

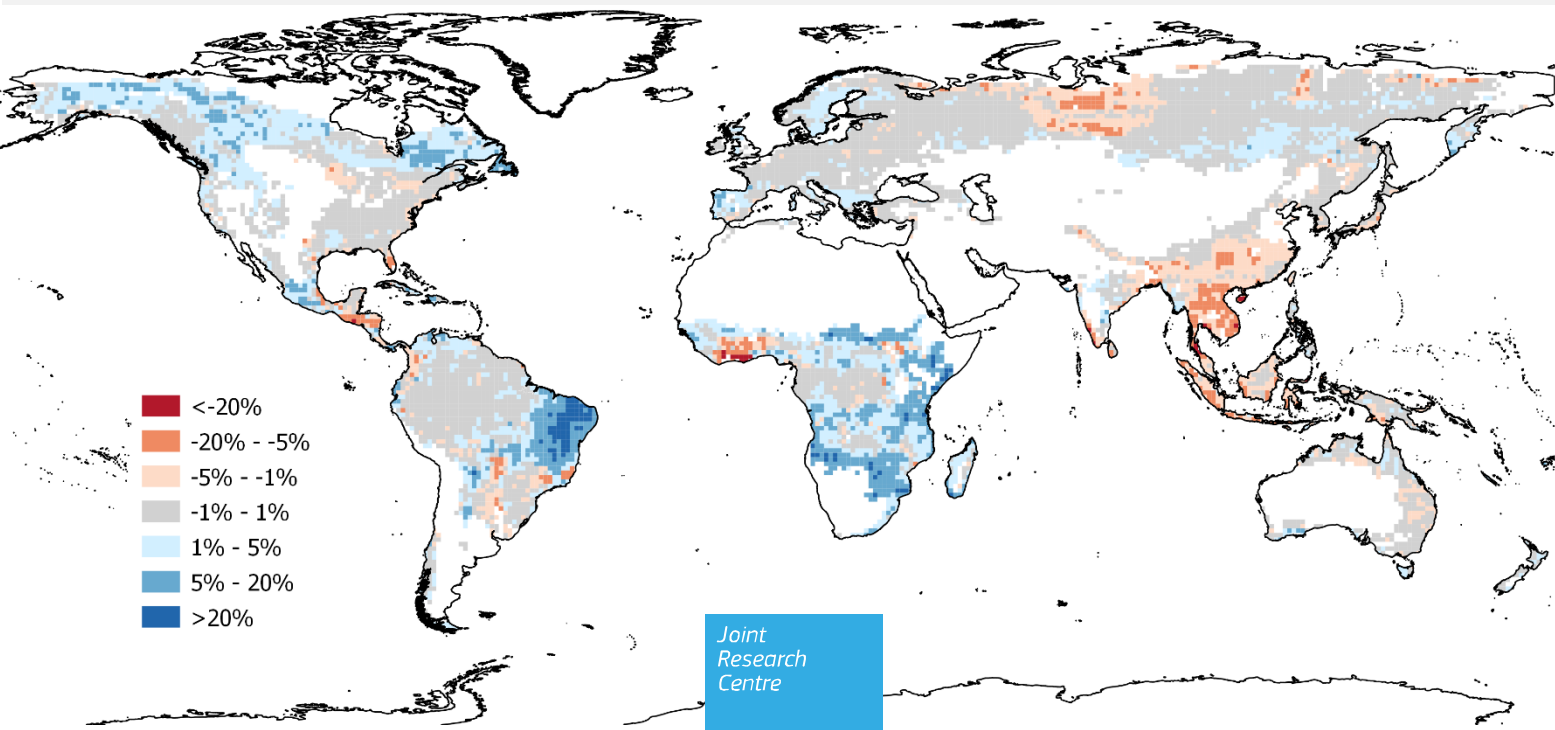


Global Forest Maps for the Year 2020 to Support the EU Regulation on Deforestation-free Supply Chains

Improved Map of Global Forest Cover (GFC2020) and Preliminary Map of Global Forest Types (GFT2020)

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Abstract

This document presents the second version of the Global map of Forest Cover for the year 2020 at 10 m spatial resolution (GFC2020 v2 dated 7 December 2024). This product is based on the combination of several global land cover / land use data sets and provides a spatially explicit representation of forest presence or absence for the year 2020. Additionally, this document presents a preliminary version of the Global map of Forest Types for the year 2020 (GFT2020 v0 dated 7 December 2024). The report describes the approaches that were developed to produce these new maps and an analysis of the results in comparison with other sources of information. GFC2020 v2 improves upon the first by incorporating new global tree height and land use datasets and revised methodologies, resulting in reduced confusion, particularly for agricultural tree crops like cocoa, coffee, rubber and oil palm. These maps are designed to support the risk assessment in the implementation of the EU Regulation on deforestation-free supply chains (EUDR, Regulation (EU) 2023/1115), but their use is not mandatory, not exclusive and not legally binding. The primary access to this map is via the EU Observatory on Deforestation and Forest Degradation.

Foreword

Forests are indispensable for life on Earth, providing a multitude of vital ecosystem services. Through photosynthesis, they produce the oxygen we breathe, while simultaneously sequestering vast amounts of atmospheric carbon, crucial for mitigating climate change. Forest ecosystems also filter air and water, maintain biodiversity, regulate water cycles, and provide essential economic resources. Furthermore, forests hold immeasurable social and cultural significance, offering spaces for recreation, spiritual connection, and serving as the foundation of many indigenous communities' existence.

A thorough definition, accurate mapping and exhaustive monitoring of forests is a complex challenge at global level. Studies and official statistics from the FAO Global Forest Resources Assessment 2020 document deforestation at an alarming rate, equivalent to the area of 25 football fields per minute. This loss underscores the urgent need for effective monitoring management and conservation.

To support these efforts, and specifically to facilitate the implementation of the EU Regulation on deforestation-free supply chains (EUDR), the Joint Research Centre (JRC) developed a global forest cover map for the year 2020. This map is a harmonized, globally consistent representation of forest presence/absence at a 10-meter spatial resolution. This report documents the revised methodology and results of the map's second version, released on 6 December 2024. In addition, the present report introduces the preliminary map of a global forest types for the year 2020, which is intended to be improved and consolidated by the end of 2025.

The EUDR mandates operators and traders to provide precise geographic location data for sourcing areas for a set of commodities and products. The freely available maps presented in this report aim to assist operators and traders in conducting spatially explicit risk assessments, possibly in combination with other spatial data, to demonstrate that commodities and products placed on the EU market or exported from it are deforestation-free, a key requirement of the EUDR. Yet, these maps are not legally binding, not exclusive meaning that other data sources can be used, and not mandatory for the implementation of the EUDR.



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Executive summary

Policy context

The “EU Observatory on Deforestation and Forest Degradation” (EUFO) provides access to global forest maps and spatial forest and forestry-related information and facilitates access to scientific information on supply chains. By linking changes in the world’s forest cover to the Union’s demand for commodities and products, the EUFO also supports the EU Regulation on deforestation-free supply chains (EUDR). Subject to this Regulation are a set of commodities and derived products that were produced on land which was deforested or forest was degraded after the cut-off date (31 December 2020). In this context, the JRC produced a revised version of the global forest cover map for year 2020 (GFC2020 v2) and a preliminary version of a global map of forest types (GFT2020 v0) both at 10m spatial resolution. Given the definition of forest degradation as transition between forest types, a map for the initial state in year 2020 only requires to separate between 1) primary forest, 2) naturally regenerating forest, and 3) other forest types, which are by definition planted or plantation forests.

Key outcomes

The GFC2020 map is a novel and unique product that is derived from the combination of most recent publicly available land cover and land use datasets or related products that indicate the potential presence or absence of forest in 2020, eventually meeting the definition of forest as set out in the EUDR. Input data have a fine spatial resolution and a global scope (Bourgoin et al., 2024).

The second version of the GFC2020 map (GFC2020 v2) is an improvement of the first version that results from (i) the use of new datasets on tree height and land use, and (ii) a revised approach for combining input datasets based on user feedback regarding the first version of the map, such as overestimation of forest cover in urban areas or agricultural commodities and products that grow under a tree canopy.

The preliminary version of the global map of forest types (GFT2020 v0) is a new unique product at global level that complements the GFC2020 map by indicating the location of three types of forests: primary forests, naturally regenerating forests (other than primary) and planted forests that includes plantation forests.

These maps (GFC2020 v2 and GFT2020 v0) are a harmonized globally-consistent representation of the presence / absence of forests and of three forest types based on EUDR definitions at 10m spatial resolution for year 2020. This is a service provided freely and openly by the European Commission via the EUFO to the global community concerned, gathering information about forest cover in 2020. In the context of the EUDR, the GFC2020 map can support operators in the assessment of the risk of deforestation after year 2020 when declaring land parcels by geolocation from which commodities (cattle, cocoa, coffee, oil palm, rubber, soya, wood) and derived products are put on the EU market or exported by Member States. For due diligence, it is strongly recommended to use the maps in combination with other forest or land use maps and datasets, in particular at national scale, if existing and available. In the context of the EUDR, it should be noted that the JRC maps have no authoritative status and have to be considered as:

- Non-mandatory: There is no obligation for stakeholders, notably operators and competent authorities concerned with the implementation of the EUDR, to use GFC2020, GFT2020 or any other map.

- Non-exclusive: These global maps on forest cover and forest types are one of many tools that can support the implementation of the EUDR. Other maps may have advantages and the regulation does not prescribe modalities of and for map use.
- Not legally binding: These maps can support the risk assessment in the due diligence. However, when overlaying polygons, the presence of forest or the indication of a forest type (primary or naturally regenerating) does not necessarily imply non-compliance, nor does the absence of forest or the indication of planted forest imply compliance. It will be up to the operator to prove thoroughly that there is no or negligible risk of deforestation and forest degradation.

Main findings

Our objective is to produce the best global spatial representation of forest cover and key forest types for the year 2020 using the EUDR definitions of forest and forest types by maximizing the value of existing global data layers via a synthesis approach. The methodology was developed and improved in various iterations, by testing the usefulness of data sets or tuning parameters. The methodology is flexible enough to potentially include additional or revised data sets with a global scope that would become available in the future. The production of potential revised versions of GFC2020 and GFT2020 maps will be aimed at improving their overall accuracies.

The second version of the GFC2020 map presents less confusion than version 1 when compared to regional or national maps for specific commodities addressed under the EUDR, notably for cocoa and coffee and in specific areas for rubber, oil palm, soy and pasture (as surrogate for cattle).

Related and future JRC work

A formal statistically and thematically sound accuracy assessment of GFC2020 has been carried out with an international network of scientists through the creation of a reference sample dataset. A separate technical report describes the approach and results of the accuracy assessment (Colditz et al., 2025). The JRC is also engaging with other services of the European Commission to ensure interoperability between the EUDR Information System and GFC2020. Thirdly, the JRC will consolidate the preliminary version of the map of forest cover types following the definition of forest degradation as set out in the EUDR. Finally, the JRC foresees a third version of the GFC2020 map and a consolidated version of the Global Forest Type map of the year 2020 to be released by the end of 2025 before the EUDR will become applicable.

Quick guide

This report describes the input data and methodology that have been used to produce the second version of the Global Forest Cover map of year 2020 and the preliminary version of the global map of forest types. The report contains comparisons with global or regional data layers to assess agreement and disagreement with forest in GFC2020. The accuracy assessment of GFC2020 is published in a separate technical report.

1 Introduction

On 7 December 2023, the “[EU Observatory on Deforestation and Forest Degradation](#)”, in the following abbreviated “EUFO”, went public ([COM 2023](#)). Besides providing access to global forest maps and spatial forest and forestry-related information, the EUFO is aimed to facilitate access to scientific information on supply chains, linking deforestation, forest degradation and changes in the world’s forest cover to Union demand for commodities and products.

Moreover, the Regulation “*on the making available on the Union market as well as export from the Union of certain commodities and products associated with deforestation and forest degradation*” ([EU 2023/1115](#)), in the following abbreviated “EUDR”, was published on 9 June 2023 in the Official Journal, went into force 20 days later, and is going to become applicable on 30 December 2025 ([EU 2024/3234](#))¹. This Regulation lays down rules and obligations for seven commodities (cattle, cocoa, coffee, oil palm, rubber, soya, wood) and derived products. Operators need to ensure due diligence, including geographic coordinates about the sourcing location, and assessment of the risk of deforestation or forest degradation after the cut-off date (31 December 2020).

As indicated in Recital 31 of the EUDR, the EUFO plays a supporting role in the implementation of this Regulation. To this end, the EUFO includes a global map of forest cover presence or absence and a preliminary map of key forest types for the year 2020, in the following abbreviated “[GFC2020](#)” and “[GFT2020](#)” respectively. These maps can serve operators in the assessment of the risk of deforestation or forest degradation when declaring land parcels by geolocation for commodities and derived products imported to or exported from the European Union market.

Given the EUFO role of a supporting - and not authoritative - tool in the context of the EUDR, information provided by GFC2020 and GFT2020 is non-mandatory, non-exclusive and not legally binding. The latter means that a spatial match between a declared point or polygon in the due diligence statement and forest in GFC2020 does not imply with full confidence that the parcel has been deforested. Likewise, a spatial match between a declared point or polygon with non-forest in GFC2020 does not automatically mean no risk or compliance with the EUDR. Analogously, conversions or non-conversions between forest types do not imply the risk or non-risk of forest degradation after 2020. Given the global scope, limitations in map accuracy and spatial resolution, the Joint Research Centre (JRC) does not see a direct use of GFC2020 or GFT2020 for the verification by competent authorities. However, these maps could be used for, e.g., selecting sample areas to carry out more detailed and robust checks with better and more detailed data sources.

The main objective of this report is to present the data that are used and the methodologies that were developed for generating the second version of GFC2020 and the preliminary version of GFT2020. The report presents also an analysis of the resulting maps (GFC2020 v2 and GFT2020 v0) in comparison with GFC2020 v1 (Bourgoin et al., 2024) and other global or regional sources of information. A robust accuracy assessment has been carried out for GFC2020 and is described in a separate technical report (Colditz et al., 2025).

¹ Recently the European Union adopted an amendment to Regulation (EU) 2023/1115 postponing the application of the regulation from 30 December 2024 to 30 December 2025 (EU 2024).

2 Data and method

The approach for identifying forest area and forest types combines existing global wall-to-wall datasets or datasets that are global for their scope. “Global for their scope” means that wall-to-wall data layers for zones or ecoregions are used if they provide a global coverage, e.g. for all tropical forests or dry forests on all continents. On the contrary, the workflow does not incorporate data at local, regional national or continental level. The maps are therefore a harmonized, globally consistent representation for the presence or absence of forest cover and sub-types in 2020, at 10m spatial resolution.

2.1 Update of the mapping approach for GFC2020 v2

2.1.1 Input datasets

Recent spatial datasets show global tree cover at a resolution of 30m or finer (Brandt et al., 2023; Brown et al., 2022; Zanaga et al., 2022). While these datasets are valuable for identifying a wide range of forest ecosystems with varying tree heights and cover, they pose a challenge: not every tree-covered pixel represents a forest. Converting tree cover data into “forest” land use requires supplementary information, as some areas may not meet the criteria for forests or may be used for other purposes, such as agriculture or urban development. Similarly, forests may temporarily lack tree cover due to disturbances like fires or logging, yet still retain their classification as forest land use.

GFC2020 v2 uses new or updated datasets (available since the release of GFC2020 v1) and incorporates user feedback to improve the accuracy and comprehensiveness of the global forest extent. This update addresses overestimations e.g. in agricultural and urban areas and underestimations such as in dry and open forest landscapes. This section details the updated input layers for land cover, land use, tree cover, and tree height used for the GFC2020 v2 map (Table 1). Most datasets represent the landscape in approximately 2020, with exceptions noted and justified in subsequent sections. Global ecological zones, forest cover change drivers, forest management type or coarse cropland classification were used as stratification layers to refine the data integration.

Table 1. Description of the datasets used as input layers in GFC2020 v2, including details of any pre-processing steps applied to certain datasets. Orange shading indicates revised / updated datasets, blue shading highlights newly introduced datasets, and original datasets used in GFC2020 v1 are white.

Dataset name	Dataset abbreviation	Description	Thematic information	Step in workflow	Resolution	Scope	Year	Reference
FAO Global Ecological Zones	FAO GEZ	Global Ecological Zones from FAO. We used the zones of Tropical rain forest, tropical moist forest, tropical dry forest and tropical mountain system as stratification	Stratification	Step 2	Various scales	Global	2010	FAO Global Ecological Zones
UMD Drivers of global forest loss	UMD Drivers	Drivers of forest cover loss. We used the areas of commodity-driven deforestation and shifting agriculture to stratify tree cover loss driven by deforestation. In GFC2020 v2, we used the forestry operation class to stratify tree cover loss driven by forest harvest in combination with historical tree cover datasets.	Stratification	Step 1 and 2	10km	Global	2001-2021	Curtis et al., 2018
ESA World Cover	ESA WC 2020 and 2021	Tree cover (class 10) and mangroves (class 95) were used in step 1. In GFC2020 v2, water (class 80), built-up (class 50), cropland (class 40), bare/sparse vegetation (class 60), snow (class 70) and herbaceous wetland (class 90) were used in step 2.	Tree cover	Step 1 and 2	10m	Global	2020 (v100), 2021 (v200)	Zanaga et al., 2022, 2021
WRI Tropical Tree Cover	WRI TTC	Tree cover inside and outside forests across the Tropics. In GFC2020 v2, we used a threshold of 50% instead of 80% in GFC2020 v1.	Tree cover	Step 1	10m	Tropics	2020	Brandt et al., 2023
UMD Tree cover 2000, 2010	UMD TC 2000, 2010	Pixel estimates of tree canopy cover derived from cloud-free annual growing season composites of Landsat data. We selected a minimal threshold of 10%.	Tree cover	Step 1	30m	Global	2000 and 2010	Hansen et al., 2013
UMD Global Forest Canopy Height	UMD GFCH	Gridded map of canopy heights from GEDI and Landsat. In GFC2020 v2, it includes an extrapolation of the model for the boreal regions.	Tree height	Step 2	30m	Global	2019	Potapov et al., 2021
Global-scale canopy height	GSCH	Global-scale canopy height estimation from Sentinel 1 and 2, GEDI and the Shuttle Radar Topography Mission.	Tree height	Step 2	10m	Global	2019-2020	Pauls et al., 2024
Very high resolution canopy height	META/WRI	Canopy height estimation from very-high resolution RGB images.	Tree height	Step 2	1m	Global	2009-2020	Tolan et al., 2024
UMD Global land cover and land use	UMD GLC <i>tree cover, cropland, other land cover, built-up</i>	Global land cover and land use from UMD. Classes of tree cover (classes 53-91 for terra firma, classes 171-211 for wetland) were used to build the potential maximum forest extent of forest (step 1). Classes 252 (cropland), 0-37, 120-157, 251 (other land cover) and 240-249	Land cover	Step 1 and 2	30m	Global	2019	Hansen et al., 2022

		(built-up) were used in step 2. Classes 51-52 (3 and 4m open trees) were no longer used as an 'other land cover' excluding mask in step 2.						
Global Mangrove Watch	GMW	Mangrove extent from Global Mangrove Watch, version 3.0.	Land cover	Step 1 and 2	25m (0.8 arc seconds)	Global	2020	Bunting et al., 2022
JRC Tropical Moist Forest	JRC TMF	Transition map and annual change datasets of forest cover change in the humid tropics from EC JRC. Undisturbed, mangroves and degraded forest (classes 1-2 from Annual Change) along with old regrowth (≥ 5 years old) of year 2020 have priority over masking layers of CH GEDI (< 5 m), GFC loss or other land cover from UMD-GLC. Deforested land including conversion to agricultural plantations and deforested mangroves (classes 3-4 from Annual Change), and young forest regrowth (< 5 years old) are used as masking layers over the Tropical rain forest ecological zone. In GFC2020 v2, other land cover classification was used for its potential to map agricultural commodities established before the monitoring period of TMF changes in early 1990s (areas excluded from the initial tropical moist forest extent).	Land cover/use	Step 2	30m	Tropics	1990-2020	Vancutsem et al., 2021, updated to version 2023
UMD Global Forest Cover loss	UMD GFC loss	Global forest cover loss from UMD GLAD. All tree cover loss from 2001-2020 over commodity-driven deforestation and shifting agriculture (Drivers of forest cover loss) areas and not overlaying with forest cover loss from fire or with Forest cover from JRC-TMF were considered as masking layer in step 2. In GFC2020 v2, areas with tree cover loss combined with UMD Tree Cover 2000 (loss year after 2001) or 2010 (loss year after 2011) identified by UMD Drivers of Forest Loss as forestry operations were considered potential unstocked forest from clear-cut harvesting when WC 2020 and 2021 showed no tree cover (step 1).	Land cover	Step 1 and 2	30m	Global	2001-2020	Hansen et al., 2013
UMD Global Forest Cover loss from fire	UMD GFC - fire	Global forest cover loss from fire from UMD GLAD was originally used in step 2 in combination with the GFC-loss dataset to prevent the exclusion of burned forests that have the capacity regrow. In GFC2020 v2, areas with tree cover loss from fire combined with UMD Tree Cover 2010 (loss year after 2011) were considered potential unstocked forest from fire disturbance when WC 2020 and 2021 showed no tree cover (step 1).	Stratification	Step 1 and 2	30m	Global	2001-2020	Tyukavina et al., 2022
JRC Global Human Settlement Layer	JRC GHSL	Global human settlement JRC, Built-Up Characteristics. All values (1-25) were considered as masking layer.	Land cover	Step 2	10m	Global	2018	Pesaresi and Politis, 2023
JRC Global Human Settlement Layer Degree of Urbanisation	JRC GHS SMOD	Degree of Urbanisation stage I methodology recommended by UN Statistical Commission. We used the suburban or peri-urban (21), semi-dense urban cluster (22), dense urban cluster (23) and urban centre (30) as input classes and created a negative buffer of 1250m to mitigate patchy effects.	Land use	Step 2	1km	Global	2020	Schiavina et al., 2023

