0.6 | 50.90% | 49.8 |
| Caribbean | 9 | 9.80% | 4.2 | 15.10% | 4.6 | 15.60% | 2 | 21.70% | 1.3 | 33.30% | 0.5 | 47.70% | 21.9 |
| North and Central America | 769 | 1.10% | 247 | 3.00% | 399 | 5.50% | 341 | 4.20% | 66 | 6.00% | 335 | 7.50% | 2 157 |
| South America | 838 | 0.80% | 155 | 2.90% | 436 | 1.60% | 191 | 2.90% | 20 | 10.30% | 94 | 4.30% | 1 734 |
| Europe | 1 026 | 1.10% | 308 | 1.90% | 504 | 3.30% | 183 | 4.50% | 63 | 5.50% | 111 | 12.00% | 2 195 |
| North Africa | 56.4 | 4.30% | 73.7 | 6.60% | 108.2 | 6.80% | 39 | 7.70% | 5.6 | 34.60% | 630.2 | 1.30% | 913.1 |
| Western and Central Africa | 289.3 | 1.90% | 221.6 | 2.40% | 138.3 | 3.90% | 117 | 4.20% | 14.6 | 11.50% | 234.9 | 2.10% | 1 015.60 |
| Eastern and Southern Africa | 228.1 | 2.00% | 165.8 | 2.80% | 282 | 3.00% | 252 | 2.90% | 14.8 | 10.70% | 48.7 | 12.10% | 990.9 |
| Africa | 574 | 1.30% | 461 | 1.90% | 528 | 2.40% | 407 | 2.30% | 35 | 8.60% | 914 | 1.20% | 2 920 |
| Western and Central Asia | 34 | 7.00% | 141.6 | 5.10% | 279.9 | 3.20% | 57 | 9.30% | 26.3 | 17.60% | 495.6 | 2.00% | 1 034.10 |
| East Asia | 261.7 | 1.90% | 177.6 | 3.60% | 328.9 | 2.80% | 110 | 5.70% | 40.8 | 8.50% | 202.6 | 4.10% | 1 121.20 |
| South and Southeast Asia | 322.2 | 1.40% | 375.1 | 1.80% | 23 | 11.40% | 42 | 10.20% | 32.9 | 8.10% | 65.3 | 6.70% | 860.6 |
| Asia | 618 | 1.10% | 694 | 1.70% | 632 | 2.10% | 208 | 4.40% | 100 | 6.40% | 764 | 1.80% | 3 016 |
| Oceania | 143 | 2.80% | 37 | 8.40% | 194 | 4.80% | 370 | 2.80% | 3 | 31.30% | 101 | 8.30% | 847 |
| World | 3 968.40 | 0.50% | 1 902.10 | 1.00% | 2 693.00 | 1.30% | 1 700.70 | 1.40% | 286.5 | 3.20% | 2 318.60 | 1.50% | 12 869.30 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

When analyzing the distribution of global forest area among the regions, the differences between the estimates based on FRA 2020 country reporting and the result reported here are within two percent in all regions and subregions. The biggest difference between the two was observed for Africa, where the RSS estimates the share of global forest area to be 14 percent against the 16 percent reported by FRA 2020. This difference is likely to be due to a number of reasons. First, the spatial resolution of the data used for the Remote Sensing Survey limits the ability of the interpreters to detect low canopy cover forests, which are typical of African tropical dry forest types such and miombo and mopane woodlands. Second, in these areas the separation of forest and other wooded land is challenging.

According to the Remote Sensing Survey, most of the world's forests are found in the tropical domain (46 percent), followed by boreal (28 percent), temperate (16 percent), and subtropical domains (10 percent). Also, these estimates are well aligned with the findings based on FRA 2020 country reporting. According to the RSS most of the other wooded land is in the tropics (40 percent), the second largest share (29 percent) was found for the subtropics, followed by boreal (15 percent) and temperate (13 percent) zones.

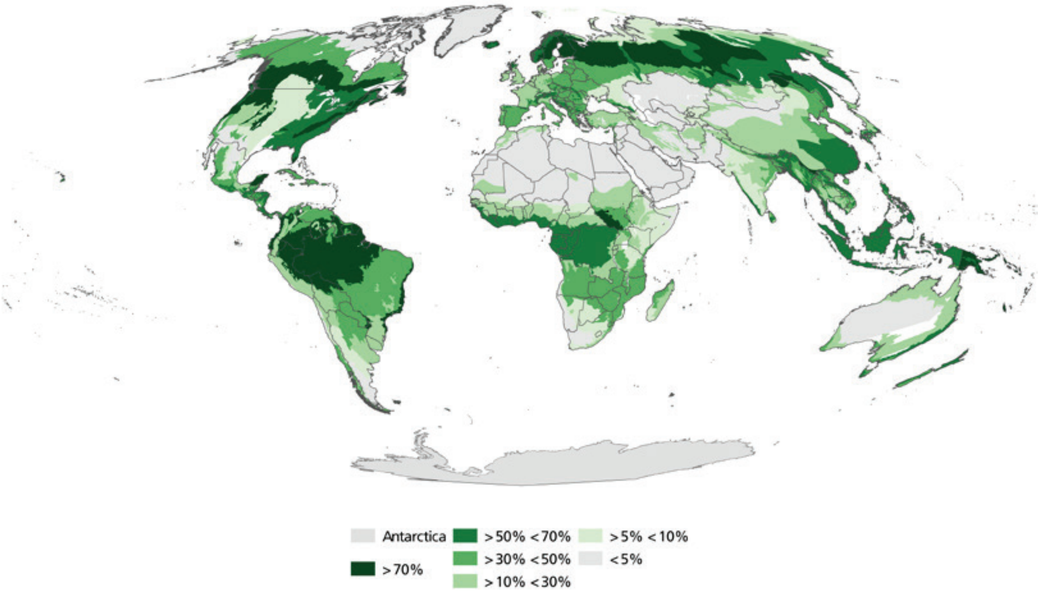
Most of the croplands (49 percent) and grasslands (37 percent) were found in the tropics.

### Table 3. FRA Remote Sensing Survey area estimates (Mha) and +/-95% confidence interval (percent) by Global Ecological Zones and FAO climatic domains in 2018

| GEZ (Mha) | Forest | ± | Cropland | ± | Grassland | ± | OWL | ± | Settlement | ± | Bare soil | ± | Land area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tropical rainforest | 983.7 | 0.70% | 199.3 | 2.30% | 167.3 | 2.90% | 47.9 | 6.20% | 20.8 | 8.70% | 8 | 16.40% | 1 426.90 |
| Tropical moist forest | 390.4 | 1.50% | 227.7 | 1.90% | 274 | 1.90% | 128.9 | 3.20% | 20.5 | 7.70% | 11.6 | 10.80% | 1 053.20 |
| Tropical dry forest | 258.9 | 1.60% | 181.1 | 1.80% | 140.3 | 2.50% | 152.3 | 2.50% | 16.9 | 8.40% | 18.9 | 9.10% | 768.5 |
| Tropical shrubland | 56.1 | 6.60% | 189 | 3.00% | 202.8 | 3.40% | 204.6 | 3.20% | 12.4 | 16.00% | 127.8 | 4.30% | 792.7 |
| Tropical desert | 0.7 | - | 48.5 | 13.10% | 137.8 | 8.50% | 92.4 | 10.80% | 15.2 | 30.10% | 978.4 | 1.40% | 1 272.90 |
| Tropical mountain system | 136.1 | 1.90% | 82 | 3.10% | 77.1 | 3.50% | 53.1 | 4.60% | 7.5 | 12.70% | 81.8 | 2.60% | 437.6 |
| Tropicals | 1 826 | 0.60% | 927.6 | 1.20% | 999.3 | 1.60% | 679 | 2.00% | 93.2 | 6.20% | 1 226.6 | 1.20% | 5 751.70 |
| Subtropical humid forest | 200.9 | 2.10% | 124.4 | 3.90% | 68.5 | 5.60% | 23 | 10.50% | 32.6 | 9.00% | 2.1 | 38.20% | 451.6 |
| Subtropical dry forest | 45.5 | 2.30% | 61.3 | 2.10% | 18.7 | 4.70% | 19 | 4.60% | 8.1 | 7.60% | 4 | 11.20% | 156.5 |
| Subtropical steppe | 36.7 | 7.00% | 79.8 | 6.20% | 118.6 | 4.70% | 123.4 | 4.20% | 11.2 | 16.60% | 91.2 | 5.20% | 460.9 |
| Subtropical desert | 7.2 | 19.20% | 14.3 | 17.40% | 45.1 | 9.60% | 271.3 | 2.20% | 7.3 | 24.90% | 173.6 | 3.10% | 518.9 |
| Subtropical mountain system | 111.1 | 2.70% | 67.7 | 5.70% | 109 | 4.20% | 60.9 | 5.80% | 13.6 | 13.00% | 120.1 | 3.90% | 482.4 |
| Subtropicals | 401.5 | 1.50% | 347.6 | 2.40% | 360 | 2.60% | 497.6 | 1.80% | 72.7 | 6.00% | 390.9 | 2.20% | 2 070.40 |
| Temperate oceanic forest | 50.7 | 3.60% | 64.4 | 3.00% | 33.4 | 5.10% | 8.1 | 11.20% | 15.1 | 8.40% | 5.3 | 12.50% | 177 |
| Temperate continental forest | 274.4 | 1.60% | 226.8 | 2.10% | 78.6 | 4.80% | 17.5 | 11.10% | 57.9 | 5.80% | 0.8 | 50.10% | 656.1 |
| Temperate steppe | 32.8 | 7.10% | 227.2 | 3.50% | 213.7 | 3.90% | 44.8 | 9.90% | 15 | 16.30% | 43.5 | 10.40% | 577 |
| Temperate desert | 13.2 | 14.50% | 39.5 | 11.90% | 259.4 | 3.40% | 81.8 | 7.90% | 7.1 | 28.20% | 136.8 | 5.70% | 537.8 |
| Temperate mountain system | 247.9 | 1.70% | 44.3 | 8.40% | 215 | 3.00% | 67.1 | 6.70% | 16 | 13.00% | 114.5 | 4.90% | 704.9 |
| Temperates | 618.9 | 1.10% | 602.3 | 1.90% | 800.1 | 1.80% | 219.4 | 4.20% | 111.1 | 4.70% | 300.9 | 3.50% | 2 652.70 |
| Boreal coniferous forest | 599.4 | 1.20% | 21.1 | 10.60% | 81.2 | 6.20% | 78.5 | 6.20% | 7.1 | 20.40% | 4.3 | 20.10% | 791.5 |
| Boreal tundra woodland | 166.2 | 2.80% | 0.2 | 95.10% | 96.3 | 3.70% | 88.1 | 4.70% | 0.2 | - | 23.4 | 7.30% | 374.5 |
| Boreal mountain system | 342.6 | 2.00% | 3.2 | 27.40% | 112.6 | 4.40% | 96.5 | 5.90% | 2 | 34.40% | 57.1 | 4.90% | 614.1 |
| Boreals | 1 108.2 | 1.00% | 24.6 | 9.80% | 290.1 | 2.70% | 263.1 | 3.20% | 9.3 | 17.40% | 84.8 | 4.00% | 1 780.10 |
| Polar | 13.8 | 29.10% | 0 | - | 243.4 | 10.20% | 41.5 | 29.20% | 0.2 | 77.40% | 315.5 | 8.80% | 614.4 |
| World | 3 968.4 | 0.50% | 1 902.1 | 1.00% | 2 693 | 1.30% | 1 700.7 | 1.40% | 286.5 | 3.20% | 2 318.6 | 1.50% | 12 869.30 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

**Figure 9. Forest by ecoregion (the combination of FRA subregions and Global Ecological Zones) in 2018, calculated as % of forest area over total ecoregion area**




*Note*: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
*Source*: UN. 2020. MapoftheWorld [online]. [Cited 1 January 2021].un.org/geospatial/file/3420/download?token=bZe9T8I91b), modified by the authors.

## Forest characteristics

The study reported forest divided into two broad categories: naturally regenerating and planted forests. In addition, the area of mangrove forest was reported separately (see Table 4 and Table 5).

**Table 4. Naturally regenerating forest area, mangroves and planted forest area (Mha) and +/-95% confidence interval (percent) by FAO region and subregion in 2018**

| Regions and subregions (Mha) | Naturally regenerating forest (excluding mangroves) | ± | Mangroves | ± | Planted forest | ± |
|---|---|---|---|---|---|---|
| North America | 706.3 | 1.1% | 0.9 | 52.3% | 29.6 | 5.9% |
| Central America | 22.9 | 6.1% | 0.4 | 84.4% | 0.2 | 59.5% |
| Caribbean | 7.6 | 11.2% | 0.7 | 47.0% | 0.7 | 44.7% |
| North and Central America | 736.8 | 1.1% | 1.9 | 33.3% | 30.5 | 5.9% |
| South America | 816.3 | 0.8% | 1.2 | 37.4% | 20.5 | 6.4% |
| Europe | 943.4 | 1.2% | - | - | 82.9 | 4.3% |
| North Africa | 55.2 | 4.4% | 0.0 | - | 1.2 | 33.1% |
| Western and Central Africa | 283.7 | 1.9% | 2.4 | 34.0% | 3.2 | 22.7% |
| Eastern and Southern Africa | 221.5 | 2.0% | 0.7 | 56.6% | 5.9 | 17.4% |
| Africa | 560.4 | 1.3% | 3.1 | 29.2% | 10.3 | 12.8% |
| Western and Central Asia | 30.7 | 7.2% | 0.0 | - | 3.3 | 30.3% |
| East Asia | 180.6 | 2.5% | - | - | 81.1 | 4.6% |
| South and Southeast Asia | 292.3 | 1.5% | 4.2 | 23.5% | 25.7 | 6.3% |
| Asia | 503.6 | 1.3% | 4.2 | 23.4% | 110.1 | 3.8% |
| Oceania | 138.3 | 2.9% | 0.9 | 49.2% | 3.8 | 14.9% |
| World | 3 699.0 | 0.5% | 11.3 | 14.2% | 258.1 | 2.4% |

**Table 5. Naturally regenerating forest area, mangroves and planted forest area (Mha) and +/-95% confidence interval (percent) by Global Ecological Zones and FAO climatic domains in 2018**

| GEZ (Mha) | Naturally regenerating forest (excluding mangroves) | ± | Mangroves | ± | Planted forest | ± |
|---|---|---|---|---|---|---|
| Tropical rainforest | 952.7 | 0.7% | 6.8 | 19.5% | 24.2 | 6.6% |
| Tropical moist forest | 373.2 | 1.6% | 2.9 | 24.9% | 14.3 | 7.4% |
| Tropical dry forest | 253.9 | 1.6% | 1.1 | 40.9% | 4.0 | 14.8% |
| Tropical shrubland | 54.5 | 6.7% | 0.2 | 87.9% | 1.4 | 46.6% |
| Tropical desert | 0.2 | 7.8% | 0.0 | - | 0.4 | - |
| Tropical mountain system | 130.7 | 2.0% | 0.0 | - | 5.4 | 13.9% |
| Tropicals | 1 765.3 | 0.6% | 11.0 | 14.4% | 49.7 | 4.7% |
| Subtropical humid forest | 121.6 | 3.4% | 0.3 | - | 79.1 | 4.0% |
| Subtropical dry forest | 36.9 | 2.7% | 0.0 | - | 8.6 | 6.1% |
| Subtropical steppe | 36.0 | 7.1% | 0.0 | - | 0.7 | 52.8% |
| Subtropical desert | 7.2 | 19.3% | 0.0 | - | 0.0 | - |
| Subtropical mountain system | 100.7 | 2.9% | 0.0 | - | 10.4 | 11.2% |
| Subtropicals | 302.5 | 2.0% | 0.3 | 89.0% | 98.8 | 3.5% |
| Temperate oceanic forest | 36.7 | 4.7% | 0.0 | - | 13.9 | 7.6% |
| Temperate continental forest | 226.1 | 2.0% | 0.0 | - | 48.3 | 5.5% |
| Temperate steppe | 26.2 | 6.8% | 0.0 | - | 6.5 | 23.6% |
| Temperate desert | 12.8 | 14.3% | 0.0 | - | 0.4 | - |
| Temperate mountain system | 231.2 | 1.7% | 0.0 | - | 16.7 | 11.0% |
| Temperates | 533.0 | 1.3% | 0.0 | - | 85.9 | 4.4% |
| Boreal coniferous forest | 576.4 | 1.3% | 0.0 | - | 23.0 | 10.6% |
| Boreal tundra woodland | 166.1 | 2.8% | 0.0 | - | 0.1 | - |
| Boreal mountain system | 341.8 | 2.0% | 0.0 | - | 0.8 | 60.8% |
| Boreals | 1 084.4 | 1.0% | 0.0 | - | 23.8 | 10.5% |
| Polar | 13.8 | 29.1% | 0.0 | - | 0.0 | - |
| World | 3 699.0 | 0.5% | 11.3 | 14.2% | 258.1 | 2.6% |

Mangroves were estimated to cover 11.3 Mha, i.e. 0.3 percent of the world's forest area. Most of them were found in Asia (37 percent), followed by Africa (27 percent), with 97 percent of them located in tropical zones (see Table 4 and Table 5). Further analysis will be provided through a specific remote sensing survey on mangroves for the period 2000–2020, which FAO is currently undertaking.

Naturally regenerating forest and planted forest were further subdivided (see Table 6 and Table 7) into stocked forest, when trees are present *in situ*, and temporarily unstocked forest. Temporarily unstocked forests are areas that have been cleared and/or have young trees that have not yet reached, but which are expected to reach, the 5 m height forest threshold. Mangroves were excluded from this level of analysis due to the small sample size in mangrove areas and the fact that they were not the focus of this remote sensing survey.

The largest areas of temporarily unstocked forests were found in North America, followed by Europe, Asia, Oceania, Africa and South America.

Of the global forest area in 2018, 5.3 percent was temporarily unstocked in 2018. Of the naturally regenerating forest, 4.7 percent (176 Mha) was unstocked, while the unstocked percentage for planted forest was 13 (33 Mha). Most of the global unstocked forest area was found in North America (34.7 percent), followed by Europe (27.2 percent) (see Table 6). Boreal zones accounted for 43.5 percent of global unstocked forest area (see Table 7).

About 8 percent of both boreal and subtropical forests were unstocked in 2018. In temperate and tropical areas, the unstocked areas accounted for 6 percent and 3 percent.

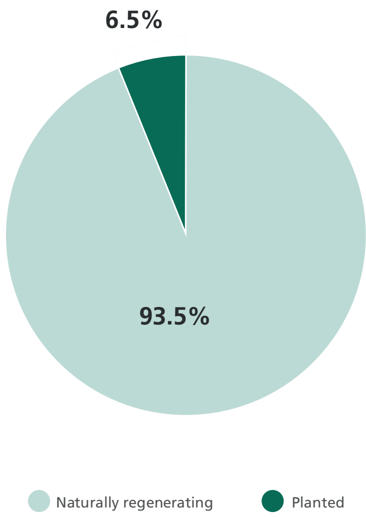
**Table 6. Area of forest (Mha) and +/-95% confidence interval (percent) by forest type and by FAO region and subregion in 2018**

| Regions and subregions (Mha) | Naturally regenerating forest stocked (excluding mangroves) | ± | Naturally regenerating forest temporarily unstocked (excluding mangroves) | ± | Planted forest stocked | ± | Planted forest temporarily unstocked | ± |
|---|---|---|---|---|---|---|---|---|
| North America | 637.9 | 1.3% | 68.5 | 4.9% | 25.5 | 6.6% | 4.0 | 12.9% |
| Central America | 22.5 | 6.2% | 0.4 | 48.0% | 0.2 | 65.6% | 0.0 | - |
| Caribbean | 7.3 | 11.7% | 0.3 | 66.2% | 0.5 | 48.8% | 0.1 | - |
| North and Central America | 667.6 | 1.2% | 69.2 | 4.9% | 26.3 | 6.5% | 4.2 | 13.0% |
| South America | 810.1 | 0.8% | 6.2 | 17.5% | 17.3 | 7.1% | 3.2 | 14.7% |
| Europe | 895.8 | 1.2% | 47.7 | 5.6% | 73.7 | 4.7% | 9.2 | 12.4% |
| North Africa | 53.1 | 4.4% | 2.1 | 33.2% | 1.0 | 33.2% | 0.2 | - |
| Western and Central Africa | 279.9 | 1.9% | 3.8 | 21.2% | 2.9 | 24.0% | 0.3 | 69.6% |
| Eastern and Southern Africa | 215.4 | 2.0% | 6.1 | 15.8% | 4.7 | 14.1% | 1.2 | 64.1% |
| Africa | 548.5 | 1.3% | 12.0 | 12.0% | 8.6 | 11.8% | 1.7 | 48.9% |
| Western and Central Asia | 29.3 | 7.2% | 1.4 | 56.2% | 2.5 | 32.5% | 0.8 | 73.7% |
| East Asia | 176.1 | 2.6% | 4.5 | 24.3% | 71.8 | 5.0% | 9.3 | 14.6% |
| South and Southeast Asia | 276.6 | 1.7% | 15.8 | 10.1% | 21.4 | 7.0% | 4.3 | 14.4% |
| Asia | 482.0 | 1.4% | 21.6 | 9.6% | 95.7 | 4.2% | 14.4 | 11.1% |
| Oceania | 119.3 | 2.8% | 19.0 | 12.8% | 3.1 | 18.2% | 0.7 | 18.3% |
| World | 3 523.3 | 0.5% | 175.7 | 3.2% | 224.7 | 2.6% | 33.4 | 6.8% |

