

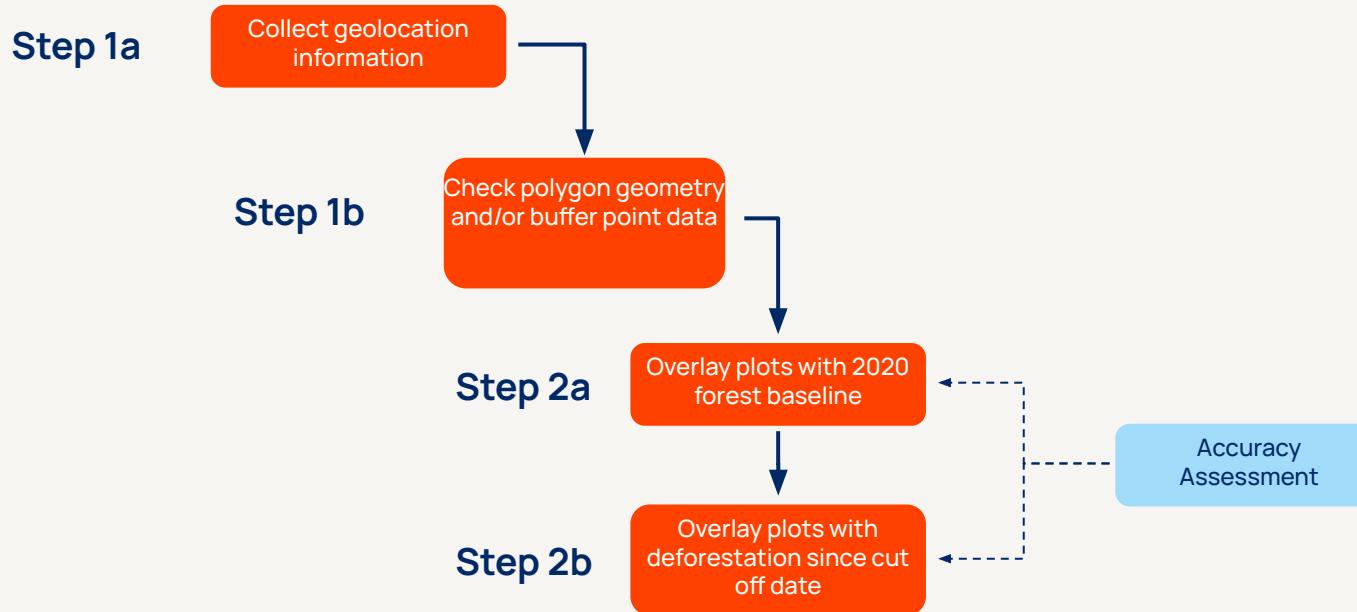
EUDR Deforestation Detection Methodology



World Cocoa
Foundation



Methodology Overview





Step 1. Plot Data Collection & Submission



Step 1a. Collection Geolocation Information

EUDR plot data can be collected and uploaded to monitoring systems as polygon or point data.

Polygon plots should be validated for geometrical integrity upon submission

Typical Data Formats:

- GeoJSON (*.geojson)
- Shapefile (*.shp, +*.pjr + *.dbf, +..)
- Geopackage (*.gpkg)



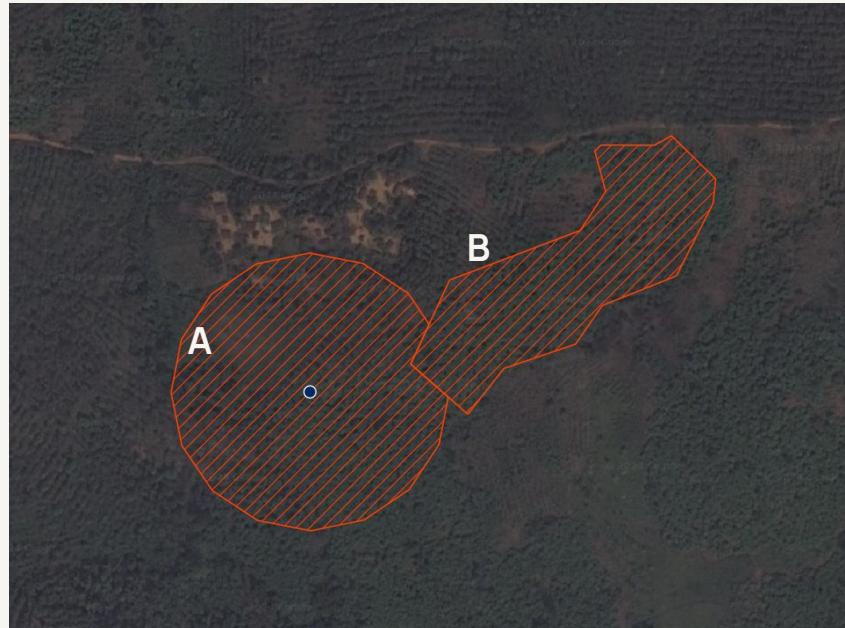
Step 1b. Check Polygon Geometry and/or Buffer Point Data

EUDR plot data can be uploaded as polygon or point data. Point data are only accepted if their area is less than 4 ha. Above this threshold only polygons are accepted following [EUDR guidelines](#).

