SalvaTerra

Biophysical land use characterization of cocoa & forests landscapes in Cote d'Ivoire and field assessment protocol for deforestation assurance

Rainforest Alliance

December 2018

Table of contents

1. Background and objectives 4
2. Pre-assessment based on existing land use and land use change data 5
2.1. Presentation of pre-assessment data 5
2.1.1. Review of satellite imagery sources 5
2.1.1.1. Global Forest Watch 5
2.1.1.2. ESA prototype land cover 20m map of Africa, 2016 6
2.1.1.3. SEP-REDD maps 7
2.1.2. Previously identified points 7
2.2. Pre-assessment of land use data 8
2.2.1. Global Forest Watch 8
2.2.1.1. Tree cover 2000 8
2.2.1.2. Tree cover 2010 9
2.2.2. ESA land cover map 10
2.2.3. SEP-REDD maps 11
2.2.1. Normalized difference vegetation index 12
2.3. Pre-assessment of land use change data 13
2.3.1. Global Forest watch 13
2.3.1.1. 2015-2016 (Salvaterra) data 13
2.3.1.2. 2012-2013 (RA) data 13
2.3.2. SEP-REDD maps 14
2.4. Conclusion of the pre-assessment 14
3. Methodology for 2018 field data collection 15
3.1. Sampling 15
3.2. Points visited 15
3.3. Field data collected 16
4. Analysis of the data collected 17
4.1. Consistency between satellite land use classifications (GFW and ESA) and field observations 17
4.2. Consistency between the cover loss data (GFW) and field observations 18
4.3. Biophysical characteristics of cocoa stands 22
4.4. Test of additional satellite images 25
4.4.1. Google Earth images 25
4.4.2. Sentinel 2 images 26
5. Recommendations for a deforestation assessment protocol 29
5.1. Desktop assessment 29
5.2. Field assessment 29
Annex I – Field mission schedule 30
Annex II – Field form 31

Annex III – Maps showing the distribution of land uses among the visited areas 32
Annex IV – Identification of deforestation on plots T8 and T20 with the help of Google Earth 36
Annex V – Sentinel 2 images for plots T2, T11, T12, T17, T19 and T27 40
Annex VI - Characteristics of cacao plots depending on their age 50

1. Background and objectives

The Rainforest Alliance Sustainable Agriculture Standard requires that forests have not been converted since 2014 or 5 years before application for certification[1] (and even since 2005 for High Conservation Value areas).

For the moment, certification auditors do not have a reliable way to verify this aspect.

The objective of the present study is to create an assessment protocol to allow Rainforest Alliance, certification bodies, and auditors to identify "deforestation" per the RA standard based on a combination of satellite data sources such as Global Forest Watch and field observations of the auditor. This assessment will be based in Cote d' Ivoire, a country with significant RA and Utz cocoa certification, but also a country with high levels of deforestation.

To create this assessment protocol, the following process was used:

- Pre-assessment based on available data for the development of a desktop protocol (see chapter 0):
    - Review of satellite imagery sources: (Global Forest Watch, ESA land use classification of Africa, data from the Permanent Executive Secretariat for REDD+ in Côte d'Ivoire), and NDVI classification of Landsat imagery (chapter 2.1)
    - Pre-assessment of satellite imagery sources with previous field data (points of cocoa plots since 2012, provided by Rainforest Alliance and points of various land uses in 2015-16, provided by Salva Terra); (chapter 2.2-2.4)
- Design of a methodology for field data collection
    - Identification of landscapes to sample (chapter 3.1-3.2);
    - Elaboration of a field form and field data collection methods (chapter 3.3
- Analysis of data and assessment of the capacity of satellite and biophysical data to describe land use and land use change events (chapter 4);
- Recommendations for a deforestation assessment protocol for desktop and field (chapter **Erreur ! Source du renvoi introuvable.**);

Annexes are included to provide greater detail; raw data were transmitted to Rainforest Alliance (for Excel data and shapefiles), remote sensing imagery can be consulted through Google Earth and https://scihub.copernicus.eu/.

[1] RA Standard critical criterion 2.2: Farms *conserve* all *natural ecosystems* and have not *destroyed forest* or other natural ecosystems in the five-year period prior to the date of initial application for SAN certification or after January 1, 2014, whichever date is earlier. Definition of destroyed forest: Conversion of a *natural ecosystem* (or portion thereof) to a different land use, or other deliberate activity that significantly alters a natural ecosystem's composition, structure, or function, Definition of Forests: humid forests (rainforest) and drier forests; lowland, montane, and cloud forests; and forests consisting of any combination of broadleaf, needle leaf, evergreen, and deciduous vegetation. See RA standard definitions pages 15-31 for full details

2. Pre-assessment based on existing land use and land use change data

2.1. Presentation of pre-assessment data

2.1.1.Review of satellite imagery sources

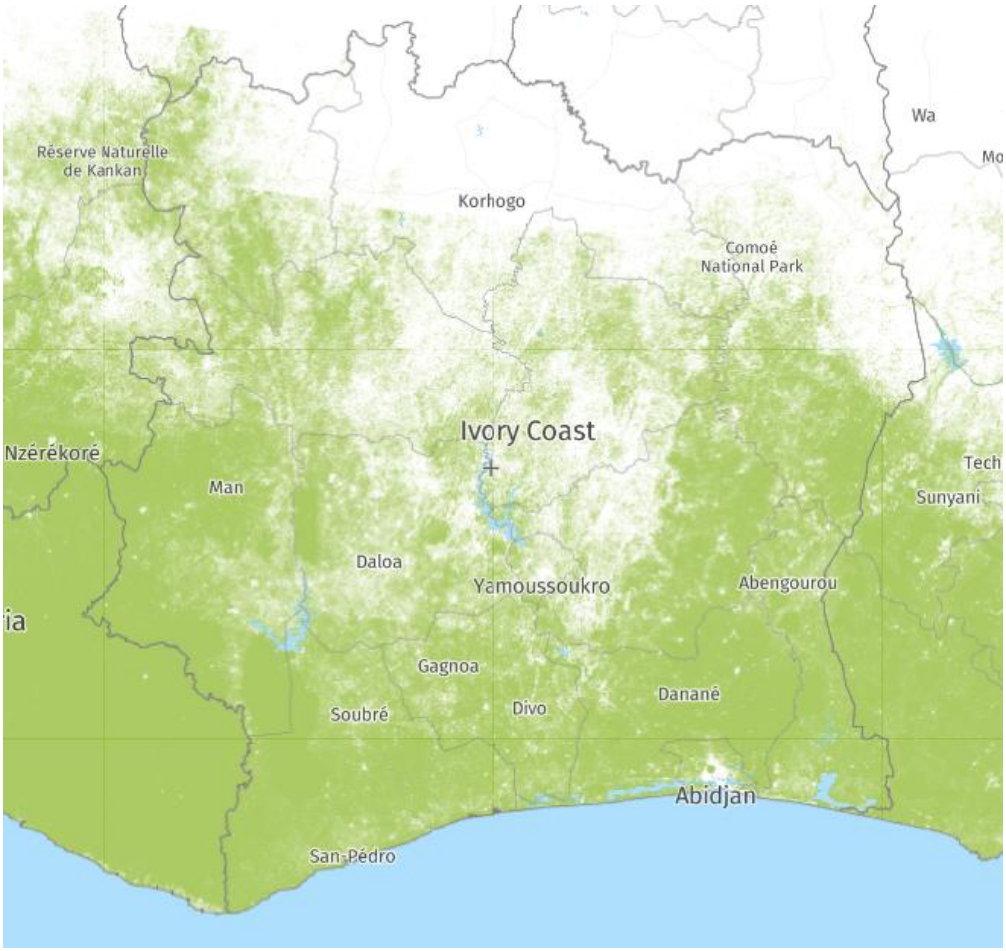
2.1.1.1. Global Forest Watch

Global Forest Watch displays data from the University of Maryland (Hansen et al., Science 2013), which are the results from time-series analysis of Landsat images in characterizing global forest extent and change from 2000 through 2017.

The following data is mobilized[2]:

Tree cover in the years 2000 and 2010, defined as canopy closure for **all vegetation** taller than 5m in height. Encoded as a percentage per output grid cell, in the range 0–100.

Year of gross forest cover loss event during the period 2000–2017, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Encoded as either 0 (no loss) or else a value in the range 1–17, representing loss detected primarily in the year 2001–2017, respectively.