Global mining land use	IIASA Mining	Visual interpretation and delineation of large-scale, artisanal and small-scale mining sites using Sentinel-2 imagery. The polygons extent was used in combination with any tree cover loss from UMD GFC loss.	Land use	Step 2	Scale not specified	Global	2019	Maus et al., 2022
JRC Global Surface Water	JRC GSW	Classes of permanent water, new permanent water and seasonal to permanent water (1,2 and 7) were used as masking layer only when not overlapping with mangrove area from JRC-TMF (classes 12, 61-64 from Transition map) or GMW. Mask of volcanic areas (lava flows) used to mask tree cover.	Land cover	Step 2 and 3	30m	Global	1990-2020	Pekel et al., 2016
UMD Global Cropland Extension	UMD Cropland	Overlapping extent of cropland mapped in 2003, 2007, 2011, 2015 and 2019 from GLAD UMD.	Land use	Step 2	30m	Global	2003-2019	Potapov et al., 2022
NASA Global Cropland-Extent Product	GCEP <i>Cropland</i>	Cropland extent from a combination of Landsat, and elevation derived data.	Stratification	Step 2	30m	Global	2015	Thenkabail et al., 2021
ESA World Cereal	ESA World Cereal	ESA World cereal for cereal crop mapping: temporary crops extent was used as masking layer.	Land use	Step 2	10m	Global	2021	Van Tricht et al., 2023
Oil palm plantation	Descals et al. <i>Oil palm plantation</i>	Industrial and smallholder map of closed-canopy oil palm plantations not overlapping with mangrove area from JRC-TMF or GMW.	Land use	Step 2	10m	Global	2019	Descals et al., 2021
Coconut plantation	Descals et al. <i>Coconut plantation</i>	Closed-canopy coconut palm. Plantation not overlapping with mangrove area from JRC-TMF or GMW.	Land use	Step 2	10m	Global	2020	Descals et al., 2023
Global mapping of oil palm planting year	Descals et al. <i>Oil palm year</i>	Year of establishment of industrial and small-holder oil palm plantation using a combination of Sentinel-1 and Landsat images. The planting year layer was used and years from 1990 to 2020 were selected as exclusion mask.	Land use	Step 2	10m	Global	1990-2020	Descals et al., 2024
Palm Probability model 2024	Clinton et al. <i>Palm probability</i>	Probability estimates of palm occurrence (version '20240312'). We selected a threshold higher or equal to 70% and manually removed noise (commission errors).	Land use	Step 2	10m	Global	2020	Clinton et al., 2024

High-resolution map of rubber	Wang et al. <i>Rubber</i>	Estimation of rubber plantation using Sentinel-2 imagery within the tree cover extent from ESA WC 2021.	Land use	Step 2	10m	Southeast Asia ²	2021	Wang et al., 2023
WRI Spatial Database of Planted Trees v1	WRI SDPT v1.0	Spatial Database of Planted Trees (version 1.0) differentiating plantation forests from tree crops (stands of perennial tree crops, such as rubber, oil palm, coffee, coconut, cocoa, and orchards) compiled by WRI. Tree crops was used as a masking layer.	Land use	Step 2	Various scales	Global	Varies	Harris et al., 2019
WRI Spatial Database of Planted Trees 2.1	WRI SDPT <i>Planted trees and Tree crops</i> v2.1	Spatial Database of Planted Trees (version 2.1). The attribute 'simpleType' was used to create a planted forests and a tree crop dataset. Planted forests were used in step 1 while tree crops were used in step 2 as a masking layer.	Land use	Step 1 and 2	Various scales	Global	Varies	Richter et al., 2024, change log report for version 2.1
IIASA Global Forest Management	IIASA Forest Management	IIASA Forest management map. Only the agroforestry class was used as masking layer when intersecting with forest cover from JRC-TMF and GFC loss.	Stratification	Step 2	100m	Global	2015	Lesiv et al., 2022
CROPGRIDS	CROPGRIDS	Stratification of potential coffee, cocoa and cashew area from the global geo-referenced dataset of crop area based on a harmonization of national statistics and gridded data. For coffee, we used a minimum threshold of 200ha of crop area when combined with other land cover from JRC-TMF and META/WRI or GSCH height maps. We lowered the threshold to 60ha and 70ha when combined with GCEP and GSCH or GCEP and META/WRI respectively. For cocoa, we used a minimum threshold of 300ha when combined with other land cover from JRC-TMF and GSCH height map. We lowered the threshold to 50ha when combined with GCEP and GSCH or GCEP and META/WRI. For cashew, we used a minimum threshold of 300ha when combined with other land cover from JRC-TMF and GSCH height map. We lowered the threshold to 50ha when combined with GCEP and GSCH and to 150ha when combined with GCEP and META/WRI.	Stratification	Step 2	0.05° (~5.6km at the equator)	Global	2020	Tang et al., 2024

Source: JRC.

² Although more than 90% of global rubber production occurs in Southeast Asia (Wang et al. 2023), this map does not include other producing regions (e.g. South and Central America, West and Central Africa) making it the sole regional dataset used in GFC2020 v2.

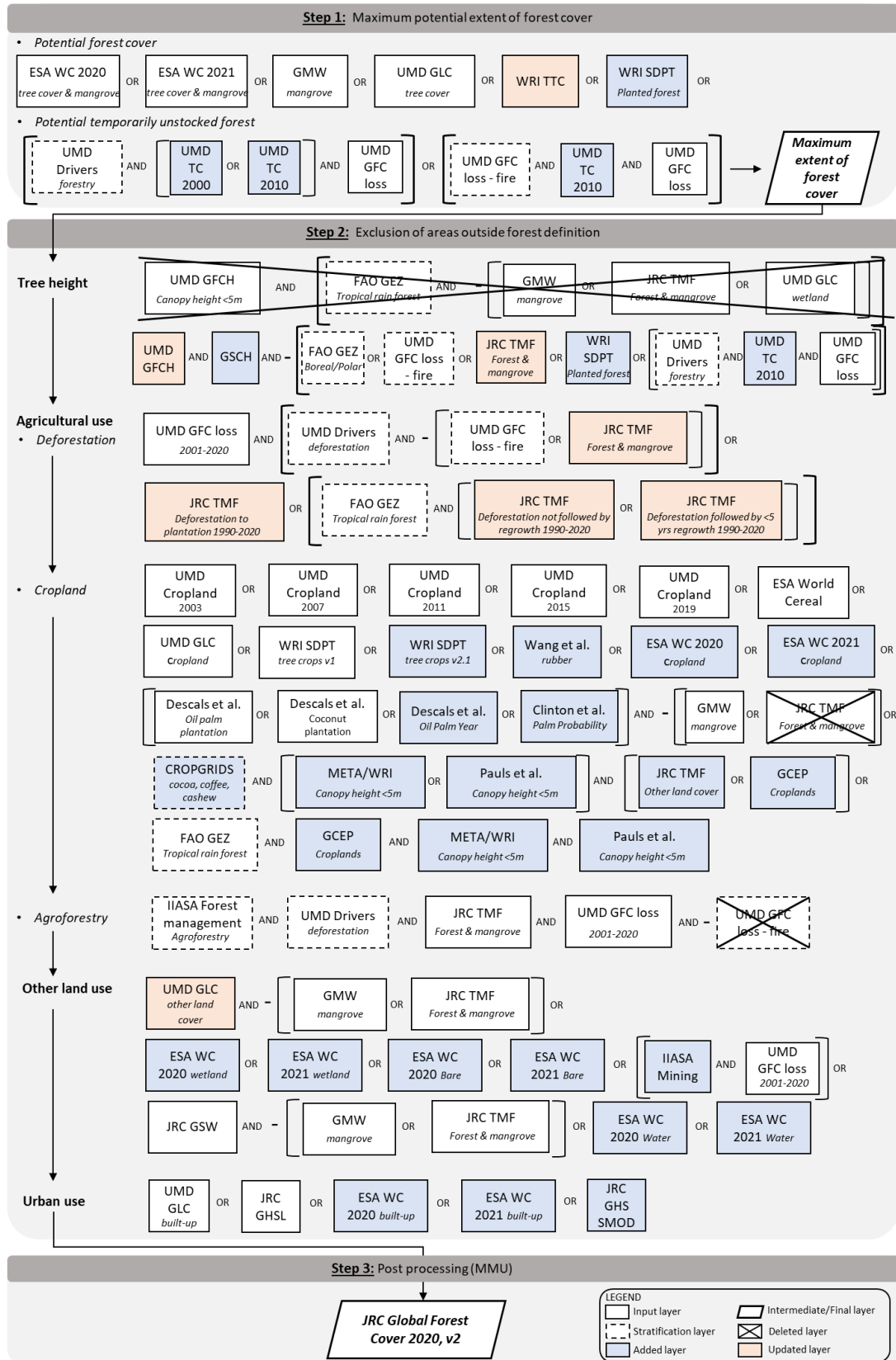
2.1.2 Approach

The approach for mapping forest areas in year 2020 at 10m resolution using the EUDR definition of forests includes three steps:

- Step 1: mapping the maximum potential extent of forest cover for year 2020 globally. This includes areas of currently unstocked forest land. This step is crucial, as areas not included in the maximum potential forest cover extent cannot be classified as forest cover in subsequent steps.
- Step 2: apply overlays and Boolean decision rules to reduce the maximum potential forest cover extent to the EUDR forest definition using global datasets that cover tree height, agricultural use, urban areas, and other land uses.
- Step 3: apply a Minimum Mapping Unit (MMU) of 0.5 ha to forest and non-forest patches and minor corrections (e.g. stripe lines removal).

Figure 1 illustrates the steps and rules in detail. As in GFC2020 v1, the selection and combination of input datasets aim to balance commission and omission errors, eventually leaning toward a moderate overestimation of forest cover.

Figure 1. Three-step process used to produce GFC2020 v2. The workflow shows the specific input layers that have been removed (crossed), revised (orange shading) or added (blue shading) compared to the approach used to produce GFC2020 v1.



2Source: JRC.

2.1.3 Step 1: Maximum potential extent of forest cover

To create the maximum potential extent of forest cover, we combined the following layers with equal weights: ESA WorldCover 2020 and 2021 tree cover and mangroves, WRI Tropical Tree Cover 2020 (50% tree cover), UMD Global land cover and land use 2019 and Global Mangrove Watch (GMW) 2020. Additionally, areas with UMD tree cover loss combined with UMD Tree Cover 2000 (loss year after 2001) or 2010 (loss year after 2011) and identified as forestry operations under UMD Forest Loss Drivers were considered potential unstocked forest from clear-cut harvesting where WorldCover 2020 and 2021 showed no tree cover. Areas with UMD tree cover loss from fire combined with UMD Tree Cover 2010 (loss year after 2011) were considered potential unstocked forest from fire disturbance when WorldCover 2020 and 2021 showed no tree cover. The extent of planted trees from SDPT v2.1 was also included in step 1 except in areas where no tree cover was identified by neither UMD tree cover 2000, 2010 nor by WorldCover 2020, 2021. Step 1 excluded pixels depicting transitions from tree or mangrove cover to water bodies between the 2020 and 2021 WorldCover datasets if these transitions occurred within areas classified as mangrove by the Global Mangrove Watch (GMW).

2.1.4 Step 2: Exclusion of areas outside forest definition

Four masks (tree height, agriculture use, other land use and urban use) were applied to the maximum potential extent of forest cover (from Step 1) to align to the forest definition.

- **Tree height:** Excluded areas with top canopy heights below 5 meters based on both UMD GFCH and GSCH (Pauls et al., 2024) gridded products, except where the JRC TMF identified the presence of any tropical moist forest type (undisturbed, degraded, regrowing or mangrove), where potential unstocked conditions existed due to fire (indicated by UMD GFC - fire), where forestry disturbances were indicated by the SDPT dataset or when a tree cover loss occurred after 2011 in areas identified by UMD Drivers of Forest Loss as forestry operations. Boreal coniferous forest, Boreal tundra woodland, Boreal mountain system, and Polar ecological zones were excluded from this mask.
- **Agricultural use:** This mask was generated by integrating multiple datasets on deforestation, cropland, tree crops and agroforestry systems.
 - Tree cover loss from 2001 to 2020 from Hansen et al., 2013 in areas dominated by commodity driven deforestation and shifting agriculture (Curtis et al., 2018) was used. We excluded from the mask areas overlapping with forest cover loss due to fire from Tyukavina et al., 2022 and JRC TMF forest (undisturbed, degraded and regrowth) and mangrove (Vancutsem et al., 2021) corresponding to areas that have potential for recovery/regeneration and where tree cover loss does not imply a change in land use.
 - Tropical moist forest conversion to agricultural plantation (mainly rubber and oil palm) was used for the whole tropical belt from the JRC TMF dataset. We added into this mask the areas of deforestation followed or not by regrowth (only regrowth of less than 5 years old were considered) from the JRC TMF, but only within the Tropical Rainforest ecological zone, to prevent commission errors in other zones (e.g., Tropical dry forest and Tropical mountain system). Areas of deforestation followed by forest regrowth of more than 5 years are not included in the mask as we assume that the dominated land use remains forest that regenerated in abandoned agricultural land. Young regrowth (less than 5 years) are included in the mask as they may not meet

the forest definition in terms of land use (e.g. in shifting agriculture systems), tree cover or height.

- We produced a maximum extent mask of global cropland from UMD during the period 2003-2019 (Potapov et al., 2022). Additionally, we used the extent of World Cereal temporary crops, ESA WorldCover cropland for year 2020 and 2021, UMD GLC cropland and tree crops polygons from the SDPT (merging both v1 and v2.1 together).
- We used the extent of rubber plantation from Wang et al. (2023).
- We used the extent of global oil palm and coconut plantation from Descals et al., 2021, 2023 and 2024 together with the palm probability dataset from Clinton et al. (2024), except in areas mapped as mangroves in GMW.
- We used coffee, cocoa and cashew crop area from CROPGRID as stratification layer to refine the masking of tree crops with specific rules based on canopy height (less than 5m from META/WRI or GSCH products), cropland (i.e. GCEP) or potential agricultural commodity datasets (i.e. other land cover classification from JRC TMF).
- Within the tropical rainforest ecological zone, we prioritized excluding cropland data from GCEP where it overlapped with areas identified as having a canopy height less than 5 meters, based on data from META/WRI and GSCH.
- We intersected the agroforestry class from the Forest Management map (Lesiv et al. 2022) with forest classes from TMF, GFC loss from UMD GLAD (not due to fire) in areas dominated by commodity deforestation and shifting agriculture. The rationale behind this is to mask out tree crops (e.g. full sun or shaded cocoa plantations) that may be classified as undisturbed, degraded or forest regrowth in the JRC TMF dataset.
- **Other land use:** We utilized the class 'other land cover' from the UMD dataset, encompassing areas classified as true desert, semi-arid, dense short vegetation, salt pan, sparse vegetation in wetlands, and ice. This dataset was applied as an exclusion layer except when overlapping with mangroves from the Global Mangrove Watch (GMW) or forested areas from the JRC TMF. Furthermore, we employed a water mask derived from the JRC Global Surface Water database, incorporating permanent, new permanent, and seasonal to permanent water transitions. This water mask was applied except where it overlapped with mangroves from GMW or forested areas from JRC TMF. Additionally, we included permanent water bodies from the 2020 and 2021 ESA WorldCover datasets within this water mask. Finally, wetland and bare soil classifications from the WorldCover dataset were also used as exclusion layers. Additionally, we included a mining dataset from IIASA to mask out trees under mining land use.
- **Urban use:** we took the maximum extent of UMD GLC built-up (0-100% built-up classes), JRC GHS-BUILT-C and built-up classifications from WorldCover (2020, 2021) to create an urban mask. We included JRC GHS SMOD to mask out trees under urban use (pre-processing details in Table 1).

2.1.5 Step 3: Post-processing

Artefacts remaining in input datasets that propagated to the final map such as the regionally visible stripe patterns due to the Landsat-7 scan line corrector failure were manually masked out or filled using World Cover Tree Cover 2021 extent. The mask from the Global Surface Water database on

lava flows was used to remove mapped forest pixels in volcanic area. To align with the forest definition, we applied a minimum mapping unit of 0.5 hectares. Patches of forest that did not reach the area of 0.5ha were labelled non-forest. Likewise, non-forest patches smaller than 0.5ha were labelled forest. This post-processing operation was based on the computation of each pixel area in square meters (latitude-dependent). We used the eight-neighbour rule to map patches using connected pixels in cardinal and intercardinal directions.

2.2 Mapping approach for GFT2020 v0

2.2.1 Definitions

The EUDR defines forest degradation as structural changes in the form of:

- Conversion of primary forest to plantation forest, planted forest or other wooded land (OWL).
- Conversion of naturally regenerating forest to plantation forest or OWL.

Wood products from such converted area cannot be placed on the EU market or exported from it. Sustainable forest management systems can be used and are encouraged, provided they do not lead to a conversion that meets the degradation definition.

Figure 2 illustrates different cases of deforestation, forest degradation or changes that are not subject of this regulation.

Figure 2. Deforestation and forest degradation as set out under the EUDR.

FOREST TYPE 2020	FOREST TYPE POST-2020	WOOD REMOVAL AND RESULTING LAND COVER OBSERVED AT POINT OF DUE DILIGENCE	EUDR DEGRADATION OR DEFORESTATION STATUS	FOREST TYPE 2020	FOREST TYPE POST-2020	WOOD REMOVAL AND RESULTING LAND COVER OBSERVED AT POINT OF DUE DILIGENCE	EUDR DEGRADATION OR DEFORESTATION STATUS
PRIMARY FOREST	PRIMARY FOREST	E.G. CLEARCUT OR SELECTIVE LOGGING	CONVERSION FREE	NATURALLY REGENERATING FOREST	NATURALLY REGENERATING FOREST	E.G. CLEARCUT OR SELECTIVE LOGGING	CONVERSION FREE
	NATURALLY REGENERATING FOREST	E.G. CLEARCUT OR SELECTIVE LOGGING	CONVERSION FREE		PLANTED FOREST	E.G. CLEARCUT OR SELECTIVE LOGGING	CONVERSION FREE
	PLANTED FOREST	E.G. CLEARCUT OR SELECTIVE LOGGING	DEGRADATION		PLANTATION FOREST	E.G. CLEARCUT	DEGRADATION
	PLANTATION FOREST	E.G. CLEARCUT	DEGRADATION		OTHER WOODED LAND	E.G. CLEARCUT OR SELECTIVE LOGGING	DEGRADATION
	OTHER WOODED LAND	E.G. CLEARCUT OR SELECTIVE LOGGING	DEGRADATION		AGRICULTURE E.G. SILVOPASTORAL LAND	E.G. CLEARCUT OR SELECTIVE LOGGING	DEFORESTATION
	AGRICULTURE E.G. SILVOPASTORAL LAND	E.G. CLEARCUT OR SELECTIVE LOGGING	DEFORESTATION				

Source: "Monitoring Forest Degradation for the EUDR | GFW Blog" 2023. Modified.

The EUDR definition of forest types is aligned with definitions adopted by the Food and Agriculture Organization under the Global Forest Resources Assessment (FAO, 2018). Annex 1 lists relevant definition as set out in the EUDR.

