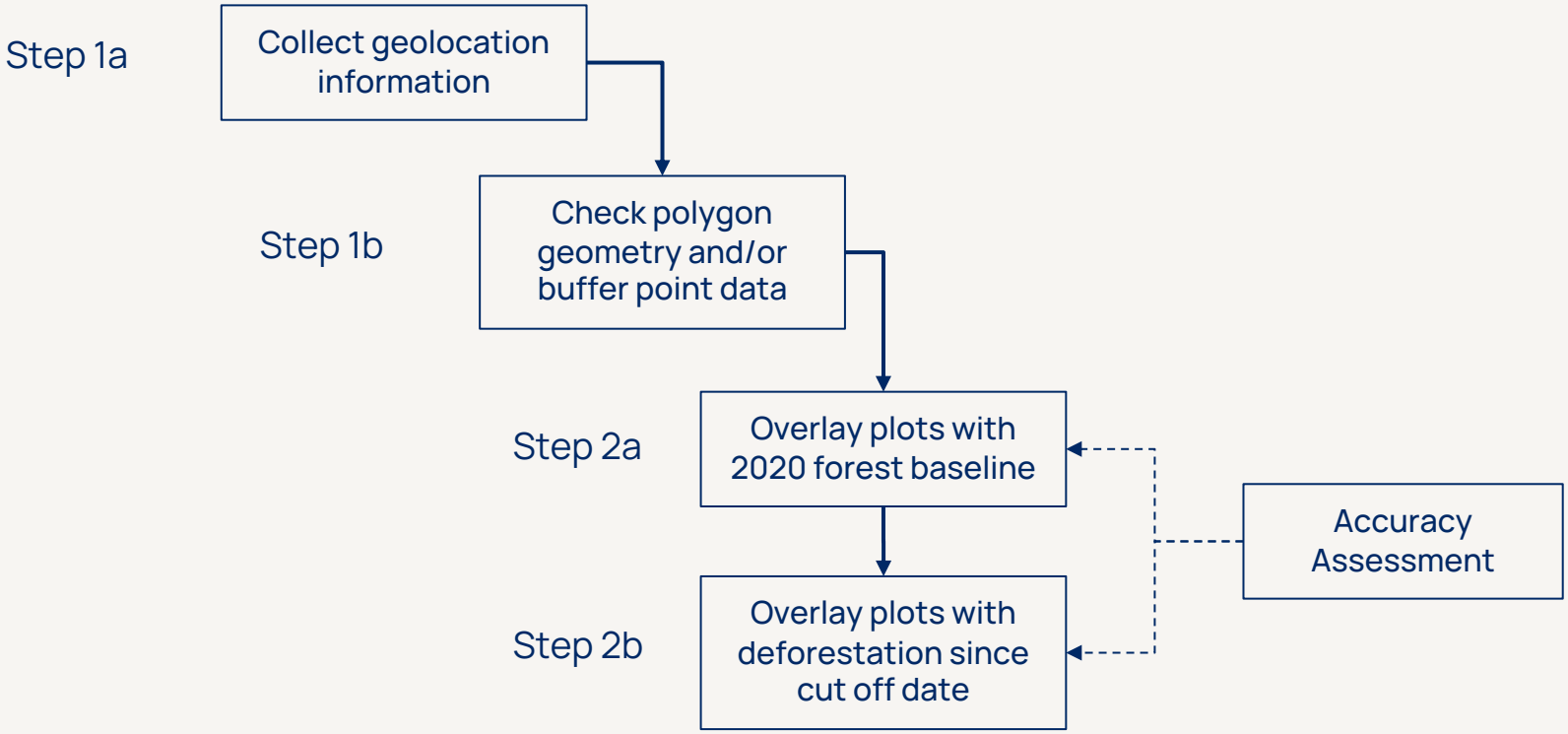
EUDR Deforestation Detection Methodology

Satelligence

Methodology Overview



Step 1.
Plot Data Collection and 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)