GFW, areas with tree cover > 30% in 2010

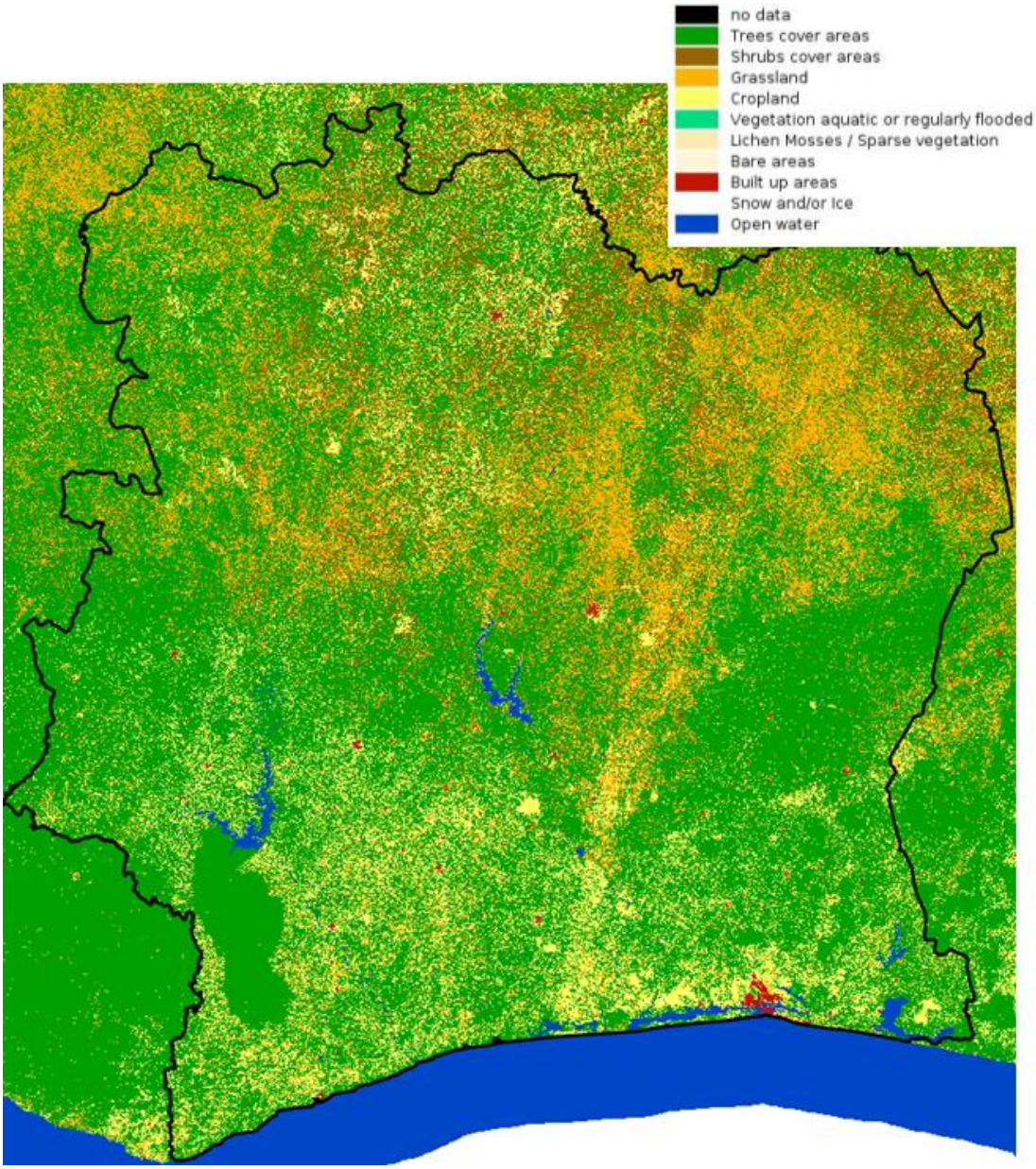
[2] https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html

2.1.1.2. ESA prototype land cover 20m map of Africa, 2016

This map is a prototype high resolution land cover map at 20m over Africa[3] based on 1 year of Sentinel-2A observations from December 2015 to December 2016.

The legend includes 10 generic classes: "trees cover areas", "shrubs cover areas", "grassland", "cropland", "vegetation aquatic or regularly flooded", "lichen and mosses / sparse vegetation", "bare areas", "built up areas", "snow and/or ice" and "open water".

Tree cover areas are defined as areas with a tree canopy cover of more than 15 % of pixel surface and higher than the shrub or the grassland canopy cover. A tree is a woody perennial plant with a single, well-defined stem carrying a more-or-less defined crown and being at least 3 m tall. Therefore, cocoa crops are included in this definition.



ESA prototype land cover 20m map of Africa – zoom on Côte d'Ivoire

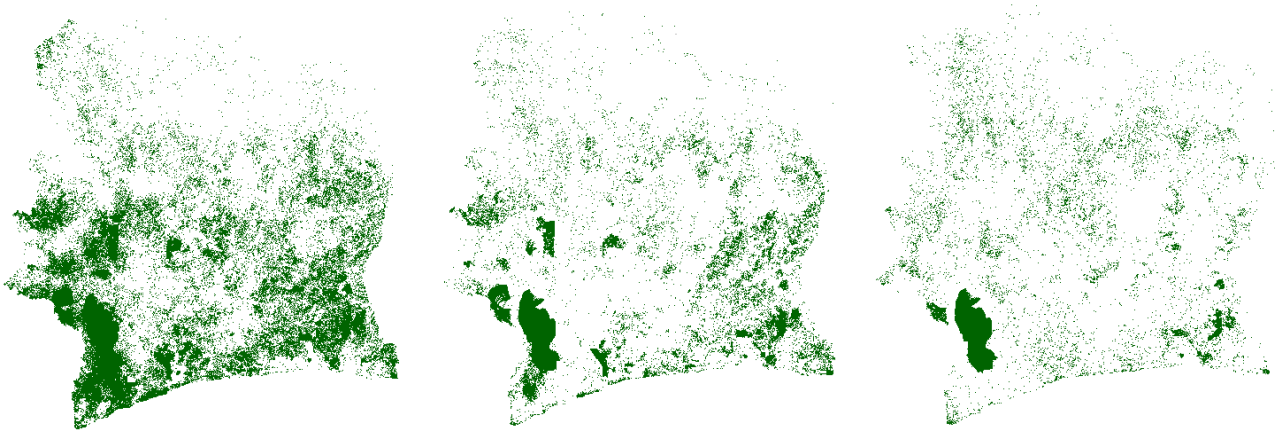
[3] http://2016africalandcover20m.esrin.esa.int/

2.1.1.3. SEP-REDD maps

These satellite products map forests in 1986, 2000 and 2015, in one category (forest / no forest). The definition for forests is based on the Ivorian forest code (2014):

- Minimal area of 0,1 ha
- Tree cover above 30%
- Tree height at maturity above 5m

These maps have been created based on field visits and the treatment an interpretation of 63 images: 21 Landsat TM images for 1986, 21 Landsat TM/ETM+ for 2000, 19 Landsat OLI and 2 GFC images for 2015.



Forest maps of 1986, 2000 and 2015 (from left to right), from SEP-REDD

2.1.2.Previously identified points

Before field research, we tested these remote satellite sources with cocoa points provided from earlier work (n=1,504). Rainforest Alliance provided points (n=515) of cocoa farms in the departments of Adzopé and Abengourou. These points were confirmed by Rainforest Alliance as cocoa stands since at least 2012-2013, but with uncertain date of original planting.

SalvaTerra provided points (n=989) from previous research in the departments of Aboisso and Abengourou. During that previous research, it was classified to the following land uses:

- Cocoa (full-sun cocoa, cocoa under light shading and cocoa under significant shading), (n=761)
- Permanent crops (rubber, coffee, palm), (n=255)
- Fallows (5 categories, from very young fallows to ancient fallow to secondary forest), (n=443)
- Forest plantations (teak and acacia), (n=8)
- Other (annual crops, localities). (n=37)

The 5 categories of fallows have the following characteristics:

Fallow 1 - Cultivated areas abandoned for 1 to 3 years. There is almost no ligneous stratum. Through remote sensing, the confusion between these fallows and young, poorly maintained and grassed cocoa stands is frequent.

Fallow 2 - Ancient cultivated areas abandoned for 4 to 10 years. The ligneous stratum is irregular and reaches 7 to 10 meters high, with a low cover (30-40%), the herbaceous layer is developed.