The definition of forest types foresees to assess declared points or polygons for a date after 2020 against the situation of the land at the cut-off date (31 December 2020). To this end, the JRC produced a preliminary map of global forest types for the year 2020 (GFT2020 v0). Given the definition in the EUDR and following the illustration in Figure 2, the initial state in year 2020 only requires to separate between 1) primary forest, 2) naturally regenerating forest, and 3) other forest types, which are by definition planted or plantation forests.

2.2.2 Input datasets

Operationalizing forest type definitions at global scale, especially differentiating between primary, naturally regenerating, planted, and plantation forests, is hindered by limited publicly available global datasets. Mapping primary forests poses a significant challenge due to the lack of consensus on spatial indicators and methodologies, reflecting the multifaceted nature of the primary forest

definition itself. This preliminary map aims to capture areas with minimal human disturbance and pressure on ecological processes. Our approach combines maps of large, continuous forest patches with those showing high levels of protection, further incorporating 20-30 year time series of forest disturbances (Table 2). To identify planted and plantation forests, we integrate a globally harmonized collection of national-scale planted forest datasets with global wall-to-wall remote sensing products on forest management type, tree cover, tree cover loss, and tree height.

Table 2. List with description of the datasets used as input layers for GFT2020 v0.

Dataset name	Dataset abbreviation	Description	Thematic information	Role in workflow	Resolution	Scope	Year	Reference
FAO Global Ecological Zones	FAO GEZ	Global Ecological Zones from FAO. We used the zones of Tropical rain forest as stratification.	Stratification	Stratification	Various scales	Global	2010	FAO Global Ecological Zones
UMD Drivers of global forest loss	UMD Drivers forest loss	Drivers of forest cover loss. We used the areas of wildfire to cancel the exclusion of GFC loss for primary forest mapping.	Stratification	Stratification	10km	Global	2001-2021	Curtis et al., 2018
IIASA Global Forest Management	IIASA Forest Management	IIASA Forest management map. Classes of planted forest (forest is managed and there are signs of plantations, rotation time is relatively long, >15 years) and plantation forest (intensively managed forest plantations for timber with short rotation, 15 years max) were used as stratification layer.	Stratification	Stratification	100m	Global	2015	Lesiv et al., 2022
JRC Global Forest Cover 2020	JRC GFC	Globally harmonized and consistent representation of forest / non-forest cover for year 2020 (GFC2020 v1).	Forest cover	Forest extent	10m	Global	2020	Bourgoin et al., 2024
UMD Global Forest Canopy Height	UMD GFCH	Gridded map of canopy heights from GEDI and Landsat. It includes an extrapolation of the model in the boreal regions.	Tree height	Inclusion layer for planted/plantation forest	30m	Global	2019	Potapov et al., 2021
UMD Global Forest Cover loss	UMD GFC loss	Global forest cover loss from UMD GLAD.	Forest disturbances (natural and anthropogenic)	Exclusion layer for primary forest; Inclusion layer for planted/plantation forest	30m	Global	2001-2020	Hansen et al., 2013
UMD Tree cover 2000	UMD TC 2000	Pixel estimates of percent maximum (peak of growing season) tree canopy cover derived from cloud-free annual growing season composite Landsat data. We selected a minimal threshold of 10%.	Tree cover	Inclusion layer for planted/plantation forest	30m	Global	2000	Hansen et al., 2013
JRC Tropical Moist Forest	JRC TMF	Transition map and annual change datasets of forest cover change in the humid tropics from EC JRC. The extent undisturbed mangroves up to end of 2020 was used.	Land cover/use	Inclusion layer for primary forest	30m	Tropics	1990-2020	Vancutsem et al., 2021, updated to version 2023

JRC Tropical Moist Forest Degradation and Deforestation Year	JRC TMF -Disturbance	Spatially-explicit areas of deforestation and forest degradation in tropical moist forests, with pixel values denoting the year of occurrence, derived using Landsat time-series imagery. Forest degradation from selective logging, fire or natural events is defined as temporary disturbances occurring for up to 2.5 years, while deforestation is a longer-term disturbance where disruptions to tree cover (absence of tree foliage cover within a 30-m pixel) are visible for more than 2.5 years. A buffer of 250m around degraded forest pixels (excluding degradation from single disruption observation and patches of less than 3 connected pixels) was applied to increase the area of exclusion around burned and selective logged (logging gaps/roads) areas.	Forest disturbances (natural and anthropogenic)	Exclusion layer for primary forest	30m	Tropics	1990-2020	Vancutsem et al., 2021, updated to version 2023
WRI Spatial Database of Planted Trees 2.1	WRI SDPT	Globally harmonized spatial Database of Planted Trees (version 2.1). We used planted forests to map planted/plantations which are defined as stands—other than tree crops—grown for wood and wood fiber production or for ecosystem protection against wind and/or soil erosion.	Land use	Planted/plantation forest	Various scales	Global	Varies	Richter et al., 2024, see the change log report for version 2.1
Global mining land use	IIASA Mining	Visual interpretation and delineation of large-scale, artisanal and small-scale mining sites using Sentinel-2 imagery. The polygons extent was used in combination with any tree cover loss from UMD GFC loss.	Land use	Exclusion layer for primary forest	Scale not specified	Global	2019	Maus et al., 2022
Intact Forest Landscape	IFL	Forest ecosystems minimally influenced by human activity, with (i) an area of at least 500 km ² (50,000 ha), (ii) a minimum width of 10 km and (iii) a minimum corridor/appendage width of 2 km. Areas with evidence of certain types of human influence are considered disturbed or fragmented and consequently not eligible for inclusion in the IFL.	Continuous expanse of natural forest with no remotely detected signs of human activity, and large enough that all native biodiversity could be maintained	Proxy for primary forest	Scale 1:1,000,000	Global	2020	Potapov et al., 2017
Forest Landscape Integrity Index	FLII	The Forest Landscape Integrity Index integrates data on observed and inferred forest pressures and lost forest connectivity to generate a continuous index of forest integrity as determined by degree of anthropogenic modification. The forest areas with an index higher of 9.6 or higher were selected.	Interiors and natural edges of more or less unmodified naturally regenerated (i.e. non-planted) ecosystems, comprised entirely	Proxy for primary forest	300m	Global	2019	Grantham et al., 2020

			or almost entirely of native species.					
World Database on Protected Areas	WDPA	Global database on protected areas from the United Nations Environment Programme and the International Union for Conservation of Nature (IUCN) and compiled by over 600 data providers ranging from governments to individuals. The highest IUCN categories were selected as proxy for primary forest: Category Ia – strict nature reserve; Category Ib – wilderness area; Category II – national park	Forest management - protection of biodiversity and ecosystem processes, absence/limited direct human impacts	Proxy for primary forest	Scale not specified	Global	Varies	www.protectedplanet.net
European primary forest database v2.0	EPFD	Harmonized geodatabase of 48 datasets of primary forests (mostly field-based) spread across 33 European countries. Primary forests definition follow the FAO and include old-growth, late-successional forests, but also some early seral stages and young forests that originated after natural disturbances and natural regeneration after management (e.g. 60–80 years after human impacts plus the length of a typical rotation cycle for clear cut forests)	Land use	Primary forest	Scale not specified	Europe	Varies	Sabatini et al., 2021 ³

Source: JRC.

³ Given the limited availability of primary forest data across Europe, this dataset served as the sole continental-level resource used in GFT2020 v0.

2.2.3 Approach

The global delineation of forest types is restricted to areas defined as forest cover within GFC2020 v1. The reason for choosing GFC2020 v1 as mapping extent is merely related to its readiness when the preliminary map of forest types was developed. Also, we wanted to ensure a swift joint release of the preliminary forest type map (GFT2020 v0) when the updated forest cover map (GFC2020 v2) was ready. All forest cover is initially labelled as **naturally regenerating**, and then this classification is revised if: (a) the area meets the criteria for labelling as primary forest, or (b) the area overlaps with spatial layers indicating potential planted or plantation forests (Figure 3). This starting point for labelling is in line with the definition of forest types which notes that in case of doubt, naturally regenerating forest should be assigned.

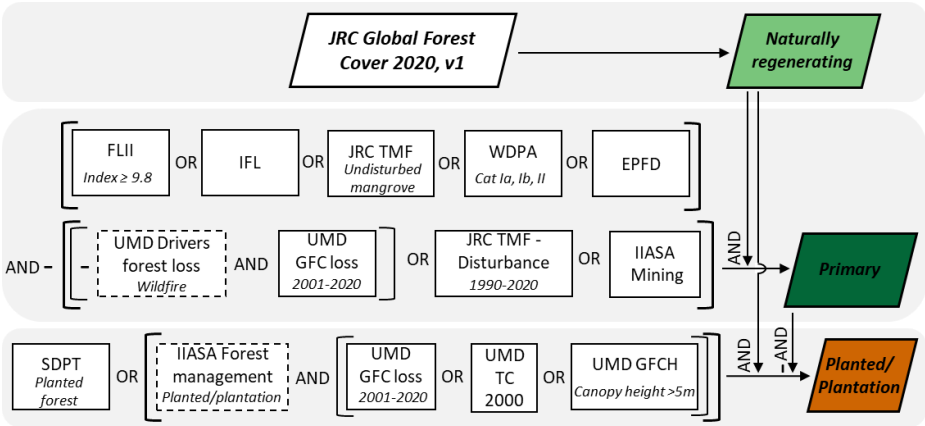
To qualify as **primary forest**, a forest cover pixel must overlap with at least one of the following datasets: (1) high landscape-level integrity areas from the Forest Landscape Integrity Index (FLII), (2) Intact Forest Landscapes (IFL) from Potapov et al. 2017, (3) undisturbed mangrove forests from JRC TMF, (4) strictly protected areas from the World Database on Protected Areas (WDPA), or (5) the primary forest database from EPFD. Subsequently, this initial classification undergoes refinement. Areas coinciding with tree cover loss from UMD GFC loss data (excluding areas identified as wildfire drivers), disturbance events from JRC TMF, or mining concessions from IIASA are subsequently removed in order to produce the final extent of primary forests.

To be classified as a **planted/plantation forest**, a forest cover pixel must intersect with: (1) planted forest areas from the WRI Spatial Database on Planted Trees dataset (SDPT), or (2) areas within the IIASA forest management dataset identified as potential planted/plantation forests, where the pixel exhibits either: (a) tree cover loss or (b) at least 10% tree cover in 2000 or (c) a canopy height of more than 5 meters in 2020, as derived from UMD datasets.

In this labelling process Planted/plantation forests take precedence over primary forests.

This approach may be subject to revisions in future versions of the Global Forest Type map, including the potential consideration of a minimum mapping unit of 0.5 hectares for each forest type, a feature currently not implemented in this preliminary version.

Figure 3. Workflow for generating the GFT2020 v0.



Source: JRC.

2.3 Input data for comparisons with GFC2020

To assess potential commission errors in GFC2020 forest cover estimates, we intersected the forest extent derived from GFC2020 v1/v2 with independent regional/global cropland and pastureland datasets not utilized in the GFC2020 v1 and GFC2020 v2 workflow. Furthermore, we compared GFC2020 forest area estimates with several national/regional land cover products (Table 3). Note that these products are usually depicting land cover by reflecting the physical characteristics of the Earth's surface, whereas GFC2020 aims to depict forest areas under a land use definition. Annexes 2-5 detail the forest/non-forest reclassification of national/regional land cover for comparison with GFC2020.

Table 3. Description of input data for GFC comparisons.

Dataset name	Description	Resolution	Scope	Year	Reference
Cocoa, oil palm and rubber Probability models 2024a	Regional probability estimates of cocoa (Côte d'Ivoire, Ghana), oil palm (global) and rubber (Thailand, Indonesia, Vietnam, Malaysia, Philippines, Hainan Island, Côte d'Ivoire, Ghana) from the Forest Data Partnership.	10m	Varies	2020	Forest Data Partnership, 2024. Cocoa model 2024a Clinton et al., 2024 Forest Data Partnership, 2024. Rubber model 2024a
Global Pasture Watch Annual Dominant Class of Grasslands v1	Annual dominant class maps of grasslands (cultivated and natural/semi-natural) from the Land & Carbon Lab Global Pasture Watch (GPW) initiative. Cultivated grasslands are intentionally planted and managed for forage production, including areas of native grasslands actively managed for human use. In contrast, natural/semi-natural grasslands are relatively undisturbed native grasslands or those with limited human impact.	30m	Global	2020	Parente et al., 2024
Copernicus CORINE Land Cover	The CORINE Land Cover inventory standardizes European land data to support environmental policy. It covers 33 EEA member countries and 6 cooperating countries, spanning over 5.8 million km ² . The CLC2018 dataset provides a pan-European land cover inventory for 44 thematic classes, referencing the 2018 land cover status.	100m	Europe	2018	This publication has been prepared using European Union's Copernicus Land Monitoring Service information: https://doi.org/10.2909/960998c1-1870-4e82-8051-6485205ebbac
Côte d'Ivoire BNETD 2020 Land Cover Map	The Côte d'Ivoire BNETD 2020 Land Cover Map was produced by the Ivorian Government with EU support, using a transparent and participatory methodology. The map combines satellite imagery and field data to provide accurate land cover information, including forest cover.	10m	Côte d'Ivoire	2020	BNETD Land Cover Map 2020
MapBiomias Brasil 2020 Land Cover Map	The MapBiomias project addressed a gap in annual land use and land cover information in Brazil by creating a 33-year dataset (1985-2017) using Landsat archive and Google Earth Engine.	30m	Brazil	2020	Souza et al., 2020
Land Cover of North America 2020 NALCMS	The 2020 North American Land Cover dataset was produced through a trilateral effort between Canada, the USA, and Mexico. The dataset combines national land cover maps from each country, using Landsat 8 data and varying classification methods, to provide a seamless and consistent land cover map of North America.	30m	North America	2020	North American Land Change Monitoring System, 2020

Source: JRC.

3 Results

3.1 Data access

The Global Forest Cover and Type maps are open source and freely accessible for visualisation and download at:

- EU Forest Observatory website (visualisation): <https://webobstest.jrc.cec.eu.int/forest/> - select under the layer symbol the map (default is GFC2020 V2).
- JRC Data catalogue (metadata):
 - GFC2020 v2: <http://data.europa.eu/89h/e554d6fb-6340-45d5-9309-332337e5bc26>
 - GFT2020 v0: <http://data.europa.eu/89h/037ca376-ba92-49db-a8f7-0c277c1e5436>
- Forobs website (download)
 - GFC2020 v2: <https://forobs.jrc.ec.europa.eu/GFC>
 - GFT2020 v0: <https://forobs.jrc.ec.europa.eu/GFT>
- WMS (visualisation, links to be placed in a GIS software)
 - GFC2020 v2: <https://ies-ows.jrc.ec.europa.eu/iforce/gfc2020/wms.py?>
 - GFT2020 v0: <https://ies-ows.jrc.ec.europa.eu/iforce/gft2020/wms.py?>
- GEE asset (visualisation and processing)
 - GFC2020 v2: https://developers.google.com/earth-engine/datasets/catalog/JRC_GFC2020_V2
 - GFT2020 v0: https://developers.google.com/earth-engine/datasets/catalog/JRC_GFC2020_subtypes_V0

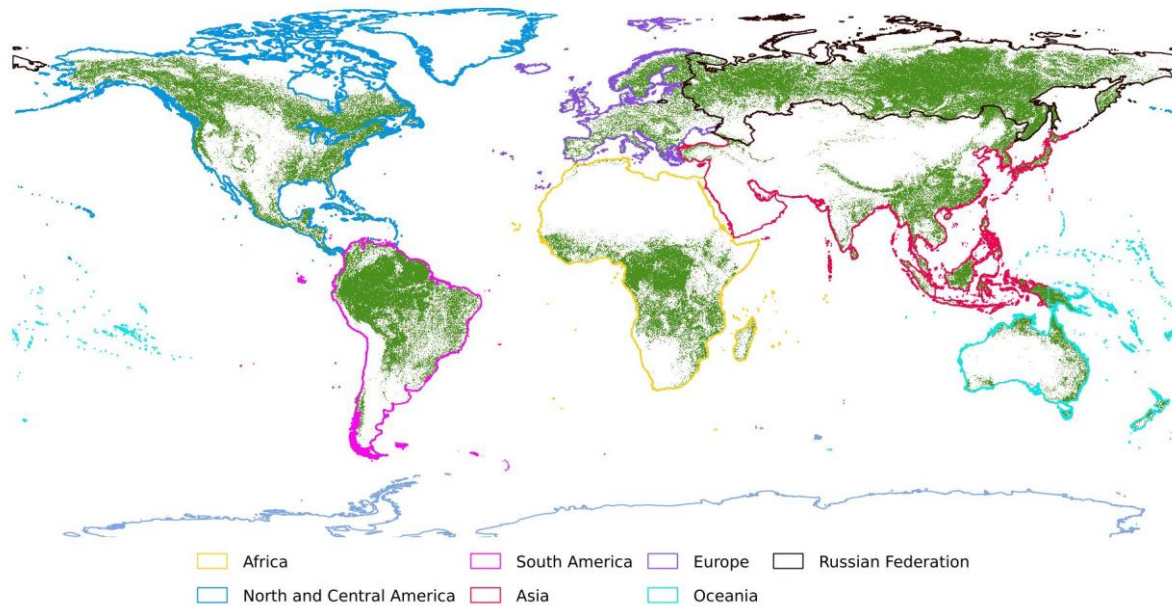
The users are invited to refer to the frequently asked questions of the EU Forest Observatory website for further information on these maps:

https://webobstest.jrc.cec.eu.int/Frequently_Asked_Questions_EUFO.docx

3.2 The global forest cover map for year 2020 v2

The Global Forest Cover map for year 2020 V2 depicts the global forest cover extent following the forest definition of the EUDR⁴ for year 2020 (). The global forest area from this map is 4,562 Mha with the following distribution by continents (see continental outlines in Figure 4): 231 Mha in Europe, 760 Mha in Africa, 830 Mha in North and Central America (including the Caribbean), 931 Mha in South America, 658 Mha in Asia, 204 Mha in Oceania and 948 Mha in Russia (Figure 5A).

Figure 4. GFC2020 v2



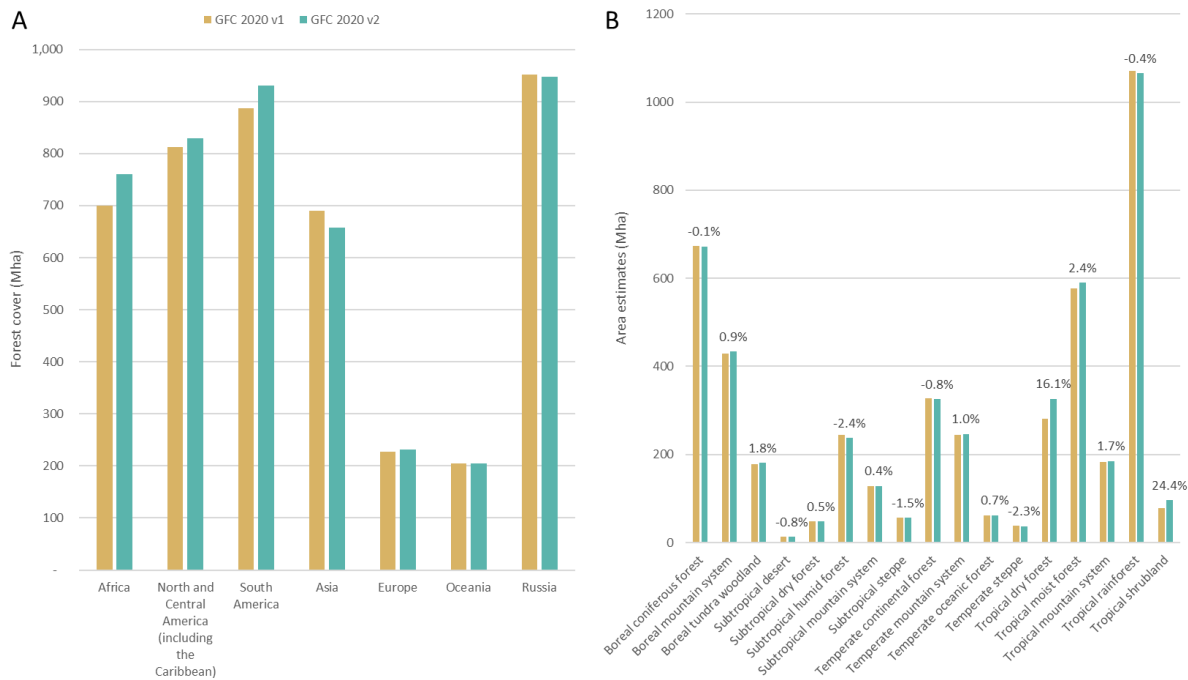
Source: JRC. [FAO GAUL](#) for sub-continent boundaries.