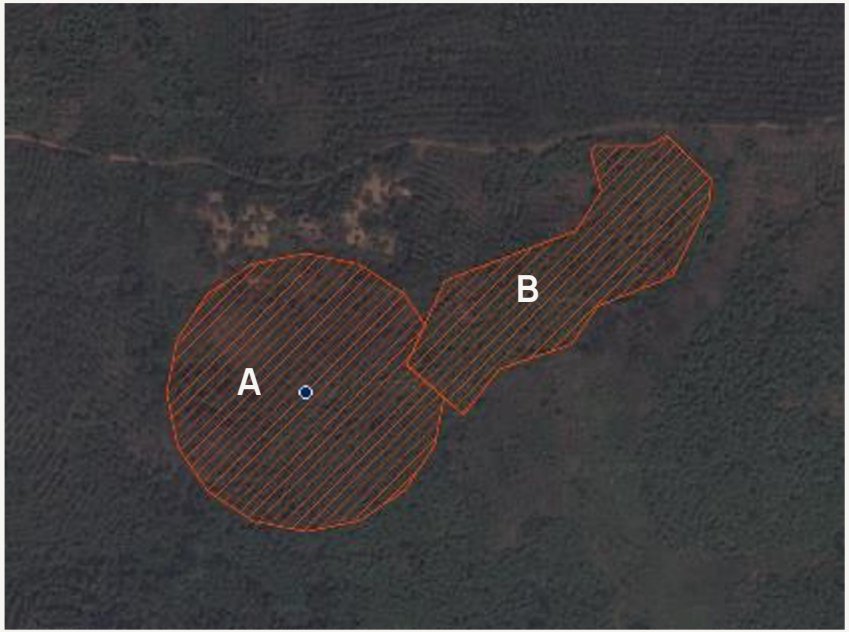
Step 1b. Check polygon geometry and/or buffer point data

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.

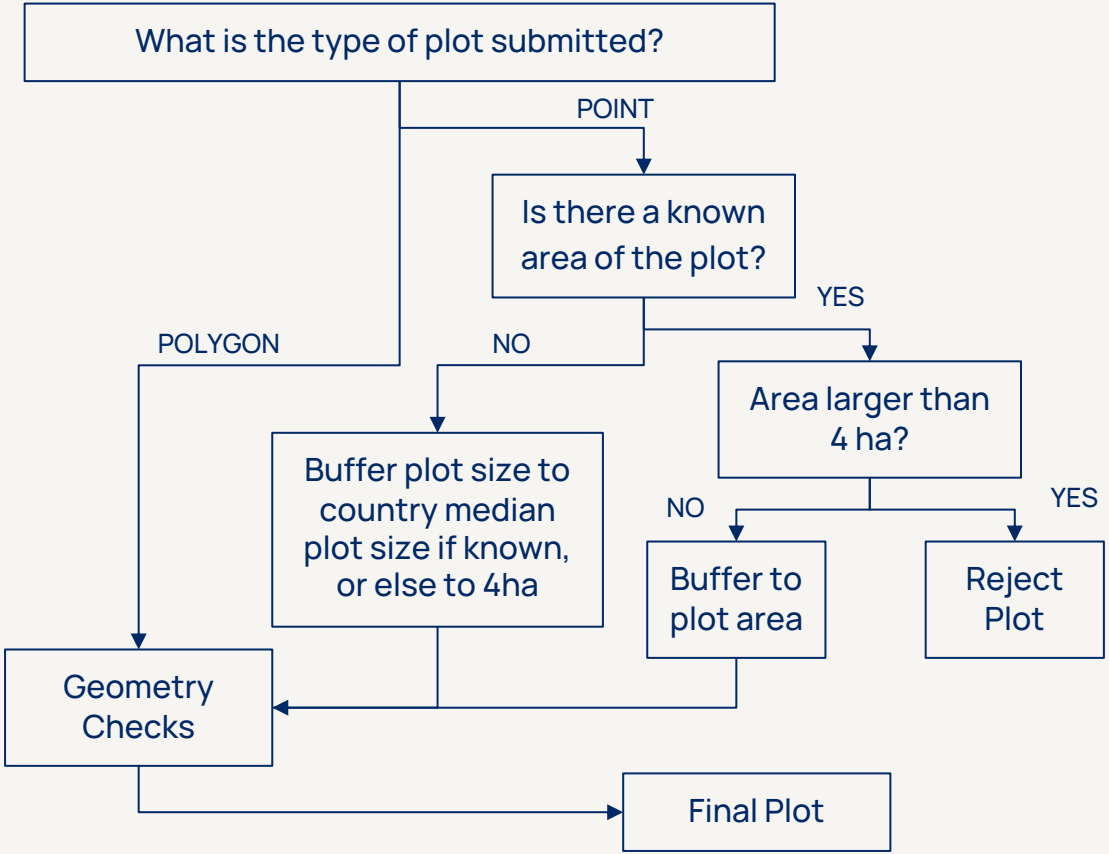
Upon submission points are buffered to simulate circular polygon plots of 4 hectares, or smaller if the plot area is indicated.

