INTACT FOREST LANDSCAPES EXTENT AND CHANGE, 2000-2025

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SUMMARY

Forest wildlands, the roadless forest landscapes not affected by conversion and industrial resource extraction, are critical for reducing the risk of species and cultural extinctions and for mitigating climate change (Talty et al., 2020). Undisturbed natural forests store more carbon per unit area than degraded forests and tree plantations (Birdsey et al., 2025), and they continuously remove carbon from the atmosphere (Markuljaková et al., 2025). Forest wildlands provide habitats for the majority of native species and, due to the absence of roads, limit overhunting and poaching (Dietz et al., 2022; Quintana et al., 2022). These areas are home to forest-dwelling Indigenous cultures, whose livelihoods depend on large, unfragmented wilderness (Fa et al., 2020).

The Intact Forest Landscape (IFL) concept provides a framework to identify and track remaining forest wildlands, supporting their conservation, and ensuring transparency and public engagement (Yaroshenko et al., 2001; Potapov et al., 2008; 2017). The IFL concept has been widely used in research to understand biodiversity loss (Betts et al., 2017), declining forest resilience (Forzieri et al., 2022), and increasing carbon emissions due to forest loss and degradation (Friedlingstein et al., 2022) over the past two decades. The direct (Potapov et al., 2017) and indirect drivers (Kan et al., 2023) of IFL reduction have been systematically analyzed. The IFL concept has informed forest conservation science (Mackey et al., 2015; Watson et al., 2018). It has been incorporated into forest conservation policies, such as the High Conservation Value Forest protection standard of the Forest Stewardship Council (FSC, 2014; Motion 65) and the Primary and Intact Forest Landscapes Policy by the International Union for Conservation of Nature (IUCN 2020; Resolution WCC-2016-Res-045-EN). The IFL concept and dataset were also integrated into the Restricted Areas mapping for transition minerals mining (Greenpeace, 2025) and into a global screening layer of Critical Habitat developed by the United Nations Environment Programme World Conservation Monitoring Centre (Dunnet et al., 2025). The 2020 IFL map was used as a baseline dataset to develop the Joint Research Centre (JRC) Global Map of Forest Types 2020 in support of the application of the EU Regulation on deforestation-free supply chains (EUDR) (Bourgoin et al., 2024).

The global IFL map for the year 2000 was created under the leadership of Greenpeace, with financial support from the Global Forest Watch (GFW), an initiative of the World Resources Institute (WRI), and with technical and expert support from multiple national and international environmental organizations. The global IFL map was subsequently updated in 2013, 2016, 2020, and 2025 by the IFL Mapping Team with the support of Greenpeace, WRI, the University of Maryland, the Wildlife Conservation Society, and other organizations. The IFL data are distributed via the dedicated data portal www.intactforests.org and are freely available for all applications, including commercial use, under the terms of the Creative Commons Attribution 4.0 International license (CC BY 4.0), provided appropriate credit is given to the data source.

The area of IFLs remaining in 2025 is 1086.2 Mha, which makes up only 8.4% of the Earth's ice-free land area and includes 21% of the global tree cover. The largest tracts of intact forests are found in the Amazon and Congo River basins and in the northern boreal forests. Eleven countries (Brazil, Canada, Chile, Colombia, the Democratic Republic of the Congo, Indonesia, Papua New Guinea, Peru, Russia, the United States, and Venezuela) host more than 90% of the global IFL area. Most other countries that still retain IFL areas have only a small portion of their forests intact.

From 2000 to 2025, the global IFL area declined by 194.7 Mha (15.2%), an extent nearly equivalent to the land area of Mexico. The largest absolute IFL losses occurred in tropical South America and the boreal regions of Eurasia and North America, which accounted for 34%, 28%, and 18% of the total area reduction, respectively. During this period, Romania lost all its IFLs, while Nicaragua, Paraguay, and Solomon Islands lost more than 75% of their IFL area. The Central African Republic, Equatorial Guinea, Honduras, Laos, and Liberia lost more than half of their IFL area.

The average rate of IFL reduction during 2000-2025 was 8.1 Mha per year, equivalent to about 22,000 ha per day. The rate of IFL area reduction increased over time from 7 Mha per year before 2013 to 10 Mha per year after 2020. Over the last eight years, Russia experienced the largest increase in the annual IFL loss due to logging, oil and gas extraction, mining, and forest fires associated with industrial infrastructure. Other countries with substantial increases in annual IFL loss include Bolivia, Brazil, Canada, Colombia, the Democratic Republic of the Congo, Suriname, and Venezuela.

Our analysis of the direct drivers of IFL reduction highlights the increasing importance of forest fires associated with actively used infrastructure, oil and gas extraction and exploration, and mining between the 2000-2013 and 2000-2025 periods. The observed increase in forest fires is primarily driven by human-caused climate change and the road network expansion (Potapov et al., 2025). Timber extraction remains the main driver of IFL loss after fires. The importance of mineral resource exploration and extraction as an IFL fragmentation driver has increased, while agricultural expansion has decreased in importance over the last four years.

We project that the global year 2000 IFL area will be reduced by half by the 2080s. Temperate regions of North America and Eurasia may lose half of their year 2000 IFL area even sooner, by the 2050s. Australia, Bolivia, Cameroon, and Madagascar may lose half of their year 2000 IFL by 2030; Gabon, Guatemala, Myanmar, and Nigeria by 2040; and the Republic of the Congo by 2045. We further project that nine countries (the Central African Republic, Guatemala, Honduras, Liberia, Madagascar, Nepal, Nicaragua, Nigeria, and Solomon Islands) may lose all their IFLs by 2060. Given the importance of forest wildlands for carbon storage and sequestration, such IFL loss will substantially reduce the natural potential to mitigate climate change. The loss of forest wildland habitat will inevitably lead to species extinctions at an unprecedented rate and will increase the vulnerability of the forest-dwelling Indigenous cultures to climate change, disease, and malnutrition.

Conservation of Intact Forest Landscapes is a matter of global importance. Our analysis shows that protected areas are the most effective mechanism for reducing IFL loss, whereas forestry certification systems, such as FSC, are ineffective. New and existing infrastructure development, timber harvesting, and mineral resource extraction should avoid fragmentation of remaining IFLs. Indigenous Peoples' rights should be recognized and upheld to support their active contribution in preventing the industrial degradation of remaining forest wildlands. Given that the remaining IFL area is far below the "30x30" conservation target of the United Nations Convention on Biological Diversity (CBD), IFLs should be prioritized when existing protected area networks are revised and expanded, or when Other Effective Area-Based Conservation Measures (OECMs) are considered.

1. DEFINITION

We define an Intact Forest Landscape (IFL) as a seamless mosaic of forests and associated natural treeless ecosystems with no remotely detected signs of human activity or habitat fragmentation, and that is large enough to maintain all native biodiversity, including viable populations of wide-ranging species (Yaroshenko et al., 2001; Potapov et al., 2017). For the practical application of the IFL concept for global mapping, we apply the following minimum thresholds for an IFL patch: (i) a minimum size of 50,000 ha (500 km^2), (ii) a minimum width of 10 km (measured as the diameter of a circle that can be entirely inscribed within the boundaries of the territory), and (iii) a minimum corridor/appendage width of 2 km. Any landscape patch that falls below these thresholds is excluded from the IFL category. Although all IFLs are located within the forest zone (present-day extent of forest ecosystem distribution), some may contain extensive naturally treeless ecosystems, including grasslands, wetlands, lakes, alpine meadows, and ice.