Point data should be collected from the center of the plot, and not at the boundaries.

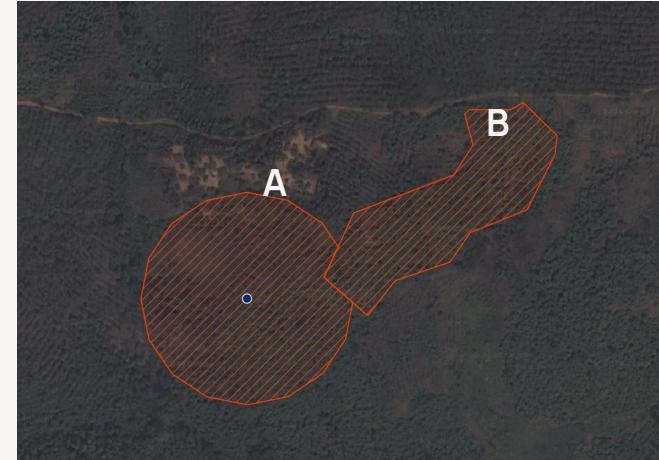
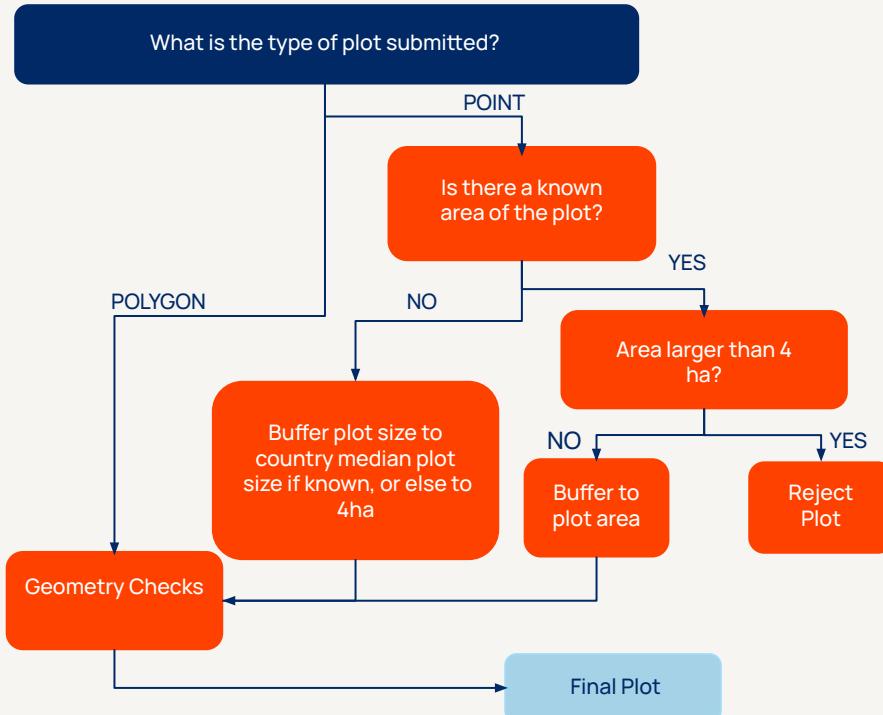
Upon submission points are buffered to simulate circular polygon plots of 4 hectares, or smaller if the plot area is indicated.

Polygon plots are validated for having valid geometries upon submission.



Plot A was submitted as point coordinate and buffered to a 4 hectare plot. **Plot B** was submitted as valid polygon, which means it will be adopted as-is for deforestation-free assessments.

Step 1b. Check Polygon Geometry and/or Buffer Point Data



Plot A was submitted as point coordinate and buffered to a 4 hectare plot.

Plot B was submitted as valid polygon, which means it is adopted as-is for deforestation-free assessments.