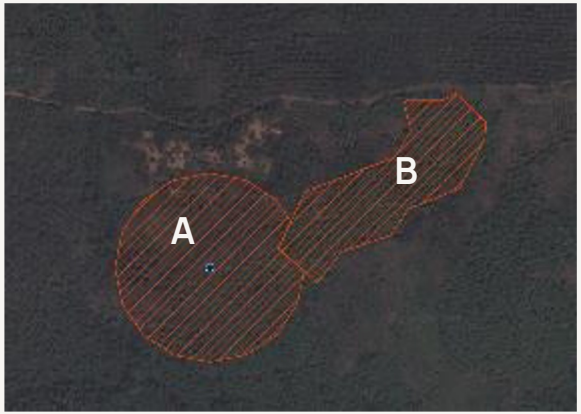
Polygon plots are validated for having valid geometries upon submission.



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

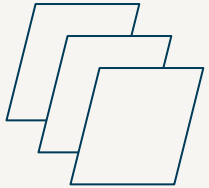
Forest Baseline
Current Commodity Map
Deforestation

Separating tree cover from forest loss

Plot Check

Step 2a. Forest Baseline

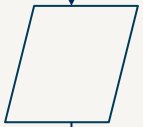
According to the new guidelines from the EC, land can be fallow up to 10 years IF can be proven that this is because of e.g. flooding, economic or succession issues etc. Otherwise the plot of land should be considered as forest when it possesses the characteristics of the FAO forest definitions.

1 

Select and/or create Forest Data Baseline Layer(s)

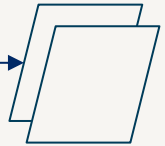
For examples see next pages

2 Conduct Quality Assessment & Prioritization on Forest Baseline Layer(s)

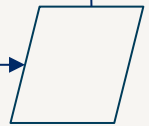


Change / Deforestation Layer up to 2020-12-31. Needed if forest layer is from before EUDR cut off date (e.g. 2018)

3 Exclude historic land cover changes in forest baseline

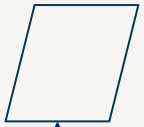


Intermediate Forest Baseline

4 

Select a 2020-12-31 **land cover layer** if available to exclude tree crops from forest baseline

5 Overlay intermediate forest baseline with 2020-12-31 land cover layer to exclude any tree crops misclassified as forest

6 

Final Forest Baseline

Select/Create Forest baselines Data and 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