Managed landscapes and forests with signs of human activity that lead to forest alteration and fragmentation are excluded from the IFL area. We exclude agricultural lands, pastures, agroforestry, and tree plantations. Settlements and infrastructure (including roads, navigable rivers, power lines, and pipelines) are excluded with a buffer zone of 1 km. Forests affected by agricultural clearing (including shifting cultivation), logging, mining, oil and gas exploration and extraction during the past 30-70 years are identified using satellite imagery and excluded from IFLs. Forest fires adjacent to actively used infrastructure, agriculture, or resource extraction sites are also excluded.

Low-intensity and old (≥50 years old) disturbances are treated as a background influence and are included within IFL. Examples of the background influence include historic (abandoned) shifting cultivation, diffuse grazing by domestic animals, low-intensity selective logging (without visible roads), and hunting.

The IFL concept was originally proposed by the research team at Greenpeace (Yaroshenko et al., 2001) for targeting forest conservation in the Russian European North. The IFL mapping was later expanded to the entire Russia (Aksenov et al., 2002) and globally (Potapov et al., 2008). The technical definition and mapping method were developed by the IFL Mapping Team and implemented for global IFL mapping and monitoring (Potapov et al., 2008; 2017).

2. METHODOLOGY

The IFL mapping and monitoring approach is based on the "inverse logic" principle. To map IFLs, we first exclude all managed, converted, and fragmented areas and consider the remaining patches of the forest zone as IFLs if they satisfy the minimum area thresholds (Potapov et al., 2017). The initial IFL mapping for the year 2000 required analysis of the entire forest zone. For the subsequent updates, we analyze forest disturbances only within the most recent IFL extent, i.e., for the 2025 update, we mapped changes only within the 2020 IFL extent.

The mapping of disturbed and converted areas is conducted through expert-based visual interpretation of satellite imagery and maps. For the year 2025 update, we primarily used composites of selected features extracted from a time series of Landsat Analysis Ready Data (Potapov et al., 2020) from 2020 to 2024. These features included annual clear-sky image composites, spectral change between the years 2020 and 2024, and spectral reflectance amplitude (Fig. 1). Additionally, we used Landsat-based annual tree cover loss maps (Hansen et al., 2013), high spatial resolution imagery from Google Earth™, and infrastructure maps from Google Maps™ and OpenStreetMap.

The image analysis was performed using QGIS, with the help of image visualization, web data access, and automatic feature buffer tools developed by NextGIS, Ltd. (https://nextgis.com/). We manually delineated IFL 2020 areas affected by industrial logging operations and agricultural clearings as polygonal objects. We also mapped burned forest areas where fires were adjacent to an actively used infrastructure, agricultural lands, mining, or logging sites. New infrastructure objects (roads, power lines, pipelines), selective logging roads, buildings, mining sites, and infrastructure for oil and gas extraction and exploration (including seismic profiles) were excluded with a buffer of 1 km to account for edge effects and indirect human influence not visible on satellite images. Narrow appendages and corridors (< 2 km width) were identified and excluded during the visual analysis.

Better satellite data and data processing tools allowed us to map disturbances that were not detected during the earlier IFL map updates. When we detected a pre-2020 forest disturbance or infrastructure that had been omitted during the preceding IFL mapping, these objects were included in the 2020-2025 IFL loss layer.

All detected and mapped disturbed, altered, and converted areas were aggregated into a single layer and excluded from the IFL extent. Following the exclusion of disturbed areas, remaining landscape patches were evaluated against the minimum area threshold of 50,000 hectares.

The IFL mapping method classifies forest landscapes on a binary scale as either intact or non-intact and does not represent gradations of alteration. This approach provides a practical, rapid, and cost-effective way for assessing forest intactness, alteration, and degradation at global and regional scales while maintaining consistency and comparability across regions and time periods (Potapov et al., 2008; 2017).

By retaining only large unfragmented patches, we ensure that the remaining intact areas are large enough to support viable populations of wide-ranging species, to maintain ecological processes, and to provide ecosystem resilience to climate change effects.

The main limitation of the strict area threshold method is that we exclude smaller natural forest fragments within intensively transformed landscapes. We acknowledge that such fragments of natural ecosystems have high conservation value and should be identified and mapped using more detailed, local-scale forest intactness analysis methods.