Step 2. Plot Check

Forest Baseline
Current Commodity Map
Deforestation

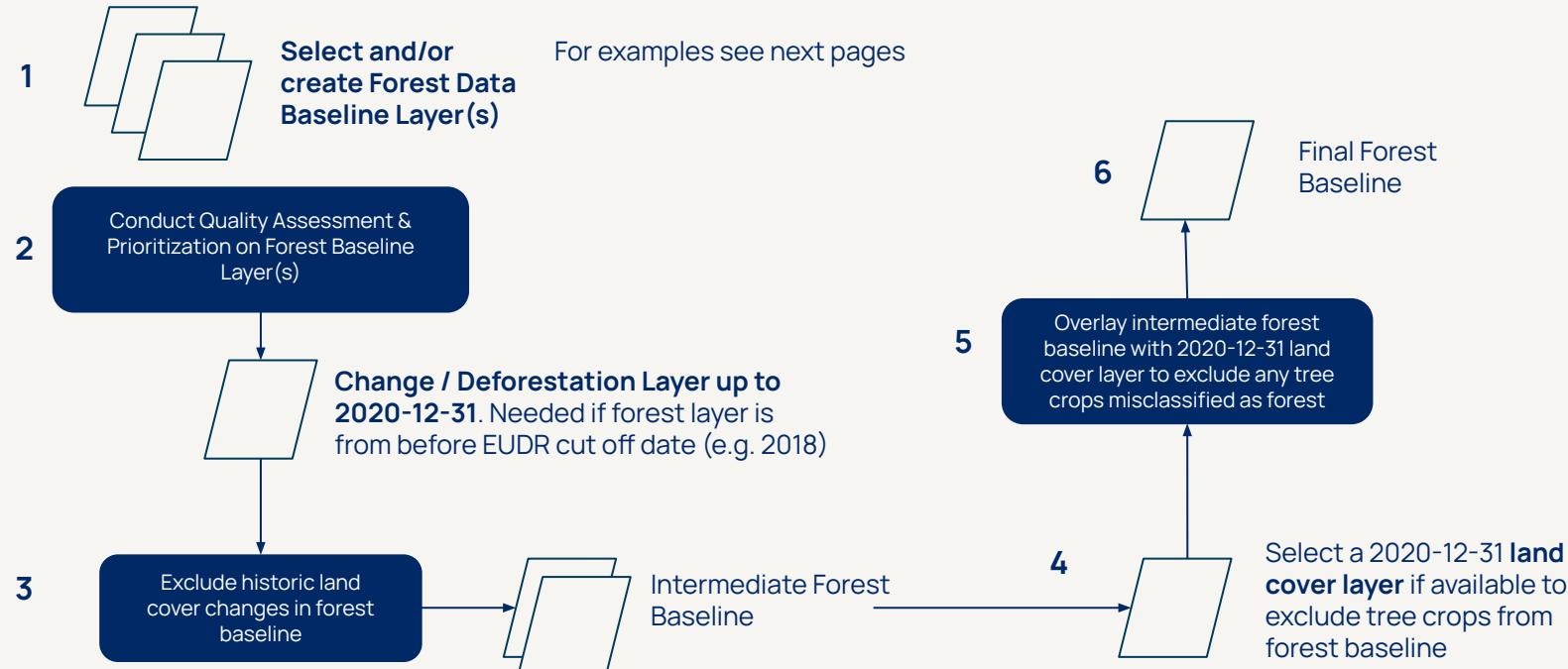
Separating tree cover from forest loss

Plot Check

Step 2a. Forest Baseline



According to the new guidelines from the EC, land can be follow up to 10 years IF it can be proven that this is because of e.g. flooding, economic or succession issues etc. Otherwise the plot of land should be considered as forest when it possesses the characteristics of the FAO forest definitions.





Select/Create Forest Baselines Data & QAQC Open data sources

European Forest Institute [1] lists potential public forest baseline datasets for **step 2a**.

Decisions on which baseline datasets to use should be based on:

- Alignment with EUDR definition
 - E.g. Forest vs Tree Cover
 - Minimum area (0.5 ha)
 - Canopy Cover & height
- Coverage of all forest types (moist & dry)
- Consistency and Accuracy

Dataset	Provider	Resolution (m)	Variable	Period	Aligned with FOA definition of forest
EU Forest observatory Global Forest cover 2020	JRC	10	Forest area	2020	Yes**
Natural Lands	WRI	30	Natural vegetation	2020	Yes**
Forest/Non forest	JAXA	25	Forest area	2017-2020	Yes**
Tropical Moist Forest	JRC	30 (available at 10m for year 2022)	Forest area	1990-2022	Needs adjustments
Tree Canopy Cover	GLAD/Hansen	30	Percentage of tree cover	2000-2022	Needs adjustments
Tree Canopy Height			Tree Height	2020	Needs adjustments
Tropical Tree Cover	WRI	10	Percentage of tree cover	2020	Needs adjustments
World Cover	ESA-JRC	10	Land cover	2020-2021	No
Global Land Cover	Copernicus	100	Land cover	2015-2019	No

** aligned with the FAO biophysical criteria to define forests, with limitation on the representation of specific land uses (i.e. agricultural plantations)