Table 1. Publicly available datasets on forest

Dataset	Provider	Resolution (m)	Variable	Period	Aligned with FAO 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 10 m for year 2022)	Forest area	1990–2022	Yes**
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 and 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	Commodities included	Short Quality Description	Known Limitations for EUDR purposes	Overall Accuracy (%)	User Accuracy (%)	Prod Accuracy (%)	Included in Satelligence Forest Baseline
JRC Tropical Moist Forests (TMF)	Global Tropical Belt, Moist forest ecosystems only	Yearly (1990-2022)	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	N/A	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	91	92	90	☑
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/Oil Palm/Coconut)	Coffee, Cocoa, Rubber, Palm Oil, Coconut, Other Tree Plantations not further described	Classes overflow into another, so a lot of preprocessing is needed	No min mum area threshold or tree height inclusion, False positive forest in plantations	N/A	N/A	N/A	☑
MapBiomas 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	Palm Oil, Agriculture not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	82	dashboard	dashboard	☑
MapBiomas Atlantic Forest COL2	Atlantic Forest in Brazil	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good Forest and Native Vegetation Classifications. Good qual ty full-sun coffee and forest plantations. Some mix of forest + plantation mis lass fications	Forest Plantation, Coffee, Tea, and Agriculture not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	N/A	N/A	N/A	☑
MapBiomas Bolivia COL1	Bolivia	Yearly (1985-2022)	30	LULC map	TMF & TDF	Good quality forest definition, but native vegetation in Chaco region is classified as forest	Agriculture not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	65.9	dashboard	dashboard	☑
MapBiomas 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	Palm Oil, Coffee, Sugarcane, Soy, Citrus, Other Tree Plantations not further described, Rice, Cotton, Other Annual crops not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	85.8	dashboard	dashboard	☑
MapBiomas Colombia COL1	Colombia	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good quality forest definition, also for dry forests. Contains Palmoil, however these fields are not as reliable as other sources	Palm Oil, Agriculture not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	91.2	dashboard	dashboard	☑
MapBiomas Ecuador COL1	Ecuador	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Good quality forest definition, also for dry coastal forests where many coffee and cocoa farms are located	Agriculture, not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	N/A	dashboard	dashboard	☑
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	Palm Oil, Forest Plantation, Agriculture, not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	87.5	dashboard	dashboard	☑
MapBiomas Venezuela COL1	Venezuela	Yearly (1985-2022)	30	LULC map	TMF, TDF & NV	Overall very usable quality if postprocessed	Forest plantation, and agriculture not further described	Overall very usable quality if postprocessed	No min mum area threshold or tree height inclusion	N/A	N/A	N/A	☑
Intact Forest Landscapes (IFL)	Global	2000, 2013, 2016, 2020	N/A	Jurisdictional vectors	NONE	N/A	N/A	Vector analysis based on buffer from tree cover. Because only available from certain years, this should be optimally be corrected with SI1 own deforestation and then buffering operations	Does not cover all forest, only intact forests	N/A	N/A	N/A	☑

Select/Create Forest baselines Data and 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	Commodities included	Short Quality Description	Known Limitations for EUDR purposes	Overall Accuracy (%)	User Accuracy (%)	Prod Accuracy (%)	Included in Satelligence Forest Baseline
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 1980's appear as primary forest.	N/A	High Accuracy for determining where forest is.	Needs correction to propagate to current time	98	99	96	☑
Bolivia national FBL	Bolivia		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	N/A	N/A	N/A	☑
DLR Urban map (WSF)	Global	2019	30	Non Vegetation Class Map	NONE	N/A	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	83	59	91	☑
ETH Cocoa Map	CI/GHana (West-Africa)	2021	30	Commodity map	NONE	High quality cocoa map. Slight overestimation in shrubland areas	Cocoa	High quality cocoa map. Slight overestimation in shrubland areas	N/A	86	80	87	☑
GFW SDPT (database of planted trees)	Global	2020	N/A	Farms/Concession Data	NONE	N/A	Acacia/Wattle mix, Acacia/Wattle,	Combination of various datasets	N/A	N/A	N/A	N/A	☑
Guatemala national forest map	Guatemala		N/A	TreeCover/Forest Map	NONE	Good Qaulity	N/A	Overall very usable quality if postprocessed	No discrimination in forest types	N/A	N/A	N/A	☑
IDEAM Colombia forest map	Colombia		30	TreeCover/Forest Map	NONE	Good Quality Forest layer. Needs some postprocessing to remove false positives	N/A	Overall very usable quality if postprocessed	No discrimination in forest types	N/A	N/A	N/A	☑
Mexico National LULC	Mexico		30	LULC map	NONE	Good Quality Forest layer. Needs some postprocessing to remove false positives	Agriculture, not further described	Overall very usable quality if postprocessed	No minimum area threshold or tree height inclusion	N/A	N/A	N/A	☑
UMD GLCLU	Global	2000, 2020	30	LC Map	NONE	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	N/A	Usable quality but only when there are no other datasets present	No minimum area threshold or tree height inclusion. False positive forest in plantations	95	93	88	☑
UMD / GFW Tree Canopy Cover	Global	2000, 2005, 2010, 2015	30	TreeCover/Forest 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	N/A	Good quality	Only available for specific years				☑
UMD Tree Height Data	Global	2019	30	TreeCover/Forest Map	NONE	Dataset is used only for EUDR definitions	N/A	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	67	89	66	☑