**Table 7. Area of forest (Mha) and +/-95% confidence interval (percent) by forest type and by Global Ecological Zones and FAO climatic domains in 2018**

| GEZ (Mha) | Naturally regenerating forest stocked (excluding mangroves) | ± | Naturally regenerating forest temporarily unstocked (excluding mangroves) | ± | Planted forest stocked | ± | Planted forest temporarily unstocked | ± |
|---|---|---|---|---|---|---|---|---|
| Tropical rainforest | 941.5 | 0.8% | 11.2 | 12.5% | 19.7 | 7.5% | 4.5 | 13.1% |
| Tropical moist forest | 364.1 | 1.6% | 9.1 | 13.4% | 12.4 | 8.0% | 1.9 | 19.6% |
| Tropical dry forest | 244.4 | 1.6% | 9.5 | 13.3% | 3.5 | 15.9% | 0.5 | 40.7% |
| Tropical shrubland | 45.8 | 7.0% | 8.7 | 21.4% | 1.1 | 51.5% | 0.3 | - |
| Tropical desert | 0.2 | 8.0% | 0.0 | 46.1% | 0.0 | 47.7% | 0.4 | - |
| Tropical mountain system | 126.0 | 2.1% | 4.8 | 15.9% | 4.7 | 15.1% | 0.7 | 38.0% |
| Tropicals | 1 722.0 | 0.6% | 43.3 | 7.0% | 41.4 | 5.0% | 8.3 | 13.7% |
| Subtropical humid forest | 116.2 | 3.5% | 5.4 | 16.5% | 70.6 | 4.4% | 8.5 | 12.2% |
| Subtropical dry forest | 34.4 | 2.8% | 2.4 | 12.7% | 7.1 | 6.9% | 1.5 | 14.4% |
| Subtropical steppe | 30.1 | 7.2% | 5.9 | 23.8% | 0.4 | 58.6% | 0.3 | 93.9% |
| Subtropical desert | 6.1 | 21.0% | 1.2 | 48.7% | 0.0 | - | 0.0 | - |
| Subtropical mountain system | 97.5 | 3.0% | 3.2 | 22.1% | 7.9 | 13.1% | 2.5 | 22.1% |
| Subtropicals | 284.3 | 2.0% | 18.2 | 10.6% | 86.0 | 3.8% | 12.8 | 9.6% |
| Temperate oceanic forest | 35.9 | 4.8% | 0.8 | 30.0% | 12.7 | 8.2% | 1.2 | 23.7% |
| Temperate continental forest | 219.1 | 2.1% | 7.0 | 13.7% | 44.8 | 5.8% | 3.4 | 20.7% |
| Temperate steppe | 23.8 | 6.9% | 2.4 | 32.2% | 6.0 | 24.9% | 0.6 | 74.9% |
| Temperate desert | 11.4 | 14.5% | 1.3 | 60.1% | 0.4 | 87.5% | 0.0 | - |
| Temperate mountain system | 215.2 | 1.9% | 16.0 | 8.3% | 14.6 | 11.8% | 2.1 | 32.3% |
| Temperates | 505.5 | 1.3% | 27.5 | 7.2% | 78.6 | 4.6% | 7.3 | 16.4% |
| Boreal coniferous forest | 534.1 | 1.5% | 42.3 | 6.4% | 18.0 | 12.6% | 4.9 | 19.3% |
| Boreal tundra woodland | 143.6 | 3.3% | 22.5 | 9.4% | 0.1 | - | 0.0 | - |
| Boreal mountain system | 320.6 | 2.2% | 21.3 | 8.7% | 0.7 | 67.8% | 0.1 | - |
| Boreals | 998.3 | 1.2% | 86.0 | 4.5% | 18.8 | 12.4% | 5.0 | 19.0% |
| Polar | 13.1 | 30.5% | 0.7 | 43.5% | 0.0 | - | 0.0 | - |
| World | 3 523.3 | 0.5% | 175.7 | 3.2% | 224.7 | 2.6% | 33.4 | 6.8% |

**Figure 10. Proportion of naturally regenerating and planted forests in 2018**

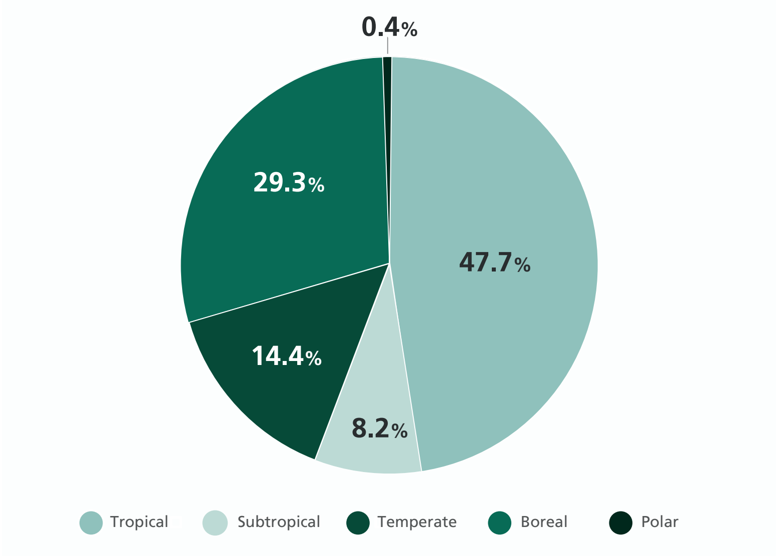



According to the Remote Sensing Survey results, naturally regenerating forests, including the area of mangroves, account for 93.5 percent (3 710 Mha) of total forest area (see Table 4 and Figure 10). Tropical and boreal are the climatic domains with the highest percentage of naturally regenerating forest: 48 and 29 percent respectively (see Figure 11).

Of the world's forest area, 6.5 percent was planted forest, corresponding to 258.1 Mha (see Table 4 and Figure 10). More than 40 percent of planted forest is located in Asia, and particularly in East Asia (81.1 Mha), where planted forest represents one-third of its total forest area. Oceania, Africa and South America are the regions with least planted forest, with only around 2 percent of forest established through planting of their total forest area (see Table 4).

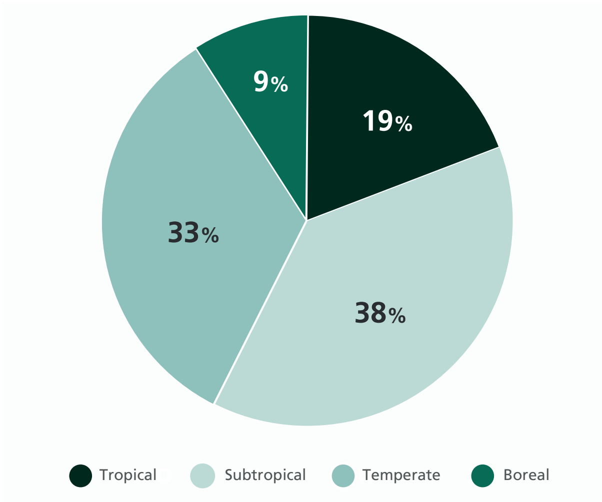
While the results presented here are well aligned with the findings of FRA 2020 at the global level, their comparison at the regional level reveals some clear differences. For example, according to the Remote Sensing Survey results, the share of planted forest area on total forest area in Asia is only 18 percent whereas the same figure based on FRA 2020 country reporting is 22.

**Figure 11. Proportion of naturally regenerating forest by FAO climatic domain in 2018**



Of the world's planted forest, 38 percent and 33 percent were in the subtropical and temperate climatic domains, respectively. Results show that 19 percent of forest in the tropical domain was planted, while planted forest represented a very small proportion of forest in the boreal domain, accounting for 9 percent of its total forest area (see Table 5 and Figure 12).

**Figure 12. Proportion of planted forest by FAO climatic domain in 2018**

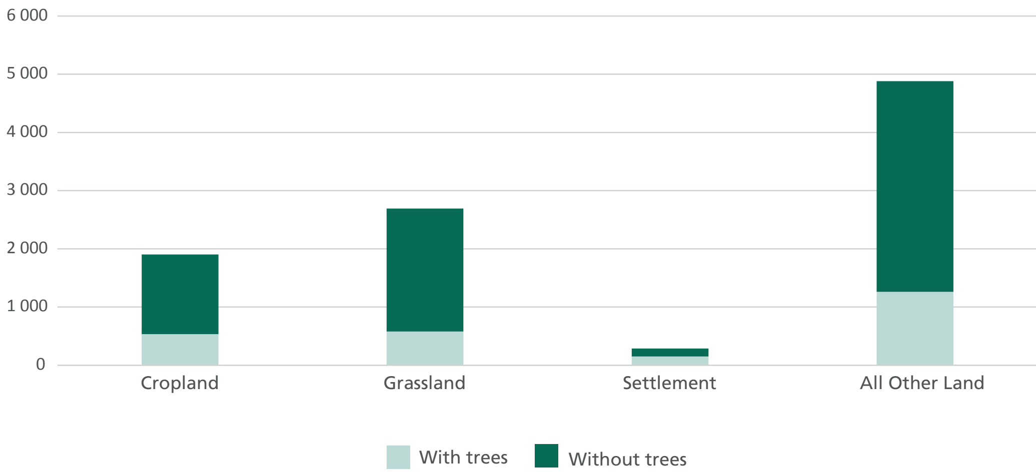



**other land with tree cover in 2018**

The FRA 2020 Remote Sensing Survey divided all the other land subclasses, except Bare soil, into land with trees and land without trees. other land with tree cover are those areas that have a land use different from forest, but meet the FAO forest definition (span an area of more than 0.5 ha, with a canopy cover of more than 10 percent of trees able to reach a height of 5 m). This gives an indication of the area with trees outside the forest (FAO defines trees outside forest as "trees on land not defined as forest and other wooded land") (FAO, 2020a).

Of all other land without a predominant forest land use, 26 percent has tree cover of above 10 percent (1 260.8 Mha). Furthermore, 28 percent (533.4 Mha) of croplands, 21 percent of grasslands (577.2 Mha) and more than half (52 percent or 150.2 Mha) of built-up areas have a tree cover reaching those thresholds (see Figure 13, Table 8 and Table 9).

**Figure 13. other land with and without tree cover above 10 % by other land categories (Mha) in 2018**




Source: FAO. 2022.

**Table 8 . Area of other land with and without tree cover above 10 % (Mha) by FAO region and subregion in 2018**

| Regions and subregions (Mha) | Cropland | | Grassland | | Settlement | | Total | |
|---|---|---|---|---|---|---|---|---|
| | With tree (including Oil palm) | Without tree | With tree | Without tree | With tree | Without tree | With tree (including oil palm) | Without tree |
| North America | 28.6 | 204.3 | 81.4 | 300.1 | 43.2 | 20.6 | 153.1 | 525.0 |
| Central America | 5.2 | 4.5 | 7.8 | 5.4 | 0.7 | 0.4 | 13.7 | 10.3 |
| Caribbean | 1.3 | 2.9 | 2.4 | 2.2 | 0.7 | 0.5 | 4.4 | 5.6 |
| North and Central America | 35.1 | 211.7 | 91.6 | 307.7 | 44.7 | 21.5 | 171.3 | 540.9 |
| South America | 22.5 | 132.7 | 133.2 | 302.4 | 8.5 | 11.1 | 164.2 | 446.2 |
| Europe | 46.0 | 261.9 | 92.1 | 411.7 | 32.6 | 30.5 | 170.7 | 704.1 |
| North Africa | 27.1 | 46.7 | 28.3 | 79.9 | 1.3 | 4.3 | 56.7 | 130.8 |
| Western and Central Africa | 124.3 | 97.3 | 65.8 | 72.5 | 8.6 | 6.0 | 198.7 | 175.8 |
| Eastern and Southern Africa | 66.4 | 99.4 | 105.6 | 176.4 | 8.3 | 6.5 | 180.3 | 282.3 |
| Africa | 217.7 | 243.4 | 199.7 | 328.7 | 18.1 | 16.8 | 435.6 | 588.9 |
| Western and Central Asia | 13.6 | 128.0 | 10.3 | 269.6 | 5.0 | 21.3 | 28.9 | 418.9 |
| East Asia | 62.8 | 114.9 | 10.9 | 318.1 | 20.4 | 20.3 | 94.1 | 453.3 |
| South and Southeast Asia | 129.1 | 246.0 | 10.0 | 13.0 | 19.6 | 13.3 | 158.7 | 272.3 |
| Asia | 205.4 | 488.9 | 31.2 | 600.7 | 45.0 | 54.9 | 281.7 | 1 144.5 |
| Oceania | 6.6 | 30.1 | 29.3 | 164.6 | 1.3 | 1.3 | 37.3 | 196.1 |
| World | 533.4 | 1 368.7 | 577.2 | 2 115.8 | 150.2 | 136.2 | 1 260.8 | 3 620.7 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

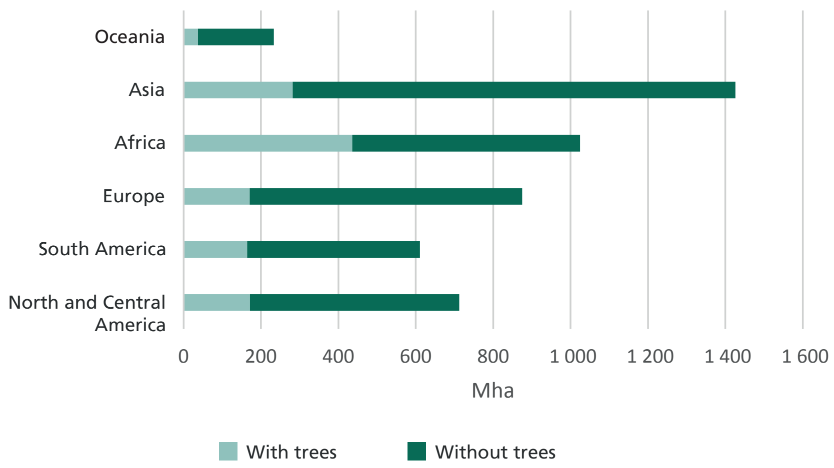
**Table 9. Area of other land with and without tree cover above 10 % (Mha) by Global Ecological Zones and FAO climatic domains in 2018**

| GEZ (Mha) | Cropland | | Grassland | | Settlement | | Total | |
|---|---|---|---|---|---|---|---|---|
| | With tree (including Oil Palm) | Without tree | With tree | Without tree | With tree | Without tree | With tree | Without tree |
| Tropical rainforest | 122.4 | 76.9 | 64.3 | 103.0 | 13.0 | 7.8 | 199.7 | 187.7 |
| Tropical moist forest | 88.6 | 139.2 | 107.4 | 166.6 | 13.2 | 7.3 | 209.2 | 313.1 |
| Tropical dry forest | 62.0 | 119.0 | 63.4 | 76.9 | 10.2 | 6.7 | 135.7 | 202.6 |
| Tropical shrubland | 57.1 | 131.9 | 77.3 | 125.5 | 5.6 | 6.7 | 140.0 | 264.1 |
| Tropical desert | 7.2 | 41.3 | 18.4 | 119.4 | 1.9 | 13.3 | 27.5 | 174.0 |
| Tropical mountain system | 35.7 | 46.3 | 22.4 | 54.7 | 3.8 | 3.6 | 61.9 | 104.6 |
| Tropicals | 373.0 | 554.6 | 353.3 | 646.0 | 47.8 | 45.5 | 774.1 | 1 246.1 |
| Subtropical humid forest | 32.7 | 91.7 | 19.7 | 48.9 | 18.8 | 13.8 | 71.2 | 154.4 |
| Subtropical dry forest | 17.2 | 44.1 | 6.0 | 12.7 | 3.1 | 5.0 | 26.3 | 61.8 |
| Subtropical steppe | 8.8 | 71.0 | 24.8 | 93.8 | 4.3 | 6.9 | 37.9 | 171.7 |

| GEZ (Mha) | Cropland | | Grassland | | Settlement | | Total | |
|---|---|---|---|---|---|---|---|---|
| | With tree (including Oil Palm) | Without tree | With tree | Without tree | With tree | Without tree | With tree | Without tree |
| Subtropical desert | 2.7 | 11.7 | 6.4 | 38.7 | 1.4 | 5.8 | 10.5 | 56.2 |
| Subtropical mountain system | 15.2 | 52.5 | 12.2 | 96.8 | 7.3 | 6.3 | 34.7 | 155.6 |
| Subtropicals | 76.6 | 271.0 | 69.1 | 290.8 | 34.9 | 37.8 | 180.6 | 599.7 |
| Temperate oceanic forest | 5.6 | 58.8 | 4.8 | 28.6 | 6.3 | 8.8 | 16.7 | 96.3 |
| Temperate continental forest | 39.1 | 187.7 | 30.0 | 48.6 | 35.9 | 22.0 | 105.0 | 258.3 |
| Temperate steppe | 15.2 | 212.0 | 21.4 | 192.2 | 8.8 | 6.2 | 45.4 | 410.4 |
| Temperate desert | 5.5 | 34.1 | 3.5 | 255.9 | 2.7 | 4.4 | 11.6 | 294.4 |
| Temperate mountain system | 14.2 | 30.1 | 17.6 | 197.4 | 8.6 | 7.5 | 40.3 | 235.0 |
| Temperates | 79.6 | 522.7 | 77.3 | 722.9 | 62.2 | 48.9 | 219.1 | 1 294.4 |
| Boreal coniferous forest | 3.5 | 17.6 | 24.4 | 56.8 | 4.6 | 2.5 | 32.5 | 76.9 |
| Boreal tundra woodland | 0.1 | 0.1 | 23.7 | 72.6 | 0.0 | 0.2 | 23.8 | 72.9 |
| Boreal mountain system | 0.6 | 2.6 | 25.0 | 87.7 | 0.8 | 1.2 | 26.4 | 91.5 |
| Boreals | 4.2 | 20.4 | 73.1 | 217.1 | 5.4 | 3.9 | 82.7 | 241.4 |
| Polar | 0.0 | 0.0 | 4.4 | 239.0 | 0.0 | 0.2 | 4.4 | 239.2 |
| World | 533.4 | 1 368.7 | 577.2 | 2 115.8 | 150.2 | 136.2 | 1 260.8 | 3 620.7 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

**Figure 14. other land with and without tree cover above 10 % (Mha) by FAO region in 2018**




While other land without trees represents the majority of the other land in all regions, the area with trees was particularly high in Africa, where it accounted for 42.5 percent of the other land in the region (435.6 Mha). In North and Central America, as well as in South America and Oceania, trees outside forest were mainly in grasslands. However, in Asia, trees outside forest were mostly found in croplands. At the subregional level, the proportion of other land with trees was highest in Central America (57 percent), followed closely by Western and Central Africa (53 percent) (see Table 8).

North America had the highest built-up area with trees (43.2 Mha), followed by

Europe (32.6 Mha) (see Table 8 and Figure 14).

The estimates reported here are significantly higher than those of FRA 2020. This can be explained by one simple factor – lack of national data. The FRA 2020 reporting coverage for other land with tree cover was particularly low for Africa, the region for which these areas were now found to be most pronounced. In Africa, the highest coverage was observed for the FRA 2020 subcategory Agroforestry, with 14 out of 58 countries – representing 15 percent of the region's total forest area – reporting on this variable.

While the coverage of the reporting was higher in other regions, the monitoring of other land with tree cover, and hence availability of those data, clearly remains a challenge in most regions.

### Stocked land

The total stocked land area meeting biophysical parts of FAO forest definition, but also considering other land with tree cover, encompasses 39 percent or 5 020 Mha of the global land area (see Table 10 and Table 11).

These data are relevant when comparing land cover maps from other global spatial datasets, as explored in Chapter 5. Discussion and conclusions.

**Table 10. Area of tree cover above 10 % (Mha) by FAO region and subregion in 2018**

| Tree cover Regions and subregions (Mha) | Forest naturally regenerating stocked | Forest planted stocked | Mangroves | Cropland with trees | Grassland with trees | Oil palm | Settlement with trees |
|---|---|---|---|---|---|---|---|
| North America | 637.9 | 25.5 | 0.9 | 28.5 | 81.4 | 0.1 | 43.2 |
| Central America | 22.5 | 0.2 | 0.4 | 4.4 | 7.8 | 0.8 | 0.7 |
| Caribbean | 7.3 | 0.5 | 0.7 | 1.3 | 2.4 | 0.0 | 0.7 |
| North and Central America | 667.6 | 26.3 | 1.9 | 34.2 | 91.6 | 0.9 | 44.7 |
| South America | 810.1 | 17.3 | 1.2 | 21.3 | 133.2 | 1.2 | 8.5 |
| Europe | 895.8 | 73.7 | 0.0 | 46.0 | 92.1 | 0.0 | 32.6 |
| North Africa | 53.1 | 1.0 | 0.0 | 27.0 | 28.3 | 0.0 | 1.3 |
| Western and Central Africa | 279.9 | 2.9 | 2.4 | 117.9 | 65.8 | 6.4 | 8.6 |
| Eastern and Southern Africa | 215.4 | 4.7 | 0.7 | 66.4 | 105.6 | 0.0 | 8.3 |
| Africa | 548.5 | 8.6 | 3.1 | 211.3 | 199.7 | 6.5 | 18.1 |
| Western and Central Asia | 29.3 | 2.5 | 0.0 | 13.6 | 10.3 | 0.0 | 5.0 |
| East Asia | 176.1 | 71.8 | 0.0 | 62.8 | 10.9 | 0.0 | 20.4 |
| South and Southeast Asia | 276.6 | 21.4 | 4.2 | 100.7 | 10.0 | 28.4 | 19.6 |
| Asia | 482.0 | 95.7 | 4.2 | 177.0 | 31.2 | 28.4 | 45.0 |
| Oceania | 119.3 | 3.1 | 0.9 | 6.1 | 29.3 | 0.5 | 1.3 |
| World | 3 523.3 | 224.7 | 11.3 | 495.9 | 577.2 | 37.5 | 150.2 |
| % of total land area | 27.4% | 1.7% | 0.1% | 3.9% | 4.5% | 0.3% | 1.2% |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

**Table 11. Area of tree cover above 10 % (Mha) by Global Ecological Zones and FAO climatic domains in 2018**

| Tree cover GEZ and FAO Climatic domains (Mha) | Forest naturally regenerating stocked | Forest planted stocked | Mangroves | Cropland with trees | Grassland with trees | Oil palm | Settlement with trees |
|---|---|---|---|---|---|---|---|
| Tropical rainforest | 941.5 | 19.7 | 6.8 | 86.8 | 64.3 | 35.6 | 13.0 |
| Tropical moist forest | 364.1 | 12.4 | 2.9 | 87.5 | 107.4 | 1.0 | 13.2 |
| Tropical dry forest | 244.4 | 3.5 | 1.0 | 61.5 | 63.4 | 0.6 | 10.2 |
| Tropical shrubland | 45.8 | 1.1 | 0.2 | 57.1 | 77.3 | 0.0 | 5.6 |
| Tropical desert | 0.2 | 0.0 | 0.0 | 7.2 | 18.4 | 0.0 | 1.9 |
| Tropical mountain system | 126.0 | 4.7 | 0.0 | 35.5 | 22.4 | 0.2 | 3.8 |
| Tropicals | 1 722.0 | 41.4 | 11.0 | 335.5 | 353.3 | 37.5 | 47.8 |
| Subtropical humid forest | 116.2 | 70.6 | 0.3 | 32.7 | 19.7 | 0.0 | 18.8 |
| Subtropical dry forest | 34.4 | 7.1 | 0.0 | 17.2 | 6.0 | 0.0 | 3.1 |
| Subtropical steppe | 30.1 | 0.4 | 0.0 | 8.8 | 24.8 | 0.0 | 4.3 |
| Subtropical desert | 6.1 | 0.0 | 0.0 | 2.7 | 6.4 | 0.0 | 1.4 |
| Subtropical mountain system | 97.5 | 7.9 | 0.0 | 15.2 | 12.2 | 0.0 | 7.3 |
| Subtropicals | 284.3 | 86.0 | 0.3 | 76.6 | 69.1 | 0.0 | 34.9 |
| Temperate oceanic forest | 35.9 | 12.7 | 0.0 | 5.6 | 4.8 | 0.0 | 6.3 |
| Temperate continental forest | 219.1 | 44.8 | 0.0 | 39.1 | 30.0 | 0.0 | 35.9 |
| Temperate steppe | 23.8 | 6.0 | 0.0 | 15.2 | 21.4 | 0.0 | 8.8 |
| Temperate desert | 11.4 | 0.4 | 0.0 | 5.5 | 3.5 | 0.0 | 2.7 |
| Temperate mountain system | 215.2 | 14.6 | 0.0 | 14.2 | 17.6 | 0.0 | 8.6 |
| Temperates | 505.5 | 78.6 | 0.0 | 79.6 | 77.3 | 0.0 | 62.2 |
| Boreal coniferous forest | 534.1 | 18.0 | 0.0 | 3.5 | 24.4 | 0.0 | 4.6 |
| Boreal tundra woodland | 143.6 | 0.1 | 0.0 | 0.1 | 23.7 | 0.0 | 0.0 |
| Boreal mountain system | 320.6 | 0.7 | 0.0 | 0.6 | 25.0 | 0.0 | 0.8 |
| Boreals | 998.3 | 18.8 | 0.0 | 4.2 | 73.1 | 0.0 | 5.4 |
| Polar | 13.1 | 0.0 | 0.0 | 0.0 | 4.4 | 0.0 | 0.0 |
| World | 3 523.3 | 224.7 | 11.3 | 495.9 | 577.2 | 37.5 | 150.2 |
| % of total land area | 27% | 2% | 0% | 4% | 4% | 0% | 1% |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

## 4.2. FOREST AREA TRENDS IN 2000–2018

This section presents the Remote Sensing Survey results for trends in forest area losses and gains worldwide, at regional and GEZ levels for the periods 2000–2010 and 2010–2018.