Select/Create Forest Baselines Data & QAQC Satelligence sources

Layers	Spatial Coverage	Temporal resolution and coverage	Spatial Resolution (m)	Map Type	Forest Types (moist, dry, native vegetation)	Observations about Forest and Commodities	Short Quality Description	Known Limitations for EUDR purposes	Included in Satelligence Forest Baseline
EU Forest Observatory Global Forest cover 2020	Global	2020	10	TreeCover/Forest Map	TMF, TDF, Temperate	Global map of forest. Many false positives in tree crops such as cocoa, but even in crops such as sugar cane. Needs a good filter if used for FBL	Potentially useful for identifying possible forest areas. But as a baseline definitely not as-is	Many forest false positives on EUDR commodities	<input checked="" type="checkbox"/>
Ecuador official land cover map	Ecuador	2020	25	LULC map	TMF & TDF	Vector map, needs thorough QA before deciding on how to incorporate	Quality assessment pending	pending	<input checked="" type="checkbox"/>
Honduras official land cover map	Honduras	2014, 2018	10	LULC map	TMF & TDF	Vector map, needs thorough QA before deciding on how to incorporate	Quality assessment pending	pending	<input checked="" type="checkbox"/>
JRC Tropical Moist Forests (TMF)	Global Tropical Belt, Moist forest ecosystems only	Yearly (1990-2023)	30	TreeCover/Forest Map	Tropical Moist Forest	Very good forest mapping in the undisturbed class. The disturbed class has quite a lot of confusion with tree plantations, especially cocoa and coffee. Dry Forests are not included, so additional forest datasets are needed	JRC 2022 release is used, not 2023, because of a major error in plantations in SE Asia as a result of a faulty backpropagation method	No dry forest or woodland	<input checked="" type="checkbox"/>
Carte d'occupation des sols de Côte d'Ivoire en 2020	Ivory Coast	2020	30	LULC map	NONE	Overestimates forest in agro-forestry plantations. Overestimates plantations in shrubland areas, and there is a lot of confusion between plantation types (especially Rubber/OilPalm/Coconut)	Classes overflow into another, so a lot of preprocessing is needed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomass Argentina COL1	Argentina	Yearly (1998-2022)	30	LULC map	TMF, TDF & NV	Good Forest and Native Vegetation Classifications. Contains palm oil, but quality is lower than that of other datasets in this list	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomass Amazonia COL5	Amazonia	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good Forest and Native Vegetation Classifications. Contains palm oil, but quality is lower than that of other datasets in this list	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomass Atlantic Forest COL3	Atlantic Forest in Brazil	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good Forest and Native Vegetation Classifications. Good quality full-sun coffee and forest plantations. Some minor forest <-> plantation misclassifications	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomass Bolivia COL2	Bolivia	Yearly (1985-2023)	30	LULC map	TMF & TDF	Good quality forest definition, but native vegetation in Chaco region is classified as forest	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomass Brasil COL 8	Brazil	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Contains soy, cotton, citrus, coffee, rice. Soy is mapped well, coffee mapping is good in the east in Minas Gerais but in many places in the West of the country coffee is completely missing and confused with pasture	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>