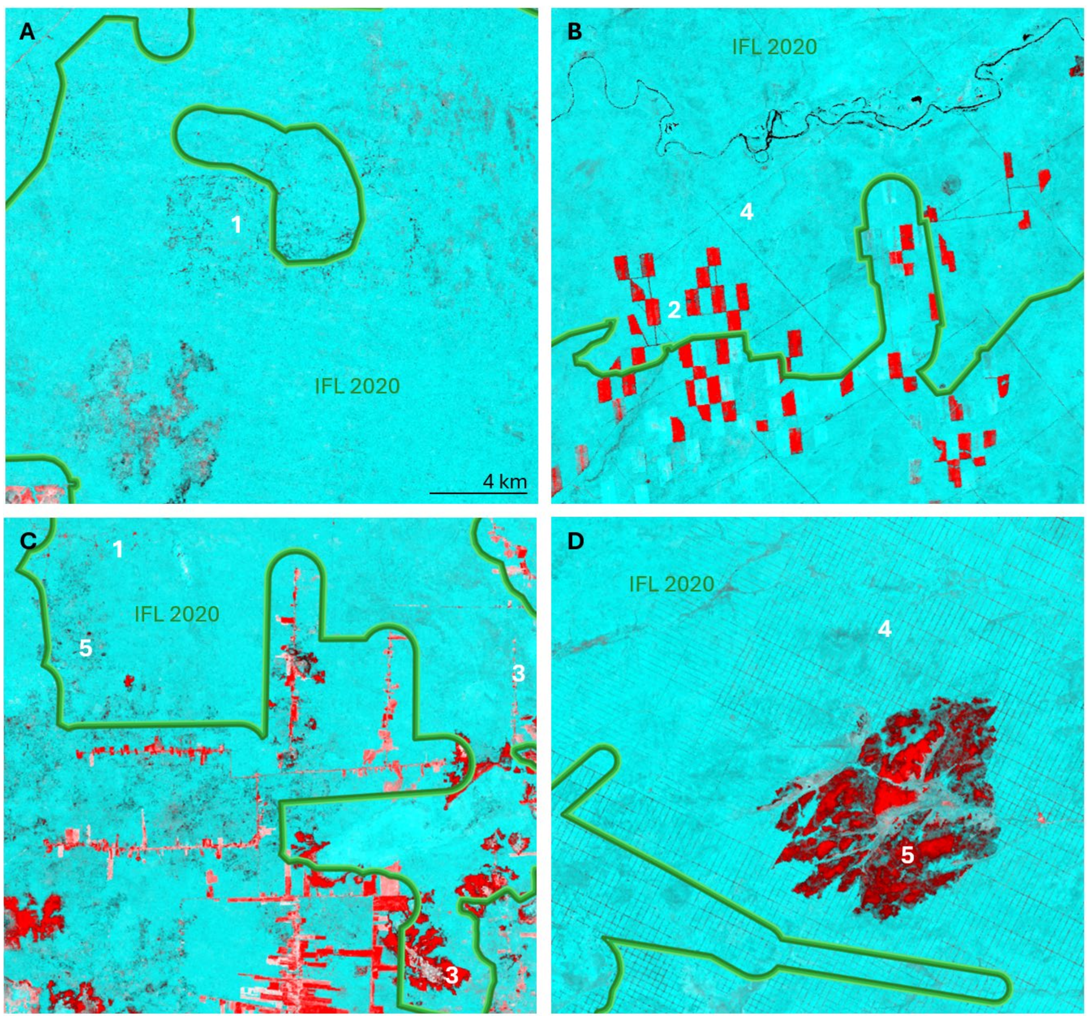

Figure 1. Landsat change detection features composites (red band represents the maximum amplitude of shortwave infrared reflectance; green and blue bands represent the average amplitude of the near infrared to shortwave infrared normalized ratio from 2020 to 2024). These composites visually separate spectrally stable land cover (blue) and land cover changes, including forest disturbance (red). The green outline shows the year 2020 IFL boundaries. White numerals highlight selected forest disturbances excluded during the IFL update: (1) selective logging, (2) clearcuts, (3) agricultural clearing, (4) seismic lines and pipeline infrastructure within oil and gas fields, (5) forest fires associated with intensively used and new infrastructure.
Sample locations: (A) Beni, Bolivia [14°47'20"S, 63°58'13"W], (B) Krasnoyarsk, Russia [59°25'2"N, 100°14'3"E], (C) Mato Grosso, Brazil [10° 7'59"S, 61°13'16"W], (D) Yakutia, Russia [60°56'57"N, 119°50'0"E].

3. ANALYSIS OF IFL DISTRIBUTION AND CHANGE, 2000-2025

3.1. IFL 2025 EXTENT

The remaining IFL area in 2025 is 1086.2 Mha, which represents only 8.4% of the Earth's ice-free land area and includes 21% of the global tree cover (defined as an area with tree canopy height of at least 5 m within the forest zone; hereinafter referred to as forest area). The largest tracts of IFLs are found in the Amazon and Congo River basins and within the northern boreal forests (Fig. 2).

The Western Hemisphere contained nearly 66% of the global IFL area (Fig. 3A). Boreal North America, tropical and temperate South America were characterized by the highest proportion of intact forest of the total forest area, at 72%, 37%, and 31%, respectively. Boreal Eurasia contained 12% of the global IFL area, with 38% of its forest still intact. Tropical Africa, while retaining large IFL tracts in the Congo basin, had only 13% of their forest intact. Temperate regions of Eurasia and North America, Southeast Asia, and Australia had a low percentage of intact forests (<10%) due to intensive forest management and historic land use conversion.

As of 2025, 64 countries still contained IFLs (Fig. 3B). Canada, Russia, Brazil, Peru, and the Democratic Republic of the Congo hosted 75% of the remaining global IFL area. Most countries (52 out of 64) retained less than 1% of the world's IFL area. Only five countries maintained more than half of their forests intact, all located in Latin America (French Guiana, Surinam, Guyana, Venezuela, and Peru). Most countries with remaining IFLs (39 out of 64) had less than 10% of their forest intact.

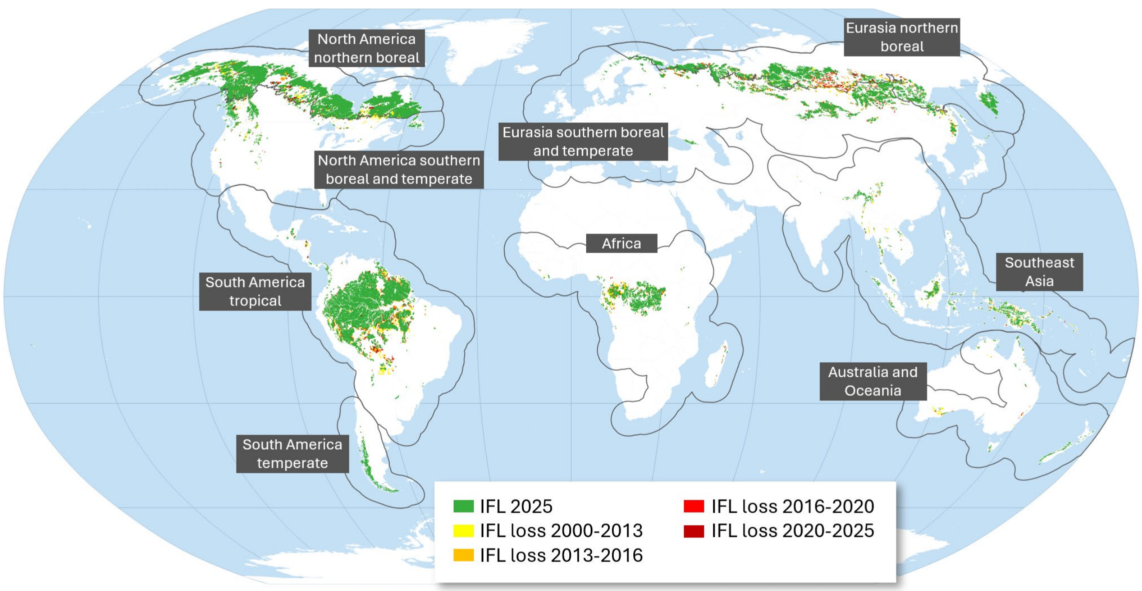

Figure 2. IFL extent for the year 2025, IFL area reduction from 2000 to 2025, and boundaries of geographic regions used for the analysis.

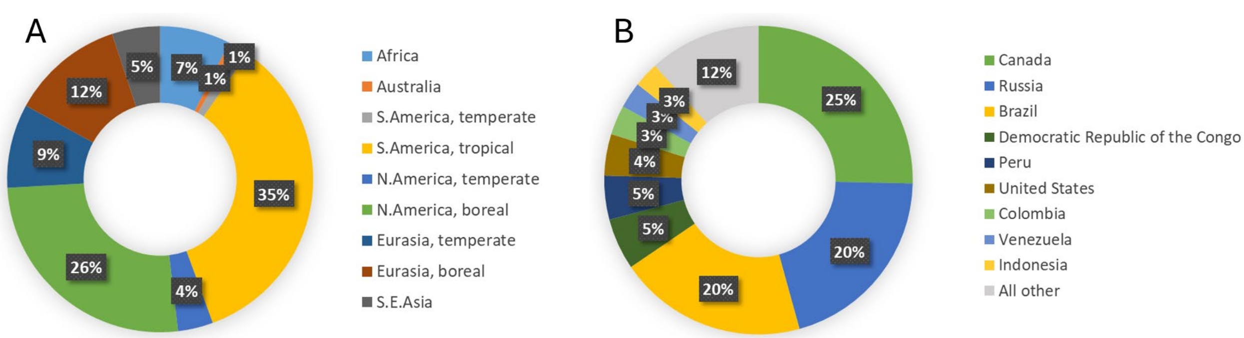

Figure 3. Year 2025 IFL area distribution by geographic regions and countries

3.2. IFL CHANGE 2000-2025

The global IFL area declined by 194.7 Mha, or 15.2%, from 2000 to 2025 (Table 1). The number of IFL patches also decreased by 9.3%. Along with the reduction in total area, the remaining IFL patches became smaller, indicating increasing IFL fragmentation. Between 2000 and 2025, the average IFL patch area decreased by 6.5%, the median patch size declined by 10.8%, and the maximum IFL patch size was reduced by 7.4%.

The largest area of IFL reduction between 2000-2025 occurred in tropical South America, 65.4 Mha, which accounted for 34% of the global IFL reduction area (Fig. 4A). The aggregated temperate and boreal regions of Eurasia were responsible for 28% of the total IFL loss, while the temperate and boreal North America were responsible for 18%. Africa accounted for 10% of the global IFL area reduction, while other regions each represented less than 10%. The relative IFL reduction (percent of the IFL area in 2000) was the highest in Australia (>30%), temperate North America and Eurasia (>20%), and Southeast Asia (>20%). The lowest relative IFL area reduction occurred in boreal North America (7%) and temperate South America (2%).