Fallow 3: - Ancient fallow, older than 10 years. The ligneous stratum is irregular and reaches 10 to 15 meters high, for a cover of 30 to 45%. The lower ligneous stratum is closed (70 to 80%).

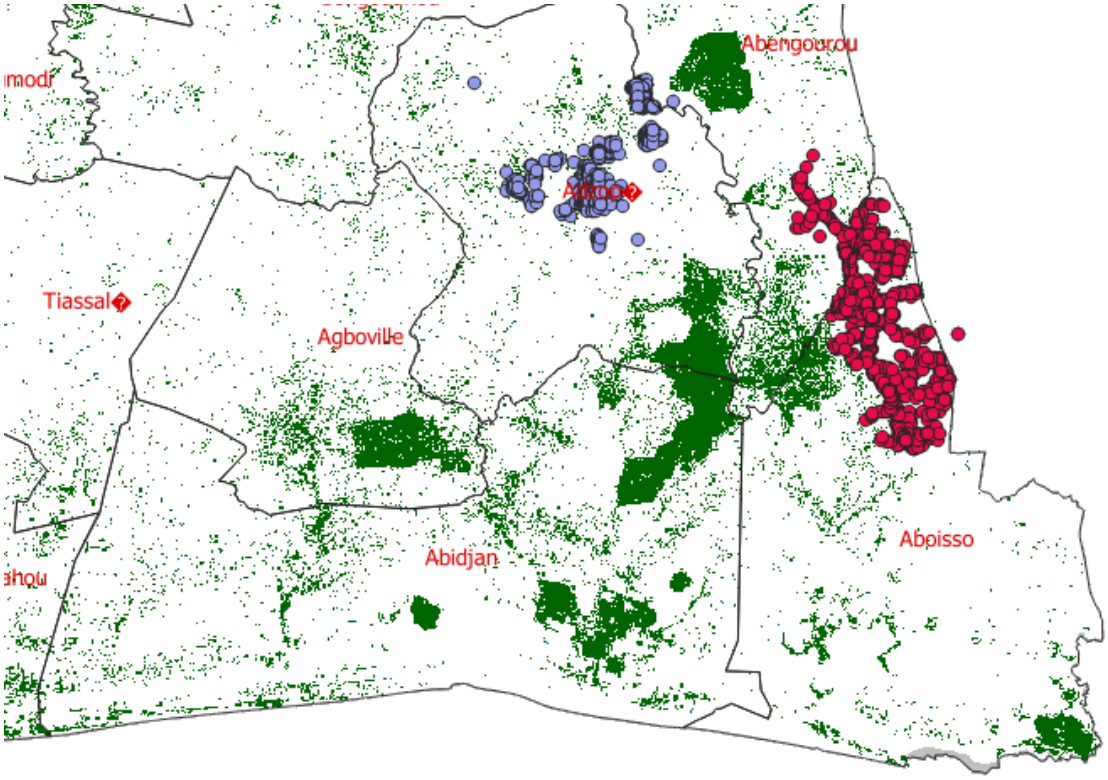
Fallow 4 - Secondary forests in a medium to poor state of conservation. These forests have 3 ligneous strata, the highest reaching 20 to 25 meters, with a low density of high diameters trees and a cover of 60 to 70%. Due to a high variability of this highest stratum, this type of secondary forest sometimes has only two strata. A secondary stratum is often observed, reaching 7 to 15 meters, with a

cover of 20 to 30% while the tertiary stratum, up to 7 meters, is characterized by a very low tree density. Traces of recent human activities (tree stumps, tracks) are frequent.

Fallow 5 - Secondary forests in a relatively good conservation state. These forests have 3 ligneous strata, the highest reaching 25 to 30 meters, with a high density of high diameters trees and a cover of 70 to 80%. The secondary stratum, reaching 7 to 15 meters, has a cover of 30 to 40% while the tertiary stratum, up to 7 meters, is characterized by a low tree density. These forests hosts climbing plants and one can observe rare traces of recent human activities (tree stumps, tracks).

For the following analyses, fallows 1 and 2 are regrouped in a "Young fallow" class, fallows 3 and 4 in an "Ancient fallow & Degraded secondary forest" class, while fallows 5 are designated as "Secondary forests".

The locations of the waypoints are shown on the map hereunder:



Waypoints provided by Rainforest Alliance (in blue) and SalvaTerra (in red)

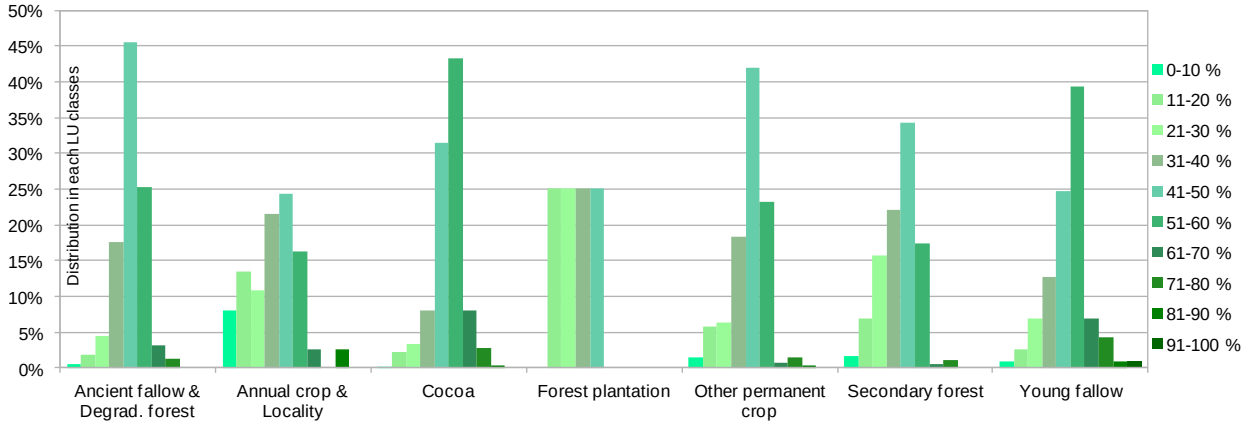
2.2. Pre-assessment of land use data

In this pre-assessment stage, the above points were analyzed using satellite imagery from Global Forest Watch, ESA, and SEP-REDD. Points from RA and from Salvaterra were both included in the analysis. All points from RA are included in the classification "cocoa".

2.2.1.Global Forest Watch

2.2.1.1. Tree cover 2000

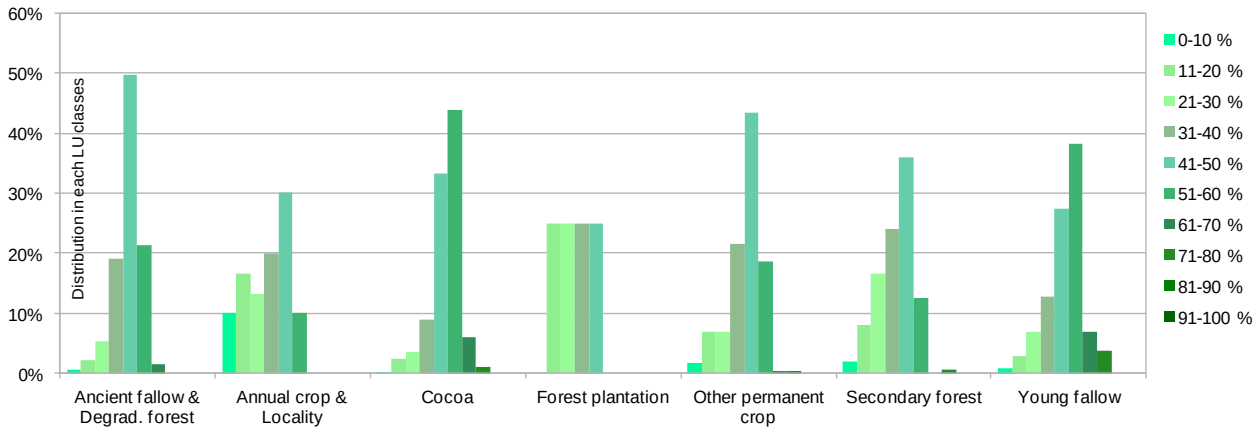
The following graph shows how the different land uses observed on the field appear on the Tree cover 2000 map of GFW:



Distribution of each observed land uses in the different classes of tree cover for 2000

Every land uses are mainly covered by the 51-60 % tree cover class, except cocoa and young fallows, which are classified mainly in the 61-70 % tree cover class.