Deforestation is defined as "the conversion of Forest to other land use independently whether human-induced or not" (FAO, 2020a).

Forest area expansion is defined as "the expansion of forest on land that, until then, was under a different land use, implies a transformation of land use from non-forest to forest" (FAO, 2020a). Forest area expansion can be natural or result from afforestation.

Forest area net change is the difference between forest area expansion and deforestation.

**Forest area trends at the global level in 2000–2018**

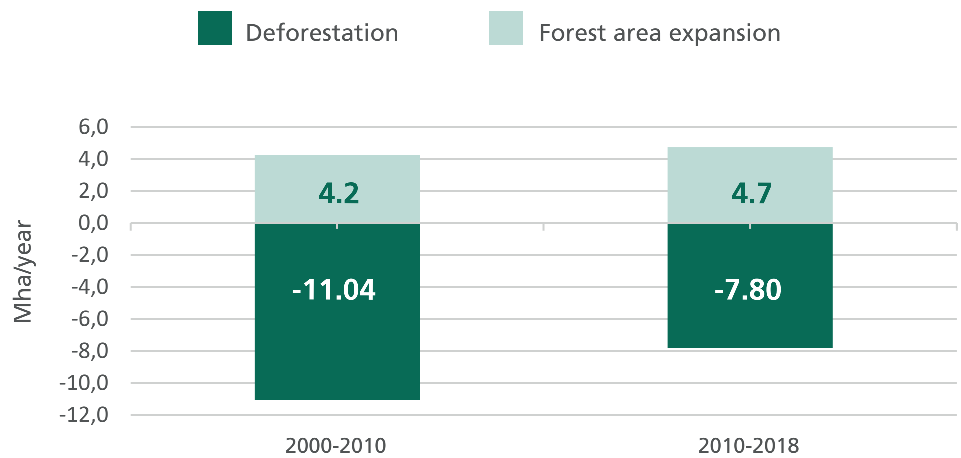
According to the FRA 2020 Remote Sensing Survey, between 2000 and 2018, 173

Mha of forest were deforested worldwide. At the same time, forest area expanded by 80 Mha. As such, this gives a net forest area loss of 93 Mha for the whole period.

Annual deforestation decreased by around 29 percent, from 11 Mha per year during the period 2000–2010 to 7.8 Mha per year during the period 2010–2018. Globally, annual forest area gain showed a slight increase, from 4.2 Mha per year in the period 2000–2010 to 4.7 Mha per year in the period 2010–2018 (see Figure 15).

The annual forest area net loss decreased from 6.8 Mha in the period 2000–2010, by more than half to 3.1 Mha in the period 2010–2018.

**Figure 15. Annual deforestation and forest area expansion (Mha) for the periods 2000–2010 and 2010–2018**




BOX 3

**Global forest area changes**

**Deforestation 2000–2018 (Mha): 172.8**

Annual deforestation (Mha/year) and +/-95% confidence interval (percent)

2000–2010 : -11.0 +/- 1.9 %

2010–2018 : -7.8 +/- 2.4 %

**Forest area gain 2000–2018 (Mha): 80**

Annual forest area gain (Mha/year) and +/-95% confidence interval (percent):

2000–2010 :4.2 +/- 4.3 %

2010–2018 : 4.7 +/- 4.2 %

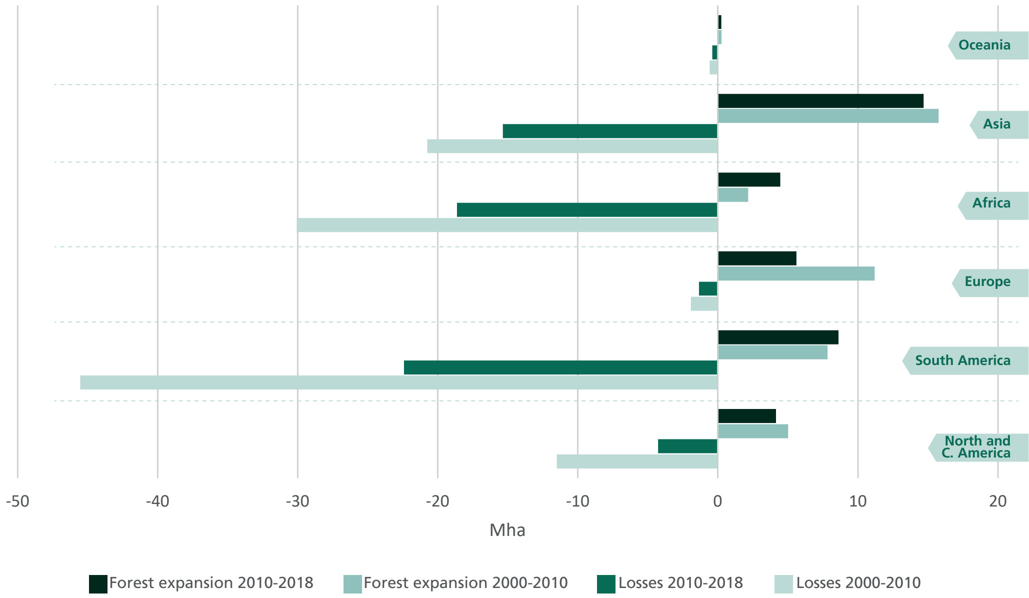
**Forest area change 2000–2018 (Mha): - 92.7**

Annual forest area net change (Mha/year) and +/-95% confidence interval (percent):

2000–2010 :-6.8 +/- 6.2 %

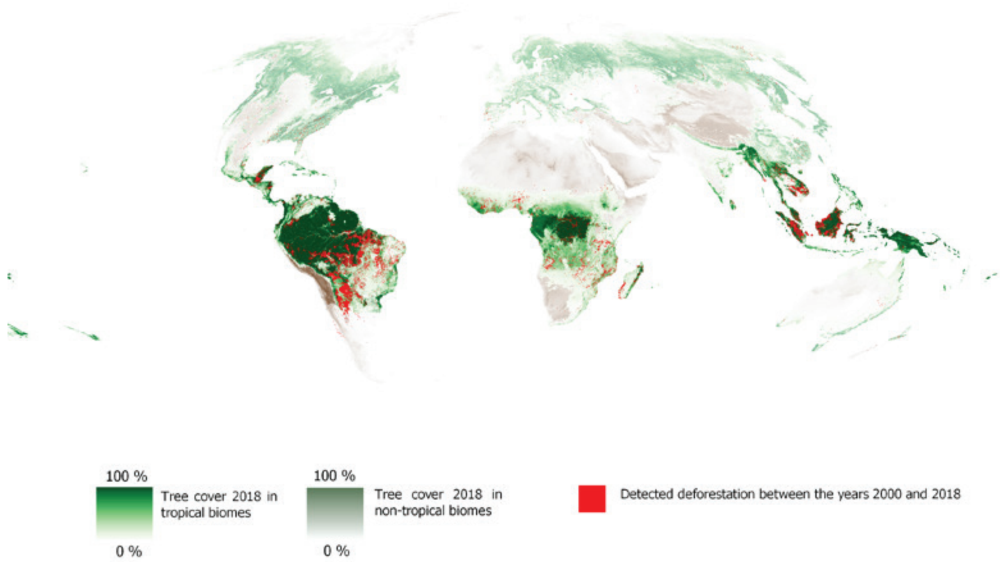
2010–2018 : -3.1 +/- 6.6%

**Figure 16. Deforestation and forest area expansion (Mha) by FAO region for the periods 2000–2010 and 2010–2018**




### Where has deforestation occurred in 2000–2018?

**Figure 17. Distribution of Remote Sensing Survey samples deforested between 2000 and 2018 in tropical and non-tropical biomes**




*Source*: Background tree cover map (Hansen *et al.*, 2013); division into tropical and non-tropical biomes (FAO, 2010); deforested samples (FAO, 2022); FAO. 2022. Projection: Goode-Homolosine.

The vast majority of deforestation between the years 2000 and 2018 took place in tropical biomes (see Figure 17). At the regional level, annual deforestation area in both the 2000–2010 and 2010–2018 periods was highest in South America, followed by Africa and Asia. South America deforested 68 Mha from 2000 to 2018, Africa deforested 49 Mha, and in Asia deforestation amounted to 36 Mha (see Table 12).

The survey shows that deforestation has slowed considerably between the periods in all regions and in most subregions (see Table 12). Annual deforestation declined by 38 percent in South America (from 4.55 Mha per year to 2.8 Mha per year), by 23 percent in Africa (from 3.01 Mha per year to 2.33 Mha per year), and by 8 percent in Asia (from 2.08 Mha per year to 1.92 Mha per year). In Asia, the highest deforestation rates were found in South and Southeast Asia and in Africa, most of the deforestations were recorded for Eastern and Southern Africa.

At the subregional level, the slowdown in deforestation was particularly notable in Central America (declining by 62 percent from 0.6 Mha per year to 0.23 Mha). Conversely, the data show a 50 percent increase in the rate of annual deforestation in East Asia, from 0.18 Mha per year to 0.26 Mha per year (see Table 12).

**Table 12. Annual rate of deforestation (Mha/year) and +/-95% confidence interval (percent) by FAO region and subregion for the period 2000-2010 and 2010-2018**

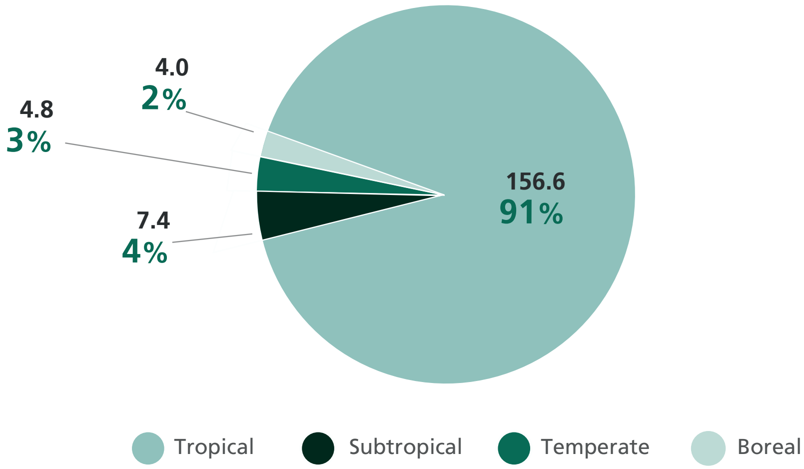
| Regions and subregions (Mha/year) | Deforestation 2000-2010 | ± | Deforestation 2010-2018 | ± |
|---|---|---|---|---|
| North America | 0.53 | 8.8% | 0.29 | 14.2% |
| Central America | 0.60 | 9.9% | 0.23 | 24.7% |
| Caribbean | 0.02 | 54.9% | 0.01 | 3.5% |
| North and Central America | 1.15 | 6.6% | 0.53 | 9.7% |
| South America | 4.55 | 2.4% | 2.80 | 3.5% |
| Europe | 0.19 | 19.6% | 0.17 | 21.5% |
| North Africa | 0.03 | 61.5% | 0.07 | 43.5% |
| Western and Central Africa | 1.38 | 6.7% | 1.04 | 7.6% |
| Eastern and Southern Africa | 1.59 | 5.5% | 1.21 | 6.1% |
| Africa | 3.01 | 4.3% | 2.33 | 4.9% |
| Western and Central Asia | 0.02 | - | 0.03 | - |
| East Asia | 0.18 | 19.7% | 0.26 | 13.6% |
| South and Southeast Asia | 1.88 | 3.9% | 1.62 | 4.5% |
| Asia | 2.08 | 4.2% | 1.92 | 4.7% |
| Oceania | 0.06 | 48.8% | 0.05 | 24.7% |
| World | 11.04 | 1.9% | 7.80 | 2.4% |

**Table 13. Annual rate of deforestation (Mha/year) and +/-95% confidence interval by Global Ecological Zones and FAO climatic domains for the periods 2000–2010 and 2010–2018**

| GEZ and FAO climatic domains (Mha/year) | Deforestation 2000–2010 | ± | Deforestation 2010–2018 | ± |
|---|---|---|---|---|
| Tropical rainforest | 4.5 | 2.6% | 3.0 | 3.5% |
| Tropical moist forest | 3.0 | 3.8% | 2.0 | 4.9% |
| Tropical dry forest | 2.1 | 4.2% | 1.5 | 4.6% |
| Tropical shrubland | 0.1 | 17.7% | 0.2 | 21.0% |
| Tropical desert | 0.0 | - | 0.0 | 42.7% |
| Tropical mountain system | 0.3 | 10.5% | 0.3 | 13.4% |
| Tropicals | 10.1 | 1.9% | 7.0 | 2.4% |
| Subtropical humid forest | 0.3 | 16.5% | 0.2 | 13.2% |
| Subtropical dry forest | 0.0 | 26.2% | 0.0 | 28.3% |
| Subtropical steppe | 0.0 | 50.2% | 0.0 | 91.9% |
| Subtropical desert | 0.0 | - | 0.0 | 80.5% |
| Subtropical mountain system | 0.1 | 39.7% | 0.0 | 40.5% |
| Subtropicals | 0.5 | 14.4% | 0.3 | 13.4% |

| GEZ and FAO climatic domains (Mha/year) | Deforestation 2000–2010 | ± | Deforestation 2010–2018 | ± |
|---|---|---|---|---|
| Temperate oceanic forest | 0.0 | 37.9% | 0.0 | 48.5% |
| Temperate continental forest | 0.1 | 14.5% | 0.1 | 17.8% |
| Temperate steppe | 0.1 | 78.0% | 0.0 | - |
| Temperate desert | 0.0 | 43.0% | 0.0 | 64.8% |
| Temperate mountain system | 0.1 | 23.3% | 0.1 | 33.4% |
| Temperates | 0.3 | 17.9% | 0.2 | 20.7% |
| Boreal coniferous forest | 0.1 | 26.9% | 0.1 | 24.4% |
| Boreal tundra woodland | 0.1 | 23.6% | 0.1 | 35.1% |
| Boreal mountain system | 0.1 | 20.0% | 0.0 | 36.0% |
| Boreals | 0.2 | 15.3% | 0.2 | 17.9% |
| Polar | 0.0 | 85.1% | 0.0 | 0.0% |
| World | 11.0 | 1.9% | 7.8 | 2.4% |

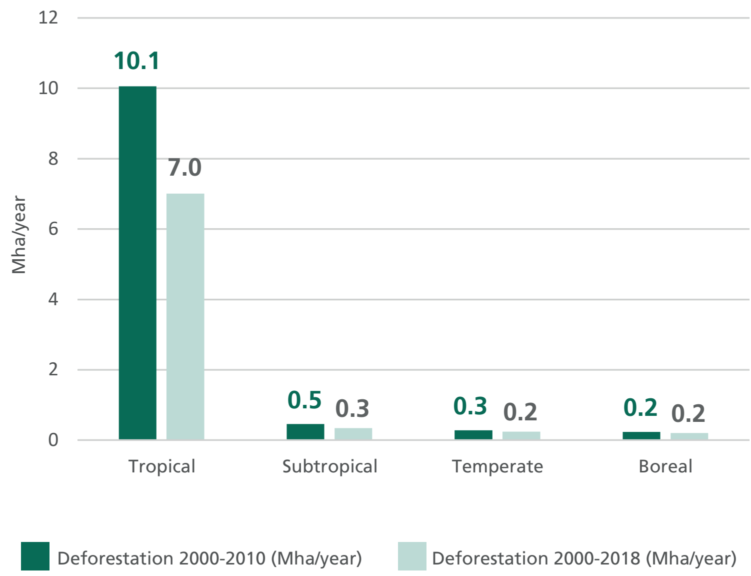
**Figure 18. Deforestation area (Mha) and as percentage of global deforestation area, by FAO climatic domain in 2000-2018**




Tropical forests registered the highest rate of deforestation from 2000 to 2018, accounting for 157 Mha of forest losses in the period, which represents more than 90 percent of global deforestation. Most of the tropical forest losses were recorded for tropical rainforests, where the losses accounted for 40 percent of the total forest losses in 2000–2018 (69 Mha deforested). The Global Ecological Zones with the second and third highest deforestation rates were tropical moist forest and tropical dry forest, which represented 27 percent (46 Mha) and 19 percent (33 Mha) of global deforestation from 2000 to 2018, respectively (see Table 13 and Figure 18).

The annual deforestation rate decreased substantially from 2000–2010 to 2010–2018 in the tropical and subtropical domains. Specifically, the rate declined by one-third in the tropical domain, from 10.1 Mha per year to 7.0 Mha per year, and by 25 percent in the subtropical domain, from 0.46 Mha per year to 0.35 Mha per year (see Figure 19).

**Figure 19. Annual rate of deforestation (Mha/year) by FAO climatic domain in 2000–2010 and 2010–2018**




If we consider the ecoregions, which combine FRA subregions and GEZ, the tropical rainforest of South America, as well as the tropical rainforests of South and Southeast Asia, were the ecoregions where the rate of deforestation was highest in 2000–2018. On average, 1.6 Mha of forest in the tropical rainforest ecoregion of South America and 1.2 Mha of forest in the tropical rainforest ecoregion of South and Southeast Asia were lost each year (see Table 14).

Nevertheless, the annual deforestation rates have quite significantly decreased in all these ecoregions in the past decade (2010–2018), compared with the previous one (2000–2010). In particular, the annual losses in the tropical rainforest of South America declined by 57 percent between both periods (see Table 14).

**Table 14. Top 10 ecoregions sorted by annual deforestation rate (000 ha/year) in the period 2000–2018, related +/-95% confidence intervals, the proportion of 2000 forest area deforested and the reduction of annual deforestation rate (%) between the periods 2000-2010 and 2010-2018.**

| Ecoregion | Annual deforestation 2000-2018 (000/ year) | ± | Deforestation (%) 2000-2018 | Percentual decrease in annual deforestation rate between 2000 - 2010 and 2010 - 2018 |
|---|---|---|---|---|
| South America Tropical rainforest | 1 593.7 | 11% | 5.2% | 57% |
| South and Southeast Asia Tropical rainforest | 1 199.8 | 15% | 11.1% | 38% |
| South America Tropical moist forest | 1 070.0 | 17% | 12.8% | 51% |
| South America Tropical dry forest | 908.1 | 17% | 17.7% | 40% |

| Ecoregion | Annual deforestation 2000-2018 (000/ year) | ± | Deforestation (%) 2000-2018 | Percentual decrease in annual deforestation rate between 2000 - 2010 and 2010 - 2018 |
|---|---|---|---|---|
| Western and Central Africa Tropical rainforest | 717.4 | 26% | 5.7% | 33% |
| Eastern and Southern Africa Tropical dry forest | 609.1 | 25% | 10.9% | 43% |
| Eastern and Southern Africa Tropical moist forest | 580.5 | 28% | 9.8% | 33% |
| Western and Central Africa Tropical moist forest | 429.4 | 40% | 12.7% | 49% |
| South and Southeast Asia Tropical moist forest | 281.1 | 37% | 9.0% | 14% |
| Central America Tropical rainforest | 225.4 | 49% | 25.2% | 57% |

An analysis of the proportion of forest area deforested since 2000 by ecoregion reveals which ecosystems are particularly threatened and disappearing quickly. Specifically, the tropical ecoregions of Central America indicate the highest proportion of deforestation between 2000 and 2018. Indeed, in Central America, 30 percent of forest in the tropical moist ecoregion, and 25 percent of tropical dry forest, rainforest and shrubland ecoregions were lost in 2000–2018. While this clearly indicates that forest ecosystems in Central America are threatened by land-use conversion, the figures have to be interpreted with care due to a low number of samples and resulting high sampling errors of the estimates. Likewise, the tropical dry forest ecoregion of South America registered a forest loss of 18 percent. This rapid loss of such rich ecosystems has unforeseeable impacts on biodiversity and ecosystem services (see Table 15 and Figure 20).