The average rate of IFL reduction during the 2000-2025 interval was 8.1 Mha per year, equivalent to 22,000 ha per day. The rate of IFL area reduction increased over time (Fig. 4B) from 7 Mha per year before 2013 to 10 Mha per year after 2020.

Comparing annual IFL loss rates between 2000-2013 and 2016-2025, Russia showed the largest increase (by nearly 2 Mha per year), due to intensification of industrial logging, oil and gas extraction and exploration, mining, and the expansion of forest fires associated with industrial infrastructure. Bolivia, Brazil, and Canada also significantly increased the rate of IFL loss (by at least 0.3 Mha per year), due to forest fragmentation and associated forest fires. Other countries with notable intensification of IFL loss rates include Colombia, the Democratic Republic of the Congo, Suriname, and Venezuela.

Paraguay showed the largest reduction in IFL loss rate (by 0.3 Mha per year), mostly due to the exhaustion of most intact forests by 2016. We observed reductions in annual IFL loss by at least 0.1 Mha per year in Australia, Gabon, Myanmar, Papua New Guinea, and the United States.

Table 1. Area and patch statistics of the global IFL extent

	2000	2013	2016	2020	2025
IFL area, Mha	1280.9	1189.3	1161.4	1126.2	1086.2
Number of IFL patches	2221	2138	2097	2053	2014
Maximum patch size, Mha	57.9	55.8	55.3	54.3	53.6
Average patch size, Mha	0.58	0.56	0.55	0.55	0.54
Median patch size, Mha	0.13	0.13	0.13	0.13	0.12

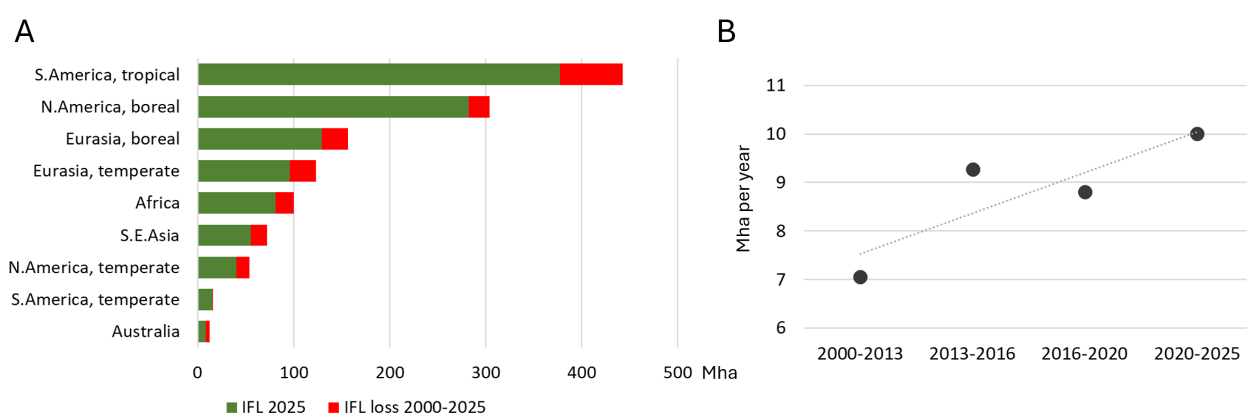

Figure 4. (A) IFL 2025 area and IFL 2000-2025 loss by geographic regions, Mha. (B) Global average annual IFL loss area for each analysis interval.

Romania was the only country that had lost all its IFLs by 2025. Nicaragua, Paraguay, and Solomon Islands lost more than 75% of their year IFL area relative to 2000 by 2025. Additional countries that lost more than half of their IFL area relative to 2000 included the Central African Republic, Equatorial Guinea, Honduras, Laos, and Liberia (Fig. 5). Out of 65 countries that had IFLs in 2000, 34 lost more than 15% of their IFL area by 2025.

Countries with significant IFL area (≥1 Mha) and low IFL reduction (<5% from 2000 to 2025) included Chile, Colombia, Finland, New Zealand, Sweden, and Venezuela. Some of the largest IFL countries, such as Canada and the Democratic Republic of the Congo, reduced their IFL area by less than 10% over the past 25 years. Brazil reduced its IFL area by 13%, which was below the global average of 15.2%.

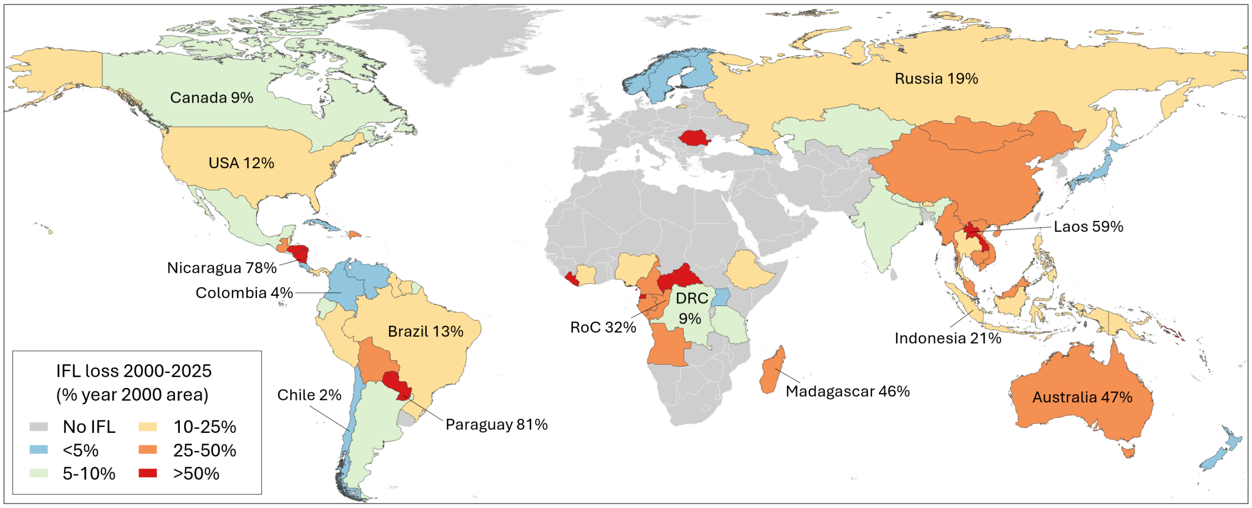

Figure 5. IFL area loss 2000-2025 as a percentage of the year 2000 IFL area by country.

3.3. IFL CHANGE DRIVERS 2020-2025

We performed an analysis of direct IFL loss drives using the sample-based approach similar to Potapov et al. (2017). The analysis was done within the areas of IFL reduction from 2020 to 2025. The IFL change area was separated by strata that represent geographic regions of analysis (Fig. 2). Within each stratum, we randomly selected 50 samples (Landsat data pixels) and visually interpreted the direct cause of IFL reduction within each sample using the same remotely sensed data as we used for the IFL map update (Section 2).

During sample interpretation, we identified the disturbance that was directly responsible for the removal of a particular IFL area. The following types of disturbances were considered: (i) agricultural expansion, including industrial-scale, smallholder (small plots of permanent agriculture), and shifting cultivation; (ii) timber harvesting, separated into clearcuts and selective logging; (iii) mining areas, pipelines, and seismic lines used for mineral resource exploration; (iv) power lines and roads not directly related to resource extraction; and (v) forest fires. We also recorded samples that represented IFL boundary corrections, where newly available high-resolution satellite data and maps revealed disturbances or roads that had been omitted in earlier mapping efforts. The proportion of each driver type was estimated using the approach and software tools provided by Tyukavina et al. (2025). We then allocated the total map-based IFL change area by the sample-based proportion of each loss driver.