Select/Create Forest Baselines Data & QAQC

Satelligence sources

Layers	Spatial Coverage	Temporal resolution and coverage	Spatial Resolution (m)	Map Type	Forest Types (moist, dry, native vegetation)	Observations about Forest and Commodities	Short Quality Description	Known Limitations for EUDR purposes	Included in Satelligence Forest Baseline
MapBiomas Ecuador COL1	Ecuador	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	coastal forests where many coffee and cocoa farms are located	land cover classes as a different class that is not included in the training data	threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomas Peru COL2	Peru	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good quality forest definition, also for dry forests where many coffee and cocoa farms are located	This dataset is good but suffers from predicting land cover classes as a different class that is not included in the training data	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
MapBiomas Venezuela COL1	Venezuela	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Overall very usable quality if postprocessed to correct for past deforestation events	This dataset seems to be less precise than other mapbiomas data	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
Intact Forest Landscapes (IFL)	Global	2000, 2013, 2016, 2020	N/A	Jurisdictional vectors	NONE	N/A	Vector analysis based on buffer from tree cover. Because only available from certain years, this should be optimally be corrected with S11 own deforestation and then buffering operations	Does not cover all forest, only intact forests	<input checked="" type="checkbox"/>
Primary forests UMD	Pantropical Region	2000	30	TreeCover/Forest Map	Tropical Moist Forest	Most used standard in the industry for primary forest in 2000. Not all forest is actually primary. Also areas that have been logged before the 1980s appear as primary forest.	High Accuracy for determining where forest is.	Needs correction to propagate to current time	<input checked="" type="checkbox"/>
Bolivia national FBL	Bolivia	2013, 2015, 2016	30	TreeCover/Forest Map	NONE	Good Quality Forest layer. Needs some postprocessing to remove false positives	Overall very usable quality if postprocessed	No discrimination in forest types	<input checked="" type="checkbox"/>
MapBiomas Chile COL1	Venezuela	Yearly (2000-2022)	30	LULC map	Native Vegetation	Overall very usable quality if postprocessed to correct for past deforestation events	This dataset seems to be less precise than other mapbiomas data	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
DLR Urban map (WSF)	Global	2019	30	Non Vegetation Class Map	NONE	N/A	Generally good map of urban area, but can sometimes include non urban areas (such as rows of trees). Does not affect commodity or forest mapping, but is used for exclusion of urban trees.	N/A	<input checked="" type="checkbox"/>
ETH Cocoa Map	CIV/Ghana (West-Africa)	2021	30	Commodity map	NONE	High quality cocoa map. Slight overestimation in shrubland areas.	High quality cocoa map. Slight overestimation in shrubland areas.	N/A	<input checked="" type="checkbox"/>
GFV SDPT (database of planted trees)	Global	2020	N/A	Farms/Concession Data	NONE	N/A	Combination of various datasets	N/A	<input checked="" type="checkbox"/>
Guatemala national forest map	Guatemala	2020	N/A	TreeCover/Forest Map	NONE	Good Quality	Overall very usable quality if postprocessed	No discrimination in forest types	<input checked="" type="checkbox"/>
IDEAM Colombia forest map	Colombia	2019	30	TreeCover/Forest Map	NONE	Good Quality Forest layer. Needs some postprocessing to remove false positives	Overall very usable quality if postprocessed	No discrimination in forest types	<input checked="" type="checkbox"/>
Mexico National LULC	Mexico	2018	30	LULC map	NONE	Good Quality Forest layer. Needs some postprocessing to remove false positives Obvious overlap with plantation forests and perennial commodities. This dataset is used to map certain TDF areas where no other datasets are present/have coverage	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	<input checked="" type="checkbox"/>
UMD GLCLU	Global	2000, 2020	30	LC Map	NONE	Does not map forest, but tree cover. Does not distinguish between planted forest and natural forest. Not useable for forest baseline as is. Dataset is used for EUDR definitions	Usable quality but only when there are no other datasets present	No minimum area threshold or tree height inclusion. False positive forest in plantations	<input checked="" type="checkbox"/>
UMD / GFW Tree Canopy Cover	Global	2000, 2005, 2010, 2015	30	TreeCover/Forest Map	NONE	Good quality	Only available for specific years	Only available for specific years	<input checked="" type="checkbox"/>
UMD Tree Height Data	Global	2019	30	TreeCover/Forest Map	NONE	Dataset is used only for EUDR definitions	Only useful to filter tree heights that are EUDR compliant. The dataset is not super reliable. But it's better than alternatives	Only available for 2019	<input checked="" type="checkbox"/>



Select/Create Forest Baselines Data & QAQC - Layers Not Included in Forest Baseline

Layers	Spatial Coverage	Temporal resolution and coverage	Spatial Resolution (m)	Map Type	Forest Types (moist, dry, native vegetation)	Observations about Forest and Commodities	Short Quality Description	Known Limitations for EUDR purposes	Included in Satelligence Forest Baseline
JAXA FNF (PALSAR)	Global	Yearly (2017-2020)	25	TreeCover/Forest Map	NONE ▾	Good quality but lots of "salt and pepper" effect in undisturbed forest in certain areas. Other datasets in this list are more consistent and more useful. This data can be used when no other better datasets are present	Only available in 100m for now, which is too low resolution. Only 2020 is available for 25m	Tree Cover, not Forest.	<input type="checkbox"/>
DLR FNF (TANDEM-X)	Global		50	TreeCover/Forest Map	NONE ▾	Obvious data gaps and data stripes makes this unusable	Can't be used effectively due to data artefacts	Tree Cover, not Forest.	<input type="checkbox"/>
Dynamic World	Global	Any	10	TreeCover/Forest Map	NONE ▾	Does not map forest, but tree cover. Very limited quality. Not usable for Forest Baseline	Low Quality: Unusable	Tree Cover, not Forest.	<input type="checkbox"/>
GLANCE (NASA)	N/S America, Europe	Yearly (2001-2019)	30	LC Map	NONE ▾	Usable quality but only when there are no other datasets present	Usable quality, but coverage is same as MapBiomass, which is better	No minimum area threshold or tree height inclusion	<input type="checkbox"/>
Indonesia official Forest map	Indonesia					Vector map. Shows designated forest areas, but does not necessarily match actual forest presence on the ground.	Not useable for a forest baseline, but can be integrated in the legality part for the risk assessment	Not everywhere good coverage of forest	<input type="checkbox"/>
India official land cover map	India	2020	30	LULC map	TMF & TDF ▾	N/A	Major reprojection error makes this map unusable. Contacts have been made to ask for a correction	No minimum area threshold or tree height inclusion	<input type="checkbox"/>