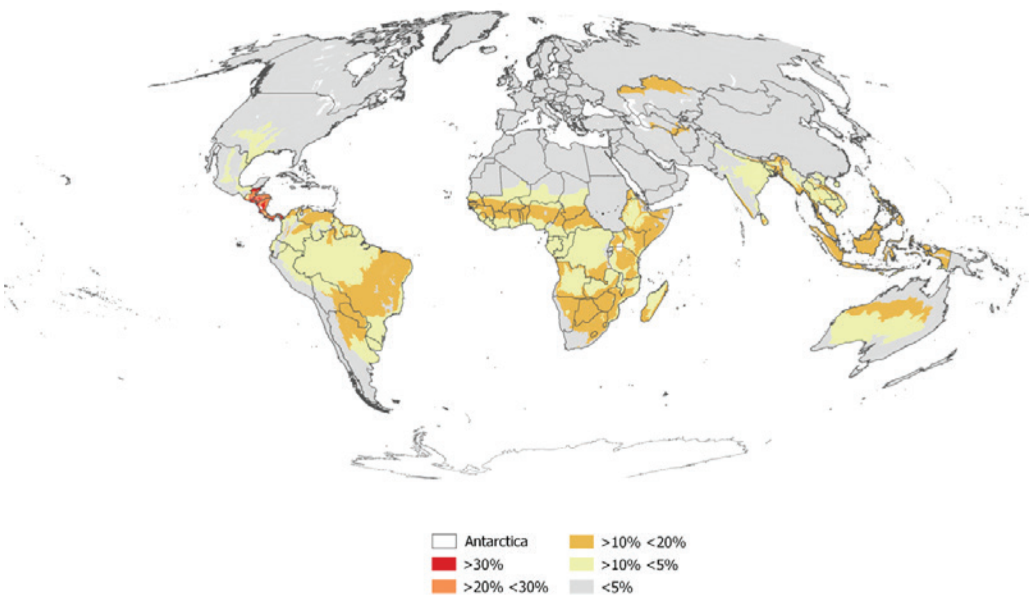
**Table 15. Top 10 ecoregions with highest proportion of deforestation (%) relative to the year 2000, between 2000 and 2018 and +/-95% confidence interval**

| Ecoregion | % Forest loss (since 2000) | Total loss (000 ha/ year) | ± |
|---|---|---|---|
| Central America Tropical moist forest | 30.3% | 171.89 | 54% |
| Central America Tropical dry forest | 25.4% | 29.59 | 148% |
| Central America Tropical rainforest | 25.2% | 225.43 | 49% |
| Central America Tropical shrubland | 25.0% | 0.96 | 198% |
| South America Tropical dry forest | 17.8% | 908.08 | 17% |

| Ecoregion | % Forest loss (since 2000) | Total loss (000 ha/ year) | ± |
|---|---|---|---|
| Eastern and Southern Africa Subtropical mountain system | 14.3% | 18.00 | 364% |
| South America Tropical moist forest | 13.8% | 1 069.99 | 17% |
| Western and Central Africa Tropical moist forest | 12.7% | 429.38 | 40% |
| Caribbean Tropical dry forest | 12.7% | 1.97 | 692% |
| Eastern and Southern Africa Tropical shrubland | 12.4% | 93.02 | 34% |

*Source*: FAO. 2022

**Figure 20. Proportion of forest loss (%) between 2000 and 2018 by ecoregion**




Note: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
*Source*: UN. 2020. MapoftheWorld [online]. [Cited 1 January 2021].un.org/geospatial/file/3420/download?token=bZe9T8I91b), modified by the authors.

Only 25 of the 125 ecoregions registered an increase in deforestation between 2000–2010 and 2010–2018. Together, those 25 ecoregions represent just 3 percent of global deforestation for the whole period 2000–2018.

## Where has forest expanded in 2000–2018?

**Table 16. Annual forest area expansion (Mha/year) and +/-95% confidence interval by FAO region and subregion for the period 2000–2010 and 2010–2018**

| Regions and subregions (Mha/year) | Forest area expansion 2000-2010 | ± | Forest area expansion 2010-2018 | ± |
|---|---|---|---|---|
| North America | 0.47 | 10.73% | 0.42 | 12.1% |
| Central America | 0.01 | 47.8% | 0.05 | - |
| Caribbean | 0.02 | 72.0% | 0.05 | 8.0% |
| North and Central America | 0.50 | 10.46% | 0.52 | 9.7% |
| South America | 0.78 | 7.8% | 1.08 | 8% |
| Europe | 1.12 | 10.5% | 0.70 | 13.4% |
| North Africa | 0.02 | 50.2% | 0.08 | 38.9% |
| Western and Central Africa | 0.10 | 31.9% | 0.22 | 21.0% |
| Eastern and Southern Africa | 0.10 | 31.0% | 0.25 | 16.7% |
| Africa | 0.22 | 20.7% | 0.56 | 12.7% |
| Western and Central Asia | 0.03 | 72.7% | 0.02 | 82.8% |
| East Asia | 1.23 | 7.2% | 1.41 | 7.5% |
| South and Southeast Asia | 0.32 | 15.6% | 0.41 | 11.9% |
| Asia | 1.58 | 6.5% | 1.84 | 6.4% |
| Oceania | 0.03 | 70.1% | 0.03 | 0.0% |
| World | 4.23 | 4.3% | 4.72 | 4.2% |

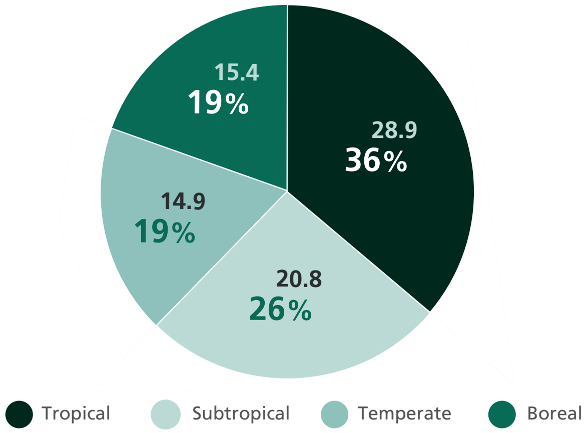
At the regional level, forest area expansion was highest in Asia (30.4 Mha), followed by Europe (16.8 Mha) and South America (16.5 Mha) during the period 2000–2018, while Oceania recorded the least expansion of forest area (0.5 Mha) (see Table 16). Trends revealing increases – with annual forest area expansion greater in 2010–2018 compared with 2000–2010 – were observed to be quite significant in Africa, where the forest area expansion increased from 0.2 Mha to 0.6 Mha per year. The same was true in South America (+37 percent), from 0.78 Mha pre year in 2000–2010 to 1.08 Mha per year in 2000–2018, and in Asia (+17 percent), from 1.58 Mha per year to 1.84 Mha per year. Europe showed a decreasing trend (-37 percent), from 1.12 Mha per year in 2000–2010 to 0.7 Mha per year in 2010–2018 (see Table 16).

East Asia was the subregion with the highest forest area expansion, with 23.5 Mha expanded between 2000 and 2018. The annual forest area expansion in that subregion also showed an increasing trend, from 1.23 Mha per year in 2000–2010 to 1.41 Mha per year in 2010–2018 (see Table 16).

**Table 17. Annual forest area expansion (Mha/year) and +/-95% confidence interval by Global Ecological Zones and FAO climatic domains for the periods 2000–2010 and 2010–2018**

| GEZ and FAO climatic domains (Mha/ year) | Forest area expansion 2000–2010 | ± | Forest area expansion 2010–2018 | ± |
|---|---|---|---|---|
| Tropical rainforest | 0.40 | 15.4% | 0.55 | 10.8% |
| Tropical moist forest | 0.50 | 10.2% | 0.87 | 9.0% |
| Tropical dry forest | 0.17 | 16.3% | 0.36 | 11.9% |
| Tropical shrubland | 0.03 | 50.5% | 0.13 | 42.9% |
| Tropical desert | 0.00 | 96.3% | 0.00 | 72.4% |
| Tropical mountain system | 0.10 | 19.8% | 0.20 | 15.2% |
| Tropicals | 1.20 | 7.3% | 2.11 | 5.9% |
| Subtropical humid forest | 0.66 | 9.6% | 0.72 | 10.6% |
| Subtropical dry forest | 0.08 | 14.5% | 0.05 | 22.8% |
| Subtropical steppe | 0.02 | - | 0.01 | - |
| Subtropical desert | 0.00 | - | 0.00 | - |
| Subtropical mountain system | 0.38 | 10.0% | 0.39 | 8.4% |
| Subtropicals | 1.14 | 6.9% | 1.17 | 7.2% |
| Temperate oceanic forest | 0.04 | 25.5% | 0.02 | 33.9% |
| Temperate continental forest | 0.49 | 10.3% | 0.48 | 12.5% |
| Temperate steppe | 0.06 | 50.2% | 0.03 | 62.6% |
| Temperate desert | 0.01 | 92.4% | 0.04 | - |
| Temperate mountain system | 0.24 | 19.3% | 0.23 | 21.2% |
| Temperates | 0.85 | 9.0% | 0.81 | 11.4% |
| Boreal coniferous forest | 0.49 | 15% | 0.35 | 20% |
| Boreal tundra woodland | 0.13 | 22% | 0.15 | 19% |
| Boreal mountain system | 0.41 | 20% | 0.13 | 40% |
| Boreals | 1.03 | 11% | 0.63 | 14% |
| Polar | 0.00 | 0% | 0.00 | 0% |
| World | 4.23 | 4% | 4.72 | 4% |

**Figure 21. Forest area expansion (Mha) and as proportion of global forest area expansion by FAO climatic domain in 2000–2018**




Of total forest area expansion in 2000–2018 (see Figure 21), 36 percent (29 Mha) occurred in tropical biomes, followed by subtropical biomes at 26 percent (21 Mha) and boreal biomes at 19 percent (15.4 Mha). With 12.3 Mha of forest area expansion in 2000–2018, the subtropical humid forest was the ecological zone with the highest forest area expansion. Highest percentual change in annual forest area expansion was observed in tropical forests, where it increased by 76 percent from 1.2 Mha per year in 2000–2010 to 2.11 Mha per year in 2010–2018. The only biome where the annual rate of expansion notably declined, from 1.03 Mha per year in 2000–2010 to 0.63 Mha in 2010–2018, was boreal forest. The high value of forest area expansion registered in the tropical moist forest ecological zone in the second decade (0.87 Mha per year in 2010–2018 versus 0.5 Mha in the first period 2000–2010), is likely to be directly due to an increase in planted forest area (see Table 17).

**Table 18. Top 10 ecoregions (GEZ × subregion) with the highest annual rates of forest area expansion for 2000–2018 and +/-95% confidence interval**

| Ecoregion | Annual rate of forest area expansion (000 ha/year) | ± |
|---|---|---|
| East Asia<br>Subtropical humid forest | 516.7 | 35% |
| South America<br>Tropical moist forest | 363.8 | 35% |
| East Asia<br>Subtropical mountain system | 344.4 | 26% |
| Europe<br>Boreal coniferous forest | 280.1 | 72% |
| Europe<br>Temperate continental forest | 272.1 | 47% |
| Europe<br>Boreal mountain system | 269.4 | 80% |
| South America<br>Tropical rainforest | 226.7 | 56% |
| East Asia<br>Temperate mountain system | 189.8 | 72% |
| North America<br>Boreal coniferous forest | 180.1 | 50% |
| North America<br>Boreal tundra woodland | 148.2 | 49% |

Considering the forest area expansion by ecoregion, the greatest expansion was observed in the subtropical humid forests of East Asia and in the tropical moist forests of South America, with total forest area expansion of 9.3 and 6.5 Mha for the period 2000–2018, respectively (see Table 18). Our results show that afforestation accounted for a significant proportion of forest area expansion in these ecoregions (see Table 18), and this warrants further investigation.

**What forest types expanded in 2000–2018?**

Globally, 53 percent of the forest area that expanded between 2000 and 2018 was due to natural expansion (39.5 Mha), while afforestation accounted for 47 percent of forest area expansion (35 Mha).

Natural expansion accounted for most of the forest area expansion in almost all regions. Europe was the region with the highest gains due to natural expansion of forest, with an increase of around 15.4 Mha in 2000–2018.

Asia is the only region where forest area expansion was mostly established through afforestation (planting or seeding of trees), with these planted forests representing 77 percent of the forest area gains (23 Mha), mainly due to the large area of planted forest in East Asia (19 Mha). In North America, planted forests also made up half of forest area expansion (1.8 Mha).

**Figure 22. Forest area expansion (Mha) in 2000–2018 by type and by region**

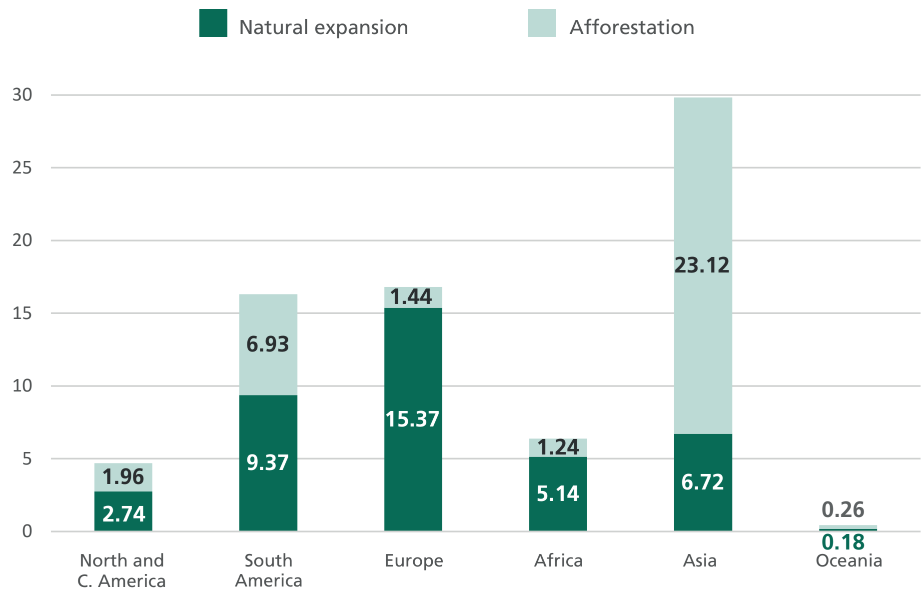


**Table 19. Forest area expansion by forest type (000 ha/year) and as a proportion of the total forest area expansion by region and subregion in 2000–2018**

| Regions and subregions (000 ha/year) | Natural expansion | % | Afforestation | % |
|---|---|---|---|---|
| North America | 100.3 | 50.5 | 98.4 | 49.5 |
| Central America | 26.2 | 89.0 | 3.2 | 11.0 |
| Caribbean | 25.8 | 78.0 | 7.3 | 22.0 |
| North and Central America | 152.2 | 58.3 | 108.9 | 41.7 |
| South America | 520.5 | 57.5 | 385.1 | 42.5 |
| Europe | 853.7 | 91.4 | 80.0 | 8.6 |
| North Africa | 40.2 | 86.6 | 6.2 | 13.4 |
| Western and Central Africa | 109.5 | 76.2 | 34.2 | 23.8 |
| Eastern and Southern Africa | 135.9 | 82.7 | 28.3 | 17.3 |
| Africa | 285.6 | 80.6 | 68.8 | 19.4 |
| Western and Central Asia | 4.8 | 21.2 | 17.8 | 78.8 |
| East Asia | 228.6 | 17.9 | 1 050.5 | 82.1 |
| South and Southeast Asia | 139.6 | 39.2 | 216.3 | 60.8 |
| Asia | 373.1 | 22.5 | 1 284.6 | 77.5 |
| Oceania | 10.1 | 41.3 | 14.3 | 58.7 |
| World | 2 195.1 | 53.1 | 1 941.6 | 46.9 |

**Table 20. Forest area expansion by forest type (000 ha/year) and as a proportion of the total forest area expanded by Global Ecological Zones and FAO climatic domains in 2000–2018**

| GEZ and FAO climatic domains (000 ha/year) | Natural expansion | % | Afforestation | % |
|---|---|---|---|---|
| Tropical rainforest | 290.4 | 62.8 | 171.9 | 37.2 |
| Tropical moist forest | 388.5 | 60.5 | 253.7 | 39.5 |
| Tropical dry forest | 205.4 | 82.4 | 43.9 | 17.6 |
| Tropical shrubland | 59.2 | 83.1 | 12.0 | 16.9 |
| Tropical desert | 0.0 | 47.6 | 0.0 | 52.4 |
| Tropical mountain system | 86.4 | 60.2 | 57.0 | 39.8 |
| Tropicals | 1 029.9 | 65.7 | 538.6 | 34.3 |
| Subtropical humid forest | 111.7 | 16.4 | 568.4 | 83.6 |
| Subtropical dry forest | 29.1 | 42.7 | 39.1 | 57.3 |
| Subtropical steppe | 0.0 | 0.0 | 9.3 | 100.0 |
| Subtropical desert | 0.7 | 100.0 | 0.0 | 0.0 |
| Subtropical mountain system | 85.2 | 22.4 | 295.7 | 77.6 |
| Subtropicals | 226.8 | 19.9 | 912.5 | 80.1 |
| Temperate oceanic forest | 11.7 | 37.5 | 19.5 | 62.5 |
| Temperate continental forest | 268.5 | 53.9 | 229.5 | 46.1 |
| Temperate steppe | 3.2 | 9.3 | 31.6 | 90.7 |
| Temperate desert | 0.0 | 0.0 | 18.5 | 100.0 |
| Temperate mountain system | 40.5 | 18.8 | 175.0 | 81.2 |
| Temperates | 324.0 | 40.6 | 474.2 | 59.4 |

| GEZ and FAO climatic domains (000 ha/ year) | Natural expansion | % | Afforestation | % |
|---|---|---|---|---|
| Boreal coniferous forest | 345.6 | 99.0 | 3.3 | 1.0 |
| Boreal tundra woodland | 12.4 | 100.0 | 0.0 | 0.0 |
| Boreal mountain system | 256.4 | 95.2 | 13.0 | 4.8 |
| Boreal | 614.4 | 97.4 | 16.3 | 2.6 |
| Polar | 0.0 | 0.0 | 0.0 | 0.0 |
| World | 2 195.1 | 53.1 | 1 941.6 | 46.9 |

### Forest area net changes and trends in 2000–2018 at the regional, subregional and z zone level

Forest area net changes are calculated by subtracting deforestation from forest area expansion.

The survey observed negative forest area net change in all regions except Europe and Oceania in the period 2000–2018. Europe recorded a positive forest area change of 13.5 Mha in this period. Negative forest area net changes were greatest in South America (-51.5 Mha), followed by Africa (-42.1 Mha) and North and Central America (-6.6 Mha).

Annual net losses were significantly lower in 2010–2018 compared with 2000–2010 in all regions. In North and Central America, net losses dropped from 0.65 Mha per year to almost zero in the second period. In South America, they halved from 3.77 Mha per year to 1.72 Mha per year. The survey also indicates a decline in net losses of 83 percent in Asia, from 0.5 Mha per year in 2000–2010 to 0.08 Mha in 2010–2018, and of 36 percent in Africa, from 2.79 Mha per year to 1.77 Mha per year. While in most regions this decrease is mainly linked to slower deforestation, in Asia, Africa and South America, reduced net losses are also associated with an increase in forest area expansion.

In Europe, the net gain in forest area declined by 43 percent from 0.93 Mha in 2000–2010 to 0.53 Mha per year in 2010–2018, due to the decrease in forest area expansion.

The data also show strong differences at the subregional level within regions. In the North and Central America region, Central America accounts for most of the net losses (7.3 Mha in 2000–2018), though the annual net losses diminished from 0.6 Mha per year in 2000–2010 to 0.2 Mha per year in 2010–2018. In contrast, North America registered positive forest area net changes or no losses in 2010–2018, and the Caribbean apparently also shows a positive trend, but due to the small size of the sample in that region, it must be further investigated. In Africa, the North Africa region did not show important forest area net changes although the sample size was small, while Eastern and Southern Africa, as well as Western and Central Africa subregions, recorded considerable net losses (23 Mha and 19 Mha in 2000–2018, respectively), despite a major reduction in net losses of around 64 percent from 2000–2010 to 2010–2018 across the African continent. In Asia, while South and Southeast Asia showed important net losses (25 Mha in 2000–2018), substantial net gains were observed in East Asia (19.6 Mha in 2000–2018), and the situation appears almost stable in Western and Central Asia (see Figure 23 and Table 21).

**Figure 23. Forest area net change (Mha/year) by FAO region for the periods 2000–2010 and 2010–2018**

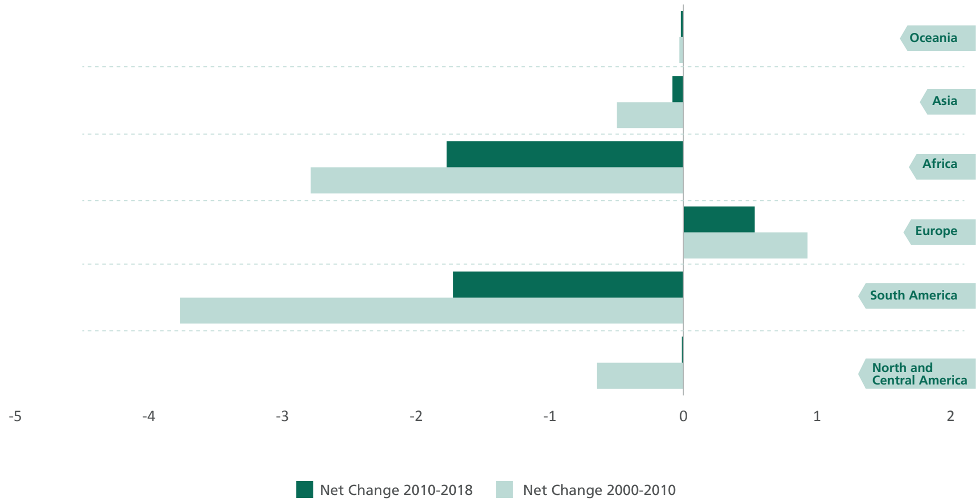



**Table 21. Annual forest area net change (Mha/year) and +/-95% confidence interval by FAO region and subregion for the periods 2000–2010 and 2010–2018**

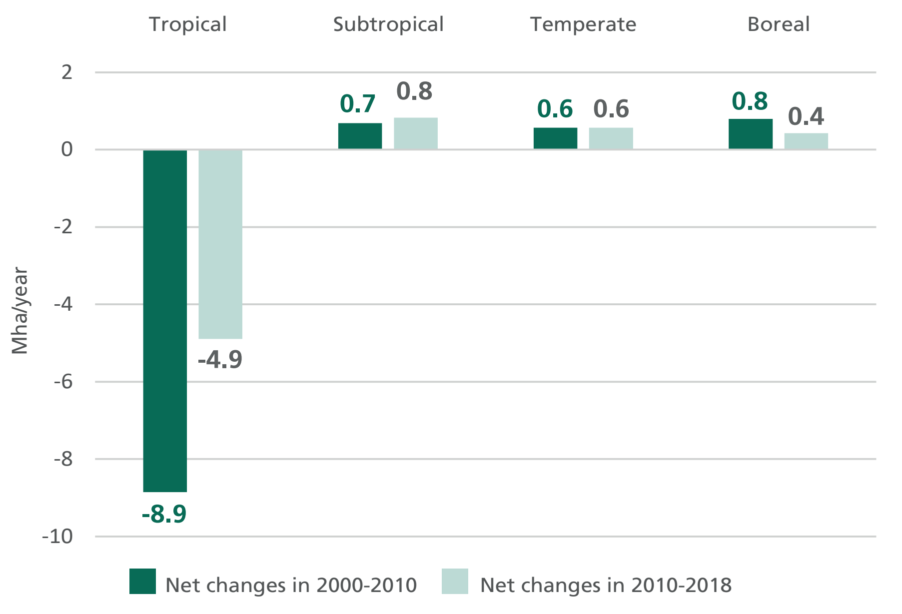
| Regions and subregions (Mha/year) | Net change 2000–2010 | ± | Net change 2010–2018 | ± |
|---|---|---|---|---|
| North America | -0.06 | 19.5% | 0.13 | 26.2% |
| Central America | -0.59 | 57.7% | -0.18 | - |
| Caribbean | 0.00 | 126.9% | 0.04 | 11.5% |
| North and C. America | -0.65 | 17.1% | -0.01 | 19.5% |
| South America | -3.77 | 10% | -1.72 | 11% |
| Europe | 0.93 | 30.1% | 0.53 | 34.9% |
| North Africa | -0.01 | - | 0.01 | 82.4% |
| Western and Central Africa | -1.29 | 38.6% | -0.82 | 28.6% |
| Eastern and Southern Africa | -1.49 | 36.5% | -0.96 | 22.8% |
| Africa | -2.79 | 25.0% | -1.77 | 17.6% |
| Western and Central Asia | 0.01 | - | -0.01 | - |
| East Asia | 1.05 | 26.9% | 1.14 | 21.0% |
| South and Southeast Asia | -1.56 | 19.6% | -1.22 | 16.3% |
| Asia | -0.50 | 10.7% | -0.08 | 11.1% |
| Oceania | -0.03 | - | -0.02 | 24.7% |
| World | -6.81 | 6.2% | -3.08 | 6.6% |