Therefore, the Tree cover 2000 map from GFW give few information on the real land use observed in 2015. As land use changes could have happened during the period 2001-2015, the same analysis is conducted only with waypoints located on areas appearing as non deforested during this period (thanks to GFW loss year data).

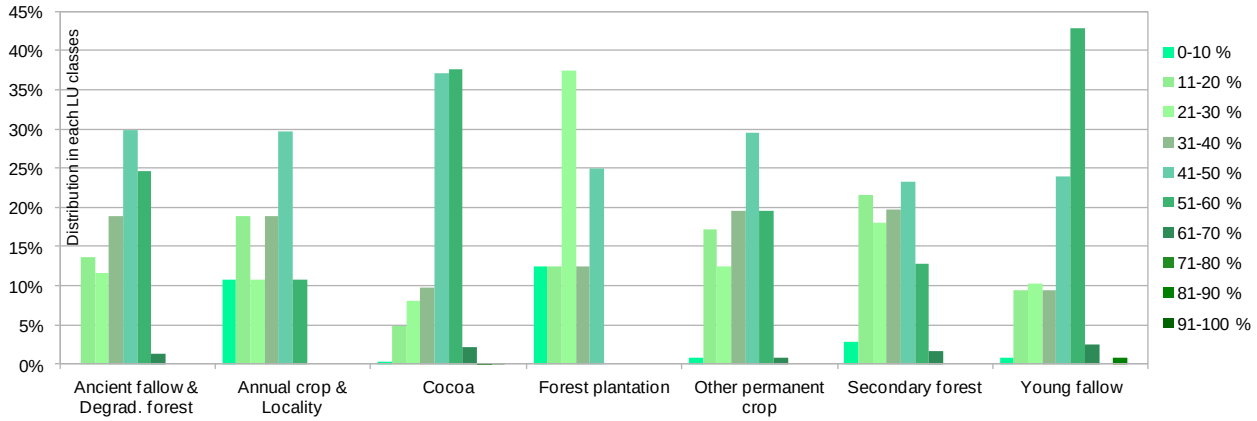


Distribution of each observed land uses in the different classes of tree cover for 2000, only for plots with no tree cover loss between 2001 and 2015

The results are almost the same and do not change the conclusion: the Tree cover 2000 map from GFW gives little information on the real land use observed in 2015.

2.2.1.2. Tree cover 2010

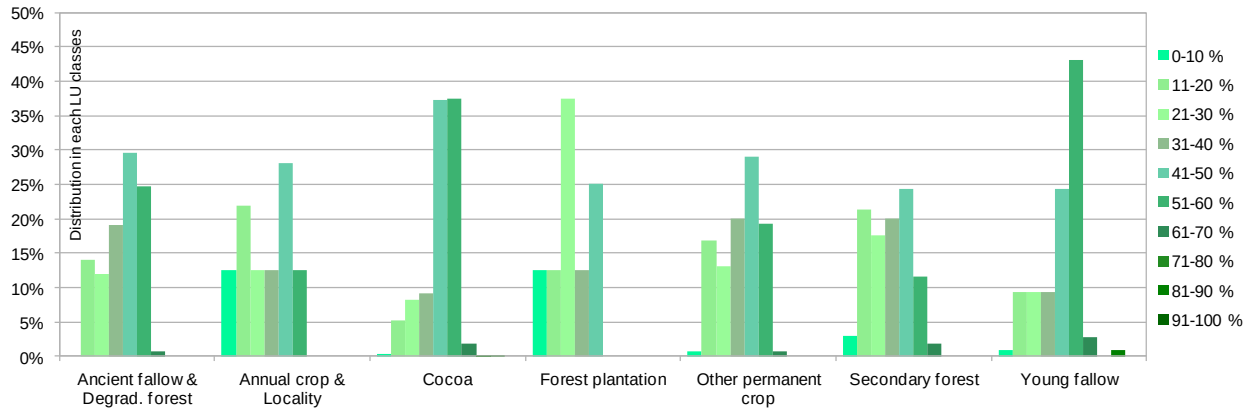
The following graph shows how the different land uses observed on the field appear on the Tree cover 2010 map of GFW:



Distribution of each observed land uses in the different classes of tree cover for 2010

The Tree cover 2010 map still integrates most of the land uses in the 51-60% and 61-70% tree cover classes. Some forest plantations appear as low tree cover land uses, while young fallows (observed in 2015) are classified in high tree cover classes for 2010 (mainly 71-80%). Here again, land use changes between 2011 and 2015 could explain some differences between the ground truth data and GFW classification.

The following graph has been obtained after removing waypoints appearing as deforested during the period 2011-2015 on GFW loss year map.



Distribution of each observed land uses in the different classes of tree cover for 2010, only for plots with no tree cover loss between 2011 and 2015

Young fallows observed in 2015 and not identified as deforested in the period 2011-2015 by the GFW data are still mainly classified by GFW data in the 61-70% tree cover class.

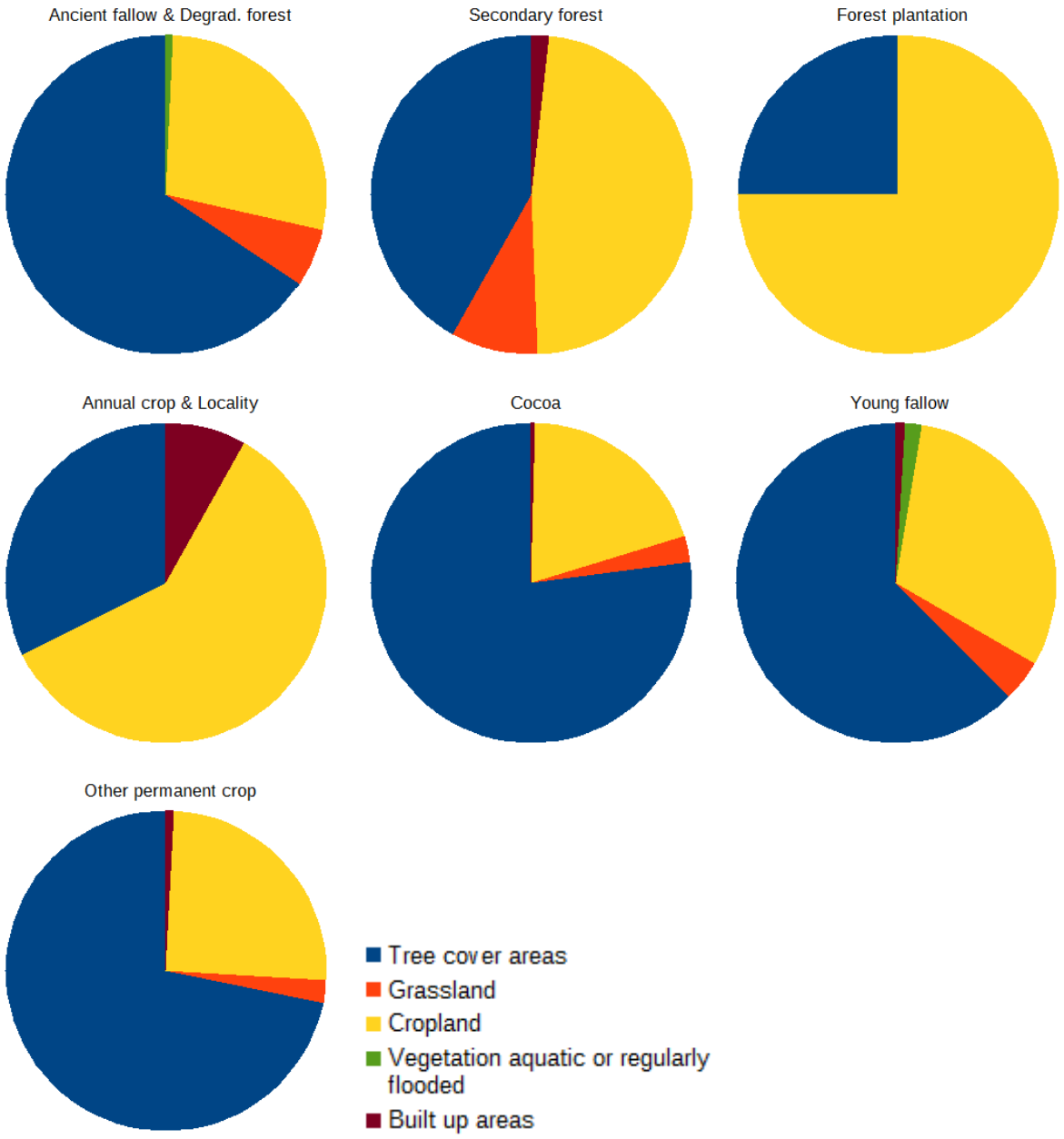
For other classes, the GFW data does not seem to allow reliable characterization of land uses, as shown by the graph. Cocoa farms are mainly classified as >30% tree cover areas.