Overlay commodity layers on Forest Baseline General

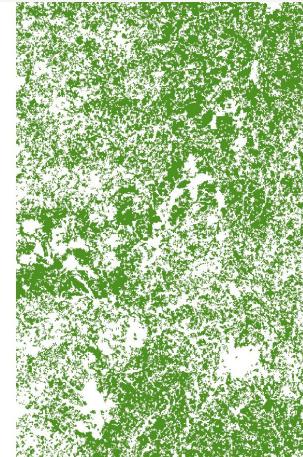
To ensure as few false positive forest areas are in the Forest Baseline, commodity layers of 2020-12-31 should be overlaid on top of the forest baseline map.

Requirements for this layer:

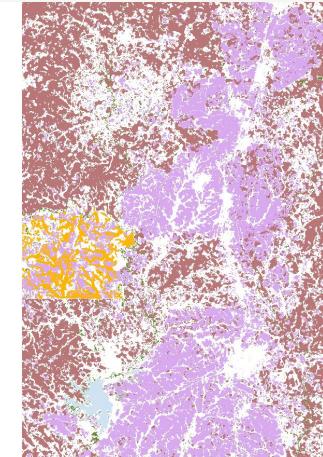
- All tree crops are mapped as being planted (i.e. not forest)
- Commission errors should be low. → High commission errors (many false positives in plantation) will lead to erroneously removing forest from the baseline



Google VHR Satellite



JRC Forest Cover



Improved forest & commodity baseline

An example of differences between the JRC forest Cover layer and an improved forest and commodity baseline in Côte d'Ivoire (5,098° -6,567°). The image above shows a recent VHR image from Google, the image in the middle shows the JRC forest Cover 2020 layer with the forest cover in green. The image on the right shows the improved forest and commodity baseline with forest in green tones, oil palm plantations in yellow, cocoa in brown, rubber in purple, water in blue, and white is 'other'.

Forest & Commodity Baseline

Methods - Satelligence



Satellite input data used

Multi-temporal stack of radar and optical imagery (Landsat-5,7,8,9, Sentinel-1 and Sentinel-2) resampled to 10m pixel size for years 1987 to now.

Data processing methods applied

For forest we use a time series approach detecting historical disturbance since 1987.

- For commodities, we use our database of parcels for different commodities and a semi unsupervised training data handling approach to prepare our classification input data.
- For classification we applied a multi-feature Random Forest machine learning algorithm on cloud and haze corrected annual Sentinel-2 and Landsat 10m mosaics, preprocessed with FORCE and FMask. Sentinel-1 data preprocessed with ISCE2 and DL speckle filtering developed together with WUR.
- Our globally scalable approach is implemented on Google Compute Platform (GCP).

Science behind it

1. Daniel Tutu Benefor et al. Assessing land-use typologies and change intensities in a structurally complex Ghanaian cocoa landscape. *Applied Geography* (2018) 99:109–119.
2. Kwabena Asubonteng et al. Effects of Tree-crop Farming on Land-cover Transitions in a Mosaic Landscape in the Eastern Region of Ghana. *Environmental Management* (2018) 62:529–547.

Forest & Commodity Baseline Accuracy



Ground Data for Model Training and Validation

Ideally, data from the field should be incorporated to measure the accuracy of forest and commodity baselines in a feedback loop. Desk studies are useful, but limiting factors like no available (or very dated) Very High Resolution satellite imagery limits the usefulness for quantitative assessments.

Quantitative Assessment (Accuracy Metrics)

Common quantitative accuracy metrics are *user's accuracy* and *producer's accuracy*. A robust (random) sampling approach should be chosen [2]. For the purpose of EUDR compliance, especially reporting on omission errors (e.g. how much forest is missing in the map) and commission errors (how much forest is in the map that is not there in reality). The balance between commission and omission errors allows for responsible use of the maps in question.

Most of the open layers publish their accuracy scores. For example, the JRC TMF has accuracies between 89-94% depending on the continent, UMD primary forest reports accuracies of >98%.

Qualitative Assessment

Besides the quantitative numbers, a visual, qualitative quality assessment is recommended, because often, only the quantitative assessment does not tell the complete story. A qualitative assessment can be done by an expert, by comparing to other maps and very high resolution satellite imagery.