**Table 22. Annual forest area net change (Mha/year) and +/-95% confidence interval by Global Ecological Zones and FAO climatic domains for the periods 2000–2010 and 2010–2018**

| GEZ and FAO climatic domains (Mha/year) | Net change 2000–2010 | ± | Net change 2010–2018 | ± |
|---|---|---|---|---|
| Tropical rainforest | -4.13 | 17.9% | -2.45 | 14.3% |
| Tropical moist forest | -2.51 | 14.0% | -1.16 | 13.9% |
| Tropical dry forest | -1.88 | 20.6% | -1.18 | 16.5% |
| Tropical shrubland | -0.12 | 68.3% | -0.03 | 63.9% |

| GEZ and FAO climatic domains (Mha/year) | Net change 2000–2010 | ± | Net change 2010–2018 | ± |
|---|---|---|---|---|
| Tropical desert | 0.00 | - | 0.00 | 115.1% |
| Tropical mountain system | -0.21 | 30.2% | -0.07 | 28.6% |
| Tropicals | -8.85 | 9.2% | -4.89 | 8.3% |
| Subtropical humid forest | 0.38 | 26.1% | 0.47 | 23.8% |
| Subtropical dry forest | 0.05 | 40.8% | 0.03 | 51.1% |
| Subtropical steppe | -0.03 | - | -0.02 | - |
| Subtropical desert | -0.03 | - | 0.00 | - |
| Subtropical mountain system | 0.30 | 49.7% | 0.35 | 48.9% |
| Subtropicals | 0.68 | 21.3% | 0.83 | 20.7% |
| Temperate oceanic forest | 0.02 | 63.5% | 0.01 | 82.5% |
| Temperate continental forest | 0.34 | 24.8% | 0.35 | 30.3% |
| Temperate steppe | 0.00 | - | 0.00 | - |
| Temperate desert | 0.00 | - | 0.03 | - |
| Temperate mountain system | 0.19 | 42.6% | 0.18 | 54.7% |
| Temperates | 0.56 | 26.9% | 0.57 | 32.2% |
| Boreal coniferous forest | 0.38 | 42.2% | 0.23 | 44.0% |
| Boreal tundra woodland | 0.08 | 45.2% | 0.11 | 53.8% |
| Boreal mountain system | 0.35 | 40.2% | 0.09 | 76.4% |
| Boreal | 0.80 | 26.5% | 0.42 | 32.3% |
| Polar | 0.00 | 0.0% | 0.00 | 0% |
| World | -6.81 | 6.2% | -3.08 | 6.6% |

**Figure 24. Annual forest area net change (Mha/year) by FAO climatic domains in 2000–2010 and 2010–2018**



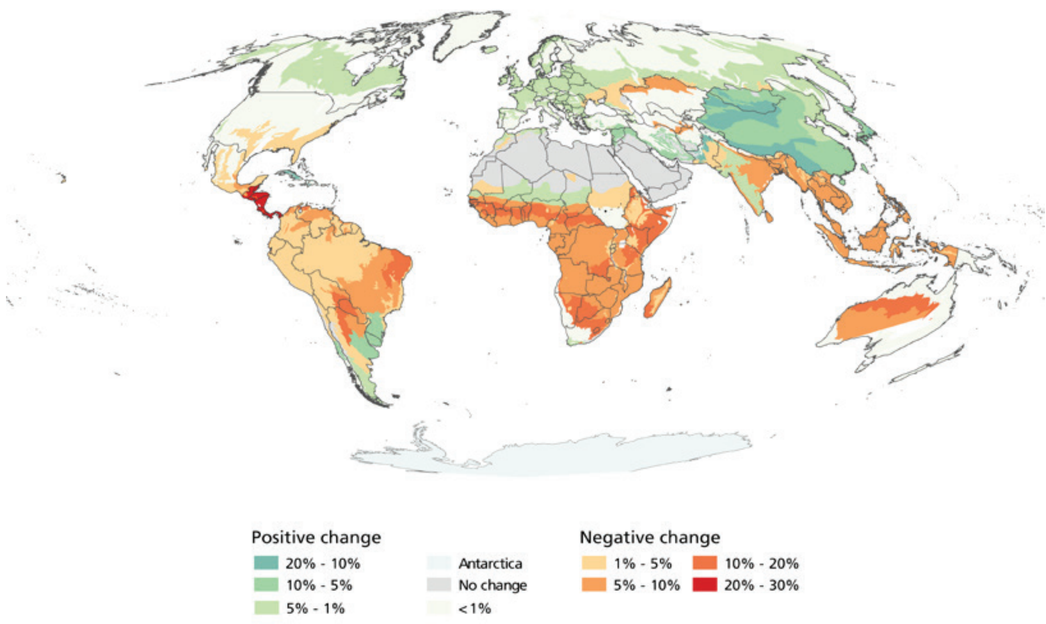

Only the tropical climatic domain registered negative forest area net changes, in both decades. For the 2000–2018 period, net forest losses amounted to 128 Mha in the tropical domain. In the decade 2000–2010, the tropical domain registered a net annual loss of 8.9 Mha per year, which declined to almost half, at a net annual loss of 4.9 Mha per year, in the period 2010–2018 (see Figure 24).

Within the tropical domain, the greatest net losses occurred in tropical rainforest, at 61 Mha in 2000–2018, representing almost half the net losses of the entire tropical biome. Nevertheless, the trends in this ecological zone marked a slowdown in net forest area losses from 4.1 to 2.4 Mha per year. The second highest losses were found in tropical moist forest, which also shows a decline in the net forest area loss from 2.45 Mha per year in 2000–2010 to 1.2 Mha per year in 2010–2018 (see Table 22).

The other biomes registered net positive changes in both periods (see Figure 24). The highest positive changes were registered in the subtropical domain in both periods and in the first decade (2000–2010) of the boreal domain. While the net forest area gains observed in the subtropical domain slowly increased (from 0.7 Mha per year to 0.8 Mha per year), they tended to remain stable from one period to the other in the temperate domain, though decreasing in a pronounced way in the boreal domain (from 0.8 Mha per year to 0.4 Mha per year). When analysing the Global Ecological Zones, the highest annual net forest area gains occurred in subtropical humid forest (7.6 Mha), in temperate continental forest (6.2 Mha), and in boreal coniferous forest (5.6 Mha) in 2000–2018 (see Table 22).

Figure 25 shows the forest area net changes distribution by ecoregion.

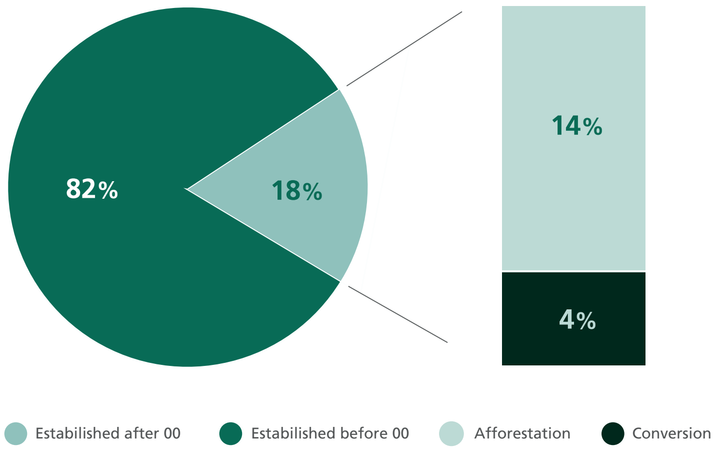
**Figure 25. Forest area net change (%) by ecoregion in 2000–2018**




*Note*: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.
*Source*: UN. 2020. MapoftheWorld [online]. [Cited 1 January 2021].un.org/geospatial/file/3420/download?token=bZe9T8I91b), modified by the authors.

### What do we know about planted forest in 2018?

**Figure 26. Share of planted forest established before and after year 2000 (pie chart) and afforestation and conversion of naturally regenerating forest to planted forest of total forest area planted since year 2000 (bar chart)**




During the period 2000–2018, 46 Mha of planted forest were established. The afforestation accounted for 76 percent of the planted forest area increase and conversion of naturally regenerating forest to planted forest for the remaining 24 percent (see Figure 26). Most of this conversion took place in South and Southeast Asia, where 5.3 Mha of naturally regenerating forest were replaced with planted forest during the study period (see Table 23).

Of the total planted forest detected in the year 2018, 212 Mha corresponded to planted forest established before 2000.

**Table 23. Area of naturally regenerating forest converted to planted forests (Mha) and annual rate of conversion (000 ha/ year) and +/-95% confidence interval by FAO region and subregion between 2000 and 2018**

| Conversion of naturally regenerating forest to planted forest in 2000–2018 by regions and subregions | Total area in 2000–2018 (Mha) | Total area in 2000–2018 (000 ha/year) | ± |
|---|---|---|---|
| North America | 1.0 | 55.3 | 29.8% |
| Central America | 0.0 | 1.4 | 60.0% |
| Caribbean | 0.0 | 2.6 | 129.9% |
| North and Central America | 1.1 | 59.3 | 34.9% |
| South America | 1.6 | 87.0 | 23.8% |
| Europe | 0.1 | 4.6 | 121.0% |
| North Africa | 0.1 | 7.7 | 126.5% |
| Western and Central Africa | 0.8 | 46.3 | 45.0% |
| Eastern and Southern Africa | 0.4 | 22.6 | 45.3% |
| Africa | 1.4 | 76.7 | 53.3% |
| Western and Central Asia | 0.1 | 4.1 | NR |
| East Asia | 1.4 | 79.6 | 35.9% |
| South and Southeast Asia | 5.3 | 295.9 | 9.2% |
| Asia | 6.8 | 379.6 | 23.1% |
| Oceania | 0.1 | 4.7 | 65.4% |
| World | 11.0 | 611.9 | 10.3% |

**Table 24. Area of naturally regenerating forest converted to planted forests (Mha) and annual rate of conversion (000 ha/ year) and +/-95% confidence interval by Global Ecological Zones and FAO climatic domains between 2000 and 2018**

| Conversion of naturally regenerating forest to planted forest in 2000–2018 by GEZ | Total area in 2000–2018 (Mha) | Total area in 2000–2018 (000 ha/year) | ± |
|---|---|---|---|
| Tropical rainforest | 4.2 | 235.8 | 11.8% |
| Tropical moist forest | 2.5 | 138.4 | 16.0% |
| Tropical dry forest | 0.9 | 48.5 | 31.2% |
| Tropical shrubland | 0.3 | 16.2 | 62.5% |
| Tropical desert | 0.0 | 0.0 | - |
| Tropical mountain system | 0.4 | 23.4 | 52.4% |
| Tropicals | 8.3 | 462.3 | 18.9% |
| Subtropical humid forest | 1.9 | 105.9 | 28.9% |
| Subtropical dry forest | 0.0 | 2.3 | 77.6% |
| Subtropical steppe | 0.0 | 1.2 | 101.7% |
| Subtropical desert | 0.0 | 0.0 | - |
| Subtropical mountain system | 0.3 | 16.2 | 65.8% |
| Subtropicals | 2.3 | 125.6 | 35.3% |
| Temperate oceanic forest | 0.0 | 2.5 | 121.1% |
| Temperate continental forest | 0.2 | 9.1 | 92.2% |
| Temperate steppe | 0.0 | 0.0 | - |
| Temperate desert | 0.0 | 2.4 | 1 294.0% |
| Temperate mountain system | 0.2 | 9.8 | 99.3% |
| Temperates | 0.4 | 23.8 | 221.0% |
| Boreal coniferous forest | 0.0 | 0.0 | - |
| Boreal tundra woodland | 0.0 | 0.0 | - |
| Boreal mountain system | 0.0 | 0.0 | - |
| Boreals | 0.0 | 0.0 | - |
| Polar | 0.0 | 0.2 | 196.6% |
| World | 11.0 | 611.9 | 10.3% |

## 4.3 DRIVERS OF DEFORESTATION BETWEEN 2000 AND 2018

### Main drivers identified in this study

The analysis of the transition between one class of land use and another allows some of the direct drivers behind the changes to be assessed. In the current study, it was considered that the driver behind the conversion of forest into cropland was **cropland expansion** (including large-scale and small-scale farming), conversion of forest to grassland was **livestock grazing** (expansion of pasture), while behind the conversion of forest to settlement was **urban and infrastructure development**.

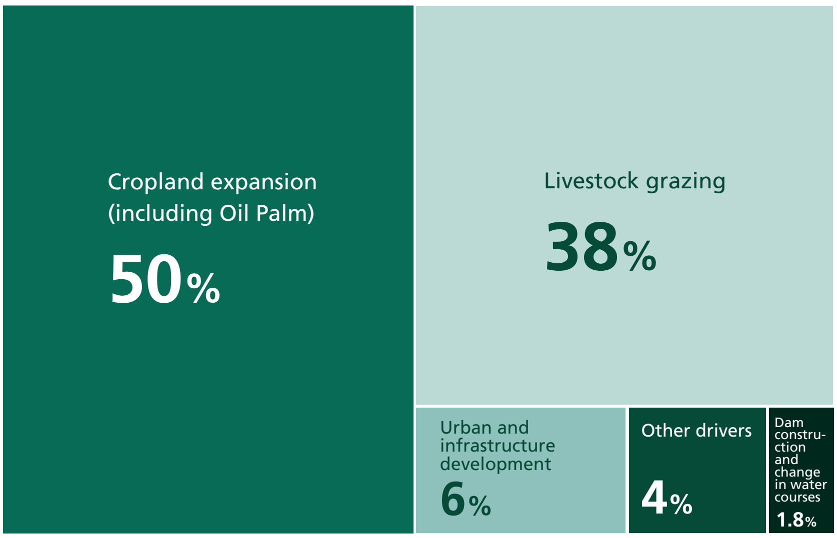
The drivers behind the replacement of forest by Other Wooded Land (OWL), Bare soil and Water are less clear. A forest can be replaced by water due to dam construction, changes in river meandering or flooding. In the study, the first two were preponderant causes observed through satellite imagery. The driver behind this conversion will be labelled as **dam construction and change in watercourses**. The probable causes for a forest becoming Other Wooded Land include human-induced or natural disturbances such as wildfires, landslides and overexploitation of forest resources (such as for fuelwood extraction or illegal logging), resulting in forest degradation. Such processes can negatively impact site conditions in a way that they will not allow sustaining tree cover that meets the biophysical definition of forest (i.e. trees are unable to reach 5 m height and comprise at least 10 percent canopy cover under current conditions). Soil depletion (i.e. soil erosion) can also affect forest growth and regeneration. A forest land can be converted to bare soil due to severe land degradation (soil erosion and landslides, among other causes). In this study, the drivers behind these conversions will be labelled as **other drivers** and further investigation is required to further assess the causes behind the conversion of forest to OWL.

**Which were the main drivers of deforestation at global level in 2000–2018?**
The result of this analysis shows that the main driver behind deforestation between 2000 and 2018 was cropland expansion (including oil palm plantations), representing almost 50 percent (86 Mha) of deforestation globally. The conversion of forest to oil palm plantations alone accounts for around 7 percent of global deforestation during that period. The second most important direct driver of forest losses was livestock grazing, accounting for 38.5 percent (67 Mha) of global deforestation (see Figure 27 and Table 25). Overall, agricultural expansion, which includes these two drivers, was responsible for almost 90 percent of deforestation worldwide during that decade. This figure is considerably higher than that concluded by earlier studies (see Chapter 5. Discussion and conclusions).

Urban and infrastructure development caused 6.2 percent of global deforestation between 2000 and 2018 (see Figure 27 and Table 25).

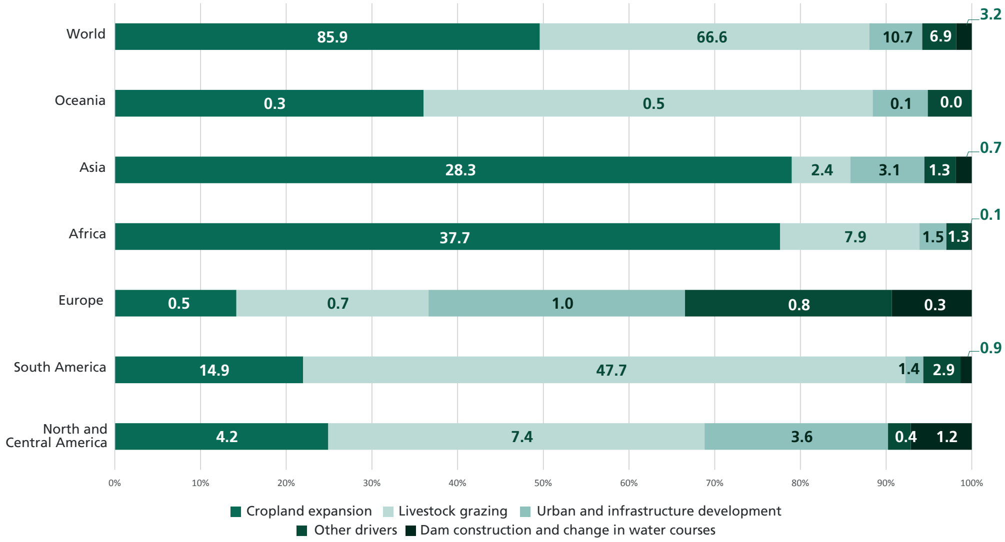
In addition, 3.7 percent of forest was lost due to severe degradation affecting its sustainability to regenerate naturally (i.e. Forest converted to Other Wooded Land).

**Figure 27. Proportion of direct drivers of deforestation in 2000–2018**



## Regional analysis of the drivers of deforestation in 2000–2018

**Figure 28. Drivers of deforestation by FAO region in 2000–2018 (Mha)**




Agriculture was a driver of most deforestation in all regions during 2000–2018. The prevalence of cropland expansion versus livestock grazing varied from region to region, and between subregions. While cropland expansion dominated forest loss in Africa and Asia, with a share exceeding 75 percent, livestock grazing was the predominant direct cause of 70 percent of forest loss in South America, 52 percent in Oceania and 44 percent in North and Central America (see Table 25).

Conversion to oil palm plantations was responsible for 29 percent of deforestation in Asia and 11 percent in Oceania. In Africa and North and Central America, it caused 1 percent of forest loss (see Table 25).

**Table 25. Direct deforestation drivers (000 ha/year) and the proportion of total deforestation drivers by FAO region and subregion in 2000–2018**

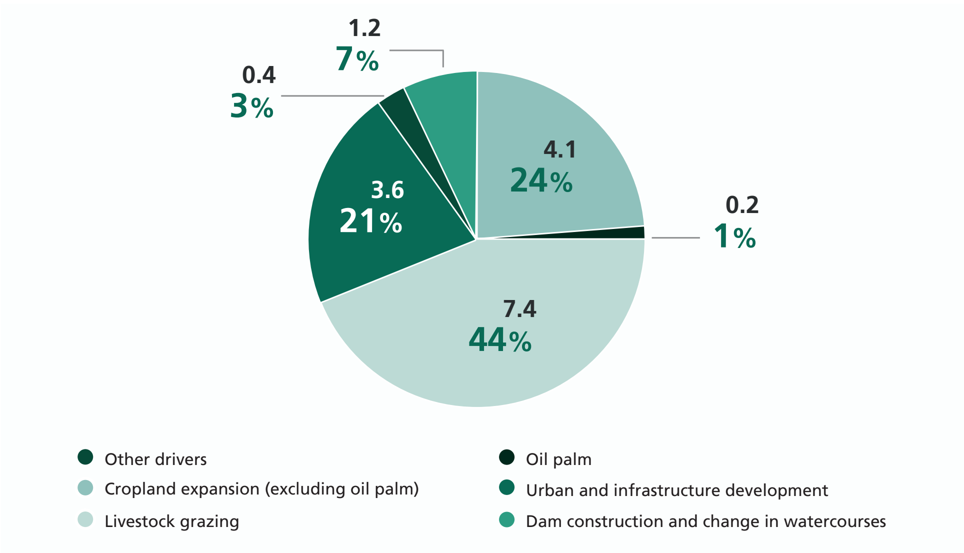
| Region and subregions (1 000 ha/year) | Cropland expansion (excluding oil palm) | % | Oil Palm | % | Livestock grazing | % | Urban and infrastructure development | % | Other drivers | % | Dam construction and change in water courses | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North America | 58.8 | 12 | 0.1 | 0 | 181.1 | 36 | 194.4 | 38 | 5.9 | 1 | 66.0 | 13 |
| Central America | 166.5 | 39 | 8.6 | 2 | 230.7 | 54 | 5.5 | 1 | 19.0 | 4 | 0.0 | 0 |
| Caribbean | 0.0 | 0 | 0.0 | 0 | 0.9 | 29 | 1.4 | 44 | 0.0 | 0 | 0.9 | 27 |
| North and Central America | 225.2 | 24 | 8.8 | 1 | 412.7 | 44 | 201.2 | 21 | 24.9 | 3 | 66.9 | 7 |
| South America | 816.2 | 22 | 11.6 | 0 | 2 647.3 | 70 | 78.5 | 2 | 163.6 | 4 | 49.3 | 1 |
| Europe | 25.2 | 14 | 0.0 | 0 | 39.8 | 22 | 53.1 | 30 | 42.9 | 24 | 16.6 | 9 |
| North Africa | 37.3 | 73 | 0.0 | 0 | 2.7 | 5 | 0.6 | 1 | 10.4 | 20 | 0.0 | 0 |
| Western and Central Africa | 976.2 | 79 | 30.5 | 2 | 165.9 | 13 | 53.0 | 4 | 0.0 | 0 | 5.2 | 0 |
| Eastern and Southern Africa | 1 050.4 | 74 | 0.0 | 0 | 270.1 | 19 | 31.1 | 2 | 64.2 | 5 | 0.1 | 0 |

| Region and subregions (1 000 ha/ year) | Cropland expansion (excluding oil palm) | % | Oil Palm | % | Livestock grazing | % | Urban and infrastructure development | % | Other drivers | % | Dam construction and change in water courses | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Africa | 2 063.8 | 77 | 30.5 | 1 | 438.7 | 16 | 84.8 | 3 | 74.6 | 3 | 5.2 | 0 |
| Western and Central Asia | 0.5 | 2 | 0.0 | 0 | 9.0 | 38 | 0.8 | 3 | 5.2 | 22 | 8.3 | 35 |
| East Asia | 108.0 | 51 | 0.0 | 0 | 12.6 | 6 | 79.7 | 37 | 11.1 | 5 | 1.4 | 1 |
| South and Southeast Asia | 893.2 | 51 | 572.6 | 33 | 114.3 | 7 | 92.0 | 5 | 56.1 | 3 | 27.9 | 2 |
| Asia | 1 001.7 | 50 | 572.6 | 29 | 136.0 | 7 | 172.4 | 9 | 72.4 | 4 | 37.6 | 2 |
| Oceania | 13.6 | 25 | 5.8 | 11 | 28.1 | 52 | 3.5 | 6 | 2.7 | 5 | 0.0 | 0 |
| World | 4 145.7 | 43 | 629.3 | 7 | 3 702.6 | 38 | 593.5 | 6 | 381.2 | 4 | 175.6 | 2 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

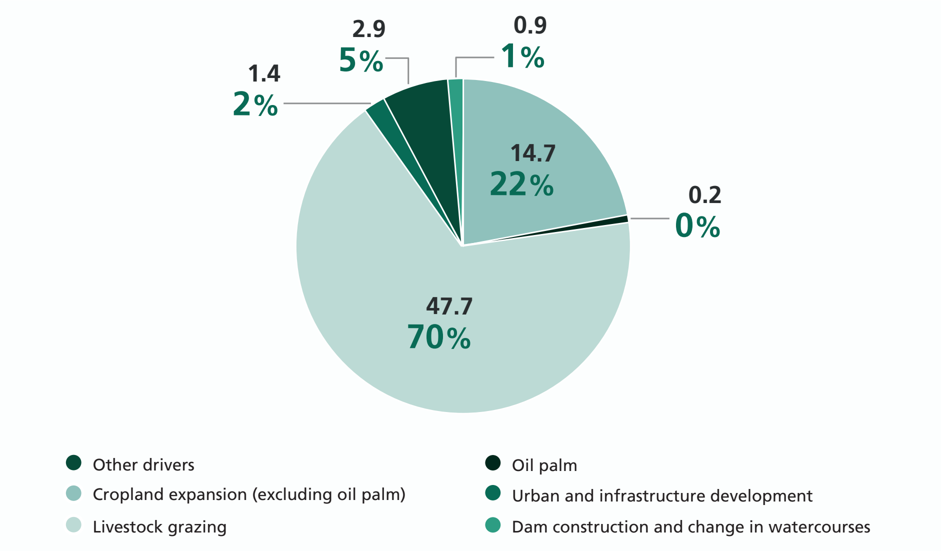
In North and Central America (see Figure 29), the main deforestation driver in 2000–2018 was expansion for livestock grazing (44 percent, 7.4 Mha of forest loss), followed by cropland expansion (24 percent, 4.1 Mha). Expansion for livestock grazing particularly drove deforestation in Central America. Urbanization and infrastructure development, which caused 21 percent (3.6 Mha) of forest losses in the region, also represented an important factor driving deforestation, notably in North America (see Figure 29 and Table 25).