This can be explained by the fact that the Landsat images used as a basis for GFW data have a medium resolution (30 meters). Furthermore the classification process implies automatic classification which necessarily leads to errors. SalvaTerra conducted previous research in Côte d'Ivoire, based on higher resolution. It concluded the great difficulty of distinguishing different tree land uses in Côte d'Ivoire, notably because of the high variability of spectral signatures of land uses and the high heterogeneity of Ivorian landscapes.

2.2.2.ESA land cover map

The ESA land cover map relies on images taken for the period December 2015 – December 2016 and is thus closer in time to SalvaTerra's data.

Once again, the observed land uses were compared to the classification of the map. Each graph below represents the distribution of each observed land uses in the different land uses categories mapped by ESA.



Distribution of each observed land uses in the different land uses categories mapped by ESA

Tree cover areas from ESA map cover all the categories, mainly Ancient fallow & Degraded secondary forest, Secondary forest, Cocoa, Other permanent crop and Young fallow. In the case of using this map to estimate subsequent deforestation, cocoa plantations on young fallows or ancient cocoa plots would be considered as deforestation.

Non negligible percentages of plots of Ancient fallow & Degraded secondary forest, Secondary forest and Forest plantation are classified as Cropland, which on the contrary could lead to an underestimation of deforestation in the future.

As in the case of Global Forest Watch data, these results show that automatic classification processes based on medium resolution (20 m here) cannot be considered reliable at a fine scale. These tools are not designed for this purpose, but are created for the evaluation of land uses on a national or even sub-regional scale.

2.2.3.SEP-REDD maps

SEP-REDD maps classify land uses in only two categories: Forest and Non-forest. The following table summarizes how these maps classify the 1,504 waypoints.

	1986		2000		2015	
	Non forest	Forest	Non forest	Forest	Non forest	Forest
Ancient fallow & Degrad. forest	83,1%	16,9%	96,8%	3,2%	100,0%	0,0%
Annual crop & Locality	97,3%	2,7%	100,0%	0,0%	100,0%	0,0%
Cocoa	50,5%	49,5%	87,4%	12,6%	98,7%	1,3%
Forest plantation	100,0%	0,0%	100,0%	0,0%	100,0%	0,0%
Other permanent crop	87,5%	12,5%	99,6%	0,4%	98,8%	1,2%
Secondary forest	80,2%	19,2%	98,3%	1,2%	99,4%	0,0%
Young fallow	72,6%	27,4%	88,0%	12,0%	91,5%	8,5%

Distribution of each observed land uses in the Forest and Non-forest categories of the SEP-REDD maps

The data for 1986 and 2000 is presented for information only. Two observations can be made on the results for 2015:

- Only a very small proportion of the points are identified as forests, even for Secondary forest, Ancient fallow & Degraded secondary forest and Forest plantation classes (no forest plantation identified as a forest).
- The land use most often identified as forest is Young fallow.

The definition of forest chosen by the SEP-REDD (based on the forest code), is probably more restrictive than the one chosen by SalvaTerra. Concerning Young fallow classified as forests, it seems that the very strong spatial heterogeneity of Ivorian landscapes makes it difficult to distinguish different classes in small areas.

The explanations concerning the low reliability of these data at a fine spatial scale are the same as for the GFW and ESA data: low images resolution, automatic classification process necessarily generating errors, high spatial heterogeneity of Ivorian landscapes and high variability of spectral signatures of land uses.

2.2.1.Normalized difference vegetation index

At the Rainforest Alliance's request, we processed a Landsat image to assess whether the NDVI could provide additional information.

We looked on https://earthexplorer.usgs.gov/ for images for the period 2008 to 2018. The specifications were as follows: Landsat 8 (Landsat 7 cannot be used without processing because of the SLC failure, since 2003), and cloud cover under 10%, Tier 1. Two images were found covering the area: one taken on the 26th of January, 2018, the other on the 25th of December of 2017. The second was used, as it was closer to the date of observation by SalvaTerra (end of 2015).

The NDVI allows assessing whether the target being observed contains live green vegetation or not. It was calculated based on the near infra red and red bands of the Landsat image (2017) ((near infra red – red) / (near infra red + red)), and then applied to the 1,504 points. This classification is summarized as follows:

	Mean	Max	Min	RSD*
Ancient fallow & Degrad. forest	0,33	0,40	0,24	9%
Annual crop & Locality	0,31	0,39	0,19	13%
Cocoa	0,34	0,39	0,17	7%
Forest plantation	0,29	0,38	0,19	22%
Other permanent crop	0,32	0,37	0,16	9%
Secondary forest	0,32	0,39	0,18	11%
Young fallow	0,32	0,39	0,15	11%

*Relative standard deviation

NDVI for each observed land uses

From the above results, we can see that NDVI provides little additional information. In the past study of SalvaTerra on land use mapping in the Bianouan area, the use of the NDVI as a classification criteria was also ineffective for this landscape. This is likely due to the fact that since NDVI is dependent on photosynthetic activity, in landscapes such as cocoa in West Africa, it is more dependent on the season and rainfall and less dependent on land use.

2.3. Pre-assessment of land use change data

The above satellite tools were also used to assess land use change in the RA and Salvaterra points.

2.3.1.Global Forest watch

SalvaTerra's waypoints and Rainforest Alliance's waypoints are analyzed separately, as they give different information on land use change (situation in 2012-2013 for RA, situation in 2015-2016 for SalvaTerra and information on the age of fallows).

2.3.1.1. 2015-2016 (Salvaterra) data

The following table summarizes the distribution of each type of land uses observed into 3 categories: tree cover loss, recent tree cover loss and no tree cover loss.

	Tree cover loss (2001-2014)	Recent tree cover loss (2010-2014)	No cover loss (<2001 and >2015)
Annual crop & Locality	13,5%	8,1%	81,1%
Cocoa	12,6%	4,9%	87,0%
Fallow 1	13,2%	5,3%	86,8%
Fallow 2	8,9%	6,3%	87,3%
Fallow 3	0,0%	0,0%	100,0%
Fallow 3-4	15,5%	7,8%	84,5%
Fallow 4	22,2%	11,1%	72,2%
Fallow 5	12,2%	5,8%	87,2%
Forest plantation	0,0%	0,0%	100,0%
Other permanent crop	13,7%	4,7%	85,9%

Distribution of each type of land uses observed by SalvaTerra depending on the dates of tree cover loss (GFW data)

Most of the waypoints are classified in the "No tree cover loss" situation. Concerning Young fallow, this result is not abnormal as if they are cultivated regularly since 2001, and these plots never hosted forests or trees during the period.

Some ancient fallows, degraded secondary forests and secondary forests (Fallows 3, 4, and 5) appear to have suffered tree cover loss recently, which is a more surprising result. Indeed, forest regrowth is a long-term process and it is unlikely that forests deforested during the 2011-2014 period (an even the 2001-2014 period) became mature fallows or secondary forests in 2015.

The tree cover loss is defined as a stand-replacement disturbance (old cocoa → new cocoa for example), or a change from a forest to non-forest state. This gives too little information about changes in land use to allow further analysis.

2.3.1.2. 2012-2013 (RA) data

Rainforest Alliance data give information only on the land use (cocoa) of the plots in 2012 and 2013 and no information on the history of the plots.

The distribution of these parcels in the different categories gives no useful information:

Tree cover loss (2001-2011)	Recent tree cover loss (2007-2011)	No tree cover loss (<2001 and >2013)
9,13 %	5,44 %	88,74 %

Distribution of each type of land uses observed by RA depending on the dates of tree cover loss (GFW data)

2.3.2.SEP-REDD maps

SEP-REDD maps of forests for 2000 and 2015 allow to classify the field data gathered in 2012-13 and 2015-16 in four categories : forest remaining forest (F → F), forest converted in non-forest or deforestation (F → nF), non-forest converted in forest or afforestation/reforestation (nF → F) and non-forest remaining non-forest.