Looking at the distribution of forest cover inside the Global Ecological Zones (GEZ) of the FAO (FAO 2012, Annex 6), 23 % of the total forest cover is located in the tropical rainforest, 14% in the boreal coniferous forest, 13% in the tropical moist forest, 9% in the boreal mountain forest, 7 % in the tropical dry forest, 7% in the temperate continental forest, 5% in the temperate mountain system and 5% in the subtropical humid forest ecoregions (Figure 5B). The rest of the ecoregions contains less than 17% of the total forest cover area.

In comparison with GFC2020 v1, GFC2020 v2 shows large increases of forest areas in the ecological zones of Tropical shrubland (+24.4%), tropical dry forest (+16.1%) and tropical moist forest (+2.4%) and decreases in ecological zones of subtropical humid forest (-2.4%) and temperate steppe (-2.3%) ecoregions (Figure 5B). Changes of less than 2% between the two map versions were observed in the remaining ecoregions.

⁴ See limitations in Section 4

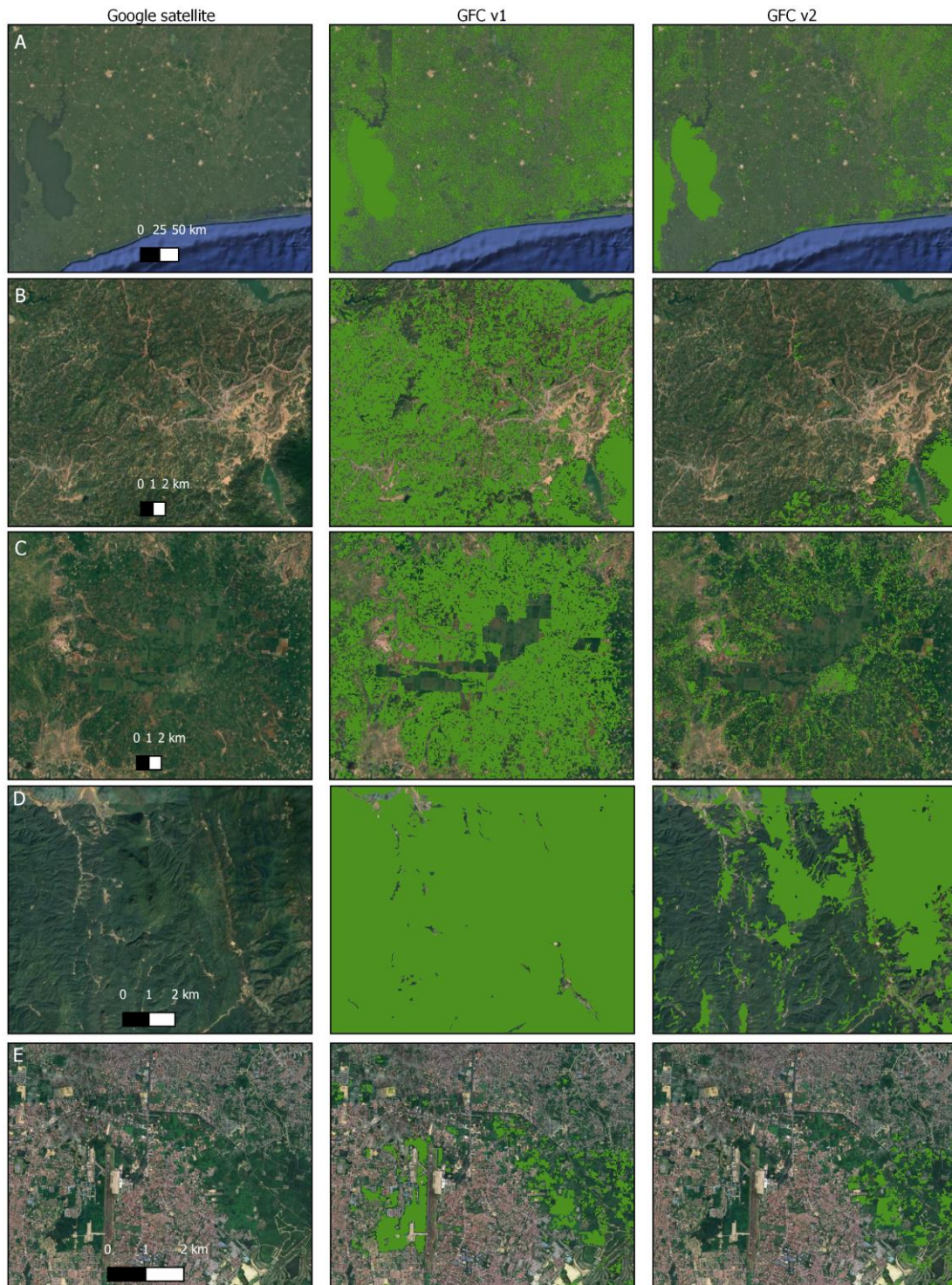
Figure 5. Areas of forest cover for GFC2020 v1 and GFC2020 v2 at sub-continental level (panel A), and at global ecological zone level (panel B, annotated percentage represent the percent difference between GFC2020 v1 and GFC2020 v2).



Source: JRC. The sub-continent boundaries are from [FAO GAUL](#) and the Global Ecological Zones from [FAO](#).

The revised approach improved the exclusion of areas that have trees but are not forests such as agricultural tree plantations and trees in urban areas. For agricultural tree plantations this improvement is explained by the inclusion of additional datasets representing tree crops for cocoa in West Africa (Figure 6A), and coffee dominated landscapes (Figure 6B and Figure 7), cashew plantations (Figure 6C) and rubber plantations in South East Asia (Figure 6D). A dedicated workflow (see Section 2.1.4, urban use) excluded trees in urban land use that were erroneously mapped as forest in GFC2020 v1 (Figure 6E).

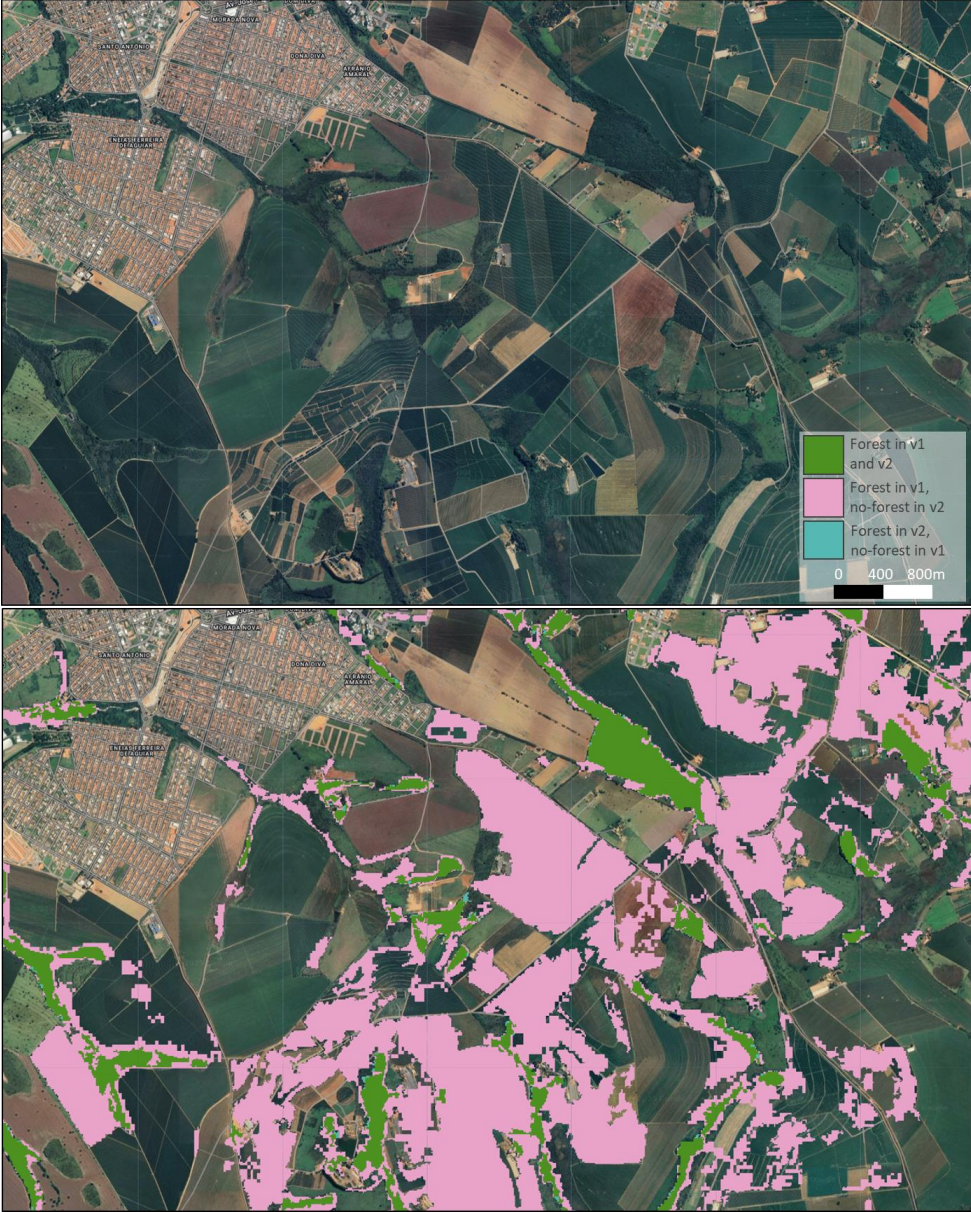
Figure 6. Zoom to different improved exclusions of trees under non-forest use. (A) Agricultural landscape dominated by cocoa plantation, Côte d'Ivoire (5.9°W,5.0°N), (B) Agricultural landscape dominated by coffee plantation, Di Linh district, Vietnam (108.1°E,11.5°N), (C) Cashew plantations, Cambodia (106.3°E,11.8°N), (D) Rubber plantations, Lao PDR (101.8°E,21.5°N) and (E) Urban trees, Riau, Indonesia (101.4°E,0.4°N).



Source: JRC. Background data: Google, © 2024 Maxar Technologies.

These improvements result from new rules and datasets on tree height and land use, and address user feedback regarding overestimation in urban (Figure 6E) and specific agricultural areas, including coffee plantations in Vietnam and Brazil (Figure 6B and 7), and cocoa plantations in Ivory Coast and Ghana (Figure 6A).

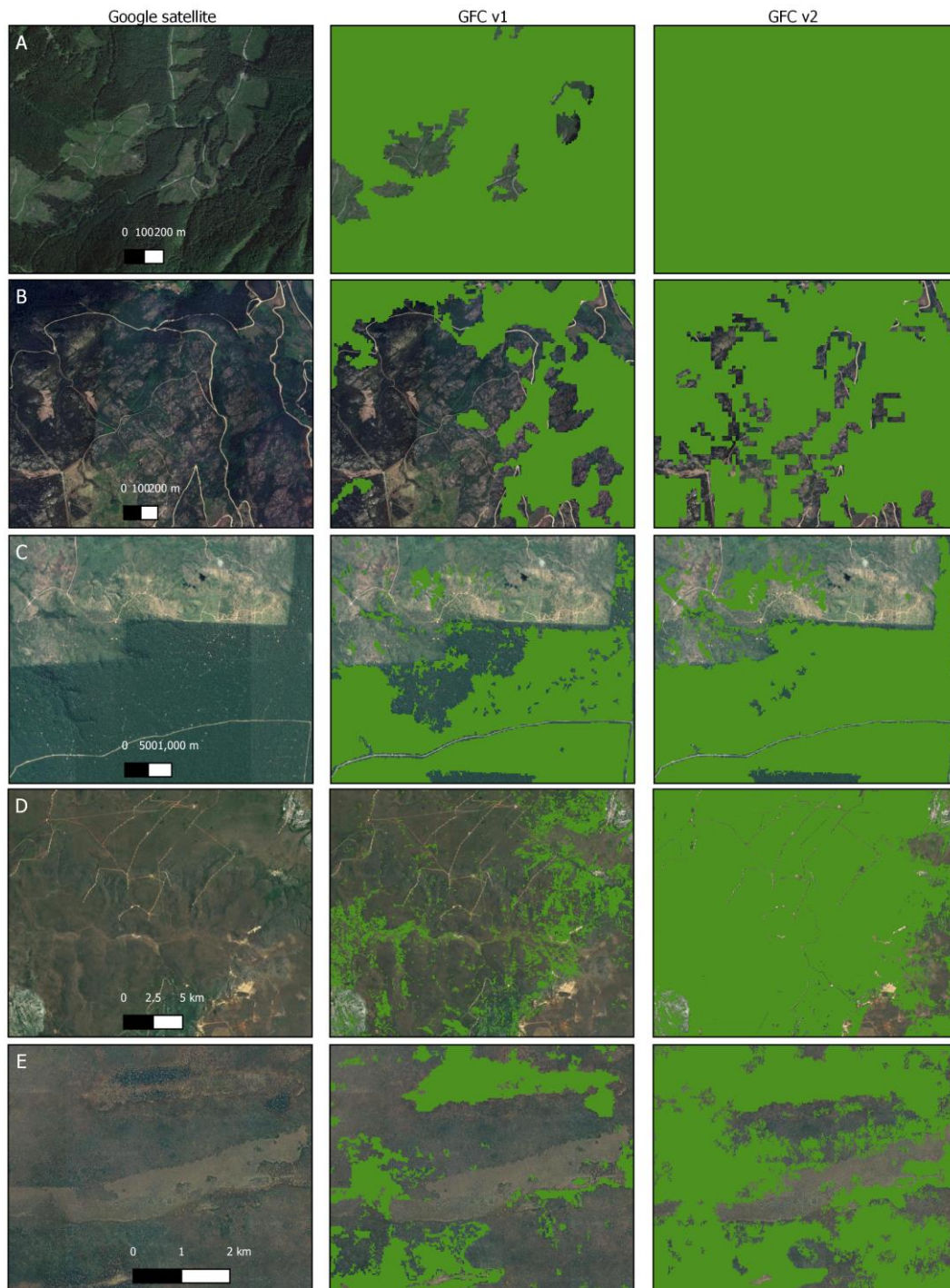
Figure 7. Comparison between GFC2020 v1 and GFC2020 v2 in an agricultural mosaic of urban, pasture, ground crop and coffee plantation in Brazil (Dom Diva, State of Minas Gerais, 46.9°W, 18.9°S).



Source: JRC. Background data: Google, © 2024 Maxar Technologies.

Figure 8 illustrates the improved inclusion of forest area to the forest map in challenging situations. GFC2020 v2 includes more areas of unstocked forest resulting from clear cut harvesting (Figure 8A) or fire (Figure 8B). Modifying the methodology over the tropical belt, young secondary forest is better captured in GFC2020 v2 (Figure 8C). Dry forests are also better captured in GFC2020 v2 (as illustrated in Figure 8D and 8E) by including more tree cover in drier regions in the first step (potential forest extent).

Figure 8. Zoom to different inclusion of forest area in GFC2020 v2 compared to GFC2020 v1. (A) Unstocked forest from clear cut harvesting, British Columbia, Canada (121.5°W,49.4°N), B) Unstocked forest from fire, Galicia, Spain (8.5°W,42.2°N), C) young secondary forest, Pará, Brazil (47°W, 3°S), D) dry tropical caatinga forest, Bahia, Brazil (41.5°W,10.6°S), E) Miombo woodland, Zimbabwe (26.5°E, 19°S).

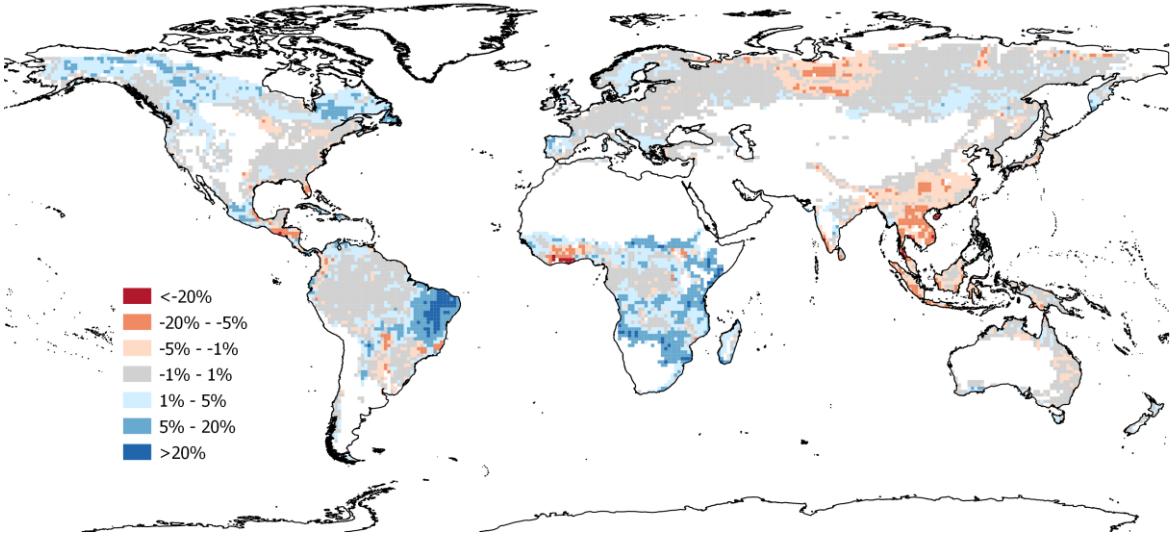


Source: JRC. Background data: Google, © 2024 Maxar Technologies.

Spatial analysis of the relative difference between GFC2020 v1 and GFC2020 v2 reveals hotspots of increased forest cover in GFC2020 v2, particularly concentrated in the dry tropics (Figure 9). Notable examples include increases of more than 20% in the Caatinga and Cerrado biomes of South America and in deciduous forests and woodland savannas across Africa. Furthermore, we observe a 5-20%

increase in forest cover in GFC2020 v2 in Canadian, US, and Swedish boreal forests. This increase may be attributed to improved representation of forest plantations and natural regeneration following disturbances in GFC2020 v2, such as wildfires in eastern Canada and potentially in Portugal. Conversely, the analysis reveals hotspots of decreased forest cover in GFC2020 v2 compared to v1. These are concentrated in West Africa (notably Ivory Coast and Ghana), Southeast Asia (including southern China), and Central America (Honduras, Guatemala). These declines often coincide with areas where improvements were made to reduce commission errors in regions dominated by tree crop agriculture. Decreases in forest cover observed in Central Russia in GFC2020 v2 probably reflect the correction of previous overestimations in wetland areas within GFC2020 v1. The substantial changes in these hotspots warrant careful scrutiny in subsequent GFC2020 versions to prevent over-adjustments and ensure accurate representation of forest cover.

Figure 9. Net relative difference in forest area estimates between GFC2020 v1 and GFC2020 v2 at 1 degree grid cell. White cells indicate areas with less than 0.1 Mha of forest cover in both versions of the map.



Source: JRC. Land boundaries are derived from [GISCO 2020](#).

3.2.1 Comparison with other datasets not included in the GFC2020 v2 workflow

To assess potential commission errors, we compared the absolute and percentage area overlap between cocoa (in Côte d'Ivoire and Ghana), oil palm (Global), and rubber plantations (in Thailand, Indonesia, Vietnam, Malaysia, Philippines, Hainan Island, Côte d'Ivoire and Ghana) from the Forest Data Partnership (Clinton et al., 2024) with areas classified as forest in GFC2020 v1 and GFC2020 v2 (Table 4). This analysis utilized two crop probability thresholds ($\geq 70\%$ and $\geq 90\%$) to identify potential misclassifications in GFC. The potential commission error due to misclassification of cocoa plantations as forest decreased significantly between GFC2020 v1 and GFC2020 v2. The overlap between GFC-classified forest and cocoa plantations decreased sharply from 43% in GFC2020 v1 to 6% in GFC2020 v2 for the 90% probability threshold and similarly for the 70% threshold. This substantial reduction strongly indicates the effectiveness of the improvements implemented for cocoa in this region. For oil palm and rubber plantations, the reduction in overlap area between GFC2020 v1 and GFC2020 v2 is less pronounced. Oil palm commission errors reduced by 6% for the 70% threshold (4% for the 90% threshold) in GFC2020 v2. For rubber plantations commission errors reduced by 20% for the 70% threshold (24% for the 90% threshold) in GFC2020 v2, yet there still remains a commission error of 34% (31%). This highlights the ongoing challenge of accurately distinguishing these crops from forest cover and underscores the potential of incorporating refined crop probability models to further improve forest cover mapping in future versions of GFC.