**Figure 29. Area (Mha) and proportion of deforestation drivers in North America and Central America**



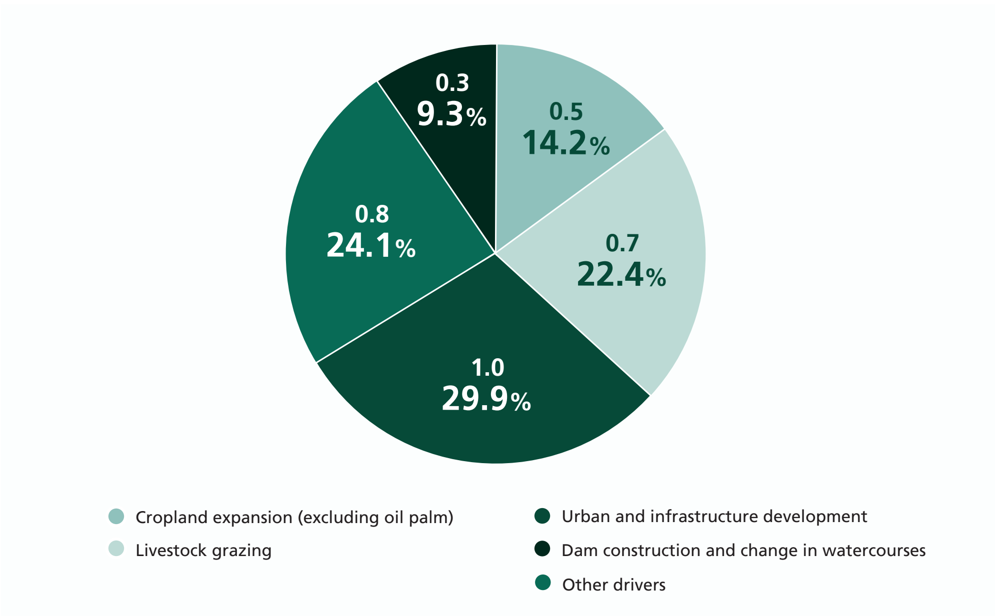
In South America, expansion for livestock grazing was a major driver, causing 70 percent of total deforestation. This is due to the ongoing expansion of cattle ranching in forested areas, particularly in the Amazon basin, Gran Chaco region and the Cerrado (see Figure 30).

**Figure 30. Area (Mha) and proportion of deforestation drivers in South America**



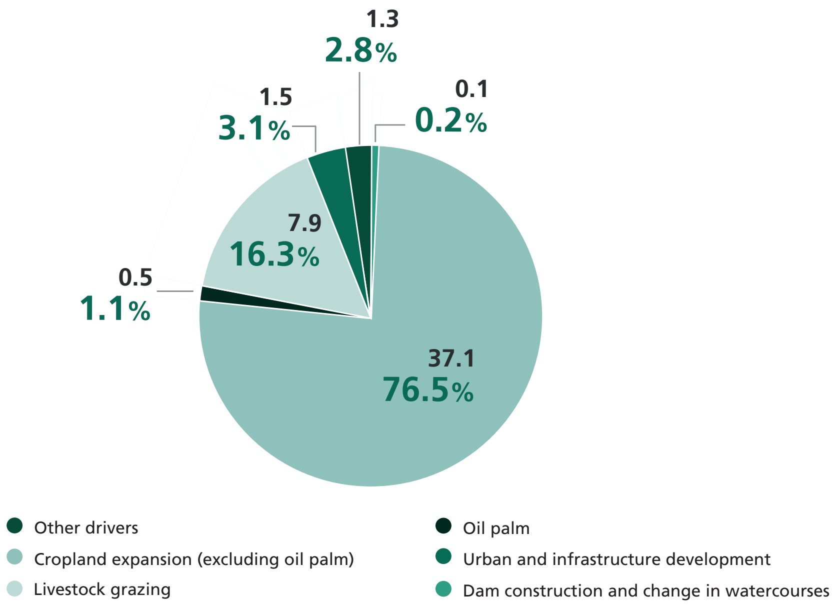

In Europe, the leading driver of forest losses was urbanization and infrastructure development, which caused 30 percent (1.0 Mha) of total forest losses. It was followed by other drivers and livestock grazing with shares of 24 and 22 percent (see Figure 31).

**Figure 31. Area (Mha) and proportion of deforestation drivers in europe**



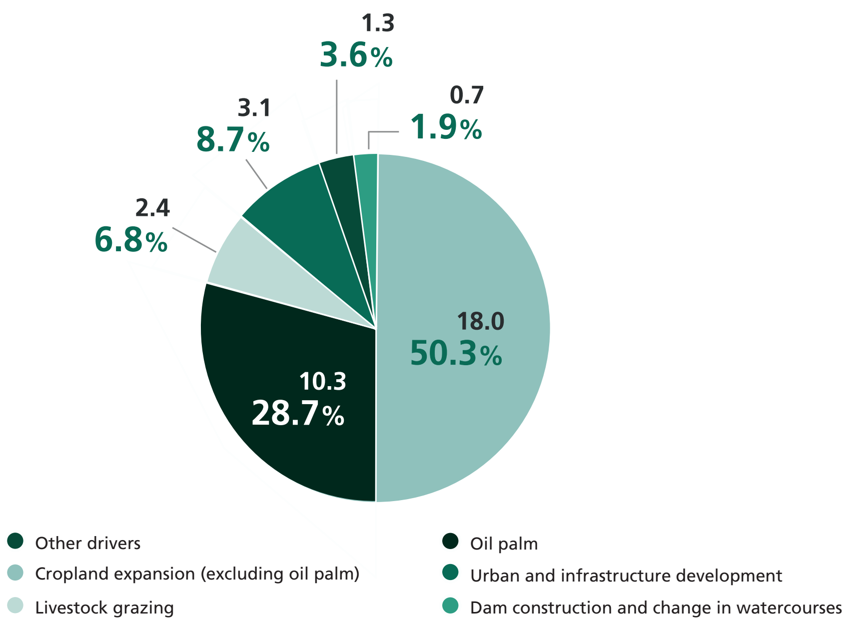

In Africa, agriculture, in particular cropland expansion, was the main direct cause of deforestation (see Figure 32). More than three-quarters of the area deforested between 2000 and 2018 (corresponding to 37.1 Mha) was converted to croplands. This situation is closely connected to increasing demographic pressure in the region. In addition, livestock grazing was responsible for 16 percent of forest losses (7.9 Mha) (see Figure 32). Forest was also replaced by OWL due to the pressures of cattle grazing and wood extraction for charcoal production.

Figure 32. Area (Mha) and proportion of deforestation drivers in Africa



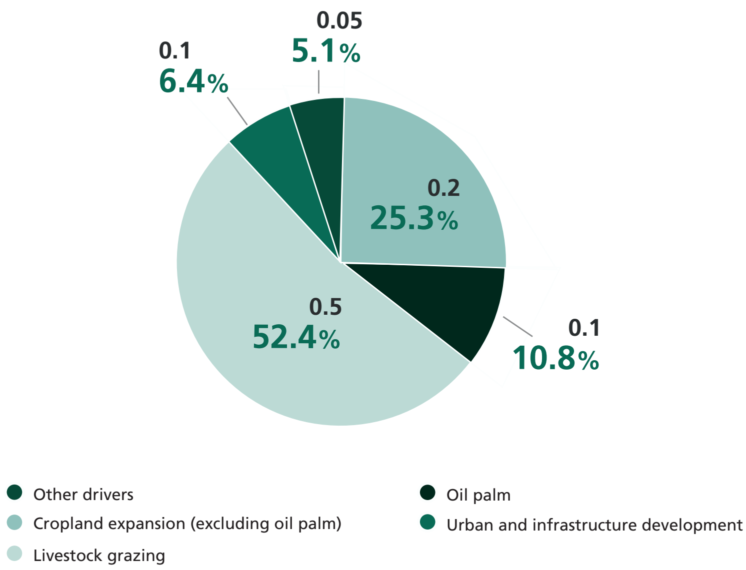

In Asia, cropland expansion (see Figure 33) caused almost 50 percent of the deforestation in 2000–2018 (18.0 Mha). In this region, oil palm plantations established in South and Southeast Asia replaced 10.3 Mha of forest, accounting for 29 percent of the forest losses in the region. Furthermore, 9 percent of deforestation (3.1 Mha) was due to urban and infrastructure development, while livestock grazing was responsible for 7 percent of deforestation (2.4 Mha) in the region during this period (see Figure 33).

Figure 33. Area (Mha) and proportion of deforestation drivers in Asia



**In Oceania**, livestock grazing (see Figure 34) caused around 50 percent of the deforestation in 2000–2018 (0.5 Mha), while cropland expansion accounted for 25 percent or 0.2 Mha. In this region, 0.1 Mha of oil palm plantations replaced forest, accounting for 11 percent of forest losses in the region. Furthermore, 7 percent of deforestation (0.1 Mha) was due to urban and infrastructure development (see Figure 34).

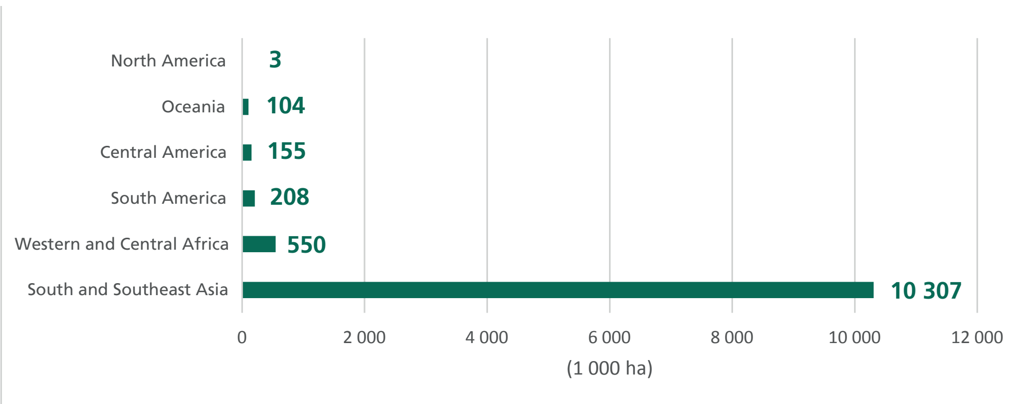
**Figure 34. Area (Mha) and proportion of deforestation drivers in Oceania**




## Where was oil palm a driver of deforestation?

The survey indicates that oil palm plantations were responsible for 11.3 Mha of deforestation from 2000 to 2018 (see Figure 35). Of this oil palm area, 91 percent was planted in South and Southeast Asia. Western and Central Africa was the second subregion in terms of area deforested for oil palm production, with an estimate of 550 000 ha of forest converted to oil palm in 2000–2018. In South America, Central America and Oceania, the area deforested for oil palm production ranged from around 100 000 ha to 200 000 ha (see Figure 35).

**Figure 35. Top 6 ecoregions for Oil palm expansion (000 ha) on forest area in 2000–2018**




## What are the main drivers of deforestation in the different biomes?

The causes of deforestation were quite different according to biome (Figure 36).

Of the **tropical** forest losses, 92.4 percent were caused by agriculture in 2000–2018. Tropical forest was principally cleared for crop production (52.6 percent, representing 82 Mha), followed by for livestock production (39.7 percent, corresponding to 61.9 Mha).

**In the subtropical biome,** urban and infrastructure development, as well as clearing for pasture and expansion of croplands, each caused about 30 percent of the deforestation in 2000–2018, accounting for losses respectively of 2.3, 2.1 and 2.1 Mha (see Figure 36 and Table 26).

The loss of **temperate** forests in 2000–2018 was mainly driven by cropland expansion (1.7 Mha) and urban development (1.6 Mha) (see Figure 36 and Table 26).

**Boreal** deforestation was led by urban and infrastructure development, which caused the clearing of 1.9 Mha of forest in the period, representing 36 percent of the total deforested area. Livestock production constituted the second most important deforestation driver in the boreal biome (29 percent, corresponding to 1.5 Mha). Furthermore, boreal biomes registered the highest conversion share of forest to water bodies (26 percent, corresponding to 1.35 Mha. However the absolute area converted was higher in the tropics, representing 1.53 Mha and 1 percent of the total changes (see Figure 36).

**Figure 36. Area (Mha) and proportion of Drivers of deforestation by FAO climatic domains in 2000–2018**

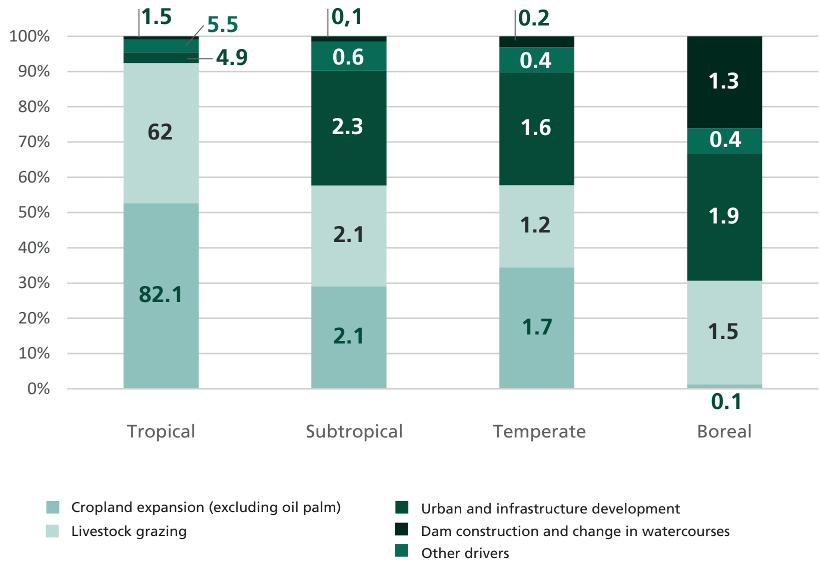


**Table 26. Direct deforestation drivers (000 ha/year), and as a proportion of total deforestation by Global Ecological Zones and FAO climatic domains in 2000–2018**

| GEZ and FAO Climatic domains (1 000 ha/ year) | Cropland expansion (excluding oil palm) | % | Oil palm | % | Livestock grazing | % | Urban and infrastructure development | % | Other drivers | % | Dam construction and change in watercourses | % | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tropical rainforest | 1 416.3 | 37 | 621.9 | 16 | 1 554.9 | 41 | 135.8 | 4 | 60.8 | 2 | 49.0 | 1 | 3 838.7 |
| Tropical moist forest | 1 391.2 | 54 | 2.3 | 0 | 1 002.3 | 39 | 69.7 | 3 | 73.2 | 3 | 19.9 | 1 | 2 558.7 |
| Tropical dry forest | 854.6 | 47 | 3.1 | 0 | 759.4 | 42 | 53.7 | 3 | 140.2 | 8 | 7.8 | 0 | 1 818.7 |
| Tropical shrubland | 97.8 | 65 | 0.0 | 0 | 33.5 | 22 | 4.1 | 3 | 15.2 | 10 | 0.3 | 0 | 150.9 |
| Tropical desert | 0.1 | 22 | 0.0 | 0 | 0.1 | 48 | 0.0 | 11 | 0.0 | 14 | 0.0 | 5 | 0.3 |
| Tropical mountain system | 169.3 | 58 | 2.1 | 1 | 87.5 | 30 | 6.7 | 2 | 18.0 | 6 | 7.4 | 3 | 291.0 |
| Tropicals | 3 929.2 | 45 | 629.3 | 7 | 3 437.8 | 40 | 270.0 | 3 | 307.6 | 4 | 84.4 | 1 | 8 658.3 |
| Subtropical humid forest | 73.3 | 28 | 0.0 | 0 | 69.2 | 26 | 98.4 | 38 | 15.5 | 6 | 5.8 | 2 | 262.1 |
| Subtropical dry forest | 7.3 | 26 | 0.0 | 0 | 4.5 | 16 | 6.6 | 24 | 9.0 | 32 | 0.5 | 2 | 27.8 |
| Subtropical steppe | 12.0 | 30 | 0.0 | 0 | 14.1 | 35 | 13.3 | 33 | 1.0 | 3 | 0.1 | 0 | 40.6 |
| Subtropical desert | 0.9 | 6 | 0.0 | 0 | 12.5 | 85 | 0.0 | 0 | 1.3 | 9 | 0.0 | 0 | 14.7 |
| Subtropical mountain system | 23.2 | 41 | 0.0 | 0 | 14.6 | 26 | 12.1 | 22 | 6.2 | 11 | 0.0 | 0 | 56.1 |
| Subtropicals | 116.8 | 29 | 0.0 | 0 | 114.8 | 29 | 130.4 | 32 | 33.0 | 8 | 6.4 | 2 | 401.4 |
| Temperate oceanic forest | 5.1 | 33 | 0.0 | 0 | 3.2 | 21 | 3.5 | 23 | 3.4 | 22 | 0.1 | 0 | 15.3 |
| Temperate continental forest | 68.5 | 45 | 0.0 | 0 | 18.9 | 12 | 55.3 | 36 | 10.2 | 7 | 0.0 | 0 | 152.9 |
| Temperate steppe | 16.1 | 36 | 0.0 | 0 | 18.0 | 40 | 1.4 | 3 | 1.0 | 2 | 8.3 | 18 | 44.8 |
| Temperate desert | 1.4 | 18 | 0.0 | 0 | 1.9 | 24 | 1.8 | 23 | 2.8 | 35 | 0.1 | 1 | 8.0 |
| Temperate mountain system | 5.1 | 9 | 0.0 | 0 | 23.1 | 39 | 27.4 | 47 | 2.6 | 4 | 0.4 | 1 | 58.5 |
| Temperates | 96.2 | 34 | 0.0 | 0 | 65.2 | 23 | 89.4 | 32 | 20.0 | 7 | 8.7 | 3 | 279.6 |
| Boreal coniferous forest | 3.2 | 2 | 0.0 | 0 | 2.9 | 2 | 91.1 | 57 | 3.2 | 2 | 59.7 | 37 | 160.1 |
| Boreal tundra woodland | 0.0 | 0 | 0.0 | 0 | 58.0 | 77 | 0.0 | 0 | 2.2 | 3 | 15.0 | 20 | 75.2 |
| Boreal mountain system | 0.3 | 1 | 0.0 | 0 | 23.4 | 45 | 12.6 | 24 | 15.1 | 29 | 0.2 | 0 | 51.6 |
| Boreal | 3.5 | 1 | 0.0 | 0 | 84.3 | 29 | 103.6 | 36 | 20.5 | 7 | 74.9 | 26 | 286.8 |
| Polar | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 100 | 0.0 | 0 | 0.0 |
| World | 4 145.7 | 43 | 629.3 | 7 | 3 702.6 | 38 | 593.5 | 6 | 381.2 | 4 | 175.6 | 2 | 9 627.9 |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

# 5 Discussion and conclusions

## 5.1 WHAT MAKES THE SURVEY USEFUL, WHAT DOES IT BRING THAT IS NEW?

The FRA 2020 Remote Sensing Survey provides a picture of the status and trends of the world's forests from 2000 to 2018 using a **consistent methodology** combined with the participation of a global network of photointerpreters with local field knowledge. The survey contributes to improved understanding of forest area trends and of the processes driving forest cover change, both globally and regionally, as well as by ecological zone.