Plot Check

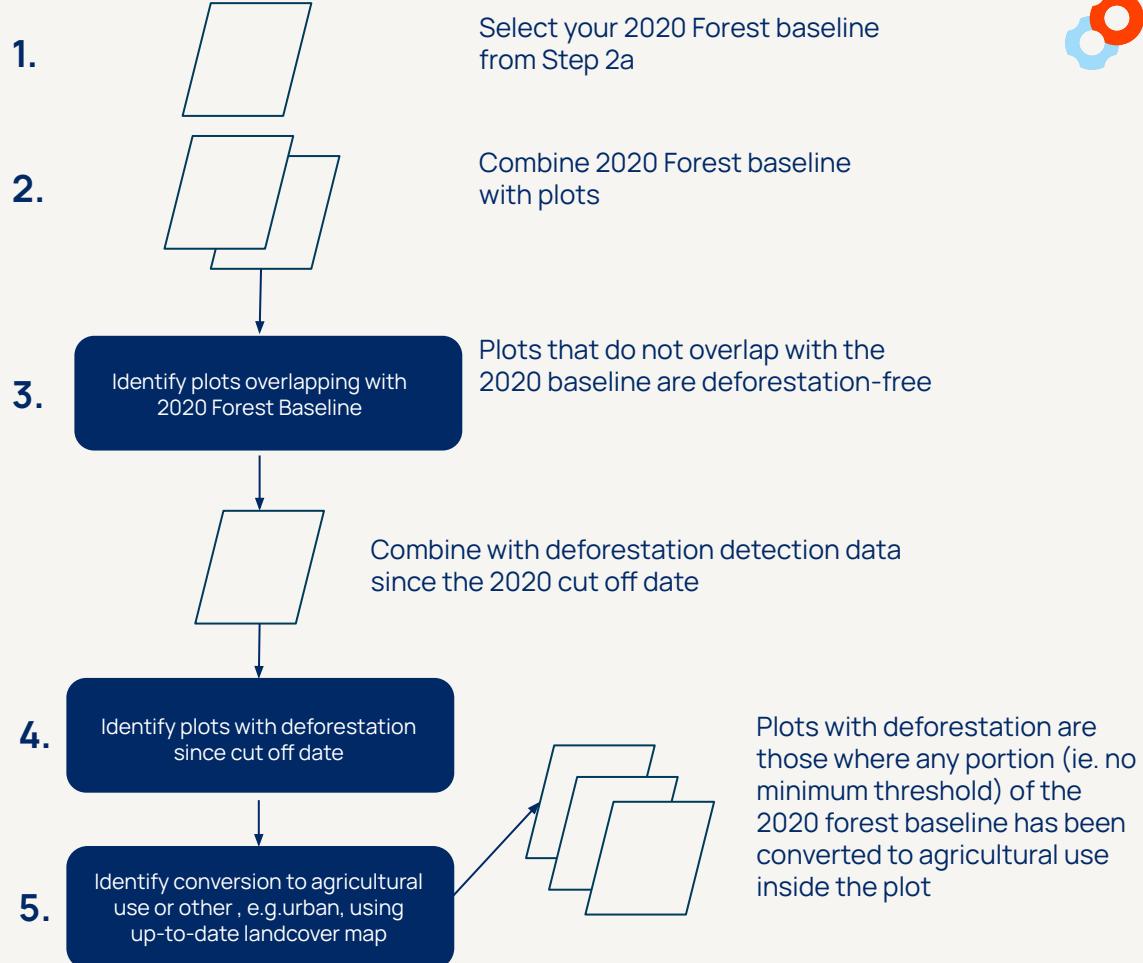
Step 2b.

Cocoa Plots & Deforestation*



* EU definitions: 'deforestation' means the conversion of forest to agricultural use, whether human-induced or not.

Conversions to e.g. roads are not considered deforestation under this definition.





Change/Deforestation Detection

Open Data

These are public datasets that could serve as deforestation data necessary for **step 2b**.

For the selection of the datasets it is important to consider:

- Spatial Coverage of the alert system
- Forest types the alert system covers (Tropical Moist Forest vs Tropical Dry Forest)
- The accuracy and consistency of the system

Table 1. Publicly available datasets on forest

Dataset	Provider	Resolution (m)	Variable	Period	Aligned with FAO definition of forest
RADD	Wageningen University	10	Deforestation alert	Alert every 14 days	No
GLAD	GLAD/Hansen	30	Deforestation alert	Alert every 14 days	No

** aligned with the FAO biophysical criteria to define forests, with limitation on the representation of specific land uses (i.e. agricultural plantations)