In contrast, comparisons between cultivated and semi-natural pastures from Global Pasture Watch (Parente et al., 2024) and GFC2020 reveal minor increases of the commission error in GFC2020 v2 compared to GFC2020 v1. Even though the percent increase is small, the increase of commission errors in terms of area is notable: 10.6 Mha for cultivated pasture and 36.92 Mha for semi-natural pasture. This highlights the inherent challenge of accurately distinguishing between pasturelands and forests, particularly in complex agricultural landscapes. Similarly to other commodity layers, it also underscores the potential of incorporating Global Pasture Watch data (dominant classes of pastureland but also annual probabilities) to refine future versions of GFC.

Table 4. Comparison with Forest Data Partnership commodity layers and global pasture watch (not ingested in GFC2020 v1 or in GFC2020 v2).

	Crop probability	Commodity area [Mha]	Commodity area labelled forest in <u>GFC2020 v1</u> [Mha]	Percentage of commodity area labelled forest in <u>GFC2020 v1</u> [%]	Commodity area labelled forest in <u>GFC2020 v2</u> [Mha]	Percentage of commodity area labelled forest in <u>GFC2020 v2</u> [%]
Cocoa	≥70%	2.72	1.25	46	0.19	7
	≥90%	1.43	0.61	43	0.09	6
Oil palm	≥70%	32.68	8.35	26	6.47	20
	≥90%	20.94	2.30	11	1.53	7
Rubber plantation	≥70%	25.24	13.68	54	8.66	34
	≥90%	16.45	9.07	55	5.14	31
GPW - cultivated pasture	/	665.52	37.78	6	48.38	7
GPW - semi natural pasture	/	3167.47	232.67	7	269.59	9

Source: JRC. See Table 3 for the reference of commodity maps.

3.2.2 Comparison with national/regional land cover products

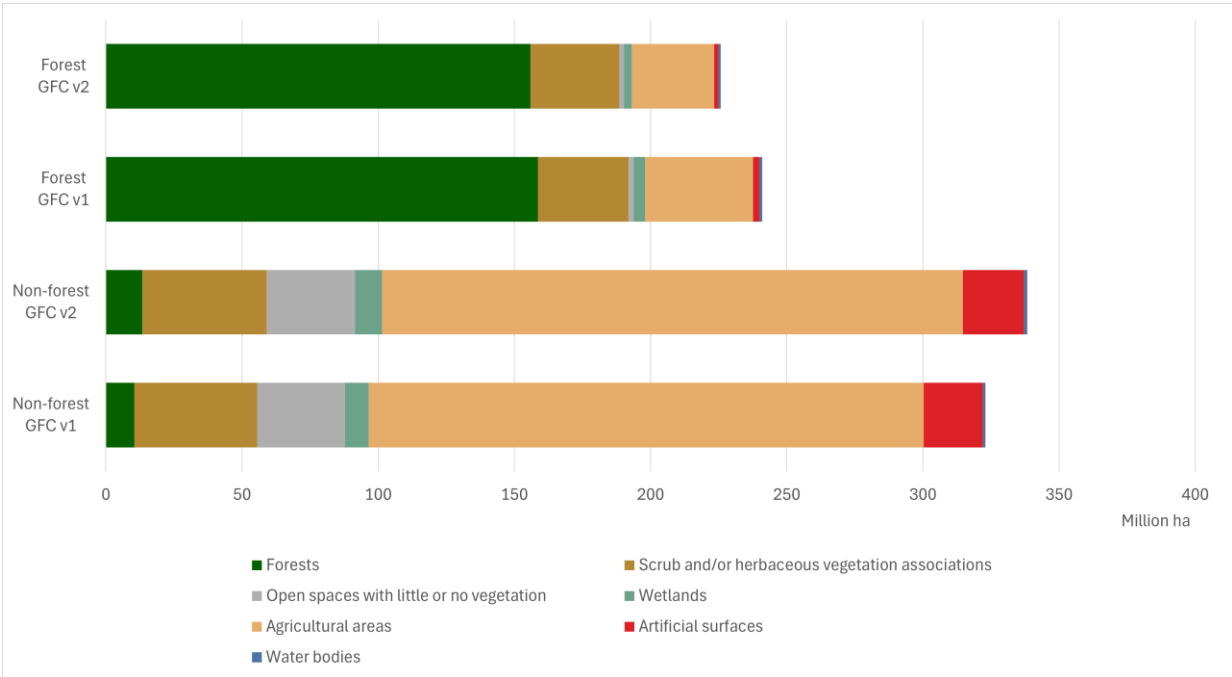
In the following sections we compare GFC2020 v1 and v2 against national, regional, and continental land cover and land use maps. We depict the results in horizontal bar plots with the total bar size showing the area of forest or non-forest. The colours within each bar show the area (directly proportional to the area proportion) of generalized land cover and land use classes in regional data sets that correspond to forest or non-forest in GFC2020 v1 and GFC2020 v2. Annex 2 to 5 show the reclassification schemes for generalized land cover and land use classes. The adjusted contingency coefficient (*C metric*) was employed to quantify the statistical association between the regional land cover classifications and GFC forest/non-forest classes in v1 or v2. A higher *C* value for GFC2020 v2 compared to GFC2020 v1 implies a higher agreement with the regional land cover map due to better spatial matching of forest/non-forest (Hartmann et al., 2023). Annex 7 shows the adjusted contingency coefficients, and measures of the agreement for forest between maps.

This analysis illustrates graphically 1) the difference in forest/non-forest area in GFC map versions, 2) the level of agreement between forest in GFC2020 and forest in the regional data set (analogously for non-forest), and 3) the allocation of disagreement to land cover and land use classes of regional data sets.

3.2.2.1 Comparison with CORINE land cover

Figure 10 shows the comparison between the two versions of the GFC map and the European Copernicus CORINE Land Cover. It illustrates that the forest cover decreased by 6.4% (15.3 Mha) in GFC2020 v2 compared to GFC2020 v1. The reduction in forest area in GFC2020 v2 is mainly due to the reclassification of 9.5 Mha of agricultural land and 2.8 Mha of forest, as identified by CORINE, from forest in GFC2020 v1 to non-forest in GFC2020 v2. The overall agreement between GFC and CORINE forest classifications is higher in GFC2020 v2 than in GFC2020 v1. In GFC2020 v2, 69.1% of mapped forests align with CORINE forest categories, whereas in GFC2020 v1, this proportion was only 65.8%. However, the proportion of forest from CORINE misclassified as non-forest in GFC slightly increased from 3.3% in GFC2020 v1 to 3.9% in GFC2020 v2. GFC2020 v2 showed improved overall agreement, with the C metric rising from 0.81 to 0.83.

Figure 10. Comparison between GFC2020 v1/v2 vs. Copernicus CORINE Land Cover map over Europe.



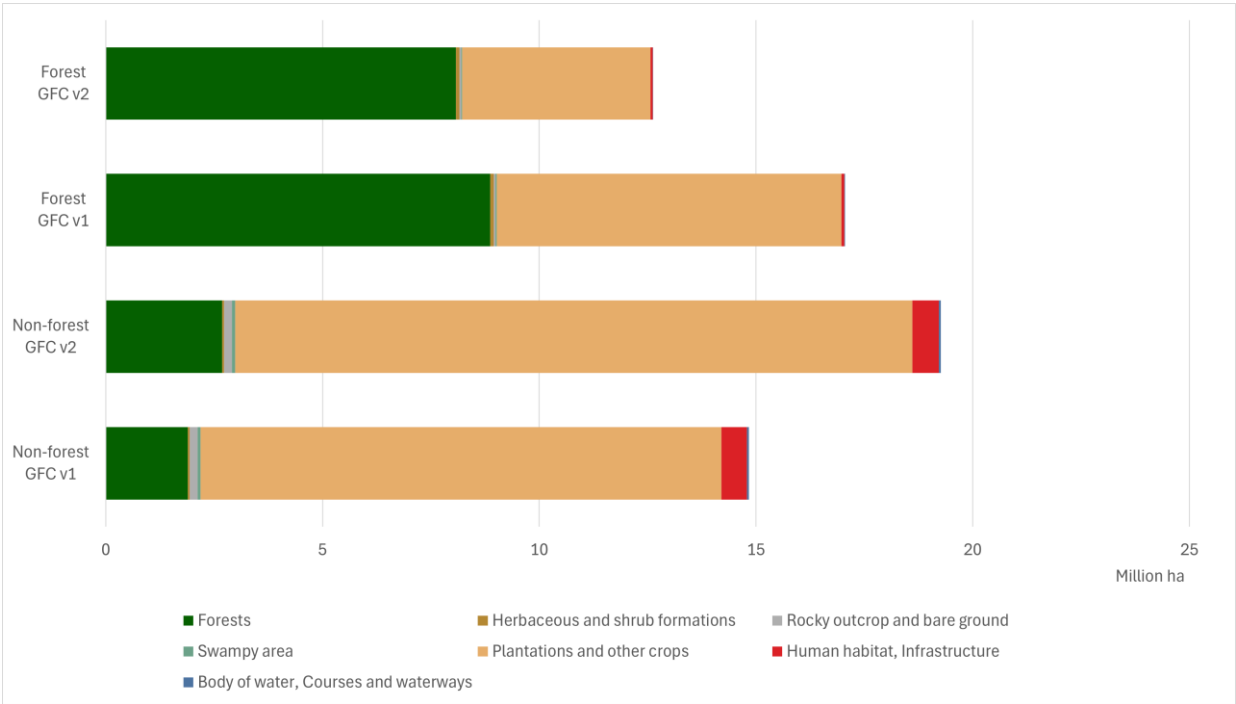
Source: JRC. See Table 3 for the reference of the regional map.

3.2.2.2 Comparison with land cover map of Côte d'Ivoire

Figure 11 shows a 25.9% (4.4 Mha) forest cover decrease in GFC2020 v2 relative to v1, leading to an increase in forest agreement with Côte d'Ivoire's BNETD 2020 Land Cover Map from 52.0% to 63.9%. This enhancement is largely due to a 45.3% reduction in plantation and crop misclassifications, as determined by BNETD, within GFC2020 v2. The proportion of forest from BNETD misclassified as non-forest in GFC2020 slightly increased from 12.7% in v1 to 13.9% in v2. GFC2020 v2 showed improved overall agreement, with the C metric rising from 0.55 to 0.66.

Verhegghen et al. (2024) previously analysed the discrepancies between GFC2020 v1 and BNETD 2020 Land Cover Map, and found that GFC2020 v1 identified 17 Mha of forest, representing an overestimation of 58.5% compared to the 10.7 Mha in BNETD 2020 map using the EUDR forest definition. By applying the same methodology, we observed that GFC2020 v2 identifies 12.6 million ha of forest, reducing the overestimation to 17.3%. This improvement aligns GFC2020 v2 more closely with the BNETD 2020 map. The overestimation in GFC2020 v1 was primarily due to forest wrongly mapped by GFC2020 in areas dominated by tree crops such as cocoa, cashew, and rubber. For instance, 68% of the BNETD 2020 cashew class, 59% of the rubber class, and 38% of the cocoa class were labelled as forest in GFC2020 v1. In GFC2020 v2, these figures dropped significantly to 37%, 11%, and 12%, respectively, reflecting improved accuracy.

Figure 11. Comparison between GFC2020 v1/v2 vs. BNETD 2020 National Land Cover Map over Côte d'Ivoire.

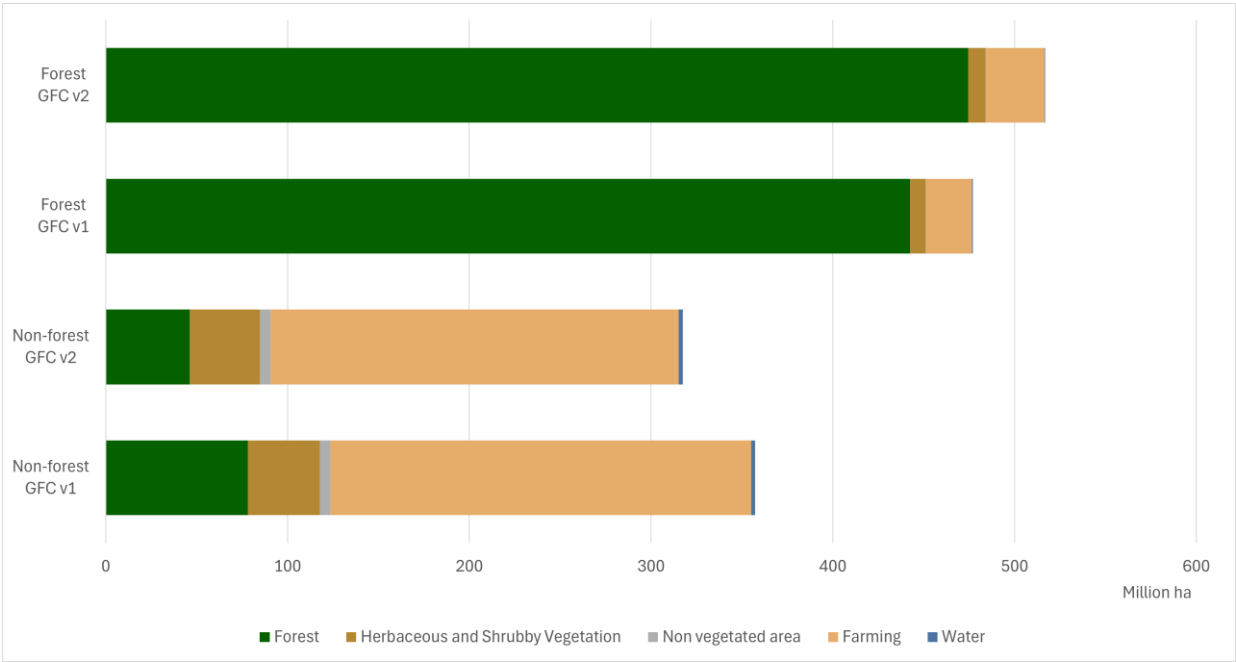


Source: JRC. See Table 3 for the reference of the regional map.

3.2.2.3 Comparison with MapBiomias for Brazil

Figure 12 shows a notable expansion in forest area, with GFC2020 v2 gaining 8.3% (39.7 Mha) of forest compared to GFC2020 v1. This gain is primarily due to classifying an additional 32 Mha of forests and 6.9 Mha of farming land in MapBiomias as forest in GFC2020 v2. Although the agreement between forest in GFC2020 and forest in Mapbiomas remained relatively stable from v1 to v2, the proportion of forest from MapBiomias misclassified as non-forest in GFC decreased from 21.9% in v1 to 14.5% in v2. This led to an improved overall agreement, with the C metric increasing from 0.83 to 0.87.

Figure 12. Comparison between GFC2020 v1/v2 vs. MapBiomias 2020 Land Cover Map over Brazil.

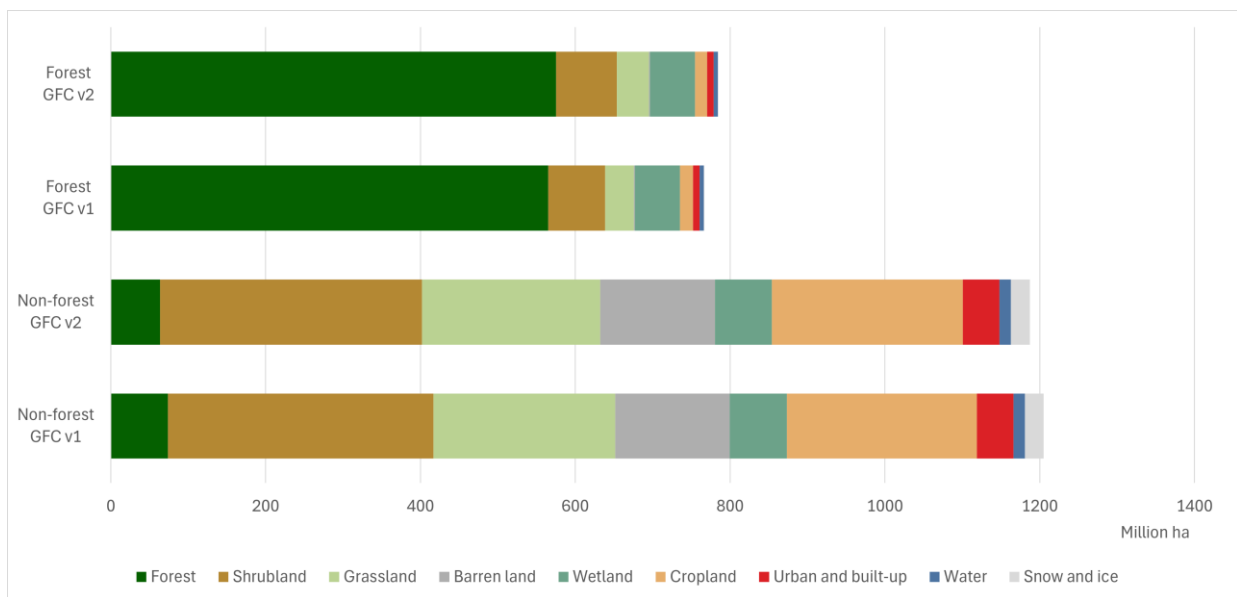


Source: JRC. See Table 3 for the reference of the regional map.

3.2.2.4 Comparison with NALCMS for North America

Figure 13 shows the comparison between GFC2020 v1 and GFC2020 v2 vs. 2020 land cover map of the North American Land Change Monitoring System (NALCMS). It highlights a slight increase of 2.3% (18 Mha) in forest area in GFC2020 v2, mainly driven by 10.4 Mha of forest area transitioning from non-forest to forest, coupled with the reclassification of 4.3 Mha of shrubland and 4.7 Mha of grassland into forest in GFC2020 v2. Although the agreement between forest in GFC2020 and forest in NALCMS remained relatively stable from v1 to v2, the proportion of forest from NALCMS misclassified as non-forest in GFC decreased from 6.1% in v1 to 5.3% in v2. This led to a small improvement in overall agreement, with the C metric increasing from 0.83 to 0.84.

Figure 13. Comparison between GFC2020 v1/v2 vs. NALCMS Land Cover 2020 map over of North America.



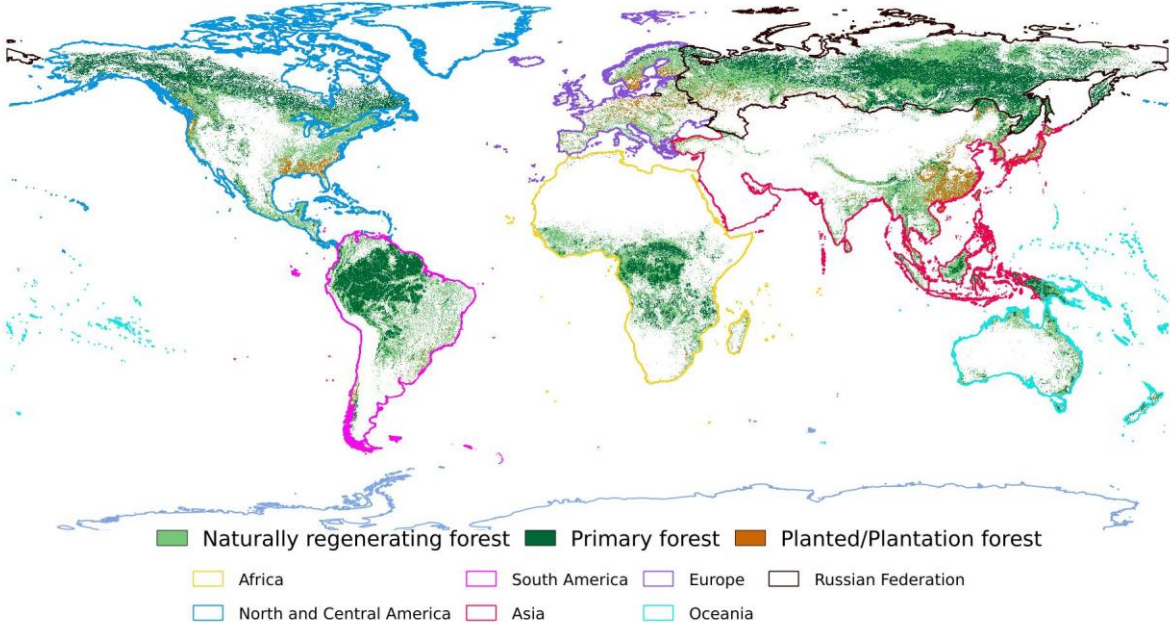
Source: JRC. See Table 3 for the reference of the regional map.

3.3 The global forest type map for year 2020 v0

3.3.1 Map results

Figure 14 illustrates the preliminary version of the Global Forest Types map for the year 2020, denoted version 0 (v0). This map shows forest types within the extent of forest in GFC2020 v1. Two shades of green represent primary and naturally regenerating forests, while orange shows plantations or planted forests.