Select/Create Forest baselines Data and QAQC

Satelligence - 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	Commodities included	Short Quality Description	Known Limitations for EUDR purposes	Overall Accuracy (%)	User Accuracy (%)	Prod Accuracy (%)	Included in Satelligence Forest Baseline
JAXA FNF (PALSAR)	Global	Yearly (2017-2020)	25	TreeCover/Forest Map	NONE	Good quality but loss 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	N/A	Only available in 100m for now, which is too low resolution. Only 2020 is available for 25m	Tree Cover, not Forest	N/A	N/A	N/A	☐
DLR FNF (TANDEM-X)	Global		50	TreeCover/Forest Map	NONE	Obvious data gaps and data stripes makes this unusable	N/A	Can't be used effectively due to data artefacts	Tree Cover, not Forest.	N/A	N/A	N/A	☐
Dynamic World	Global	Any	10	TreeCover/Forest Map	NONE	Does not map forest, but tree cover. Very limited quality. Not usable for Forest Baseline	N/A	Low Quality. Unusable	Tree Cover not Forest.	73.8	N/A	N/A	☐
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	N/A	Potentially useful for identifying possible forest areas. But as a base line definitely not as is	Many forest false positives on EUDR commodities	76	95.2	60.3	☐
GLANCE (NASA)	N/S America, Europe	Yearly (2001-2019)	30	LC Map	NONE	Usable quality but only when there are no other datasets present	N/A	Usable quality, but coverage is same as MapBiomas, which is better	No minimum area threshold or tree height inclusion	documentation	N/A	N/A	☐
Ecuador official land cover map	Ecuador	2020	25	LULC map	TMF & TDF	Vector map, needs thorough QA before deciding on how to incorporate	Many	Quality assessment pending	pending	pending	pending	pending	☐
Indonesia official Forest map	Indonesia					Vector map. Shows designated forest areas, but does not necessarily match actual forest presence on the ground.	N/A	Not usable for a forest baseline, but can be integrated in the legality part for the risk assessment	Not everywhere good coverage of forest.	-	-	-	☐
Honduras official land cover map	Honduras	2013, 2018	10	LULC map	TMF & TDF	Vector map, needs thorough QA before deciding on how to incorporate		Quality assessment pending	pending	pending	pending	pending	☐
India official land cover map	India	2020	30	LULC map	TMF & TDF	N/A	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	N/A	N/A	N/A	☐