Compared to the 2000-2013 IFL loss drivers (Potapov et al., 2017), the importance of fire as a cause of IFL loss nearly doubled (from 21% to 40% of the total IFL reduction area, Fig. 6). A sharp increase in burned forest area within IFL in 2023 and 2024 (Potapov et al., 2025) contributed to the observed high proportion of fires as the IFL reduction driver during the last four years. While fires within IFL cores are considered a natural disturbance, those fires that spread into wildlands from roads, agricultural lands, and mining sites are considered a cause of IFL loss. Regionally, the highest fire-related IFL reduction area increase was found in South and North America (Fig. 7).

Timber extraction remained the primary IFL loss driver after fires. Logging was the primary driver of IFL reduction in Africa, Southeast Asia, and temperate Eurasia. The area of the annual IFL loss due to logging increased in boreal Eurasia, where clearcuts expanded into northern forests. This expansion appeared to be linked to oil and gas infrastructure, which provided access routes for timber extraction in areas where logging road construction had previously been prohibitively expensive.

The importance of mineral resource exploration and extraction, and associated infrastructure development, increased from 12.1% to 18.8% of total IFL loss. In boreal Eurasia, nearly 60% of total IFL reduction was due to mineral exploration and extraction, particularly linked to the expanding oil and gas production in eastern Siberia, driven by the Russian attempt to change energy export from Europe to Asia. The annual area of IFL reduction attributed to mining in South America nearly doubled between 2000-2013 and 2020-2025 analysis intervals. This highlights the importance of industrial and illegal mining in the Amazon basin as the driver of forest fragmentation and degradation.

Agricultural expansion reduced its importance as the IFL loss driver between 2000-2013 and 2020-2025 analysis intervals. Even in tropical South America, where agricultural expansion continued to play an important role in IFL fragmentation, the annual IFL loss area due to agricultural expansion decreased by more than 40%. The IFL loss due to road expansion increased within most geographic regions. Road construction was driven by multiple objectives, including resource extraction, rural development, tourism, and military projects.

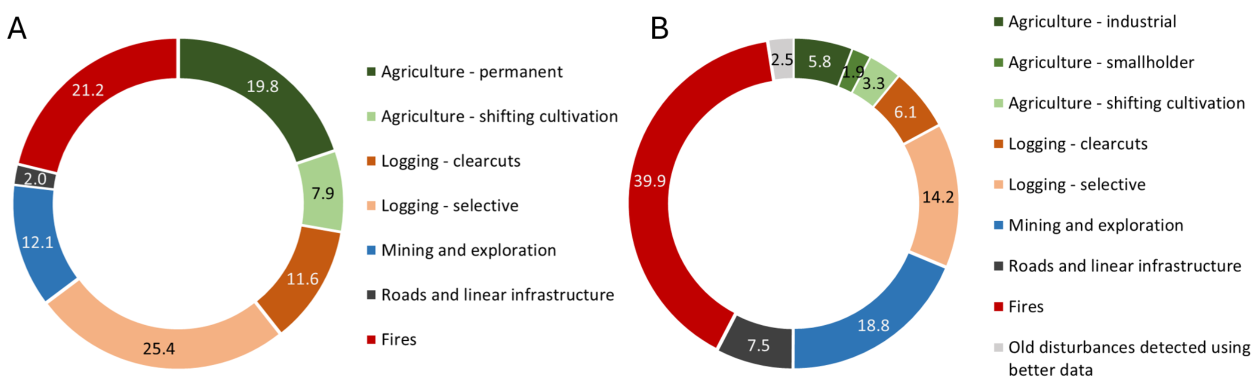

Figure 6. Total percentage of IFL loss by each direct driver. (A) 2000-2013 IFL loss (data from Potapov et al., 2017). (B) 2020-2025 IFL loss.

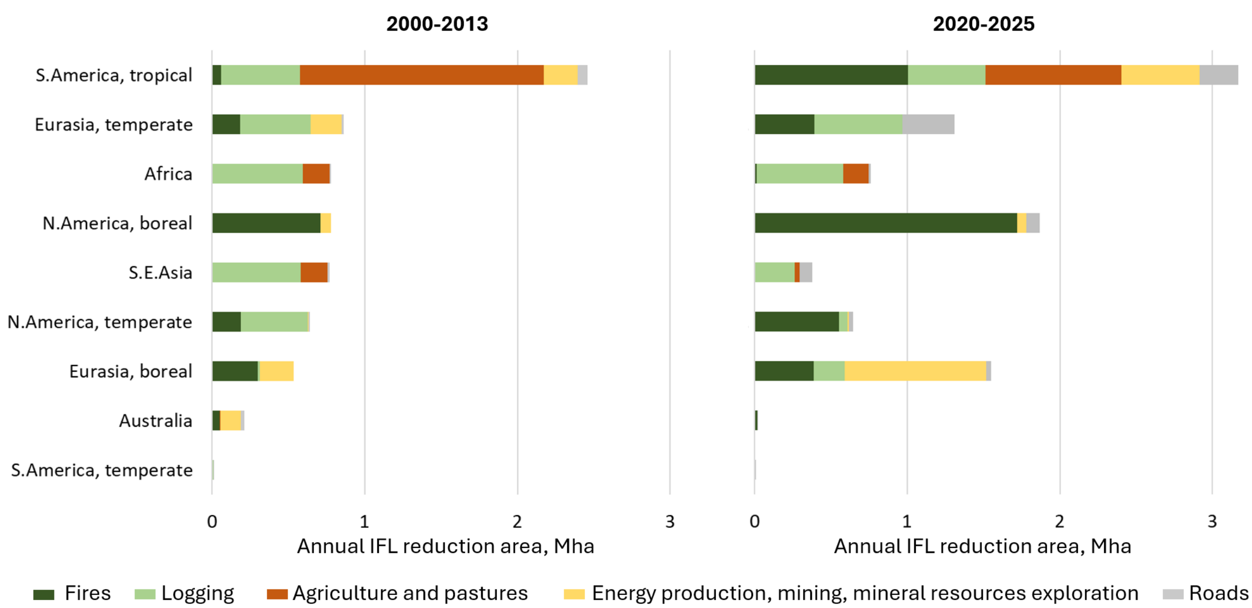

Figure 7. 2000-2013 and 2020-2025 annual IFL loss area (Mha) and major IFL loss drivers attributed using sample data, by geographic region. The 2000-2013 IFL loss data are from Potapov et al. (2017).

3.4. EFFECTIVENESS OF IFL PROTECTION

Establishment and support of nature protection areas is the best direct long-term solution for IFL conservation. The IFL area under strict legal protection, defined as nature protected areas with the IUCN category I-III, experienced lower rates of fragmentation and conversion compared to non-protected IFLs (Potapov et al., 2017). Using the World Database on Protected Areas (WDPA; UNEP-WCMC and IUCN, 2024) for the year 2024, we estimated that 36% of the global IFL area was located within some form of protected area in 2024, and 16% fell within IUCN Category I-III protected areas.

The percentage of the IFL area reduction between 2000 and 2025 was more than two times lower within IUCN Category I-III protected areas (7.9%) than outside protected areas (17.9%). The IFL area reduction between 2000 and 2025 within all protected areas was 11.7%. Our findings emphasized the need for expansion of the protected areas network to all remaining IFLs. However, IFL loss was still observed even within strictly protected areas, indicating persistent challenges related to protected area management and enforcement.