Change/Deforestation Detection

Satelligence

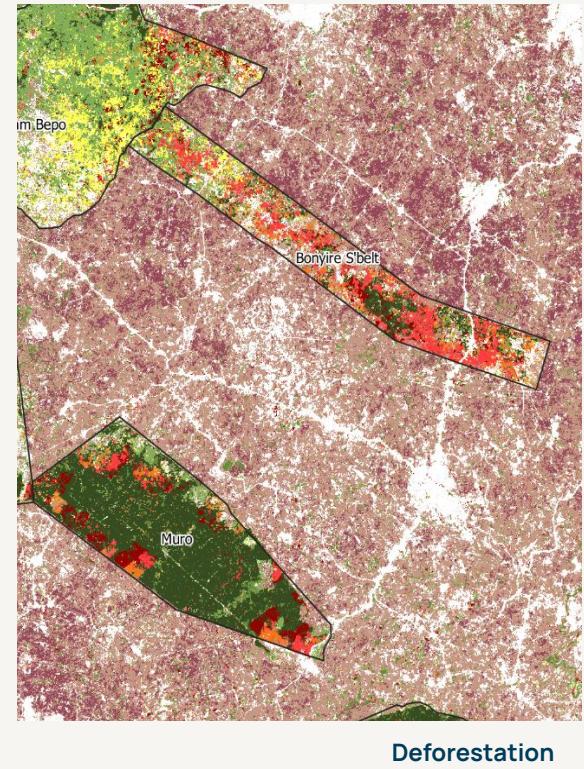
Comparing satellite imagery from 2021 until present to monitor any vegetation change over time.

Algorithm: 'Bayesian Iterative Updating' [3], a probability-based method, reducing false positives. Any change is flagged with their first detection date, resulting in a land cover change map.

Any change within the forest baseline, is classified as deforestation. The minimum mapping unit of the service is 0.1 ha, ie. the smallest surface area that can be reliably classified as being deforestation.

Accuracy: Depending on the region and satellite coverage, between **94-99%**.

Satellite input data used: Multi-temporal stack of radar and optical imagery (Landsat-7,8,9, Sentinel-1 and Sentinel-2) resampled to 10m pixel size for years 2021 - 2024.



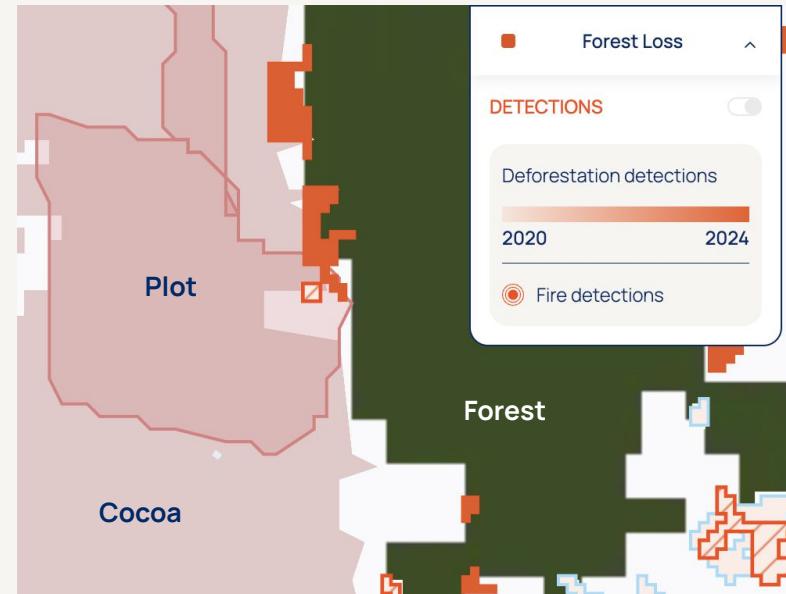


Change/Deforestation Detection

Threshold Satelligence

The threshold for detecting deforestation is determined by the minimum mapping unit of the system which is set to 0.1 ha because the minimum surface area that is reliably classified as a deforestation event is 0.1 ha.

If one pixel that is part of a 0.1 ha (or larger) deforestation event is within a plot then this means that deforestation is identified within a plot.



Deforestation event with individual pixels overlapping with a plot.

Scientific literature





Annex - Scientific references

[1] EFI. 2023. The role of spatial information for EUDR due diligence. Cocoa Insight / November 2023. Available online.

[2] See e.g. Olofsson, Pontus, et al. "Good practices for estimating area and assessing accuracy of land change." *Remote sensing of Environment* 148 (2014): 42-57.

[3] Reiche, J.; Verhoeven, R.; Verbesselt, J.; Hamunyela, E.; Wielaard, N.; Herold, M. Characterizing Tropical Forest Cover Loss Using Dense Sentinel-1 Data and Active Fire Alerts. *Remote Sens.* 2018, 10, 777. <https://doi.org/10.3390/rs10050777>.