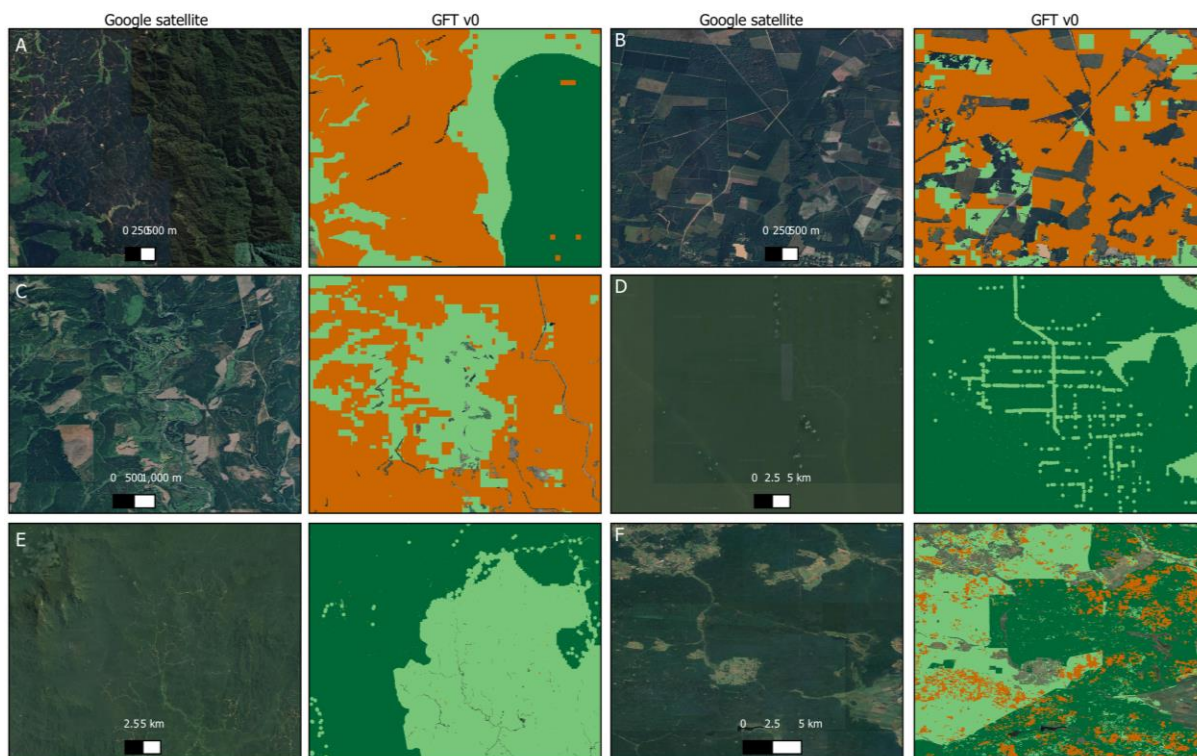
Figure 14. GFT2020 v0.



Source: JRC. FAO GAUL for sub-continent boundaries.

Figure 15 visualizes small regions of various forest types across six study sites. As shown in Insets A and B, GFT2020 v0 effectively distinguishes planted/plantation forests from natural forests (naturally regenerating and potential primary) when high-quality data on planted/plantation areas are available. However, coarser data (Inset C) lead to less accurate delineation of planted/plantation forests, with unstocked forest or young plantation often misclassified as naturally regenerating forest. Insets D and E illustrate how past human activity, such as logging roads and gaps, can cause primary forests to be classified as naturally regenerating forest. Finally, Białowieża Forest (Inset F), a protected area within Białowieża National Park of Poland, is predominantly classified as primary forest by GFT2020 v0. However, the presence of planted/plantation forests creates a "salt and pepper" effect.

Figure 15. Close-ups from the global forest type map for the year 2020, A) Pine plantation at the border of natural forest of Te Urewera National Park, New Zealand (176.8°E, 38.2°S), B) Pine plantation of the Landes, France (1.2°W,44.1°N), C) North West US planted forest (123.6°W,47.2°N), D) Primary forest and selectively logged forest in Republic of the Congo (16.8°E,2.8°N), E) Primary forest and selectively logged forest in Kalimantan, Indonesia (112.8°E,0.8°S) and F) primary forest of Białowieża in Poland (23.9°E,52.6°N).



Source: JRC. Background data: Google, © 2024 Maxar Technologies

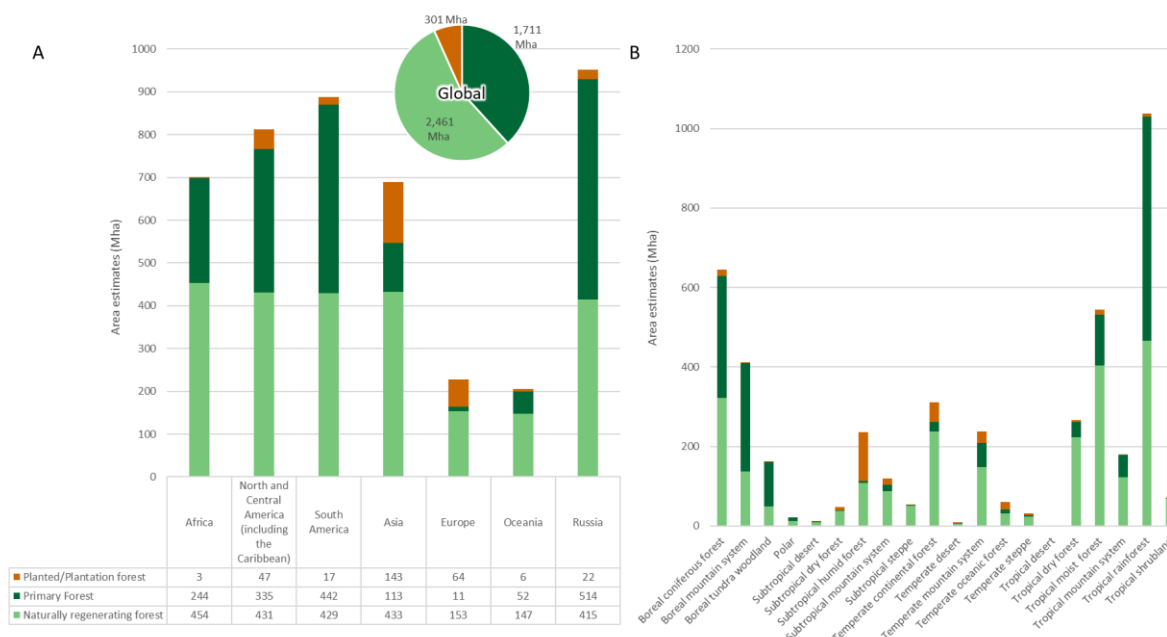
The Global Forest Types map for 2020 (V0) classifies 1,711 Mha (38% of the total forest area) as primary forest, 2,461 Mha (55%) as naturally regenerating forest and 301 Mha (7%) as planted/plantation forest (Figure 16A).⁵

Asia accounts for the largest share (143Mha or 48%) of global planted/plantation forest area, followed by Europe (64Mha or 21%) and North America (47Mha or 15%). However, Europe has the highest proportion of planted/plantation forest relative to its total forest area (28%), followed by Asia (21%).

30% (514 Mha) of global primary forest are located in Russia forest followed by South America (335Mha or 26%), North and Central America (335Mha or 20%) and Africa (244Mha or 14%). Most primary forest occurs in tropical rainforests (35%), boreal coniferous forests (19%), and boreal mountain systems (17%) (Figure 16B). While only 5% of total European forests are classified as primary, significantly higher proportions (i.e. area of primary forest relative to total forest area at continental level) are found in Russia (54%), South America (50%), and North and Central America (41%).

⁵ The total forest area reported in GFT2020 v0 (4,473 Mha) differs from that of GFC2020 v1 (4,460 Mha, see Bourgoin et al., 2024) due to the use of distinct continental boundary datasets for zonal statistics (ESRI vs GAUL here), even though the two maps share the same forest extent.

Figure 16. Areas from the Global Forest Type map for the year 2020 at global and subcontinental level (panel A) and at global ecological level (panel B).

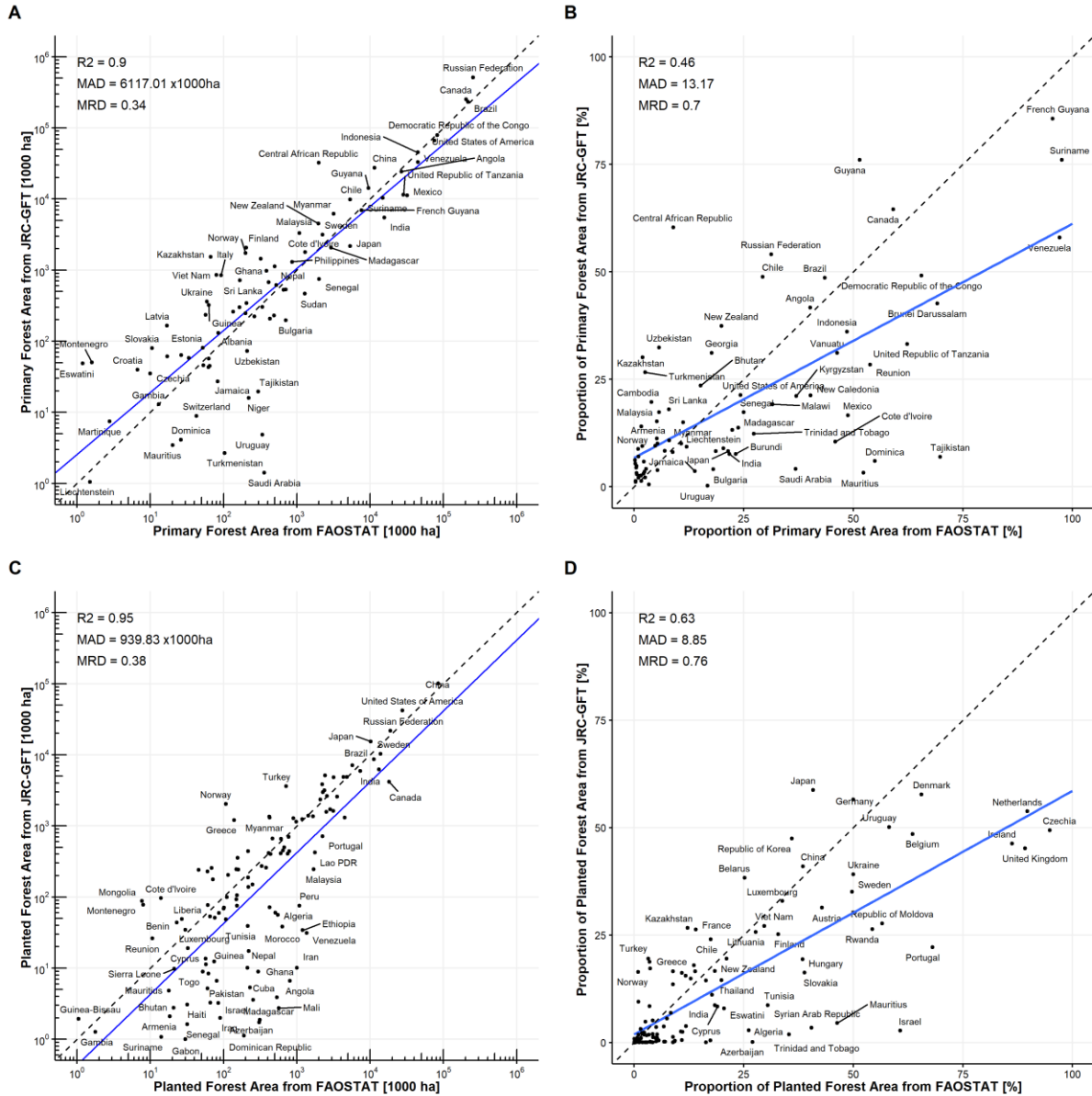


Source: JRC. The sub-continent boundaries are from [FAO GAUL](#) and the Global Ecological Zones from [FAO](#).

Figure 17 shows a comparison of primary and planted/plantation forest type area and proportion per country between FAO-FRA 2020 (x-axis) and area totals from GFT2020 v0. We excluded countries reporting less than 1,000 ha of forest or not reporting on forest types. We found a strong agreement between the two datasets regarding primary forest area (r^2 : 0.9, Mean Absolute Difference (MAD): 6.1 Mha, Mean Relative Difference (MRD): 0.34), particularly in countries reporting over 1 million hectares. Compared to the FAO FRA 2020 data, GFT2020 v0 shows smaller extent of primary forests in dry tropical regions (e.g., India, Tanzania, Mexico) and larger extent in countries reporting small (<1 Mha) primary forest area (e.g. Italy, Finland, Ghana, Vietnam). Figure 17B shows that GFT2020 v0 generally reports lower proportions (i.e. area of primary forest relative to total forest area at country level) of primary forest compared to FAO FRA 2020. This discrepancy may be partly due to GFT2020 v0 (and GFC2020 v1) overestimating total forest area in some countries, such as Côte d'Ivoire, relative to FAO FRA 2020. Canada, French Guiana, Brazil, and Indonesia exhibit strong agreement between the datasets.

GFT2020 v0 tends to report smaller areas of planted/plantation forests compared to FAO FRA 2020, particularly in countries reporting less than 1 million hectares of planted forests (Figure 17C). For countries with over 1 million hectares of planted/plantation forest, agreement between the two datasets is typically higher. However, Canada is a significant outlier, where GFT2020 v0 area of planted/plantation forests is more than four times lower than the area reported under FAO FRA 2020. As shown in Figure 17D, GFT2020 v0 exhibits lower planted/plantation forest proportions than FAO FRA 2020, with significant discrepancies in countries exceeding 50% coverage (e.g., Ireland, Portugal, Sweden or the Netherlands). Conversely, a subset of countries displays high agreement (e.g., China, New Zealand, Vietnam or Germany). Overall agreement with FAO FRA is higher than for primary forest, as indicated by a greater r^2 value.

Figure 17. Country-level comparison of primary forest area (panels A and B) and planted forest area (panels C and D) between the JRC Global Forest Types map and FAO FRA 2020 database. r^2 , MAD and MRD metrics refer to the R-squared, Mean Absolute Difference (in 1000ha) and Mean Relative Difference, respectively. Dashed line represents the 1:1 line. The solid blue line represents the linear regression applied to the linear data.



Source: JRC. Country delineation comes from FAO GAUL.

3.3.2 Forest degradation workshop held in June 2024: summary and perspectives

In June 2024 the JRC gathered a group of experts⁶ on global forest mapping, monitoring and reporting with Earth Observation data to discuss several aspects related to forest degradation. The first part of the workshop focussed on forest degradation as set out under the EU Regulation on deforestation-free supply chains (EUDR, Regulation (EU) 2023/1115) for the risk assessment by operators and traders. During the second part, experts discussed potential means and needs towards verification by competent authorities and other approaches to map and monitor forest degradation. Annex 8 contains the detailed workshop agenda and list of participants.

First, experts confirmed the JRC's understanding of mapping needs regarding the three classes (primary forest, naturally regenerating forest, other forests which are comprised of planted forest and plantation forest) for the GFT2020 map. Second, experts provided feedback on a draft map that was circulated prior to the meeting⁷. In this feedback experts indicated their general satisfaction with the draft map. Some specific issues were discussed, such as:

- Mapping of small primary forest patches in highly managed environments, because these could be excluded by the coarser resolution of some input data sets. The issue relates to minimum or average patch size that varies among world regions.
- Artefacts like checkerboard patterns that were researched to originate from a specific input dataset.
- Possibilities for the inclusion of uncertainty estimates ideally at pixel level, at coarser resolution or at regional level.
- Possibilities to build on the convergence of evidence by using multiple data sets.

Experts noted specific forthcoming data sets, e.g. the revised natural forest land map from WRI, a map of forest management in the year 2020 from IIASA, an updated version of the FAO global ecological zones, updates of the Spatial Database of Planted Trees from WRI, non-stand replacing forest degradation maps by the University of Maryland, or the inclusion of already existing data layers of tree height, e.g. from WRI/Meta at 1m spatial resolution. Experts strongly advised to communicate that GFT2020 is not a reference map. Besides data sets, the FAO plans to release a special study on primary forests and intends to embark on work towards mapping forest degradation. Eventually, experts advised on a set of improvements that was followed up for the release of the preliminary map of Global Forest Types for the year 2020.

All participants shared the view that GFT2020 could be a useful support tool offered by the EU for the risk assessment by operators and traders. The status of this map should be similar to the map of global forest cover for the year 2020 (GFC2020), i.e. 1) not mandatory to be used in the risk assessment, 2) not exclusive meaning that other data sets have at least equal value and 3) not legally binding. The latter means that, for example, the presence of primary forest in GFT2020 for a parcel of land declared planted or plantation forest post 2020 does not imply forest degradation, and likewise the absence of primary forest in GFT2020 for this parcel does not imply the no risk of forest degradation.

⁶ The workshop took place in Ispra, Italy on 17 and 18 June 2024.

⁷ This draft map was, to the extent possible, improved based on the feedback given in this meeting and became the preliminary GFT2020 map that is presented in this report.

While producing a map for the assessment of the risk of forest degradation is one task, another is to ensure compliance with the regulation via checks by competent authorities. A principal concern shared by all experts is that competent authorities may consider the global maps offered by the JRC (GFC2020, GFT2020) as references against which to check and conclude about compliance with the regulation. This was clearly deemed inadequate and experts recommended to clearly communicate the above noted non-legal status of the maps. Competent authorities may use the JRC maps as a first filter, but even then the potential omission of forest in the map needs to be considered in subsequent steps. The maps by the JRC could also serve as a layer to focus the attention on certain areas. In a next step, competent authorities should consult other sources or could acquire data of very high spatial resolution.

Experts underlined the value of image interpretations, especially when conducted by professionals. Such interpretations are of higher quality than data sets derived automatically from various different sources. In addition, time series, including from Sentinel 2, can enrich or improve the mapping, e.g. fine tune the date of a forest disturbance or onsets of trends. As an example, expert noted that VHR data could be used to detect clear cuts and once located, Sentinel 2 time series may serve to identify the date of the disturbance or at least to limit the period during which the disturbance took place.

Experts discussed VHR data scarcity and the lack of tools for easy interpretation of multiple sources. Not all parts of the World are covered well with high spatial resolution images, let alone at high cadence. Even though there are several sources for high spatial resolution data, it is still challenging to combine those. To their best knowledge there is only Google Earth Pro as ready to use application, that is free-of-charge and with many easy-to-use functionalities. It holds a wealth of high spatial resolution data in one interface and allows for very comfortable interpretations. Experts also noted the reliable display of the correct acquisition date or month, and the inclusion of other geospatial information such as photos from Street View. Another source is the ESRI Wayback catalogue of VHR imagery, which is freely accessible via the OGC WMTS standard, allowing integration into custom tools. Also, tools like Geo-wiki integrate different data sets and can be customized for specific interpretation tasks, including crowd sourcing.

Operational recommendations for checks by competent authorities, in case of consulting spatial data layers are:

- 1) Use existing data layers or a combination thereof to identify risk areas that require further checking by very high resolution data. This could be based on GFC2020, GFT2020, WRI Natural land, GFW, RADD, etc. The Open Foris Whisp tool (D'Annunzio et al., 2024), developed by FAO and partners under the Sustainable Agriculture for Forest Ecosystems Programme, is a good example of how multiple open and public data layers can be combined to implement convergence of evidence and perform a risk assessment at the plot level.
- 2) Focus on specific sites with available or forthcoming tools: Copernicus Land Service, Copernicus Data Space Ecosystem, NICFI, Global Forest Watch Pro, Geowiki S2 viewer via ESA network of resources, Google Earth Pro.

Ideally, all those data sources and functionalities would be made available in one tool.

At last, experts were asked to think about ways to define or develop a conceptual framework for forest degradation that can be mapped and monitored with geospatial data. Experts noted different dimensions of forests that may or may not be affected by disturbance events or processes. Forest carbon, and hence biomass, is an indicator for forest degradation that is frequently considered and also researched (Qin et al., 2021). Less frequent, and harder to quantify, are changes in forest structure and spatial analysis of forest biodiversity (Barlow et al., 2016). Some aspects of forest

degradation are only related to fauna, e.g. overhunting (Gardner et al., 2019; Osuri et al., 2020). Others may relate to changes in the phenology but with no or hardly notable impacts on plants or biomass (Koltunov et al., 2009). The human factor with recurring interventions such as shifting cultivation by local communities may play a role in several tropical ecosystems, by which, a new equilibrium is reached over time (Ghazoul et al., 2015; Vásquez-Grandón et al., 2018). Experts noted that most studies based on EO data target the mapping of forest disturbances by an instance with its intensity, frequency, duration and spatial extent (Gao et al., 2020). Studies with focus on slow onset processes are rare. Also, forest degradation may differ among world regions. For instance, forest degradation in Europe is more linked to wood extraction, pest damage, drought and wildfire (Chen et al., 2021). Experts agreed that EO can only be one source of information to define, map and monitor forest degradation, and in many cases the mapping and monitoring will be done via proxies.