Implementation of sustainable forestry standards, such as the Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC) volunteer certification systems, has been promoted as a solution for IFL protection. The FSC adopted a policy to ensure protection of the IFL cores within the certified management units (FSC 2014), which was intended to reduce the IFL loss within certified forest concessions compared to the rest of the forest area. However, subsequently, it has weakened this requirement in key IFL countries and has dropped any threshold for IFL protection at the October 2025 FSC General Assembly (Motion 45).

Contrary to expectations, earlier analysis of IFL change in Central Africa from 2000 to 2013 showed that the IFL loss within FSC-certified concessions was 3.4 times higher than the national average in Cameroon, 2.4 times higher in the Republic of Congo, and 1.6 times higher in Gabon (Potapov et al., 2017). Here, we found that the IFL reduction within FSC-certified forest concessions in Russia from 2000 to 2025 was 2.9 times higher than for the rest of the country. IFLs within FSC-certified concessions showed the fastest rate of annual area reduction, which reached a 6.1% reduction of the remaining IFL area per year between 2016 and 2020. After the implementation of economic sanctions against Russia and the termination of the FSC certification system in the country, the annual IFL reduction area declined to 3.9% per year within formerly certified concessions, while it remained the same for non-certified forests. Our observations suggest that the FSC certification did not prevent IFL loss and, in some cases, accelerated it.

Other mechanisms, such as Other Effective Area-Based Conservation Measures (OECMs; CBD 2018) and Indigenous Lands (Sze et al., 2022), provide alternative opportunities for strengthening the IFL protection. Recently emerging funds, such as the Tropical Forest Forever Facility (https://tfff.earth/) and the Cali Fund (https://www.cbd.int/califund), offer the potential to support IFL conservation initiatives. However, it will require a substantive effort by governments, multilateral organizations, the private sector, and civil society to reverse the current trend of accelerating IFL loss and ensure their long-term protection.

Threats to IFLs arise not only from their area loss and fragmentation, but also from processes affecting the entire biosphere. The recent increase in the extent and intensity of forest fires (Potapov et al., 2025) is primarily driven by human-caused climate change, which has led to longer fire seasons and more frequent and severe extreme fire weather events. These fires affected the forest not only near infrastructure (which is taken into account in our study) but also deep within wildlands (which, according to the IFL definitions and methodology, were considered a natural forest disturbance). The global climate models predict the future increase in temperature and extreme fire weather, which will result in intensifying forest burning within the remaining IFLs (Jones et al., 2022). These processes, amplified by the positive feedback (Zheng et al., 2021), may permanently transform forest ecosystems, especially where changes in fire dynamics are more pronounced, such as humid tropics and northern boreal forests.

3.5. IFL CHANGE PREDICTION 2025-2100

The fast rate of IFL decline indicated that some of the countries and regions may lose most or all of their intact forests in the near future unless urgent and strong conservation efforts are implemented. To highlight countries with the highest probability of IFL reduction, we implemented a locally weighted scatterplot smoothing (LOWESS) linear regression method to estimate the IFL area change from 2026 to 2100. We used the national IFL change estimates 2000-2025 to calibrate each model and applied a span of 0.75, effectively limiting the training dataset to the 2016-2025 interval. The standard error of the model was used as the uncertainty of our prediction. Projections were generated for each country up to the year 2100. For each country, we recorded the year when the IFL area declined below 50% of its IFL area in 2000, as well as the year of complete IFL loss (when the IFL area declined below the minimum IFL patch threshold of 50,000 ha). To estimate the uncertainty in years, we subtracted the standard deviation from the projected IFL area values, identified the corresponding threshold-crossing year, and calculated the difference between the two estimates.

We projected that the global IFL area will be reduced by 50% of its extent in 2000 by 2079 ± 8 years (Fig. 8). Temperate regions of North America and Eurasia were projected to lose 50% of their IFL area sooner, by 2057 (± 11) and 2055 (± 8), respectively. Among the countries that still retained more than half of their IFL area in 2025 (relative to 2000), Australia, Bolivia, Cameroon, and Madagascar were projected to lose half of their IFL area from the year 2000 by 2030, Gabon, Guatemala, Myanmar, and Nigeria by 2040, and the Republic of the Congo by 2043.

We also projected that nine countries (Central African Republic, Guatemala, Honduras, Liberia, Madagascar, Nepal, Nicaragua, Nigeria, and Solomon Islands) may lose all their IFLs by 2060. Laos and Equatorial Guinea, which had already lost 50% of their IFL by 2025, may lose the remaining IFLs by 2073 and 2086, respectively. Countries with a fast rate of IFL reduction require urgent conservation strategies for their protection.

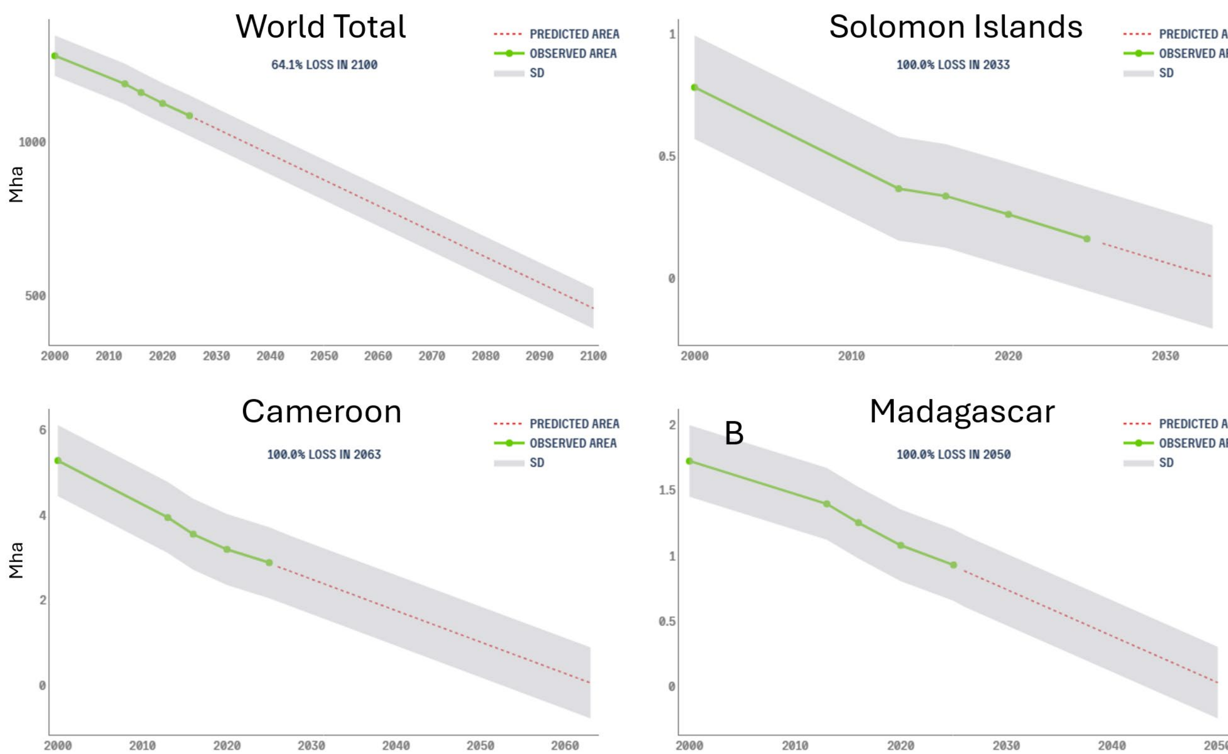

Figure. 8. Observed and predicted IFL area for the entire world and selected countries.