	F → F	F → nF	nF → F	nF → nF
Ancient fallow & Degrad. forest	0,00 %	3,25 %	0,00 %	96,75 %
Annual crop & Locality	0,00 %	0,00 %	0,00 %	100,00 %
Cocoa	0,79 %	11,83 %	0,53 %	86,86 %
Forest plantation	0,00 %	0,00 %	0,00 %	100,00 %
Other permanent crop	0,00 %	0,39 %	1,18 %	98,43 %
Secondary forest	0,00 %	1,16 %	0,00 %	98,26 %
Young fallow	4,27 %	7,69 %	4,27 %	83,76 %

Distribution of each type of land uses observed by SalvaTerra depending on the land use change categories extracted from the SEP-REDD data

As stated above, the restrictive definition of forests adopted by the SEP-REDD leads to the classification of a large number of waypoints in the non-forest category.

Some results, however, indicate that these maps do not reliably assess a plot-level risk of deforestation (a situation of interest to us in this study):

- Permanent crops and young fallows sometimes appear as reforestation,
- Forest plantations are considered as non-forest,
- Some ancient fallows and degraded secondary forests appeared as deforested, implying that a subsequent conversion to cocoa would not be considered as deforestation.

However, some cocoa plots observed in 2012-2016 appear as deforested during the 2000-2015 period, which could indicate actual deforestation, or at least a replacement of the stand.

2.4. Conclusion of the pre-assessment

In conclusion, none of the tools reviewed demonstrated sufficient accuracy to allow a reliable assessment of the risk of deforestation **at the spatial scale of interest**.

This situation can be explained by two limitations:

1. Ivorian landscapes are very heterogeneous in space and time. Reliable assessment of land-use changes requires high to very high resolution remote sensing data, as well as frequent evaluation (annually). To our knowledge, no initiative has achieved a sufficient level of reliability for plot-level assessment.

2. The field data available to us only gives a static picture of the land uses, which greatly limits the analysis.

3. The GFW and ESA maps are based on tree cover detection. Since cocoa trees are trees, cocoa stands are often classified in the same category as forests, especially since the tree cover rates of cocoa stands can be quite high.

The collection of data on plots of which we will know the history (at least in terms of presence or absence of deforestation) will allow better understanding how these tools can be used within the framework of an audit.

3. Methodology for 2018 field data collection

Based on the results of the pre-assessment, a field research plan was developed to better characterize the land use in the cocoa growing region of Cote d'Ivoire and use these findings to develop a field assessment protocol to conduct deforestation assurance.

3.1. Sampling

The sampling was designed to allow the identification of parcels providing several types of indications:

1. Biophysical characteristics of the plots allowing distinguishing cocoa plots planted on forests and cocoa plots planted on other land uses: the sample should contain parcels that we are sure were planted on the forest and others that we are sure were planted on other types of use. We do not know the land use (LU) and land use change history (was there forest at one time? when did it disappear? was there another land use before cocoa?) of any plots (we just have a picture for 2012-13 and 2015-16). The best solution to get this information was to ask to cooperatives in trust. We identified two cooperatives with which we thought we could obtain this information: *Coopérative de Kpangbankro* near Soubré and *Coopérative cacao bio de N'Brimbo N'zianouan* near Tiassalé.

2. Explain recent tree cover losses in cocoa and forest plots identified with the GFW data (cocoa remaining cocoa with shade removal or renovation? replacement of forest / fallow by cocoa?): the sample should contain plots classified as cocoa and forests/ancient fallows in 2015 and having suffered tree cover loss since. We identified such plots in the sample collected by SalvaTerra in 2015, near Bianouan.

3. Explain tree cover losses before the observation of the cocoa plots in 2015 (period 2010-2015), by asking farmers "what happened in that 2010-2015 time period?": the sample should contain cocoa plots with tree cover loss between 2010 and 2015. We identified such plots in the sample collected by SalvaTerra in 2015, near Bianouan.

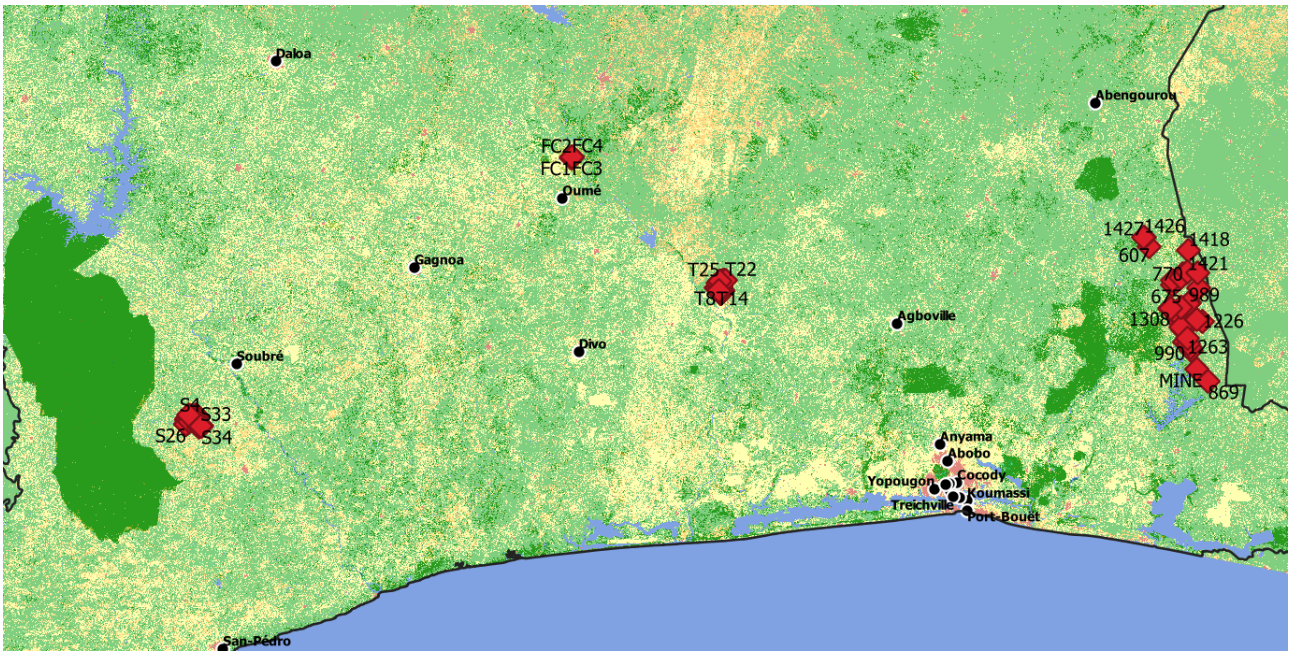
3.2. Points visited

The 2018 field data collection mission allowed visiting 106 plots:

- 37 in the Ketesso/Bianouan/Songan area, of which 30 from the sampling (on the 41 selected, some of them being too difficult to reach) and 7 added, because the parcels seemed interesting to take into account (Ad01 to Ad07 and Mine).
- 35 in the Soubré area (S1 to S35)
- 30 in the Tiassalé area (T1 to T30)
- 4 in the Téné Classified Forest (FC1 to FC4)

The owner could be identified for a large part of the plots of Soubré and Tiassalé, allowing the collection of the desired information on the plot history. This was not the case for the first area (Ketesso/Bianouan/Songan). The visit to the classified forest was allowed by a Cote d Ivoire forest development society (SODEFOR) agent who gave us the information he knew.

Sites were visited in October 2018 (see Annex 1 for detailed schedule).



Location of the plots visited (ESA map of forest (green) and other land use classifications as background)

3.3. Field data collected

For all parcels visited, a biophysical data assessment was completed (see complete form in Annex II). The information collected concerned:

- Basic information on the producer;
- Current land use (cocoa, rubber, fallow – with with expert age assessment, locality, annual crops, secondary forest - any type of natural or semi-natural ecosystem with native tree cover and closed or semi-closed canopy);
- Information on the land use history of the plot (year of plantation, replanting, potential "deforestation" or events affecting the cover (as described by the landowner), land use before cleaning, etc.);
- Information on the general environment of the plot (state of local forests, fertility);
- Detailed biophysical data for vegetation in terms of basal area, canopy coverage, and species diversity, for cocoa, shrubs, and trees, in three ligneous strata;
- Presence and state of tree stumps in a 20 m radius circle;
- Humus depth, quantity of organic matter;
- Herbaceous cover.