4 Limitations and lessons learnt

4.1 Limitations

The GFC2020 v2 and GFT2020 v0 maps include a number of data limitations (i.e. omission or commission errors) linked to datasets and technical mapping issues (see Annexes 9 - 12 for non-exhaustive lists of specific and general known issues). Updates of the tables shown in these annexes can be consulted at <https://forobs.jrc.ec.europa.eu/GFC> and <https://forobs.jrc.ec.europa.eu/GFT>

The issues associated with the input datasets primarily stem from the propagation of omission and commission errors into the final GFC2020 and GFT2020 maps. Additionally, the spatial resolution of the input datasets varies, ranging from 10m to 30m, with a few datasets at coarser resolutions. This variability can result in sharp boundaries between forest and non-forest areas and may lead to a low precision in forest edge detection.

Mapping issues are due to several issues that are detailed hereafter:

- **Limited data on agricultural tree plantations at global scale:**

GFC2020 may incorrectly classify tree plantations intended for agriculture as forest if there is a lack of data or data layers are partly incomplete or not fully consistent across the globe. In particular tree crops are not mapped comprehensively for all crop types and regions. Global datasets for oil palm plantations are increasingly available while rubber, coffee and cocoa datasets are only available at regional or national level. This is due to technical challenges in detecting agricultural practices below a tree canopy and availability of in-situ data to build robust classification models. Moreover, mapping old plantations (older than the monitoring period with Earth observation data) or smallholder plantations remain challenging.

However, thanks to the availability of new tree crop layers, we were able to substantially improve the exclusion of tree crops from the forest class as demonstrated in section 2.1.1. We included a new layer for oil palm from Clinton et al., (2024) and substituted the oil palm map with a refined version of Descals et al., (2024) including information on the planting year. We included a map of rubber from Wang et al., 2023 that reduced the commission errors due to confusion of forest with rubber, mainly in South East Asia. We enhanced the exclusion of coffee and cocoa plantations by leveraging the updated WRI SDPT dataset (version 2.1), which provides refined spatial data, particularly for cocoa in the Ivory Coast and Ghana, and coffee in Brazil. Additionally, we combined CROPGRIDS stratification with canopy height, cropland, and TMF land cover data to more accurately target cocoa, coffee, and cashew plantations.

- **Challenges in mapping agroforestry systems:**

Agroforestry systems still remain extremely hard to identify and exclude from forest cover (Yang et al., 2025). Cocoa and coffee can grow in the shade of a higher tree canopy (agroforestry systems), which can be confused with degraded forest when observed with optical satellite images. The removal of single trees observed over the last two to three decades (e.g. identified as forest degradation in JRC TMF) in combination with data on forest management type from Lesiv et al. (2022) may partially tackle this issue. However, Lesiv et al report an underestimation of 207Mha in the extent of agroforestry systems globally (Lesiv et al., 2022).

- **Challenges in mapping shifting cultivation and forest regrowth:**

The forest class of GFC2020 includes areas under shifting cultivation or land that is temporarily not used for agricultural production (set aside agricultural land with young tree growth). In the tropical belt, the JRC TMF maps shifting cultivation as non-forest or deforestation depending on the age of shifting cultivation systems. In the JRC TMF dataset, shifting cultivation that started from 1990s is characterised as long-term forest disturbance or multiple short term forest clearances. Areas of tropical moist forest regrowth that are less than 5 years old were excluded from GFC2020 forest class to minimise potential confusion with shifting cultivation systems. GFC2020 does not apply any time threshold for fallow land outside the humid tropics due to the absence of global datasets regarding forest regrowth.

- **Challenges in depicting unstocked forests:**

GFC2020 may not map all temporarily unstocked forests, i.e. forest land use on which standing trees are absent in year 2020 but will regrow in the future. An absence of trees from land that was, is and will be used as forest may be due to recent fires, other natural disturbances (storms, diseases) or clear-cut harvesting.

We improved the inclusion of unstocked forests by adding potential forest area to the first step in GFC2020 v2. To that aim we combined the SDPT Planted forest, UMD Tree Cover 2000 and 2010 in combination with the forestry class from UMD Drivers of Forest Loss and GFC loss due to fire. Tree cover loss up to year 2020 from Hansen et al dataset (2013) is not included in the exclusion step (step 2) if this loss overlays with a fire from Tyukavina et al. map (2022) or with the “forestry driver” class from Curtis et al. map (2018)

We will be able to improve further the inclusion of unstocked forest with the new version of the WRI map of forest loss drivers that will increase the spatial resolution of this stratification layer from 10km to 1km (Sims et al., 2024).

- **Challenges in mapping forests with low canopy cover density or low canopy height:**

Mapping forests with low canopy cover density or low canopy height is very challenging. Delineating forest from non-forest as binary classes has inherent challenges in open and low tree height forested land which can be subject to debate among experts. The inclusion of an intermediate class such as other wooded land (OWL) will not solve the problem of ambiguity with assigning discrete classes. In addition, mapping canopy height and tree cover percentage accurately remains a challenge for the remote sensing community. Based on feedback and in-depth regional analysis we lowered the threshold of the WRI TTC dataset. This led to an increase in forest area in the dry tropical ecoregion. However, including those areas of lower TC density challenged the rest of the methodology. The Global Pasture Watch data classifies some of these areas as semi-natural grasslands. To prevent the exclusion of newly included low tree cover (TC) density regions, such as the Caatinga and Cerrado dry forests, we opted not to integrate that dataset into GFC2020 v2. We acknowledge the potential value of the Global Pasture Watch data and plan to assess it further for possible inclusion in subsequent GFC releases. Canopy height products, on the other hand, lack sub-meter accuracy, and low-canopy forests may be obscured if these layers are used indiscriminately. A 5m threshold from a global canopy height product cannot be applied globally or in isolation; it must be combined with auxiliary datasets to focus on specific regions (e.g., CROPGRIDS, other land cover classes from JRC-TMF for targeting agricultural tree plantations) to ensure greater accuracy. The convergence of global canopy height products, such as UMD GFCH and GSCH,

in areas where canopy height is below 5m provided a potential solution to this challenge. However, its impact on differentiating forest from other wooded land in dry tropics regions may be limited. We expect further advancements in this field, with sub-meter accuracy becoming achievable at the tree stand level (Wagner et al., 2024).

- **Challenges in excluding urban forests:**

While the previous methodology relied on various datasets related to human settlements, built-up areas, and land use in the built environment, large patches of urban trees were still incorrectly classified as forest in GFC2020 v1. GFC2020 v2 addresses this issue by incorporating a dataset on urbanization degree (i.e., GHSL SMOD) to better identify urban centers and exclude these trees from the forest classification. Although this update improved forest land use classification in dense urban areas, it did not fully address dispersed or low-density urban areas to avoid over-masking of forest cover in complex landscapes. This limitation arose from the use of a negative buffer to mitigate patchy visual effects caused by the coarse resolution of GHSL SMOD. To enhance the accuracy of forest mapping in urban areas, it is crucial to improve the spatial resolution of urban land use datasets beyond the current high resolution of built-up areas.

- **Challenges in mapping planted and plantation forests:**

- Although the majority of planted/plantation forest data is derived from the WRI SDPT dataset, the lack of a complete, wall-to-wall remote sensing approach leads to an underestimation of its actual extent. Future development could include the use of time series data (Ling et al., 2023) or canopy texture analysis (Xu et al., 2024).
- Global datasets, such as WRI SDPT and Curtis' forest harvest data, generally do not distinguish between planted and plantation forests. The IASA Forest Management map of 2015 is an exception, defining "planted forests" as 'managed forests with evidence of planting within a 100m pixel and a relatively long rotation time (>15 years)', and "plantation forests" as 'intensively managed timber plantations with short rotations (≤15 years)'. However, the product's accuracy for both classes is low, with omission errors of 65% and 64%, and commission errors of 29% and 42% for planted and plantation forests, respectively (Lesiv et al., 2022). Therefore, we currently use the IASA product but cannot reliably separate planted and plantation forests in GFT2020 v0. Future development could expand the stratification of potential planted/plantation forests to include "naturally regenerating forests with signs of management, such as logging or clear cuts," but this would require integration with other datasets (e.g., GFC loss). We also anticipate a revised IASA product, potentially offering improved accuracy for these two classes at a resolution of 100 meters or finer, updated to the year 2020.

- **Challenges in primary forest mapping:**

The lack of a universally agreed definition and operationalized method for distinguishing natural from anthropogenic disturbances limits our ability to map primary forests accurately. Integrating direct measures of natural forest composition, structure, function, and dynamics is crucial (Picard et al., 2024), as mapping human-driven disturbances alone is insufficient. Current datasets rely on indirect proxies like connectivity, patch size, and recent (2-4 decades) human disturbance, but a longer timeframe is needed.

4.2 Lessons learned

The development of the GFC2020 v2 map followed an iterative approach, using “the try and error principle”. Below, we discuss some of the insights gained during this “lessons learnt” process.

- Relying solely on global canopy height and tree cover density products is insufficient for accurately defining forest extent. These products often fail to accurately represent forests with low-density (~10%) and low-canopy (~5m) characteristics. Critically, forest definitions are not based solely on these physical characteristics. Land use is a key factor, meaning some areas with trees are not considered forests, while other areas lacking these physical attributes may still qualify as forests due to their land use designation. Spatial variations in product quality and temporal inconsistencies in data acquisition also limit their use for global, wall-to-wall mapping.
- The WRI SDPT (v2.1) dataset offers valuable information for excluding trees from forest cover, but careful application is essential. It's important to be aware that the dataset may occasionally misclassify certain tree crops, such as rubber or oil palm plantations in Indonesia and China, as planted forests. Additionally, its reliance on concession data in some regions, like Cameroon, and the omission of certain tree crops present in earlier versions, such as orchards in Spain, require consideration. To effectively exclude agricultural tree crops like coffee, cocoa, and cashew, an expert-driven framework for defining stratification thresholds is recommended.

5 Conclusions

The Global Forest Cover map for the year 2020 (GFC2020) provides a harmonized, globally consistent representation of forest/non-forest in 2020 at 10m spatial resolution, meeting the definition of forest as set out under the EU Regulation on deforestation-free supply chains (EUDR). The second version of GFC2020 improves part of the mapping errors from the first version that were identified by the JRC production team or flagged by external users and EUDR stakeholders during 2024. In particular, this second version better captures areas of temporally unstocked forests, low-density tropical forests, and secondary tropical forests that have regrown for at least five years. Additionally, the approach has been enhanced to more effectively exclude trees in urban areas, mining sites, wetlands, areas with shifting cultivation and agriculture tree plantations. This is achieved by utilizing a revised set of global maps of canopy height, crop area, and specific crop commodity maps. This revised set of global spatial data as input to the GFC2020 mapping approach allows distinguishing more accurately forests from trees under agricultural use, and significantly improved the mapping of forest, e.g. in Western Africa. Comparison of the second version of GFC2020 with independent regional and national maps show less confusion between the forest extent and plantations of cocoa, coffee and rubber than in its first version.

The preliminary version of the Global map of Forest Types for the year 2020 (GFT2020 v0) provides a spatial representation of primary forest, naturally regenerating forest and planted forest (including plantation forest) at a 10-meter spatial resolution. The justification for only mapping those three forest types roots in the definition of forest degradation in the EUDR as a set of changes in forest types between the cut-off date and the date for which the due diligence declaration is submitted. For the initial cut-off date (31 December 2020), it is only necessary to separate between 1) primary forests, 2) naturally regenerating forests (other than primary), and 3) other forests. Other forests are corresponding by definition to planted forests that include plantation forests as sub type. This preliminary version of GFT2020 was built on the forest cover extent from the first available version of GFC2020 as developed in parallel to the second version of GFC2020. The GFT2020 v0 map combines multiple datasets on forest landscape integrity, intactness, protected areas, forest disturbances, canopy heights, forest management types and land use. We aim to consolidate the GFT preliminary version by the end of 2025 based on user feedback and additional or improved global data sets.

In the context of the EUDR, GFC2020 and GFT2020 maps can be used as sources of information in the risk assessment phase of the due diligence exercise. More specifically GFC2020 and GFT2020 maps are intended to assist operators in assessing the risk of deforestation and forest degradation, respectively, when declaring plots of land from which EUDR-relevant commodities are put on the EU market or exported by Member States. Both GFC2020 and GFT2020 maps are non-mandatory, non-exclusive, and not legally binding and their use is up to the discretion by the stakeholder. The EUDR does not prescribe any mandatory spatial data source but emphasizes flexibility for operators and traders to choose the sources of information that they would consider as most suitable for their risk assessments. Competent authorities may also decide to use the GFC2020 map, e.g. to pre-identify regions where to acquire and assess more adequate data for verification of compliance. To support this assessment, the European Commission plans for interoperability between the GFC2020 map and the information system where due diligence statements will be recorded.

For the deforestation risk assessment by operators, it is strongly recommended to use other spatial datasets on forest cover at national or regional level in combination with GFC2020 or as alternative source of information, especially if such datasets are considered more appropriate, e.g. due to higher accuracy at local level or with more spatial detail (Verhegghen et al., 2024).

The JRC plans to release a third version of the Global Forest Cover map for the year 2020 and a consolidated version of the Global Forest Type map of the year 2020 by end of 2025. These updates will incorporate new and improved global datasets that will become available during year 2025, including (but not limited to) rubber, coffee and cocoa probability maps from Google/Forest Data Partnership, the revised WRI map on forest drivers at 1km resolution and with more thematic classes, and the improved IIASA Forest Management map for 2020, along with workflow refinements to potentially address present limitations and issues that will be reported by the user community.

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List of abbreviations and definitions

Abbreviations	Definitions
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
EUDR	EU Regulation on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation
EUFO	EU Observatory on deforestation and forest degradation
FAO	Food and Agriculture Organization of the United Nations
FRA	Global Forest Resources Assessment
GAUL	Global Administrative Units Layer
GEDI	Global Ecosystem Dynamics Investigation
GEE	Google Earth Engine
GFC	Global Forest Change (from UMD)
GFC2020	Global Forest Cover for the year 2020
GFT2020	Global Forest Types for the year 2020
GFW	Global Pasture Watch
GIS	Geographical Information System
GISCO	Geographic Information System of the Commission
IFL	Intact Forest Landscape
IIASA	International Institute for Applied Systems Analysis
JRC	Joint Research Centre
MAD	Mean Absolute Difference
MMU	Minimum Mapping Unit
MRD	Mean Relative Difference

Abbreviations**Definitions**

UMD

The University of Maryland

V1

Version 1

V2

Version 2

WDPA

World Database on Protected Areas

WMS

Web Map Service

WRI

World Resources Institute

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Annexes

Annex 1. Forest definitions under the EUDR

The following definitions are set out in Article 2 of the EUDR (EU 2023). Underlines terms indicate additional definitions.

'forest' means land spanning more than 0,5 hectares with trees higher than 5 metres and a canopy cover of more than 10 %, or trees able to reach those thresholds in situ, excluding land that is predominantly under agricultural or urban land use;

'agricultural use' means the use of land for the purpose of agriculture, including for agricultural plantations and set-aside agricultural areas, and for rearing livestock;

'agricultural plantation' means land with tree stands in agricultural production systems, such as fruit tree plantations, oil palm plantations, olive orchards and agroforestry systems where crops are grown under tree cover; it includes all plantations of relevant commodities other than wood; agricultural plantations are excluded from the definition of 'forest';

'relevant commodities' means cattle, cocoa, coffee, oil palm, rubber, soya and wood;

'primary forest' means naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed;

'naturally regenerating forest' means forest predominantly composed of trees established through natural regeneration; it includes any of the following:

- (a) forests for which it is not possible to distinguish whether planted or naturally regenerated;
- (b) forests with a mix of naturally regenerated native tree species and planted or seeded trees, and where the naturally regenerated trees are expected to constitute the major part of the growing stock at stand maturity;
- (c) coppice from trees originally established through natural regeneration;
- (d) naturally regenerated trees of introduced species;

'planted forest' means forest predominantly composed of trees established through planting and/or deliberate seeding, provided that the planted or seeded trees are expected to constitute more than 50 % of the growing stock at maturity; it includes coppice from trees that were originally planted or seeded;

'plantation forest' means a planted forest that is intensively managed and meets, at planting and stand maturity, all the following criteria: one or two species, even age class, and regular spacing; it includes short rotation plantations for wood, fibre and energy, and excludes forests planted for protection or ecosystem restoration, as well as forests established through planting or seeding, which at stand maturity resemble or will resemble naturally regenerating forests;

'other wooded land' means land not classified as 'forest' spanning more than 0,5 hectares, with trees higher than 5 metres and a canopy cover of 5 to 10 %, or trees able to reach those thresholds in situ, or with a combined cover of shrubs, bushes and trees above 10 %, excluding land that is predominantly under agricultural or urban land use;

'deforestation-free' means:

- (e) that the relevant products contain, have been fed with or have been made using, relevant commodities that were produced on land that has not been subject to deforestation after 31 December, 2020; and
- (f) in the case of relevant products that contain or have been made using wood, that the wood has been harvested from the forest without inducing forest degradation after 31 December, 2020;

'deforestation' means the conversion of forest to agricultural use, whether human-induced or not;

'forest degradation' means structural changes to forest cover, taking the form of the conversion of:

- (a) primary forests or naturally regenerating forests into plantation forests or into other wooded land; or
- (b) primary forests into planted forests;

'relevant products' means products listed in Annex I that contain, have been fed with or have been made using relevant commodities;

Annex 2. Legend and reclassification scheme for comparing the CORINE Land Cover with GFC2020

Category number	Legend in CORINE	Reclassification
111	Continuous urban fabric	Artificial surfaces
112	Discontinuous urban fabric	Artificial surfaces
121	Industrial or commercial units	Artificial surfaces
122	Road and rail networks and associated land	Artificial surfaces
123	Port areas	Artificial surfaces
124	Airports	Artificial surfaces
131	Mineral extraction sites	Artificial surfaces
132	Dump sites	Artificial surfaces
133	Construction sites	Artificial surfaces
141	Green urban areas	Artificial surfaces
142	Sport and leisure facilities	Artificial surfaces
211	Non-irrigated arable land	Agricultural areas
212	Permanently irrigated land	Agricultural areas
213	Rice fields	Agricultural areas
221	Vineyards	Agricultural areas
222	Fruit trees and berry plantations	Agricultural areas
223	Agricultural areas > Permanent crops > Olive groves	Agricultural areas
231	Pastures	Agricultural areas
241	Annual crops associated with permanent crops	Agricultural areas
242	Complex cultivation patterns	Agricultural areas
243	Land principally occupied by agriculture, with significant areas of natural vegetation	Agricultural areas
244	Agro-forestry areas	Agricultural areas
311	Broad-leaved forest	Forests
312	Coniferous forest	Forests
313	Mixed forest	Forests
321	Natural grasslands	Scrub and/or herbaceous vegetation associations
322	Moors and heathland	Scrub and/or herbaceous vegetation associations
323	Sclerophyllous vegetation	Scrub and/or herbaceous vegetation associations
324	Transitional woodland-shrub	Scrub and/or herbaceous vegetation associations
331	Beaches, dunes, sands	Open spaces with little or no vegetation
332	Bare rocks	Open spaces with little or no vegetation
333	Sparsely vegetated areas	Open spaces with little or no vegetation
334	Burnt areas	Open spaces with little or no vegetation
335	Glaciers and perpetual snow	Open spaces with little or no vegetation
411	Inland marshes	Wetlands
412	Peat bogs	Wetlands
421	Salt marshes	Wetlands

422	Salines	Wetlands
423	Intertidal flats	Wetlands
511	Water courses	Water bodies
512	Water bodies	Water bodies
521	Coastal lagoons	Water bodies
522	Estuaries	Water bodies
523	Sea and ocean	Water bodies

Annex 3. Legend and reclassification scheme for comparing the Côte d'Ivoire BNETD 2020 Land Cover with GFC2020