4. TECHNICAL DESCRIPTION OF THE IFL DATASET

4.1. PRODUCT HISTORY

IFL 2000 (IFL_2000.gpkg)

The first global IFL map was prepared in 2005-2006 under the leadership of Greenpeace, with contributions from Biodiversity Conservation Center, International Socio-Ecological Union, and Transparent World (Russia), Luonto Liitto (Finnish Nature League), Forest Watch Indonesia, and Global Forest Watch, a network initiated by the World Resources Institute. The map was subsequently updated by Greenpeace Russia and the University of Maryland in 2012 using the year 2000 global cloud-free Landsat data composites. The map shows the extent of the IFLs as of the end of the year 2000. This map served as the basis of the first scientific publication focused on IFL methodology, values, and documenting IFL extent (Potapov et al., 2008). During the 2013-2020 updates, the year 2000 IFL map was corrected in a few instances where the available high-resolution satellite data from Google Earth(TM) revealed pre-2000 infrastructure that was not visible on the year 2000 Landsat data

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IFL 2013 (IFL_2013.gpkg)

The global IFL map update for the 2013 extent was performed in 2014-2015 by Greenpeace, the University of Maryland, and Transparent World, with support from the World Resources Institute and WWF Russia. The resulting dataset represents the IFL extent as of the year 2013 and the IFL loss since 2000. To ensure consistency, the IFL map update for the year 2013 was based on the same data sources and methodology as the year 2000 mapping. To map forest disturbances and land use conversion within IFLs, we leveraged annual cloud-free Landsat composites and the 2001-2013 tree cover loss map produced by the University of Maryland. During the IFL update, all human-induced forest clearing, new infrastructure, and burned areas adjacent to actively used infrastructure (permanent roads, rivers, pipelines, and power lines) were excluded from the year 2000 IFL, and the remaining areas were attributed as the year 2013 IFL if they passed our size criteria. The year 2013 IFL map and 2000-2013 IFL change were published in Potapov et al. (2017). The 2013 IFL map was partially updated during the 2020 update.

IFL 2016 (IFL_2016.gpkg)

Between late 2017 and early 2018, the University of Maryland, Wildlife Conservation Society, Greenpeace, and Transparent World completed the update of the global IFL map for the year 2016. The project was funded by the Wildlife Conservation Society and Greenpeace. The update employed Landsat data and annual forest cover change products produced by the Global Land Analysis and Discovery (GLAD) lab. We used the latest available cloud-free Landsat observation composites for visual IFL change assessment. The IFL map update methodology was the same as for the 2013 update. The updated map represents IFL boundaries for the end of the year 2016 and the beginning of the year 2017. The map supported the Forest Stewardship Council (FCS) responsible forest management certification, which requires the IFL extent for January 1, 2017. The 2016 map was partly updated in 2020 for the areas where newly available high-resolution data revealed older disturbances or infrastructure.

IFL 2020 (IFL_2020.gpkg)

The 2020 IFL map update was performed by the IFL Mapping Team, which included satellite data interpretation specialists from the University of Maryland and Greenpeace. The analysis followed the same IFL mapping methodology as the earlier updates. The GLAD analysis-ready Landsat data (Potapov et al., 2020) supported the global IFL conversion and fragmentation detection. We also employed Sentinel-2 imagery, high-resolution data from Google Earth(TM), and Planet data provided by Norway's International Climate and Forest Initiative (NICFI) Program. The 2020 IFL map provides information on the IFL extent for the end of the year 2020. In a few cases, we were not able to determine the exact date of the disturbance or the fragmenting infrastructure that was detected using the newly available high-resolution data. In such cases, the change of the IFL boundary from 2016 to 2020 may represent an earlier disturbance.

IFL 2025 (IFL_2025.gpkg)

The latest 2025 global IFL map update represents the IFL extent as of January 1, 2025. The update was completed by the IFL Mapping Team, including specialists from the World Resources Institute, the University of Maryland, and Greenpeace International Global Mapping Hub (https://maps.greenpeace.org/). Similar to the year 2020 update, this work was done by volunteers, and the map update was not directly funded by any organization or donor. Image composites and change detection features extracted from Landsat ARD (Potapov et al., 2020) and high-resolution data from Google Earth(TM) served as the primary remotely sensed datasets for change detection. We also utilized forest change layers produced by the GLAD lab (https://glad.earthengine.app/view/global-forest-change) and infrastructure and settlement data from Google Maps(TM) and OpenStreetMap. The visual interpretation and mapping of changes within IFL were done using QGIS, with the support of freeware tools developed by NextGIS, Ltd. (https://www.nextgis.com/). During the IFL update, if a pre-2020 infrastructure or disturbance was detected using better satellite data by 2025, it was excluded from the 2025 IFL map (earlier IFL maps were not corrected).

4.2. TECHNICAL DESCRIPTION

The global IFL map is provided in the GeoPackage format in geographic coordinates using the WGS84 coordinate system. The IFL boundaries are provided as polygonal objects. The recommended scale for data visualization is 1:1,000,000. The dataset includes the IFL extent for five reference years: 2000, 2013, 2016, 2020, and 2025 (**IFL_2000.gpkg, IFL_2013.gpkg, IFL_2016.gpkg, IFL_2020.gpkg, IFL_2025.gpkg**).

The attribute table in each GeoPackage coverage includes three fields, listed in Table 2. The unique IFL patch ID is based on the 2000 IFL extent map. Each polygon in the year 2000 map was assigned a unique ID combined from the IFL region code (Table 3) and a unique ID within the region, e.g., "AFR_25". The same ID was retained for the year 2013, 2016, 2020, and 2025 datasets. When an original IFL patch was separated into separate patches, an additional unique index was added to the IFL ID (e.g., "AFR_25_1", "AFR_25_2").

Table 2. IFL layer database fields

Field name	Type	Description
fid	Integer	Internal unique object ID
IFL_ID	Text	Unique IFL patch ID
Area{Year}	Decimal	IFL patch area in hectares

Table 3. Regional abbreviations used for IFL IDs

Continent	Abbreviation
Africa	AFR
Australia and New Zealand	AUS
North and Central America	NAM
Northern Eurasia	NEA
South America	SAM
Southeast Asia	SEA

The area of each IFL patch was calculated using the QGIS function *$area*, which calculates the ellipsoidal (WGS84) area of each polygon in hectares. Due to the limitations and possible uncertainties in exact area estimation, the actual area threshold for the IFL patch inclusion was 48,000 ha rather than 50,000 ha.

The **Forest_Zone.gpkg** layer delineates the forest zone boundary (see details in Potapov et al., 2017). The extent of the forest zone was mapped using the global year 2000 tree canopy cover dataset (Hansen et al., 2013) with a 20% tree canopy cover threshold. Inland water bodies and naturally treeless ecosystems were included in the forest zone. Fragments of land in the forest zone with a contiguous area smaller than 50,000 ha were excluded from consideration. The database DB field [Region] specifies geographic regions used for the IFL analysis (Table 4). Geographic regions within the forest zone were delineated using natural boundaries between forested areas. The boundary between northern boreal and southern boreal/temperate regions in North America and Northern Eurasia was based on Landsat data analysis and represents the *de facto* dividing line between lands that have, and have not, been subject to industrial logging as of the year 2013. To delineate this boundary, we used Landsat images for the year 2013 to map the northernmost extent of industrial logging, applied a 5-km buffer around detected logging, and connected the resulting polygons (Potapov et al., 2017).