Some information needed to be exchanged with the farmer responsible for the plot, which was not possible for some plots, especially for those located near Bianouan where we did not know the producers. In these situations, it was possible to visually assess the age of the plantations (rubber, cocoa). Other information requiring an exchange with the producer has not been collected.

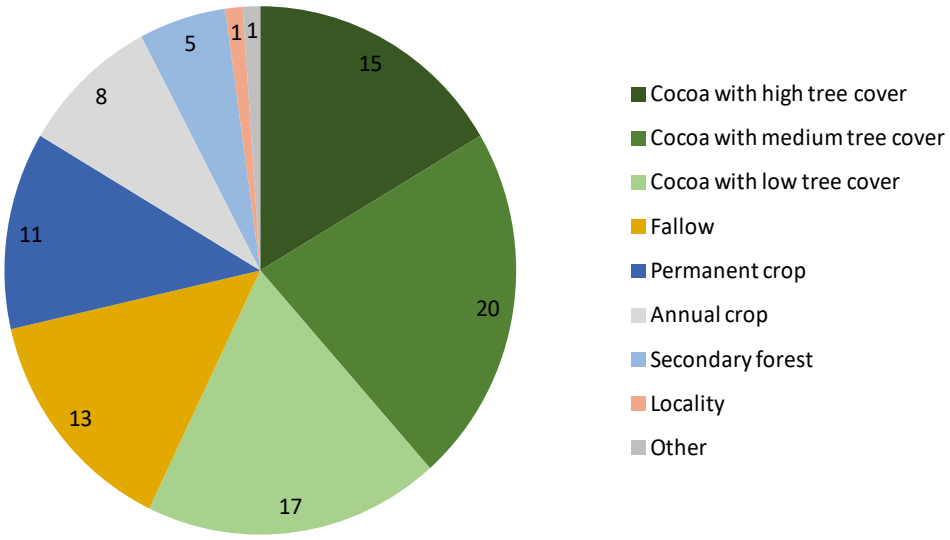
The cocoa farms were classified a posteriori in 3 categories:

Based on field data, sites were classified according to the following land uses:

- Cocoa with high tree cover (cocoa with greater than 5 % tree cover in the highest stratum and over 1 m² of basal area for the tree stratum)
- Cocoa with medium tree cover (cocoa with 1 % - 5% tree cover in the highest stratum and 0 - 2 m² of basal area for the tree stratum)
- Cocoa with low tree cover (cocoa with less than 1% tree cover in the highest stratum and under 0,5 m² of basal area for the tree stratum)

4. Analysis of the data collected

Plots were classified according to the land use classes described in the methodology (n=106), and are distributed as follows:

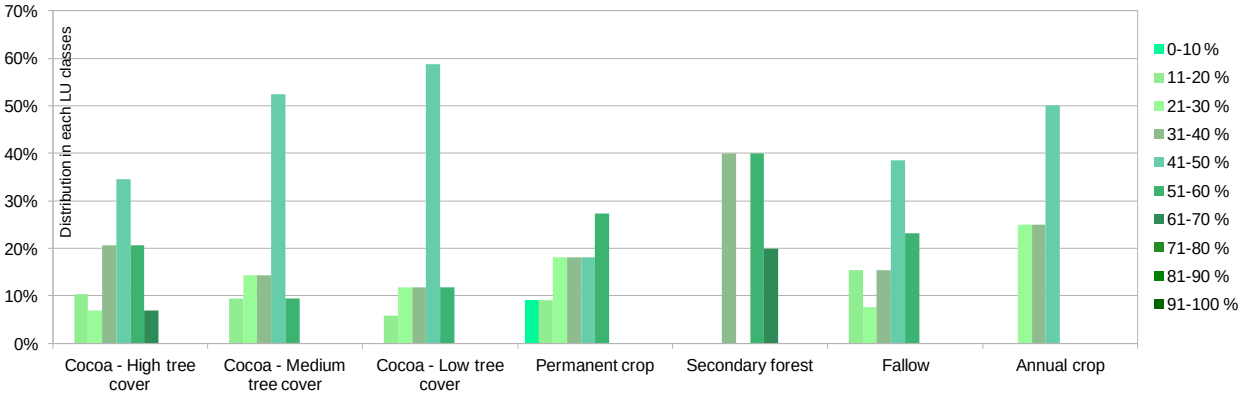


Distribution of the plots visited in different land use categories

A total of 52 points were classified as various types of cocoa. Maps showing the distribution of the land uses among the visited areas are placed in annex III.

4.1. Consistency between satellite land use classifications (GFW and ESA) and field observations

Plots were then compared to the % tree cover categories from Global Forest Watch. The following graph shows how the different land uses observed on the field appear on the Tree cover 2010 map of GFW (the most recently available classification):

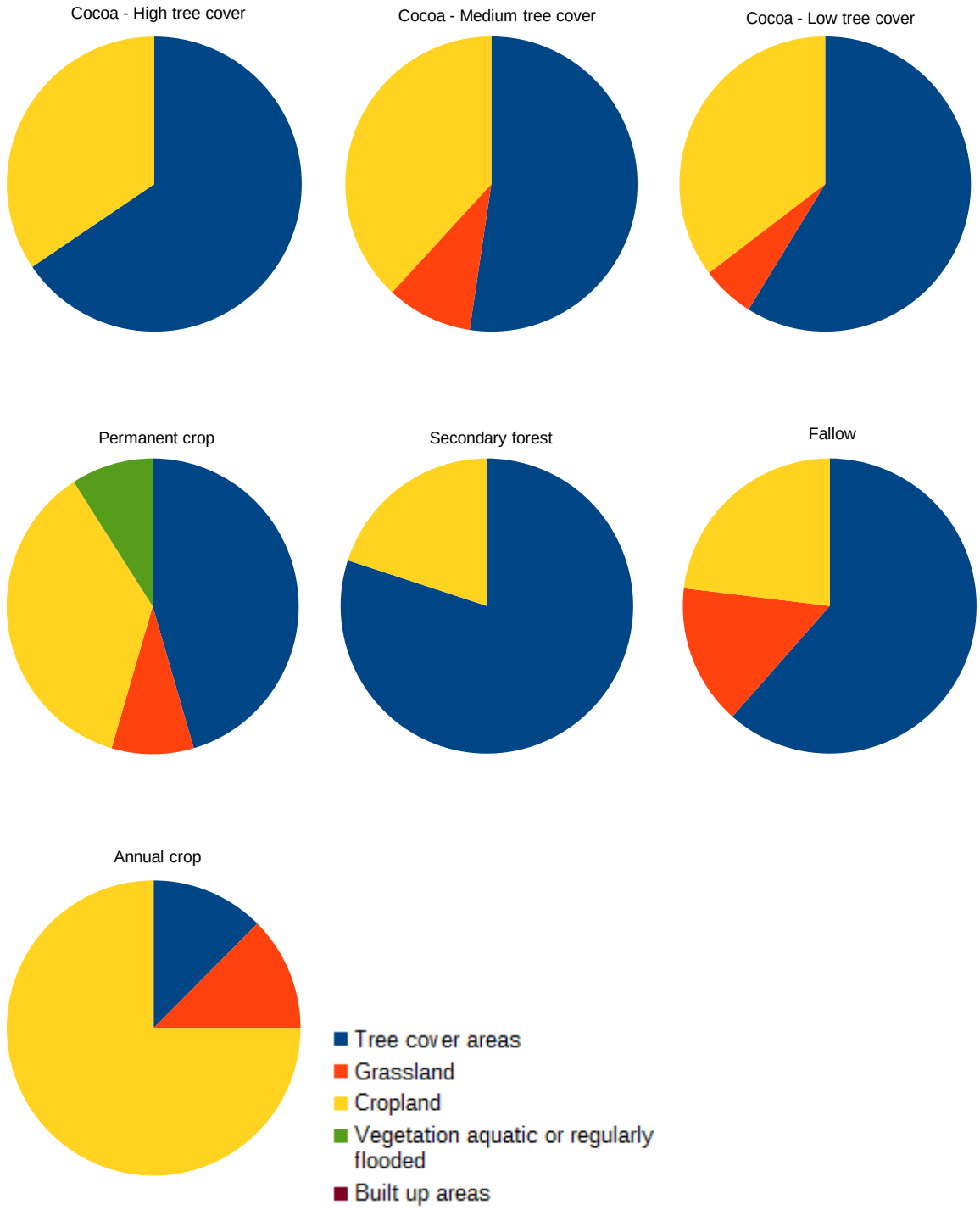


Distribution of each observed land uses in the different classes of tree cover for 2010

As with the previous data, it seems complicated to use GFW data to determine the land use in the field. The distinction between the different types of cocoa plots provide only little additional information: 30% of the high tree cover and only 10% of the medium and low tree cover cocoa plots are >50% tree cover. The difference is not significant enough to allow use of GFW data for the purpose of distinguishing cocoa classes.

as the tree cover classes of GFW are not so different between the 3 categories (most of the plots are in the 41-50% of tree cover class). More problematic, the data do not allow distinguishing tree covered plots (cocoa, permanent crop, secondary forest) and annual crops. However, this analysis is of little interest given the difference in dates between the data of GFW (2010) and the field (2018).