Category number	Legend in Côte d'Ivoire BNETD	Reclassification
1	Dense forest	Forests
2	Light forest	Forests
3	Forest gallery	Forests
4	Secondary forest/degraded forest	Forests
5	Mangrove	Forests
6	Forest plantation/Reforestation	Forests
7	Swamp forest/Forest on hydromorphic soil	Forests
8	Coffee Plantation	Plantations and other crops
9	Cocoa Plantation	Plantations and other crops
10	Rubber plantation	Plantations and other crops
11	Oil palm plantation	Plantations and other crops
12	Coconut Plantation	Plantations and other crops
13	Cashew plantation	Plantations and other crops
14	Fruit plantation / Arboriculture	Plantations and other crops
15	Agricultural development/Other crops/Orchards/Fallow land	Plantations and other crops
16	Tree savannah	Forests
17	Shrub formations/ Thickets	Herbaceous and shrub formations
18	Herbaceous formations	Herbaceous and shrub formations
19	Body of water, Courses and waterways	Body of water, Courses and waterways
20	Swampy area	Swampy area
21	Human habitat, Infrastructure	Human habitat, Infrastructure
22	Rocky outcrop	Rocky outcrop and bare ground
23	Bare ground	Rocky outcrop and bare ground

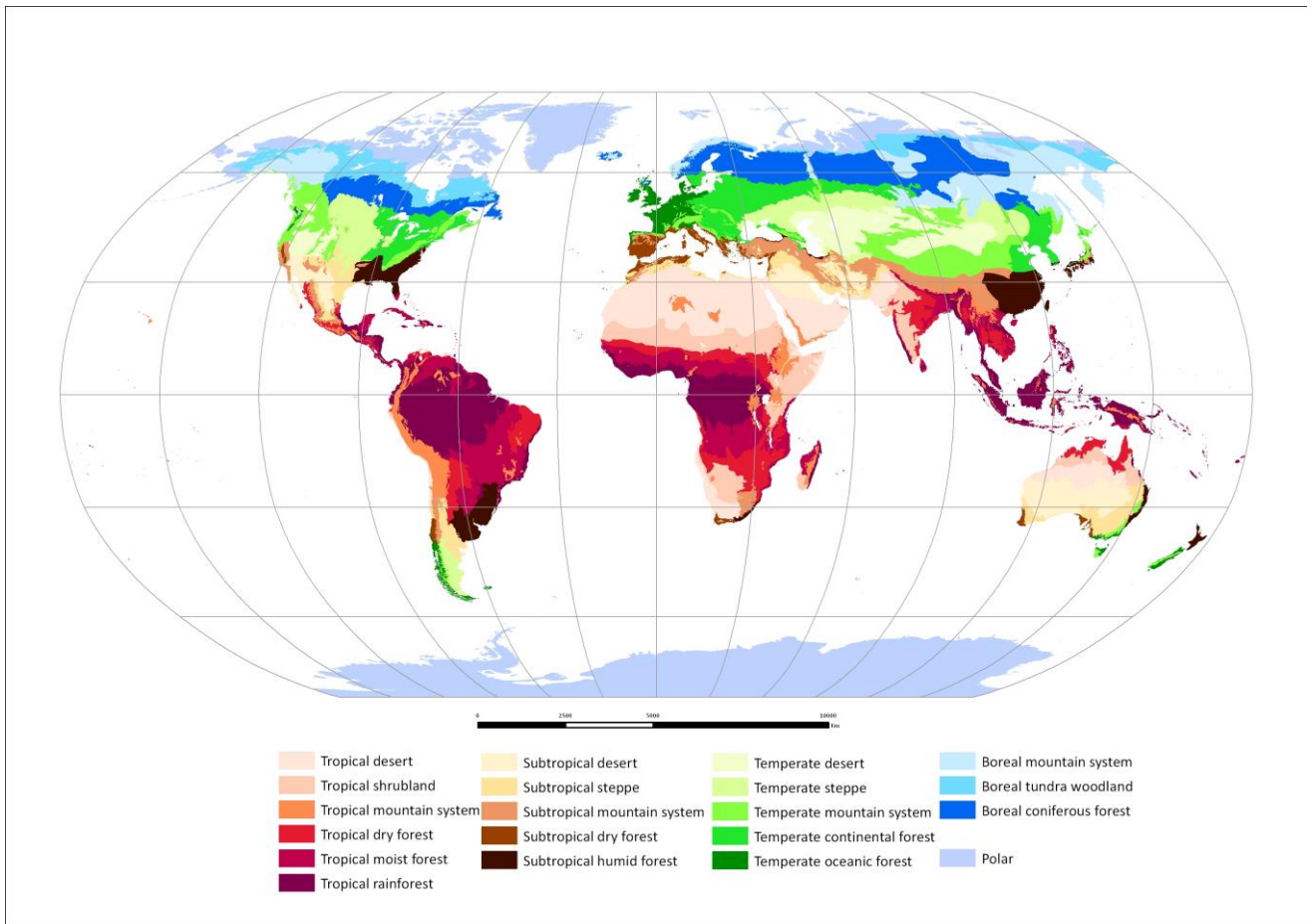
Annex 4. Legend and reclassification scheme for comparing MapBiomias Brazil 2020 Land Cover with GFC2020

Category number	Legend in MapBiomias Brasil	Reclassification
3	Forest Formation	Forest
4	Savanna Formation	Forest
5	Mangrove	Forest
6	Floodable Forest	Forest
49	Wooded Sandbank Vegetation	Forest
11	Wetland	Herbaceous and Shrubby Vegetation
12	Grassland	Herbaceous and Shrubby Vegetation
32	Hypersaline Tidal Flat	Herbaceous and Shrubby Vegetation
29	Rocky Outcrop	Herbaceous and Shrubby Vegetation
50	Herbaceous Sandbank Vegetation	Herbaceous and Shrubby Vegetation
15	Pasture	Farming
39	Soybean	Farming
20	Sugar cane	Farming
40	Rice	Farming
62	Cotton	Farming
41	Other Temporary Crops	Farming
46	Coffee	Farming
47	Citrus	Farming
35	Palm Oil	Farming
48	Other Perennial Crops	Farming
9	Forest Plantation	Forest
21	Mosaic of Uses	Farming
23	Beach, Dune and Sand Spot	Non vegetated area
24	Urban Area	Non vegetated area
30	Mining	Non vegetated area
25	Other non-vegetated Areas	Non vegetated area
33	River, Lake and Ocean	Water
31	Aquaculture	Water

Annex 5. Legend and reclassification scheme for comparing Land Cover of North America 2020 from the North American Land Change Monitoring System (NALCMS) with GFC2020

Category number	Legend in NALCMS	Reclassification
1	Temperate or sub-polar needleleaf forest	Forest
2	Sub-polar taiga needleleaf forest	Forest
3	Tropical or sub-tropical broadleaf evergreen forest	Forest
4	Tropical or sub-tropical broadleaf deciduous forest	Forest
5	Temperate or sub-polar broadleaf deciduous forest	Forest
6	Mixed forest	Forest
7	Tropical or sub-tropical shrubland	Shrubland
8	Temperate or sub-polar shrubland	Shrubland
9	Tropical or sub-tropical grassland	Grassland
10	Temperate or sub-polar grassland	Grassland
11	Sub-polar or polar shrubland-lichen-moss	Shrubland
12	Sub-polar or polar grassland-lichen-moss	Grassland
13	Sub-polar or polar barren-lichen-moss	Barren land
14	Wetland	Wetland
15	Cropland	Cropland
16	Barren land	Barren land
17	Urban and built-up	Urban and built-up
18	Water	Water
19	Snow and ice	Snow and ice

Annex 6. Global Ecological Zones (2010), available at:
<http://foris.fao.org/static/data/fra2010/ecozones2010.jpg>



Annex 7. Metrics behind the comparison of GFC2020 v1/v2 vs. national/regional land cover products

	Share of agreement for forest between maps: forest area in GFC2020 that spatially agrees with forest in the regional data sets against the total forest area in GFC2020		Share of agreement between forest in regional map and non-forest in GFC2020: non-forest area in GFC2020 that spatially agrees with forest in the regional data sets against the total non-forest area in GFC2020		Adjusted contingency coefficient	
	GFC2020 v1	GFC2020 v2	GFC2020 v1	GFC2020 v2	GFC2020 v1	GFC2020 v2
CORINE	65.82	69.06	3.26	3.94	0.81	0.83
Côte d'Ivoire's BNETD	52.00	63.99	12.75	13.92	0.55	0.66
MapBiomass	92.77	91.82	21.88	14.55	0.83	0.87
NALCMS	73.73	73.38	6.13	5.35	0.83	0.84

Annex 8. Forest degradation workshop agenda

17 June 2024	Day 1 - Mapping forest types for risk assessment
14:00-14:10	Welcome and Introduction, Greet Maenhout
14:10-14:15	Workshop goals and practicalities, Rene Colditz
14:15-14:30	Context on Forest Degradation in the EU Deforestation-free Regulation, Emanuele Pitto, Diego Torres
14:30-14:40	Global Forest cover map 2020, René Colditz
14:40-15:25	Initial thoughts on forest degradation mapping, all participants
15:25-15:40	Questions and first reflections
15:40-15:45	Summary, Frédéric Achard
15:45-16:00	<i>Coffee Break</i>
16:00-17:45	Open discussion of data sources for present definition of degradation in EU Deforestation-free Regulation
17:45-18:00	Operational conclusions
18 June 2024	Day 2 – Verification of degradation and alternative approaches
09:00-09:10	Introduction René Colditz
09:10-09:30	Initial thoughts on implementation by Competent Authorities, all participants
09:30-10:15	Open discussion
10:15-10:30	<i>Coffee break</i>
10:30-10:50	Initial thoughts on alternative definitions, all participants
10:50-11:45	Open discussion
11:45-12:00	Conclusions

List of participants (in alphabetical order) and institution:

- Frederic Achard, Joint Research Centre (JRC)
- Clement Bourgoïn, JRC
- Andreas Brink, JRC, invited internally
- Sarah Carter, World Resources Institute (WRI), invited
- Rene Colditz, JRC
- Remi D’Annunzio, Food and Agriculture Organization of the United Nations (FAO), invited
- Loic Dutrieux, JRC, invited internally
- Steffen Fritz, International Institute for Applied Systems Analysis (IIASA), invited
- Valery Gond, Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), invited
- Greet Maenhout, JRC
- Anssi Pekkarinen, FAO, invited
- Astrid Verhegghen, JRC

Annex 9. Non-exhaustive list of known issues for GFC2020 v2 by coordinates (7 December 2024)

Longitude	Latitude	Description of the issue	Date	Source
-60.39555	-18.33929	Stripes	12/6/2023	Producer
13.84255	8.77345	Stripes	12/6/2023	Producer
23.6801	10.02	Straight line across Africa	12/6/2023	Producer
24.80143	9.6225	Stripes	12/6/2023	Producer
26.04346	9.29019	Stripes	12/6/2023	Producer
30.17033	6.45132	Stripes	12/6/2023	Producer
31.24432	4.85705	Stripes	12/6/2023	Producer
33.02064	4.41722	Stripes	12/6/2023	Producer
31.485	-10.014	Straight line across Southern Africa	12/6/2023	Producer
20.0363	-10.4397	Stripes	12/6/2023	Producer
19.7457	-9.0165	Stripes	12/6/2023	Producer
20.4062	-8.8466	Stripes	12/6/2023	Producer
19.6471	-8.0315	Stripes	12/6/2023	Producer
19.91755	-7.11935	Stripes	12/6/2023	Producer
-2.1058	8.8034	Stripes	12/6/2023	Producer
14.794	7.7276	Stripes	12/6/2023	Producer
19.7644	9.446	Stripes	12/6/2023	Producer
21.7979	9.4115	Stripes	12/6/2023	Producer
21.7333	10.4042	Stripes	12/6/2023	Producer
97.9	26.3	Stripes	23/1/2025	Producer
64.1821	67.9923	commission error in polar areas	12/6/2023	Producer
41.689082	-0.816276	Omission of dry forest	12/6/2023	Producer
179.9415	-16.184	Missing forest area – straight line	12/6/2023	Producer
29.78134	-0.99987	Straight line between forest and non-forest	29/10/2024	Producer
115.4062	-2.237514	Potential underestimation of forest area	29/10/2024	Producer
98	26.5	Stripes and straight lines	29/10/2024	Producer
109.25	18.79	Large areas of forests and tree plantations (which resemble timber plantations) are not included in forests, whereas bare lands are	29/10/2024	Producer
6.4	4.4	Rivers wider than 10 meters mapped as forests	29/10/2024	Producer
-8.5	7.54	Industrial mine and bare lands wrongly classified as forest	29/10/2024	Producer
-7.15	41.53	Olive tree plantations classified as forest	29/10/2024	Producer
-6.8	41.275	Coarse classification, no clear delimitation between forest and non-forest	29/10/2024	Producer
-176.53	-44.07	Removal of large patches of forest	29/10/2024	Producer
-15.6	28.1	Overestimation of forest	29/10/2024	Producer
17.8	-19.4	Omission of dry forest areas	23/1/2025	Producer
3.35	7.91	Shrubland and bare land considered as forest	29/10/2024	Producer
6.689	4.987	Palm tree plantations and bare land classified as forest	29/10/2024	Producer
7.444	4.601	Bare land and forest areas classified	29/10/2024	Producer
45.05	59.75	Bare land areas wrongly classified as forest at the edge	29/10/2024	Producer

-8.498	7.675	Agricultural palm tree plantation classified as forest	29/10/2024	Producer
5.66	33.48	Agricultural tree plantation (probably date palm) classified as forest.	29/10/2024	Producer
-5.64	8.27	Block pattern in North Ivory Coast	21/10/2024	Producer
57.6179	64.37941	River considered as forest	21/10/2024	Producer
79	44.8	Large areas of grassland classified as forests	21/10/2024	Producer
-96.38994886	58.99829197	Underestimation of forest area	22/10/2024	Producer
-119.5399653	66.54306862	Underestimation of forest area	22/10/2024	Producer
-136.7822638	64.92407444	Underestimation of forest area	22/10/2024	Producer
-89.14038516	17.97903504	Underestimation of forest area	22/10/2024	Producer
-93.25872384	17.89919355	Underestimation of forest area	22/10/2024	Producer
9.286121046	56.24023284	Overestimation of forest area	24/10/2024	Producer
15.14556587	57.74107253	Overestimation of forest area	24/10/2024	Producer
15.14556587	57.74107253	Overestimation of forest area	24/10/2024	Producer
13.71685914	41.52737767	Overestimation of forest area	24/10/2024	Producer
-7.15	41.53	Olive tree plantations classified as forest	24/10/2024	Producer
37.62165	-0.79218	Sharp removal of forest on a homogeneous area	24/10/2024	Producer
31.24986	-1.41056	Artefact - sharp line	24/10/2024	Producer

Annex 10. Non-exhaustive list of known issues for GFC2020 v2 by regions (7 December 2024)

Region	Issue
Urban areas	Heterogeneous categorization of urban forests and residual woodlands. Some urban parks may be included as forests in the final map (commission errors)
Global	Artefacts (striping patterns) linked to data and technical issues from Landsat 7 ETM+ satellite sensor (commission errors).
Global	Salt and pepper effect although it has been mitigated by the post-processing steps
Global	Geometric shifts due to crossing of different input layers that result in commission or omission errors along forest edges
Global	heterogeneous classification of forest in seasonally inundated areas (areas along riparian forests and rivers)
Global	Errors of commission with small rivers
Mountainous areas	Underestimation of forests in areas with high slopes (omission errors)
Tropical dry forest	Separation between tropical dry open forests and shrublands are often difficult to capture, leading to mapping with heterogeneous accuracy in tropical dry domain (mix of omission and commission errors)
Indonesia, Malaysia, West Africa	Overestimation of forest cover in areas with small-holder oil palm plantations or mixed oil palm plantations (oil palm mixed with other crops) or oil palm plantations with low canopy coverage resulting in commission errors
Ivory Coast, Ghana, Cameroon	Overestimation of forest cover in cocoa production area, mainly in shaded cocoa agroforestry systems (commission errors)
New Caledonia	Overestimation of forest in landscapes with low density of tree cover
Sri Lanka	Overestimation of forest in tree crops areas
Global	Potential confusion between forest cover and tree plantation for agricultural use (e.g. orchards) or rubber plantations
Global	Recently burned and clear cut logged forests may be classified as non-forest cover due to the absence of standing trees (omission errors)
Tropics	Forest edges in heterogeneous landscapes may not be accurately mapped due to the complex mosaics between forests and other land cover (omission errors)
Easternmost Siberia	Block of forested land mapped in no tree or very sparse tree area
180 degree longitude	Missing forest area

Annex 11. Non-exhaustive list of known issues by coordinates for GFT2020 v0 (15 November 2024)

Lon	Lat	Issue	Date	Source
2.154517	6.980362	Teak plantation in Benin, some part are not identified as forest in GFC2020 and therefore are not classified as planted forest. The planted area is a bit patchy even if from the VHR it seems correct. Part of forest plantations are classified as regenerating forests	15/11/2024	Producer
-4.79542	7.84188	Identified as 'primary forest' in GFT2020 and as tree plantation/regeneration in national data of Cote d'Ivoire	15/11/2024	Producer
-4.69844	7.54198	Identified as 'primary forest' in GFT2020 and as tree plantation/regeneration in national data of Cote d'Ivoire	15/11/2024	Producer
-9.06482	7.401116	Patchy effect of planted/plantation forest	15/11/2024	Producer
-59.9846	-2.43842	Naturally regenerating forests north of Manaus are not so extensive as suggested by the map	15/11/2024	Producer
-54.3717	-4.43818	Naturally regenerating forests east of FLONA Tapajos are also not as extensive as indicated in the map	15/11/2024	Producer
-62.8794	-0.34097	I don't see any evidence of naturally regenerating forests in this region - not sure why they are not being mapped as primary forest	15/11/2024	Producer
109.8225	19.1256	Wrong classification of plantation-planted forest	15/11/2024	Producer
102.6654	0.4829	Stripe classified as planted forest	15/11/2024	Producer
98.9013	15.0235	Intense buffering effect around primary forest extent	15/11/2024	Producer
111.6957	-2.46621	Potential overestimation of planted/plantation forest	15/11/2024	Producer
-157.912	21.3992	Isolated planted/plantation pixels that should be classified in the forest type as their nearest neighbouring pixels	15/11/2024	Producer
32.92007	-26.4613	Potential overestimation of planted/plantation forest	15/11/2024	Producer
80.59996	5.9814	Potential overestimation of planted/plantation forest	15/11/2024	Producer
-123.686	41.35209	Primary forest interfringes with planted forest	15/11/2024	Producer
-8.26542	41.84439	Area where primary and planted forest are mixed	15/11/2024	Producer
10.87936	64.17649	Isolated pixel of planted forest in the middle of primary forest	15/11/2024	Producer
-78.0798	8.648594	Potential overestimation of planted/plantation forest	15/11/2024	Producer
-78.2949	8.536958	Potential overestimation of planted/plantation forest	15/11/2024	Producer

Annex 12. Non-exhaustive list of known issues by regions for GFT2020 v0 (15 November 2024)

Region	Issue	Date	Source
Brazilian Amazon	Patches of primary forests may not meet the MMU (lower due to buffer around selective logging pixels)	15/11/2024	Producer
Global	Delineation of planted/plantation looking coarser than 10m resolution	15/11/2024	Producer
North America	Planted forest appears in blocks of ca. 100m. However, in some cases this general pattern is modulated with 10m data (10m holes, adjustments along boundaries)	15/11/2024	Producer
North America	The origin from a vector dataset is still visible for primary forests by having smooth forms or circles	15/11/2024	Producer
Mexico, Sierra Madre Occidental	Blocky pattern of 100m grid cells for primary forests when separated from naturally-regenerating forest, This effect is also visible in other regions but particularly notable here	15/11/2024	Producer
Canada, Alaska	There is a fringe of 100-200 km between primary forest in the boreal and the tundra non-forest area mapped as naturally-regenerating	15/11/2024	Producer
Kenya-Tanzania	Buffer on primary forest creates lots of fragmented patches	15/11/2024	Producer
Côte d'Ivoire	Patches of primary forests may not meet the MMU (lower due to buffer around selective logging pixels)	15/11/2024	Producer
France - Hautes Alpes	Old plantations / planted forests are mostly not depicted. Small patches of plantations (one or few 100m res pixels) look even more strange when located within primary forest's extent (e.g. in Parc des Ecrins)	15/11/2024	Producer
Boreal zone	Forests at highest latitudes appear as naturally regenerating forests (very large areas in Canada and Russia) just above a long belt of primary forests. It might be the effect of a low forest integrity index	15/11/2024	Producer
Tropical zone - Northern Thailand and Northern Laos	The filtering of primary forests with a 250m buffer around tropical moist forest degraded pixels leads to very fragmented patches. Specifically in Northern Thailand and Laos where there is a lot of shifting cultivation, the map seems to overestimate forest areas and primary forests	15/11/2024	Producer

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