BOX 4

**Summary of key figures from the FRA 2020 Remote Sensing Survey**

- The world's forest area covered 3.97 billion ha in 2018, i.e. 30.8 percent of the global land area. Naturally regenerating forests accounted for 93 percent of the total forest area, with the remaining 7 percent being planted forest. Of the global forest area, 5 percent was temporarily unstocked.
- The FRA 2020 Remote Sensing Survey confirms a slowdown in global deforestation. Annual deforestation decreased by around 29 percent in 2010–2018 compared with 2000–2010 (from 11 Mha/year to 7.8 Mha/year). Conversely, global annual forest area expansion showed a slight increase, from 4.2 Mha/year in the period 2000–2010 to 4.7 Mha/year in the period 2010–2018.
- Net forest area losses more than halved between the first and second periods studied, decreasing from 6.8 Mha/year in 2000–2010 to 3.1 Mha/year in 2010–2018.
- At regional level, the highest deforested area in 2000–2018 was found in South America, where it reached 68 Mha. It was followed by Africa, with 49 Mha of total deforestation.
- Tropical forests registered more than 90 percent of global deforestation from 2000 to 2018, accounting for 157 Mha. However, annual deforestation in the tropical domain declined substantially, from 10.1 Mha/year to 7 Mha/year, when comparing the period 2000–2010 with 2010–2018.
- Combining global ecological zones and subregions for the period 2000–2018, deforestation was highest in the tropical rainforest of South America, as well as in the tropical rainforest of South and Southeast Asia.
- The tropical ecoregions of Central America are the ecoregions most severely threatened by land-use conversion: 30.3 percent of forest in the Central America tropical moist ecoregion and 25.2 percent of Central American tropical rainforest were lost in 2000–2018. Similar phenomena were detected in Central American tropical dry forest and Central American tropical shrubland, but given the small size of the sample in these ecoregions, further investigations are required to confirm this.
- Cropland expansion (including oil palm plantations) is the main driver of deforestation, causing almost 50 percent of global deforestation, followed by livestock grazing, accounting for 38.5 percent. Overall, agricultural expansion, which includes these two drivers, is responsible for almost 90 percent of deforestation worldwide. Oil palm alone accounted for 7 percent of global deforestation in 2000–2018.

- Of the planted forest in 2018, 82 percent was established before 2000. During the period 2000–2018, 46 Mha of new planted forest area were established. One-quarter of those new planted forests, corresponding to 11 Mha, was established after clearing naturally regenerating forests, with half of this area in the South and Southeast Asia ecoregion.
- Integrating knowledge from national experts, the Remote Sensing Survey also produced estimates of Other Wooded Land (OWL) and other land with tree cover area. OWL accounted for around 13 percent of global land area in 2018 (1 701 Mha), while 26 percent of all other land (1 261 Mha) had more than 10 percent of tree cover.

The survey provides robust remote-sensing based estimates of **forest area expansion and deforestation, and enables the detection of where those change occurred.**

Particularly importantly, the survey sheds new light on **how forest area is changing by ecological zones**, demonstrating which forest ecosystems are the most threatened and require particular attention and conservation measures.

Furthermore, the survey provides updated information on the **drivers of deforestation and forest changes at both global and regional level**. Previous analyses of deforestation drivers are either outdated or only partially covered the world's forests (Hosonuma *et al*., 2012; Curtis *et al*., 2018; Pendrill *et al*., 2019; Hoang and Kanemoto, 2021; Jayathilake *et al*., 2021). For example, the analysis by Hosonuma *et al*. (2012) was based on data from 46 tropical and subtropical countries covering the periods 2005–2010 or 2000–2010.

The Remote Sensing Survey also suggests that **the areas of Other Wooded Land** and **other land with tree cover** are significantly higher than previously thought. The differences are likely to be due to two reasons. First, many countries face challenges reporting on OWL area due to the difficulties in monitoring areas that have low tree-canopy cover. Second, the reporting coverage of FRA 2020 on other land with tree cover was low, which resulted in the area under this category being underestimated.

The survey produced new estimates for the area of **naturally regenerating forest replaced with planted forest**. Although these estimates need to be interpreted with care due to the difficulty in separating naturally regenerating and planted forests in certain conditions, the results can nevertheless help to understand global and regional dynamics of the conversion of naturally regenerating forests to planted forests.

In addition, the survey provided new estimates for **unstocked forest area**, which can help in understanding differences between the forest area estimates derived using various land use and land cover products.

When compared with other available datasets, such as data from other mapping products and FRA results, the survey findings can be used as an additional source for data **cross-checks** at regional and global levels.

Most importantly, the FRA 2020 RSS results can be used by governments, researchers and civil society to make better informed **decisions** regarding the world's forest resources.

## 5.2 HOW DO THE RESULTS OF THE REMOTE SENSING SURVEY COMPARE WITH FRA REPORTING RESULTS AND OTHER SPATIAL GLOBAL DATASETS?

While the FAO Global Forest Resources Assessment (FRA) relies on official national statistics reported through national correspondents formally nominated by countries, the results presented here have been produced through an independent process which does not have a similar formal standing. RSS should be seen as a complementary data source, at regional and global levels, which allows confirmation of some of the results collected in FRA reporting, provides new information on variables that are not part of the FRA questionnaire, and enables regions to be identified where these two data sources are in disagreement and where further analysis on data quality and coverage should be carried out.

Some of the results of the FRA 2020 Remote Sensing Survey were compared with those of FRA 2020 reporting, the FRA 2010 Remote Sensing Survey, and other sources, including the following global geospatial datasets (see Table 27).

**Table 27. List of geospatial datasets used for comparison with FRA 2020 Remote Sensing Survey data**

| Dataset | Source |
|---|---|
| Global Forest Change 2000–2018 (UMD tree cover) (Hansen et al., 2013) | https://glad.earthengine.app/view/global-forest-change#dl=1;old=off;bl=off;lon=20;lat=10;zoom=3 |
| GlobeLand30 2000 and 2010 | www.globallandcover.com/Page/EN_sysFrame/dataIntroduce.html?columnID=81&head=product&para=product&type=data |
| Global PALSAR-2/PALSAR Forest/Non-Forest Map | https://earth.jaxa.jp/en/data/2555/index.html |
| MODIS Land cover map MCD12Q1 | https://modis.gsfc.nasa.gov/data/dataprod/mod12.php |
| Copernicus Global Land Cover | https://land.copernicus.eu/global/products/lc |
| ESA WorldCover 10 m 2020 | https://esa-worldcover.org/en |
| ESRI 2020 Land Cover | www.arcgis.com/home/item.html?id=d6642f8a4f6d4685a24ae2dc0c73d4ac |
| ESA CCI Global land cover | www.esa-landcover-cci.org/?q=node/197 |

*Source*: Compiled by authors from sources listed in the table.

## 5.3 COMPARISON OF FOREST AREA AT GLOBAL LEVEL AND REGIONAL LEVEL

### FRA 2020 Remote Sensing Survey versus other FAO estimates

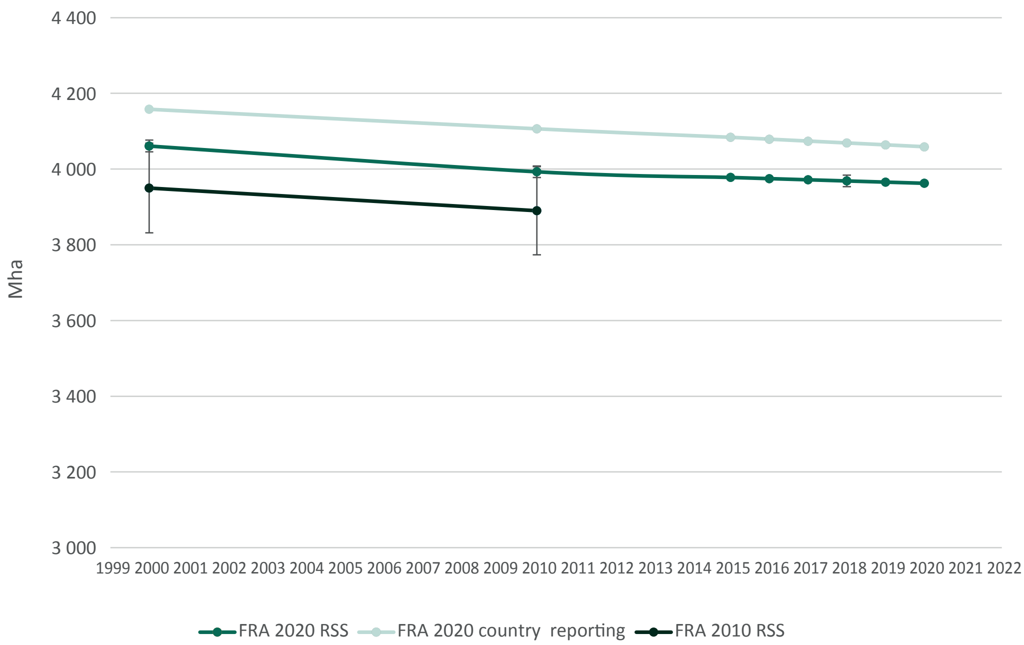
Figure 37 shows the comparison between different FAO estimates of the world's forest area for the reference years 2000, 2010 and 2018. All comparisons were done between the absolute values without calibration to harmonized total land area. When available, 95 percent confidence intervals are also displayed on the graph. An overlap of the confidence intervals implies that the difference in the estimates is statistically insignificant. If the confidence intervals do not overlap, then the estimates are significantly different. Confidence intervals are not available for the estimates derived from the FRA 2020 country reporting process.

Estimates of global forest area from the FRA 2020 Remote Sensing Survey are in the same range as those of FRA 2020 country reporting (FAO, 2020b) and the FRA 2010

Remote Sensing Survey (for years 2000 and 2010). However, while the estimates of the FRA 2010 RSS (FAO, 2010) are statistically comparable with those from the FRA 2020 Remote Sensing Survey, FRA 2020 country reporting gives higher global forest area for all the years than the estimates from the FRA 2020 RSS.

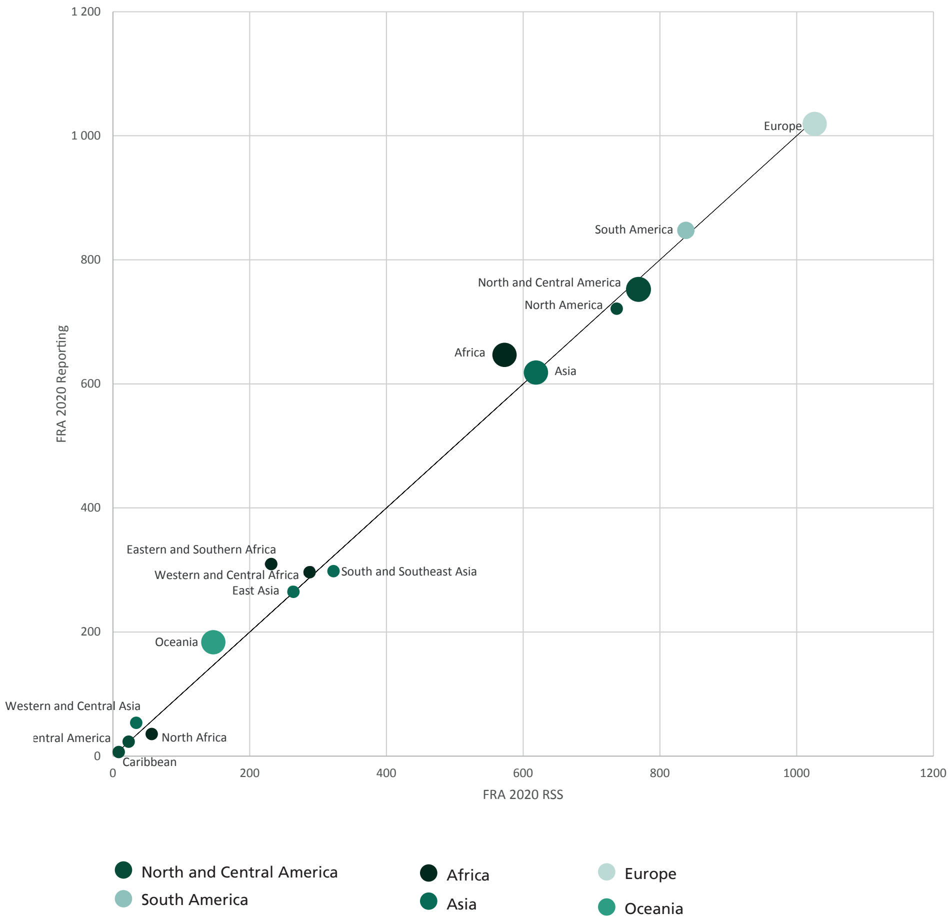
As indicated in Figure 38, most of the differences between FRA 2020 country reporting and Remote Sensing Survey estimates are due to a few regions and subregions. The graph (see Figure 38) identifies those regions and subregions where the FRA 2020 country reporting forest area estimates for 2018 are similar to the FRA RSS estimate (close to the straight line), higher (above the line), or lower (below the line). The majority of the regions and subregions are very close to the line, demonstrating similarity of the forest area estimates, with the exception of Africa and Oceania, for which estimates from the FRA 2020 Remote Sensing Survey are lower than those calculated from FRA 2020 country reporting. Most of the forest area difference in Africa is due to Eastern and Southern Africa. The differences observed there, and in Oceania, may be due to weaknesses in some of the data reported to FRA, as well as to difficulty in identifying open forest formations, and in separating shrubs from trees on satellite imagery in the Remote Sensing Survey.

**Figure 37. Comparison of global forest area estimates from FAO remote sensing surveys and FRA 2020 country reporting (Mha)**




*Note*: 95 percent confidence intervals are displayed on the graph, when available. Forest area in 2018 for FRA 2020 country reporting was calculated through linear interpolation of forest area estimates in 2015 and 2020.

**Figure 38. Comparison of regional and subregional forest area estimates in 2018 from FRA 2020 remote sensing survey and FRA 2020 country reporting (Mha)**



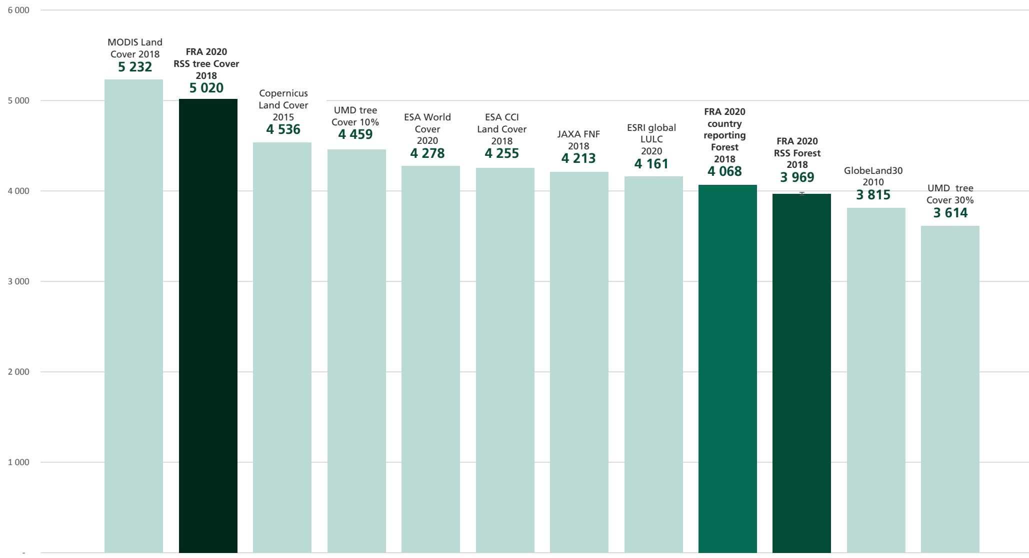

*Note*: The graph compares forest area estimates for 2018 from FRA 2020 Remote Sensing Survey and FRA 2020 country reporting. Forest area in 2018 for FRA 2020 country reporting was calculated through linear interpolation of forest area estimates in 2015 and 2020. Dots close to the right line mean similar estimates; dots below the line indicate higher estimates from the FRA 2020 RSS compared with country reporting; dots above the line indicate smaller estimates from the FRA 2020 RSS compared with country reporting.

## FRA 2020 Remote Sensing Survey versus other global geospatial datasets

The FRA 2020 RSS forest and tree cover area estimates were also compared with those generated from other global land cover and land-use geospatial datasets (listed in Table 27) available for 2018 (see Figure 39). Comparison between these datasets shows a high variability in the estimates of forest area, which range from 3 614 Mha to 5 232 Mha.

The difference in forest area/tree cover estimates can be explained by the various methodological differences, including satellite sensors used, image resolution, classification scheme applied, study year(s), and image analysis method. However, the high variability also demonstrates that estimating forest area globally in a consistent way remains a scientific challenge.

**Figure 39. Comparison of global forest and tree cover area estimates from different global datasets around the year 2018 (Mha)**




The emphasis placed on integrating local expert knowledge in the analysis, as well as in consistently using FRA land-use classes, results in closer estimates between FRA 2020 country reporting and FRA 2020 RSS compared with most of the other products. All datasets, except the Global Forest Change estimate, calculated using a 30 percent tree cover threshold, and GlobeLand 30 2010, give higher global forest area estimates (see Figure 39). One reason for this is that most of the remote sensing-based products monitor tree cover and not 'forest' land use. Hence, these products classify areas of tree crops and other agroforestry systems with tree cover as 'forest', which leads to overestimating forest area. This is confirmed by the high tree cover area estimate of the FRA 2020 RSS, calculated using all samples with more than 10 percent tree cover. This estimate is substantially higher than the Remote Sensing Survey forest area estimate.

The level of variability between the sources depends on the regions and forest types, as can also be seen in Table 28, which gives a few statistical measures of variability between regional and global estimates derived from the different datasets.

The highest variability, as expressed by the standard error, is observed in Africa and Oceania (highest standard errors). This reflects the challenges in data availability and quality, as well as in estimating forest area using remote sensing in these areas.

**Table 28. Statistical measures of variability in forest area estimates between the global datasets by region and for the world**

| Region | Minimum (Mha) | Maximum (Mha) | Average (Mha) | Median (Mha) | Standard deviation (Mha) | Standard error of the mean (Mha) | Standard error % |
|---|---|---|---|---|---|---|---|
| North and Central America | 670 | 1 033 | 805 | 803 | 95.8 | 26.6 | 3% |
| South America | 766 | 1 120 | 887 | 859 | 94.3 | 26.2 | 3% |
| Europe | 881 | 1 252 | 1 066 | 1 029 | 102.2 | 28.3 | 3% |
| Africa | 513 | 1 018 | 722 | 711 | 158.9 | 42.5 | 6% |
| Asia | 531 | 864 | 670 | 654 | 101.0 | 28.0 | 4% |
| Oceania | 93 | 232 | 170 | 177 | 39.1 | 10.9 | 6% |
| World | 3 614 | 5 232 | 4 323 | 4 255 | 450.8 | 125.0 | 3% |

*Note:* Cropland and Grassland estimates presented here are not comparable with those of FAOSTAT (see Box 2).

## 5.4 COMPARISON OF FOREST AREA CHANGE AT GLOBAL LEVEL AND REGIONAL LEVEL

When comparing the FRA 2020 Remote Sensing Survey with other datasets, differences in forest area changes are more pronounced than those in forest areas.

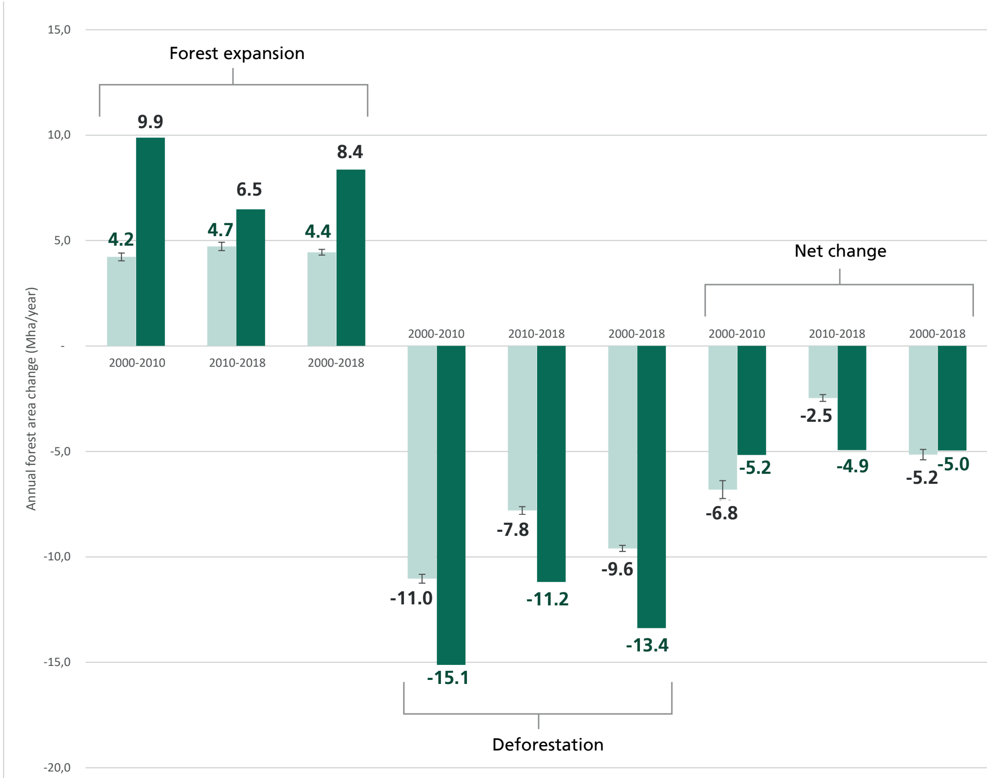
**FRA 2020 Remote Sensing Survey versus country reporting estimates**

Comparison of estimates for the forest area net change, forest area expansion and deforestation between the FRA 2020 Remote Sensing Survey and results based on the FRA 2020 country reporting reveal that while their global annual forest area net change estimates are comparable for the period 2000–2018, all other estimates are statistically different. Global net loss estimates are higher for the period 2000–2010 in the FRA 2020 Remote Sensing Survey compared with FRA 2020 country reporting results, but lower in the second period 2010–2018. Both annual forest area expansion and deforestation estimates are lower in the FRA 2020 Remote Sensing Survey compared with FRA country reporting estimates in all studied periods. Annual deforestation is about one-third lower throughout all periods. Differences in annual forest gain are also large, especially for the period 2000–2010, where RSS estimates are only about half of those reported by countries in FRA 2020.

The analysis at regional and subregional levels (see Figure 41, Figure 42 and Figure 43) shows that annual forest area expansion estimates in 2000–2018 are lower in most of the regions and subregions. The difference in Asia is notably high, with estimates three times lower in the FRA 2020 Remote Sensing Survey compared with country reporting, and accounting for most of the difference. The FRA 2020 RSS also gives lower estimates of annual deforestation in 2010–2018 in Asia, South America and Oceania, and higher estimates in North and Central America. For forest area net changes, the FRA 2020 RSS gives net losses in Asia, while the country reporting showed net forest area expansion in the region. Net losses estimated by FRA 2020 RSS for Africa and America are lower compared with country reporting.

The reasons behind these differences may be the following: a) forest area net changes estimates are more reliable than deforestation and forest area expansion estimates in FRA country reporting, due to lack of specific data on deforestation and forest area expansion in many countries; b) country-reported trend estimates are based on extrapolation from past and potentially outdated trend data; c) reported forest area expansion figures may include restoration in forestland, as well as areas where the afforestation efforts were unsuccessful; and d) recently afforested areas may be difficult to identify on satellite imagery due to the small size of trees.