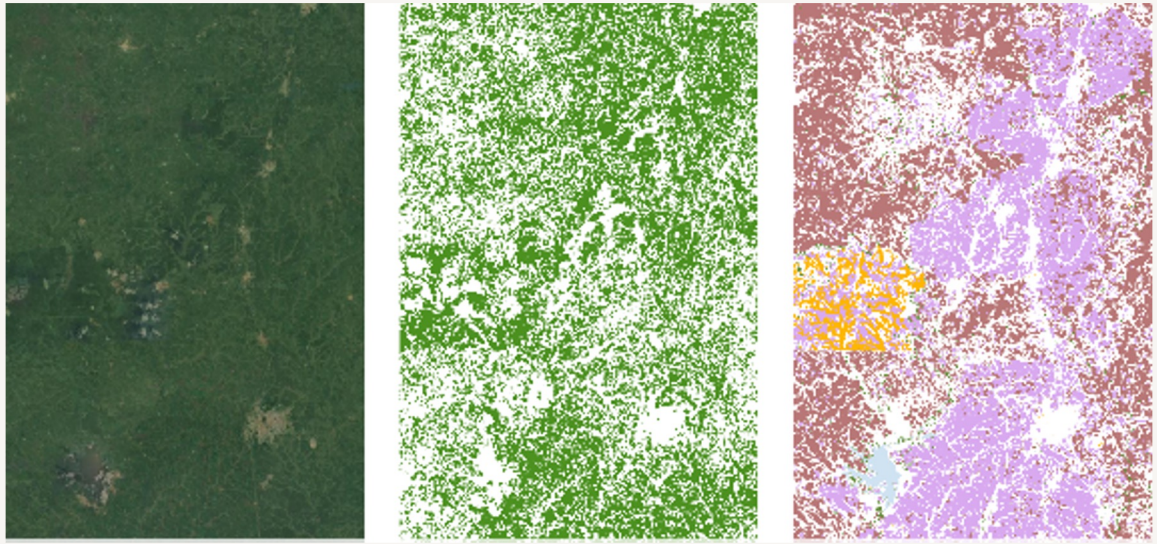
Overlay commodity layers on Forest Baseline

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 (ie 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 and 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

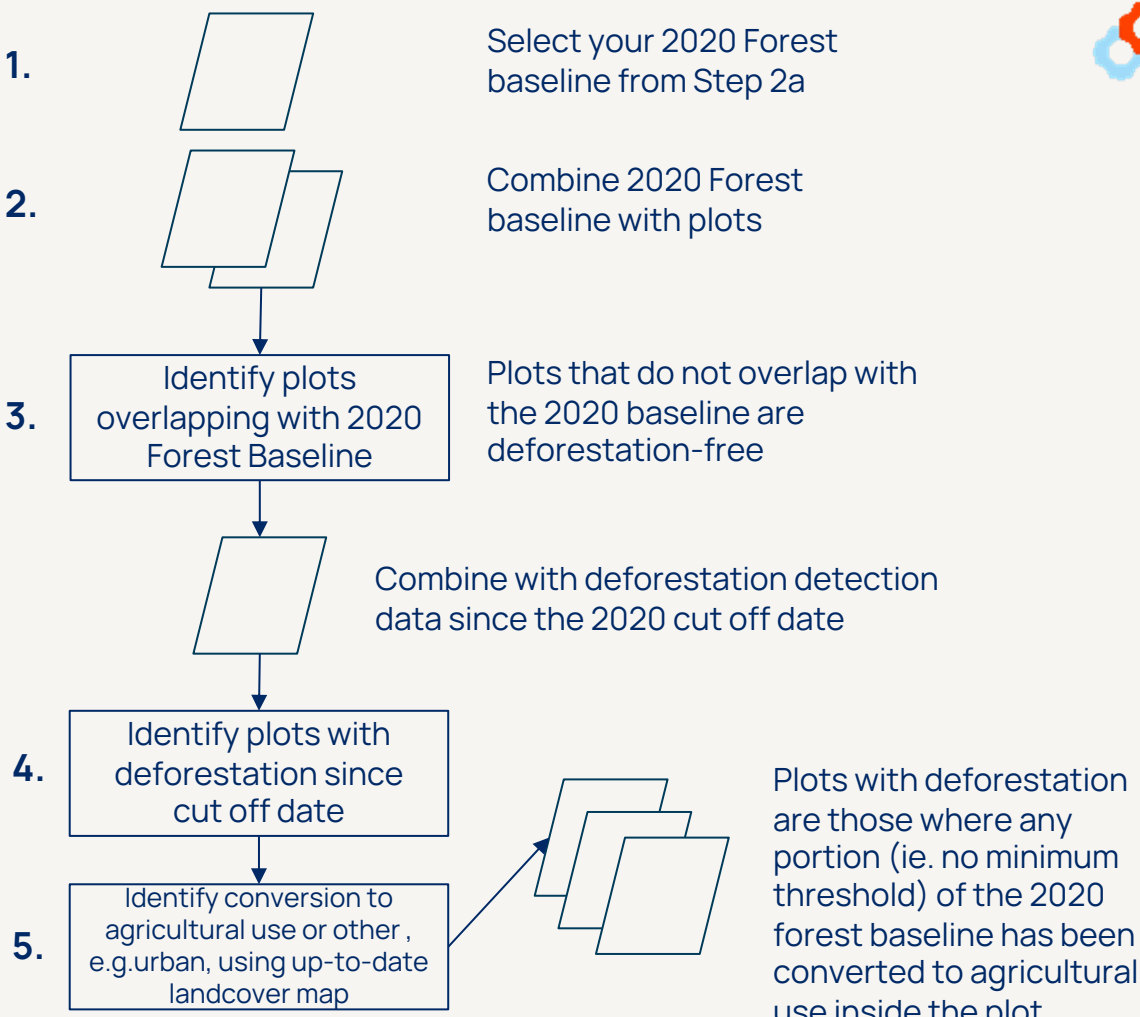
Besides the quantitative numbers, a visual, qualitative quality assessment is recommended, because often, only the quantitative assessment does not tell the complete story. A qualitative assessment can be done by an expert, by comparing to other maps and very high resolution satellite imagery.