Table 4. List of geographic regions within the forest zone and corresponding DB codes

Code	Region
1	Africa
2	Australia and New Zealand
3	Temperate South America
4	Tropical and subtropical South America and Mesoamerica
5	Temperate and southern boreal North America
6	Northern boreal North America
7	Temperate and southern boreal Eurasia
8	Northern boreal Eurasia
9	Western Hemisphere Pacific Islands
10	Southeast Asia and Oceania

4.3. DATA DISTRIBUTION AND LICENSING

IFL maps are available from the dedicated data portal www.intactforests.org in formats suitable for use in GIS software. The IFL Mapping Team is continuing to improve the IFL base map and to provide periodical updates as new data, technologies, and more sophisticated sources of information become available. Please check News & Updates of the data portal for information about the latest map releases.

The IFL data is shared under the Creative Commons Attribution 4.0 International license (CC BY 4.0). Users may copy and redistribute the dataset and build upon the dataset for any purpose, even commercial, as long as appropriate credit to the data source is provided and changes to the dataset (if any) are explained.

We suggest the following citation format for the IFL dataset:

Potapov, P., Hansen, M.C., Laestadius, L., Turubanova, S., Yaroshenko, A., Thies, C., Smith, W., Zhuravleva, I., Komarova, A., Minnemeyer, S., Esipova, E., 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances 3, e1600821. https://doi.org/10/f9nd3s

For the web-based applications, the suggested reference is as follows:

The IFL Mapping Team. “Intact Forest Landscapes 2000-2025” Available at www.intactforests.org

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APPENDIX

NATIONAL AND GLOBAL IFL AREA 2000-2025 AND PROJECTED IFL AREA CHANGE

Country	IFL area, Mha					Projected IFL loss year (±S.D.)	
	2000	2013	2016	2020	2025	50% loss*	100% loss*
Angola	0.3	0.2	0.2	0.2	0.2	2064 ± 38	N/A
Argentina	4.0	3.9	3.9	3.8	3.8	N/A	N/A
Australia	8.2	5.5	5.4	4.4	4.3	2026 ± 0	2062 ± 12
Belize	0.4	0.4	0.4	0.4	0.4	2088 ± 13	N/A
Bhutan	0.6	0.5	0.5	0.5	0.5	N/A	N/A
Bolivia	23.2	18.6	17.4	15.2	11.8	2026 ± 0	N/A
Brazil	247.6	231.9	227.7	220.7	214.8	2089 ± 8	N/A
Brunei	0.2	0.2	0.2	0.2	0.2	2072 ± 15	N/A
Cambodia	0.1	0.1	0.1	0.1	0.1	2073 ± 47	N/A
Cameroon	5.3	3.9	3.6	3.2	2.9	2029 ± 3	N/A
Canada	304.0	289.8	286.2	284.4	275.3	N/A	N/A
Central African Republic	0.9	0.6	0.5	0.4	0.4	lost by 2016	2044 ± 12
Chile	13.1	13.0	13.0	12.9	12.9	N/A	N/A
China	4.5	4.0	3.4	3.3	3.2	2092 ± 34	N/A
Colombia	34.9	34.5	34.4	33.9	33.7	N/A	N/A
Costa Rica	0.3	0.3	0.3	0.3	0.3	N/A	N/A
Cote d'Ivoire	0.5	0.4	0.4	0.4	0.4	N/A	N/A
Cuba	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Democratic Republic of the Congo	64.4	61.7	60.9	59.7	58.5	N/A	N/A
Dominican Republic	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Ecuador	5.3	5.0	5.0	5.0	4.9	N/A	N/A
Equatorial Guinea	0.4	0.2	0.2	0.2	0.2	lost by 2016	2086 ± 36
Ethiopia	0.4	0.3	0.3	0.3	0.3	N/A	N/A
Finland	1.0	1.0	1.0	1.0	0.9	N/A	N/A
French Guiana	6.5	6.2	6.1	6.0	6.0	N/A	N/A
Gabon	10.9	8.4	8.1	7.6	7.0	2040 ± 12	N/A
Georgia	0.9	0.9	0.9	0.9	0.9	N/A	N/A
Guatemala	0.6	0.5	0.5	0.4	0.4	2031 ± 5	2051 ± 6
Guyana	14.4	12.8	12.3	11.7	11.1	2057 ± 9	N/A
Honduras	0.7	0.5	0.5	0.4	0.2	lost by 2025	2033 ± 6
India	3.4	3.3	3.2	3.2	3.1	N/A	N/A
Indonesia	35.9	32.0	30.6	29.3	28.5	2072 ± 12	N/A
Japan	0.1	0.1	0.1	0.1	0.1	N/A	N/A

Kazakhstan	0.4	0.4	0.4	0.4	0.4	2090 ± 5	N/A
Laos	0.9	0.4	0.4	0.4	0.4	lost by 2013	2073 ± 31
Liberia	0.5	0.3	0.3	0.3	0.2	lost by 2025	2045 ± 9
Madagascar	1.7	1.4	1.3	1.1	0.9	2027 ± 1	2050 ± 8
Malaysia	2.1	1.6	1.5	1.5	1.5	2084 ± 35	N/A
Mexico	1.5	1.5	1.4	1.4	1.4	2099 ± 6	N/A
Mongolia	1.2	1.0	1.0	1.0	0.9	2041 ± 6	2069 ± 5
Myanmar	5.3	3.6	3.2	3.1	2.9	2036 ± 10	N/A
Nepal	0.1	0.1	0.1	0.1	0.1	N/A	2032 ± 6
New Zealand	4.3	4.3	4.2	4.2	4.2	N/A	N/A
Nicaragua	1.0	0.6	0.6	0.5	0.2	lost by 2016	2030 ± 4
Nigeria	0.3	0.3	0.3	0.2	0.2	2038 ± 4	2056 ± 5
Norway	0.2	0.2	0.2	0.2	0.2	N/A	N/A
Panama	1.5	1.4	1.3	1.3	1.3	N/A	N/A
Papua New Guinea	16.0	13.9	13.2	12.7	12.4	2072 ± 14	N/A
Paraguay	4.4	0.9	0.9	0.9	0.9	lost by 2013	N/A
Peru	56.7	53.3	52.3	50.9	49.9	N/A	N/A
Philippines	0.4	0.4	0.4	0.4	0.4	N/A	N/A
Republic of Congo	13.9	11.4	10.7	10.0	9.4	2043 ± 11	N/A
Romania	0.1	0.0	0.0	0.0	0.0	N/A	lost by 2013
Russia	274.4	256.6	247.0	233.5	221.2	2055 ± 7	N/A
Samoa	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Solomon Islands	0.8	0.4	0.3	0.3	0.2	lost by 2013	2031 ± 5
Suriname	10.7	10.1	9.8	9.3	8.9	2058 ± 6	N/A
Sweden	1.2	1.1	1.1	1.1	1.1	N/A	N/A
Tanzania	0.4	0.4	0.4	0.4	0.4	N/A	N/A
Thailand	1.9	1.8	1.7	1.7	1.7	N/A	N/A
Uganda	0.1	0.1	0.1	0.1	0.1	N/A	N/A
United States	53.9	49.7	49.0	48.4	47.2	N/A	N/A
Vanuatu	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Venezuela	31.3	30.8	30.6	30.3	29.8	N/A	N/A
Vietnam	0.4	0.3	0.3	0.3	0.3	N/A	N/A
World	1280.9	1189.3	1161.4	1126.2	1086.2	2079 ± 8	N/A

* Of the IFL area for the year 2000