**Figure 40. Comparison of global annual forest area changes estimates (forest area net change, deforestation and forest area expansion) (Mha/year) between FRA 2020 Remote Sensing Survey and FRA 2020 country reporting in 2000–2010, 2010–2018 and 2000–2018**




*Note*: FRA 2020 estimates for the 2010–2018 period were calculated as weighted average of the 2010–2015 annual change rate and three years of the 2015–2020 annual change rate. When available, 95% confidence intervals are also displayed on the graph.

**Figure 41. Comparison of regional and subregional annual forest area expansion estimates (Mha/year) between FRA 2020 Remote Sensing Survey and FRA 2020 country reporting in 2000–2018**

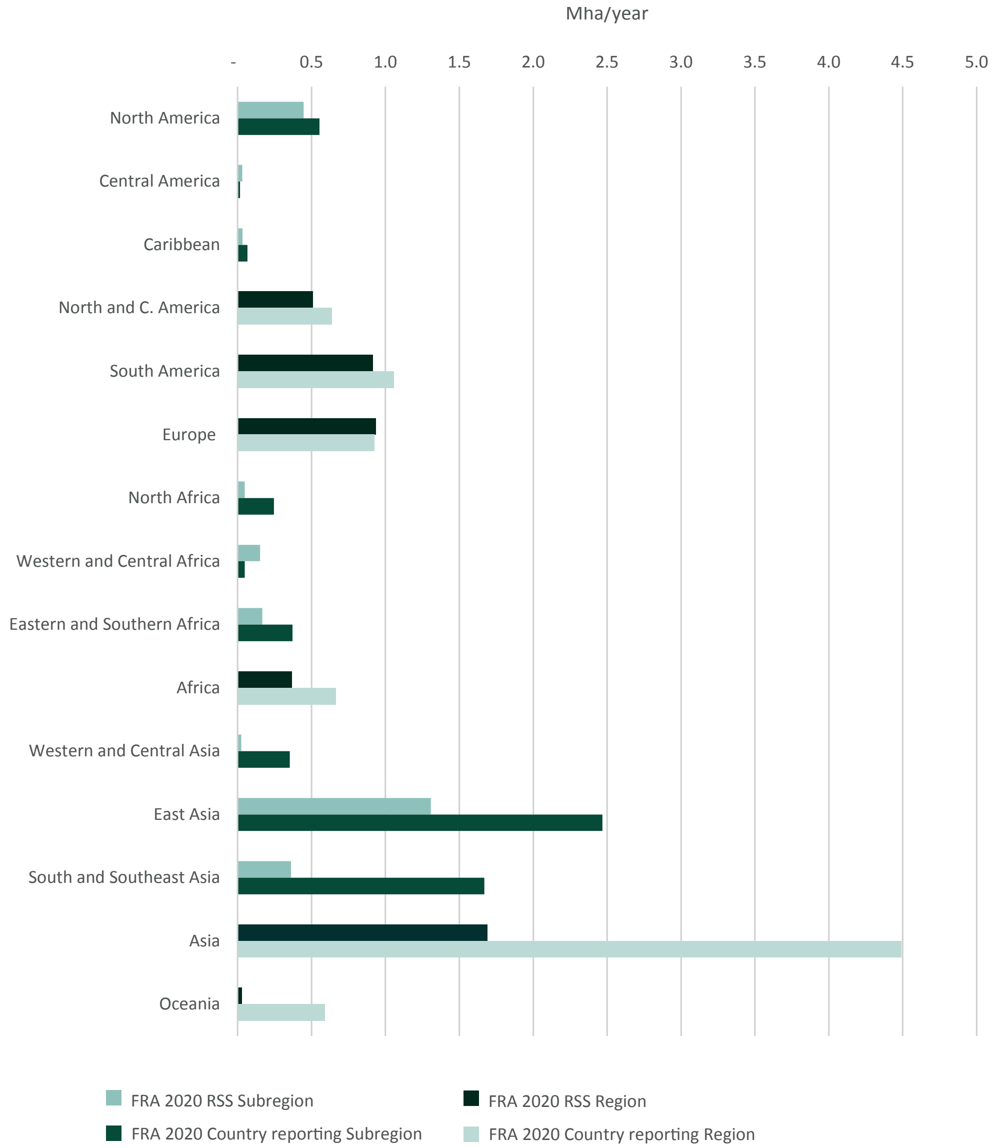


**Figure 42. Comparison of regional and subregional annual deforestation estimates (Mha/year) between FRA 2020 Remote Sensing Survey and FRA 2020 country reporting in 2000–2018 (Mha/year)**

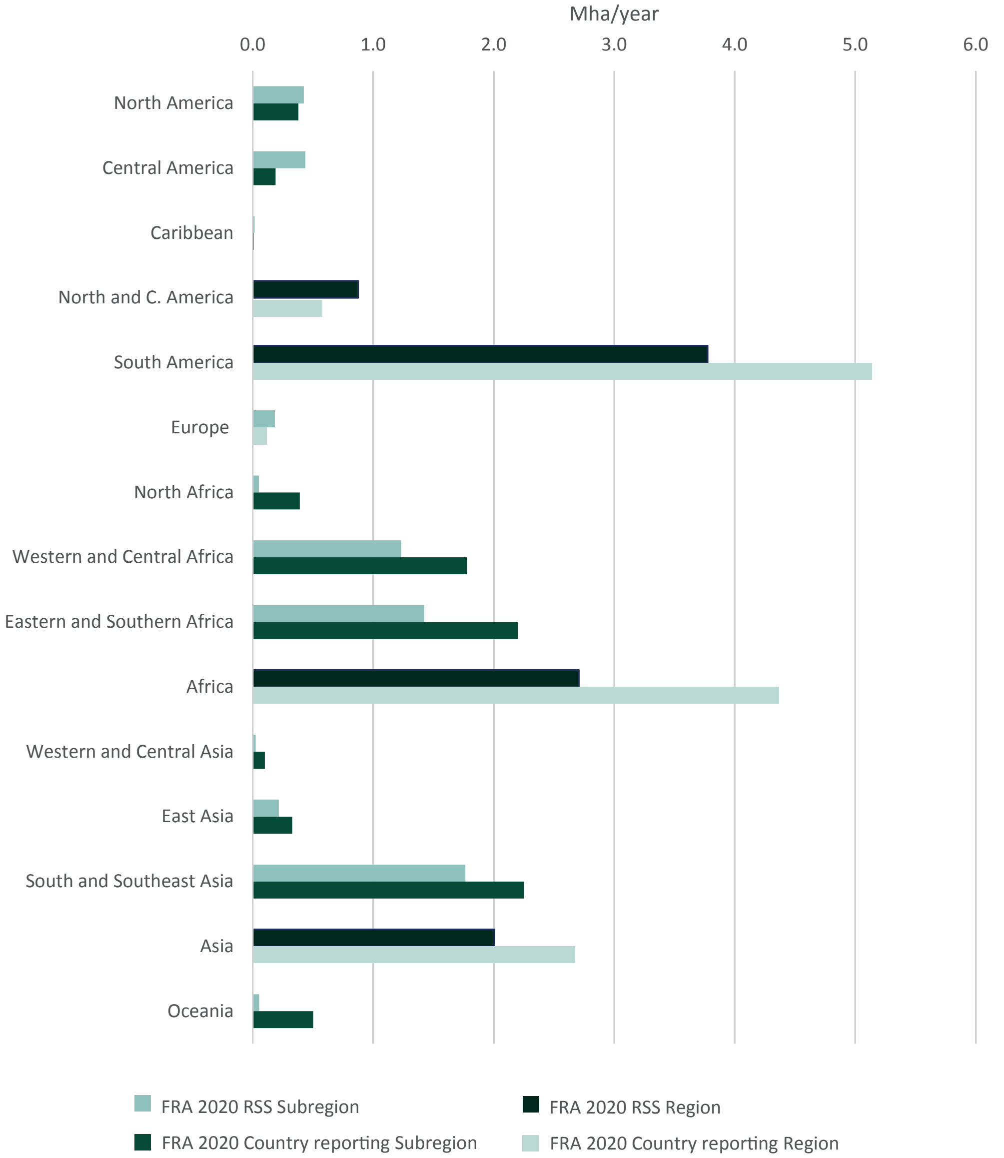
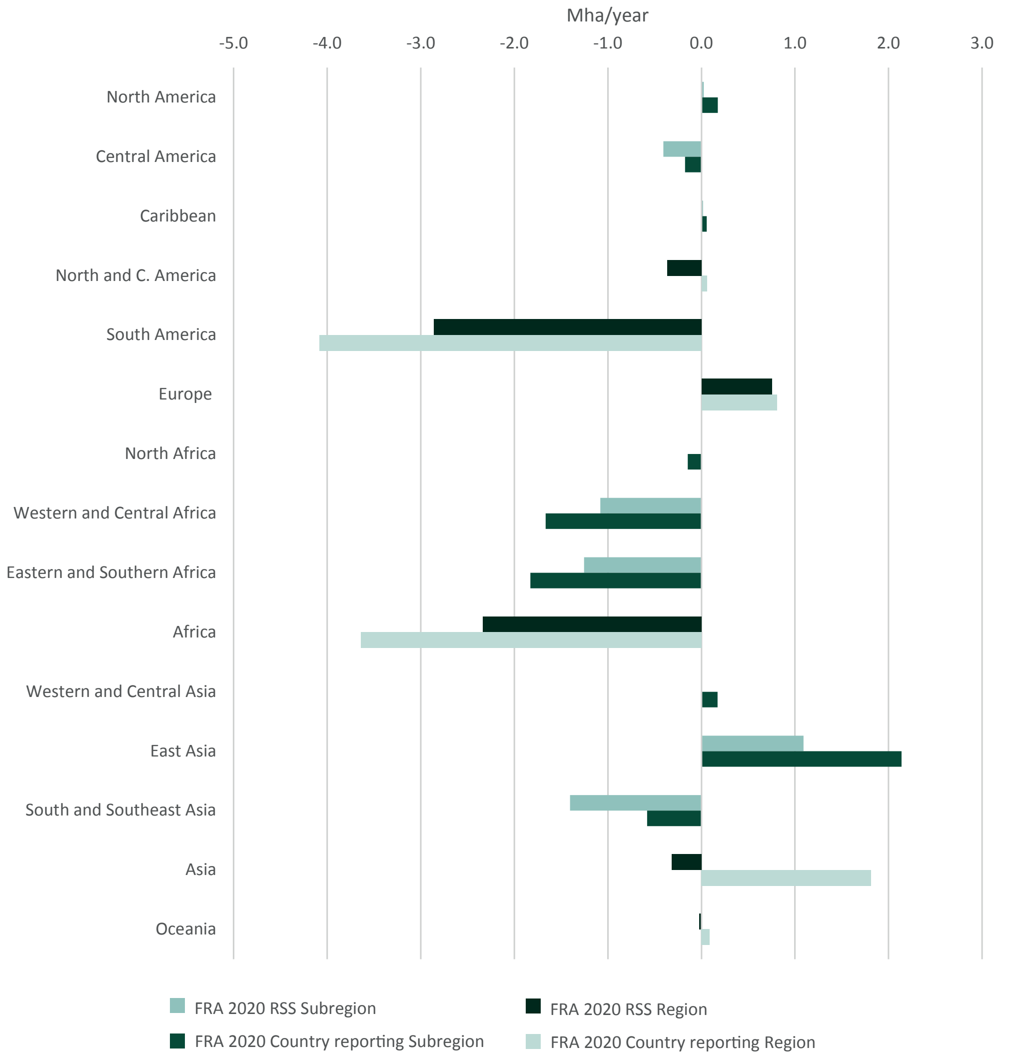


**Figure 43. Comparison of regional and subregional annual forest area net change estimates (Mha/year) between FRA 2020 Remote Sensing Survey and FRA 2020 country reporting in 2000–2018**




### FRA 2020 Remote Sensing Survey versus other global spatial datasets

The level of discrepancy is much higher for global change estimates than for forest area estimates, as indicated in Table 29, which compares the forest area change estimates from the FRA 2020 Remote Sensing Survey and other datasets. Global annual forest area net change estimates in 2000–2010 range from 0.8 Mha/year (MODIS Land cover map) to -47 Mha/year (GlobeLand 30). The difference between the Global Forest Watch forest loss dataset and FRA 2020 RSS estimates on deforestation is quite low in the first period studied 2000–2010, but very high in the second period studied 2010–2018. The high values in Global Forest Watch Tree cover 10% in the second period are probably linked to methodological changes introduced after 2015, which affect the data series consistency (Ceccherini *et al.*, 2020).

**Table 29. Annual global forest change estimates (Mha/year) from different datasets in 2000–2010, 2010–2018 and 2000–2018**

| Datasets | Forest area expansion | | | Deforestation | | | Forest area net change | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000–2010 | 2010–2018 | 2000–2018 | 2000–2010 | 2010–2018 | 2000–2018 | 2000–2010 | 2010–2018 | 2000–2018 |
| FRA 2020 RSS | 4.2 (+/-0.2) | 4.7 (+/-0.2) | 4.4 (+/-0.1) | -11.0 (+/-0.2) | -7.8 (+/-0.2) | -9.6 (+/-0.1) | -6.8 (+/-0.4) | -2.5 (+/-0.2) | -5.2 (+/-0.2) |
| FRA 2020 country reporting | 9.9 | 6.5 | 8.4 | -15.1 | -11.2 | -13.4 | -5.2 | -4.9 | -5.0 |
| FRA 2010 RSS | 10.2 | | | -15.5 | | | -6.0 | | |
| UMD Global Forest Change (tree cover 10%) | | | | -18.2 | -32.6 | -24.6 | | | |
| GlobeLand30 | | | | | | | -47.0 | | |
| Modis Land cover map | | | | | | | 0.8 | | 0.01 |
| ESA CCI Land cover | | | | | | | -0.2 | -0.4 | -0.2 |

Note: FRA 2020 country reporting estimates for the 2010–2018 period were calculated as weighted average of the 2010–2015 annual change rate and three years of the 2015–2020 annual change rate. When available, 95% confidence intervals are also displayed on the graph.

## 5.5 COMPARISON OF OTHER VARIABLES

**Other Wooded Land** area estimates are much higher, almost double, in the FRA 2020 Remote Sensing Survey compared with results based on FRA 2020 country reporting (see Figure 44). Difficulties in assessing tree canopy cover ,ranging from 5-10 percent, and the lack of reliable country data in this land category largely explains this difference. Estimates from other spatial datasets show very high variability, ranging from 937 Mha (GlobeLand30) to nearly 5 billion ha (ESRI global LULC). The FRA 2020 RSS estimates represent the second highest value.

**Figure 44. Comparison of global Other Wooded Land (OWL) area estimates (Mha) from different global datasets around the year 2018**

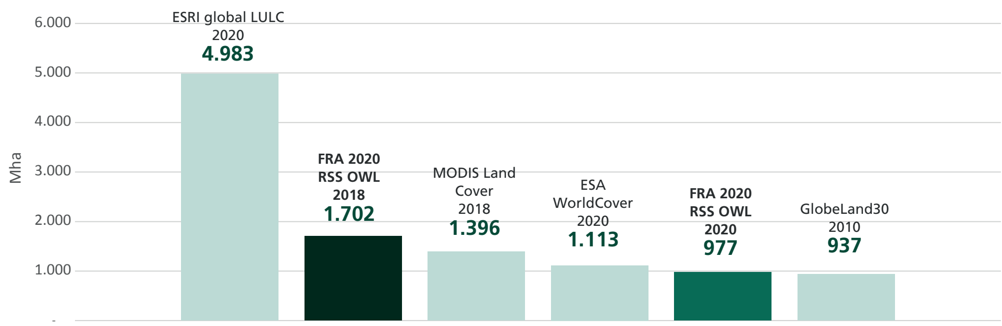


**Table 30. Statistical measures of variability in OWL area estimates (mha) between the global datasets by Region and for the world**

| Region | Minimum (Mha) | Maximum (Mha) | Average (Mha) | Median (Mha) | Standard deviation (Mha) | Standard error of the mean (Mha) | Standard error % |
|---|---|---|---|---|---|---|---|
| North and Central America | 91 | 779 | 319 | 265 | 242.0 | 98.8 | 31% |
| South America | 88 | 519 | 226 | 183 | 151.6 | 61.9 | 27% |
| Europe | 29 | 529 | 206 | 142 | 196.2 | 80.1 | 39% |
| Africa | 196 | 1 327 | 524 | 427 | 416.1 | 169.9 | 32% |
| Asia | 50 | 1 260 | 309 | 137 | 471.0 | 192.3 | 62% |
| Oceania | 2 | 568 | 267 | 252 | 226.7 | 92.6 | 35% |
| World (Mha) | 937 | 4 983 | 1 851 | 1 255 | 1 560.9 | 637.2 | 34% |

Note: Datasets used in this analysis include FRA 2020 RSS OWL (2018), FRA 2020 Country reporting (2020), ESA WorldCover (2020), ESRI global LULC (2020), GlobeLand30 (2010), MODIS land cover (2018).

Similarly, **other land with tree cover estimates** are more than ten times greater in the FRA 2020 Remote Sensing Survey compared with what is reported in FRA 2020 country reporting, as most countries did not report on this subclass, which is likely to be substantially underreported. However, more research on this topic is needed to confirm the estimates presented here.

## 5.6 WHAT ARE THE STRENGTHS AND WEAKNESSES OF THE APPROACH, AND POSSIBLE IMPROVEMENTS?

The strengths and weaknesses of the FRA 2020 Remote Sensing Survey approach are inherent in the use of a remote sensing-based methodology combined with the participation of a global network of experts with local field knowledge and the use of an online tool for visual photointerpretation.

The methodology brings together a **complete and consistent dataset over time and between regions**. The use of visual interpretation and time series of remote sensing data with a focus on forest change analysis allowed the use of a consistent methodology to derive the change estimates and to avoid false changes resulting from variation in the applied method or the imagery (for example, due to seasonality, different sensor or spatial resolution of the image). Globally, all the remote sensing data were acquired for the same reference years (2000, 2010 and 2018), avoiding any use of models for projection through interpolation and extrapolation, and their associated uncertainties. Moreover, remote sensing data were processed uniformly. The same tools and methods were applied for the visual analysis of all samples, and all experts involved in the photointerpretation of the satellite imagery were trained in the same manner, enabling the way that they analysed the imagery to be standardized. An exception to this rule was for the samples located in Australia and Canada, where the results had to be generated in a different manner. As a result, these had to be carefully quality checked.

The analysis was based on **best freely available satellite data** for the reference years. This was facilitated by the use of cloud-free composites derived using images from Landsat and Sentinel archives. High-resolution satellite images available on Google Earth and Planet, Mapbox, DigitalGlobe and Bing Maps images available through the Collect Earth Online platform, were used as an additional source of information to enhance the quality of the photointerpretation. In some areas of the world, where the quality of the available Landsat and Sentinel imagery was not sufficient (for example, where cloud cover is constant, such as northern Brazil or some countries on the Atlantic coast in the Western and Central Africa region), they were the primary source of information for the analysis.

The applied **statistical sampling design** proved to be efficient and was a notable improvement compared with previous FRA remote sensing surveys, with a 95 percent confidence interval with ±0.4 percent margin of error for forest area estimates and ±2 percent margin of error for forest area change at the global level. This is better than the previous FRA 2010 Remote Sensing Survey, which gave a ±3 percent margin of error for forest area at the same level. In the FRA 2000 Remote Sensing Survey, the margin of error for pan-tropical forest area estimate was around 8 percent. Further improvements are likely to be achieved not so much by increasing the sampling intensity, but rather by further enhancing the sampling design, as well as the quality of photointerpretation.

The use of both square and hexagon samples allowed comparison of the statistics obtained from both sampling unit designs. Our preliminary analysis of the differences of these two approaches showed that the 40 ha hexagon gave statistically more precise forest and forest area change estimates than the 1 ha square. However, a more detailed analysis is currently under way and will be published later.

**The participation of more than 800 national experts from 126 countries** with local field knowledge was a unique asset: it incorporated a comprehensive and global source of field knowledge on local vegetation, land uses and land-use dynamics in the analysis process. However, it should be noted that even with local expertise, photointerpretation can be difficult in some areas, particularly in dry ecological zones, where forests are open, have low canopy cover or tree height, or where there are crops under tree cover (such as cocoa and coffee), which cannot be observed with satellite imagery. Ideally, additional ground truthing would be required to support photointerpretation in areas with high uncertainties, which could not be carried out during this survey.

The survey also notably contributed to **capacity-building**. A total of 34 workshops were conducted by FAO from 2018 to 2021 to improve technical capacity for monitoring forest resources and using new online tools. Indeed, the global network of remote sensing specialists, brought together through this exercise, represents a powerful human resource for enhanced technical capacity and proficiency in countries.

## 5.7 WHAT'S NEXT?

The survey offers a mine of data for **in-depth spatial and statistical analysis** on forest trends and dynamics at different scales. Overlaid with other spatial datasets, or with complementary analysis and expert knowledge, it can provide further insight into direct and indirect factors causing deforestation. An additional analysis of the agricultural drivers of deforestation is already ongoing in order to understand if deforestation through agriculture is mainly due to smallholders, or is a result of large-scale investments.

Additional analysis will also be carried out to **explain further differences between the results based on the FRA country reporting process and those of the Remote Sensing Survey.**

Moreover, an expert meeting will be held on **lessons learned** from this survey and recommendations for improving the approach.

If countries choose and have the resources to do so, the methods have the potential for developing more detailed reporting capabilities at **national level**. By intensifying the sampling on a national or subnational scale, countries could produce statistically robust results that could be used to complement or cross-check their national statistics. These data could also be used to support reporting to international processes and conventions, and to inform national policy-makers, civil society and academia.

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# FRA 2020 Remote Sensing Survey

Since 1990, FAO FRA Remote Sensing Surveys have served as a complement to the country-based FRA reporting process. The fifth FAO FRA Remote Sensing Survey was started in 2018 as part of the Global Forest Resources Assessment 2020.

The Survey presents a clear and detailed picture of changes in forest-related land use and land cover at global and regional levels for the periods 2000–2010 and 2010–2018, as well as highlights the drivers of deforestation and the ecological zones it threatens.

The Survey is based on visual interpretation of more than 400 000 sample sites worldwide, using satellite images and Collect Earth Online, an open source cloud-based platform for land monitoring jointly developed by FAO and partners.

By providing information on where and why deforestation and forest area expansion are occurring this assessment will contribute to a better understanding of which forest ecosystems are the most threatened and the effectiveness, or otherwise, of area-based forest conservation measures currently in place.

European Commission
NICFI
Norway's International Climate and Forest Initiative

ISBN 978-92-5-136147-4 ISSN 0258-6150
9 789251 361474
CB9970EN/1/05.22