Plot Check

Step 2b. Cocoa Plots and 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	Alerts every 14 days	No
GLAD	GLAD/Hansen	30	Deforestation alert	Alerts 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

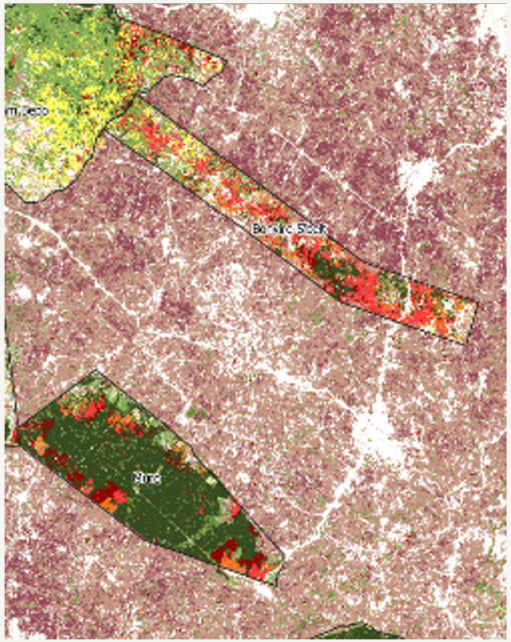
Comparing satellite imagery from 2021 until present to monitor any vegetation change over time.

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

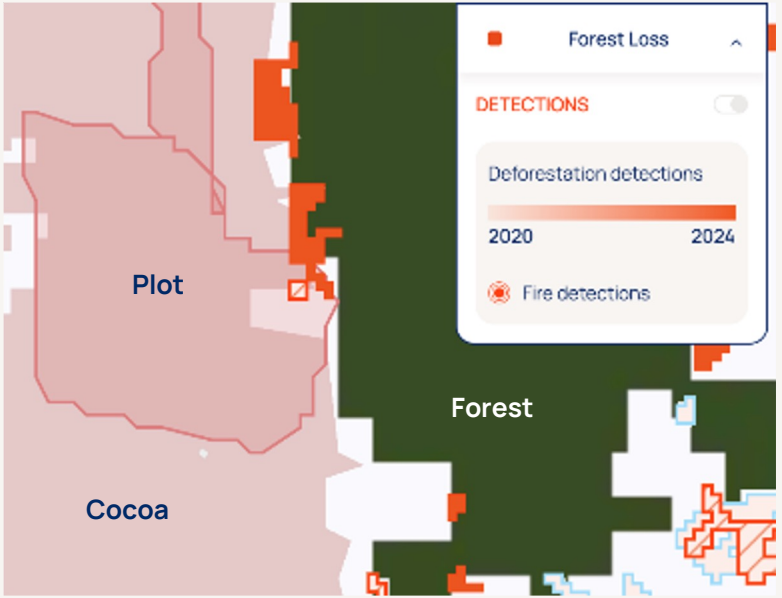


Change/Deforestation Detection Threshold

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