Similarly, the following graphs show that ESA data are not able to accurately represent the field, at such a fine scale:



Distribution of each observed land uses in the different land uses categories mapped by ESA

If Annual crops are quite well differentiated, the fact that the forests, fallows and tree crops are mainly in the category of "Tree cover areas" implies that it is not possible to use this information to distinguish young cocoa, old cocoa, abandoned cocoa or fallow, and forest.

4.2. Consistency between the cover loss data (GFW) and field observations

The following table compares the observations on the field with the data from GFW.

The column "land use" describes the land use classification by the Salva Terra team. The column "Deforestation" indicates the year the landowner described "deforestation", the period covered by the GFW data. Landowners described "deforestation" as removal of native forest and replacement with cocoa (similar to the definition in the RA standard). Plots marked as "no (deforestation since 2001)" indicate that land was already in cocoa or the other land use before 2001.

The next column (GFW tree cover loss year) indicates the year of tree cover loss as described in GFW, for the pixel in which is the point considered (0 means no tree cover loss during the 2001-2017 period).Tree cover loss in GFW is understood to refer to tree cover loss at the 30% tree cover threshold (but not explicitly mentioned in the GFW dataset). One pixel in GFW is a 30m*30m Landsat tile (0.09 ha).

The next column (Survey deforestation = GFW Loss Year) describes the agreement / disagreement between the two sources considering the exact date of deforestation as indicated by the owners. The results are encoded as following: **N (No)**: Evidence show that the GFW data does not identify the landowner's report of deforestation (deforestation not spotted or cover loss not explained by the field); **Y (Yes)**: Evidence show that GFW data identifies a tree cover loss event during the year/period identified by the landowner; **P (Possible)**: GFW data does not confirm or disprove field observation (for example, plots where the producers declares deforestation or no deforestation in 2002-03 or 2016-18, and then +/- 3 year time window falls outside of the range of the GFW data; N**D (ND Data)**: GFW data do not cover the period where the landowner identified "deforestation" (2017 and 2018).

This agreement / disagreement is also applied within a range of +/- three years, considering that the owners could have made slight errors in their estimation of year of "deforestation".

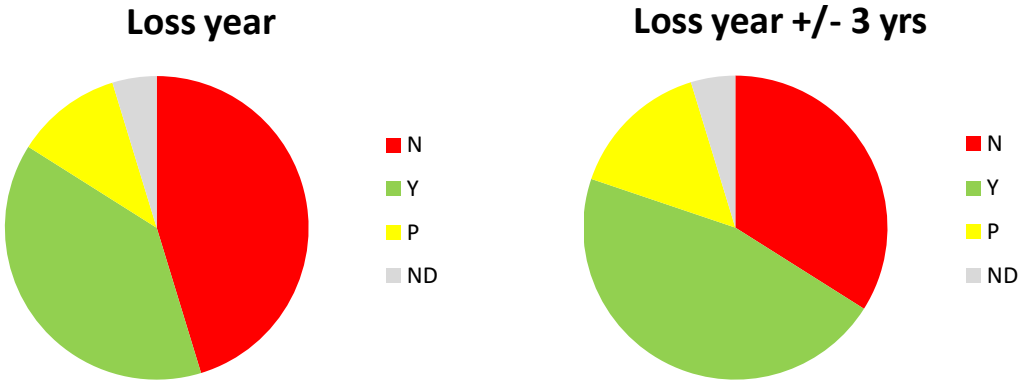
ID	Land use	Year of deforestation (as reported by landowner)	GFW tree cover loss year	Survey deforestation = GFW Loss Year	Survey def = GFW LY +/- 3 yrs
Mine	Other	2018	0	ND	ND
S20	Annual crop	2018	0	ND	ND
T27	Cocoa - High tree cover	2018	0	ND	ND
S18	Annual crop	2018	0	ND	ND
1427	Annual crop	2017	2016	N	Y
T19	Cocoa - Medium tree cover	2017	0	ND	ND
1332	Permanent crop	2016	2016	Y	Y
1426	Locality	2016	2016	Y	Y
T11	Cocoa - High tree cover	2016	0	N	N
T17	Cocoa - High tree cover	2016	0	N	N
S13	Cocoa - High tree cover	2015	0	N	N
T2	Permanent crop	2015	2014	N	Y
1409	Annual crop	2014	2016	N	Y
T16	Cocoa - High tree cover	2014	2015	N	Y
S21	Permanent crop	2012	0	N	N
T20	Cocoa - High tree cover	2012	0	N	N
T21	Cocoa - Medium tree cover	2012	2001	N	N
FC2	Cocoa - High tree cover	2010	0	N	N
T1	Cocoa - Low tree cover	2010	2012	N	Y
T24	Cocoa - Low tree cover	2010	0	N	N
T5	Cocoa - Low tree cover	2010	0	N	N
T7	Cocoa - High tree cover	2010	0	N	N
T8	Cocoa - High tree cover	2010	0	N	N
812	Cocoa - Medium tree cover	2009	2008	N	Y
S5	Cocoa - Medium tree cover	2009	0	N	N
T6	Cocoa - High tree cover	2009	0	N	N
S3	Cocoa - Medium tree cover	2007	0	N	N

S24	Permanent crop	2007	0	N	N
1421	Annual crop	2006	2007	N	Y
T4	Cocoa - High tree cover	2006	2007	N	Y
T9	Cocoa - High tree cover	2006	0	N	N
S4	Cocoa - Medium tree cover	2004	0	N	N
T26	Cocoa - Low tree cover	2004	2009	N	N
550	Cocoa - High tree cover	2004	2013	N	N
748	Cocoa - Low tree cover	2003	2014	N	N
S7	Cocoa - Medium tree cover	2003	0	N	P
FC3	Cocoa - Medium tree cover	2002	0	N	P
FC4	Cocoa - Medium tree cover	2002	0	N	P
T13	Cocoa - Medium tree cover	2002	0	N	P
554	Cocoa - High tree cover	2000	2006	N	N
FC1	Cocoa - Low tree cover	2000	0	Y	Y
S25	Annual crop	2000	0	Y	Y
S35	Fallow	1999	0	Y	Y
811	Cocoa - Low tree cover	1998	2014	N	N
1263	Cocoa - Low tree cover	1998	2011	N	N
T30	Cocoa - High tree cover	1993	0	Y	Y
S32	Fallow	1984	0	y	y
S1	Cocoa - High tree cover	1983	0	Y	Y
S22	Cocoa - Medium tree cover	1983	0	Y	Y
S33	Cocoa - Medium tree cover	1983	0	y	y
S6	Cocoa - Low tree cover	1983	0	Y	Y
T23	Fallow	1983	0	Y	Y
T15	Cocoa - Low tree cover	1982	0	Y	Y
S30	Cocoa - Medium tree cover	1980	0	y	y
S23	Cocoa - Medium tree cover	1979	0	Y	Y
S10	Cocoa - Low tree cover	1978	0	Y	Y
S12	Cocoa - Medium tree cover	1978	0	Y	Y
S17	Cocoa - High tree cover	1978	0	Y	Y
S16	Cocoa - Low tree cover	1977	2016	N	N
S2	Cocoa - Low tree cover	1977	0	Y	Y
S31	Fallow	1976	0	y	y
S28	Fallow	1973	0	Y	Y
S27	Cocoa - Low tree cover	1972	0	Y	Y
T22	Cocoa - Medium tree cover	1972	0	Y	Y
S11	Cocoa - Medium tree cover	1970	0	Y	Y
T10	Cocoa - Medium tree cover	1970	0	Y	Y
T14	Cocoa - Low tree cover	1970	0	Y	Y
T18	Fallow	1970	0	Y	Y
T29	Cocoa - Medium tree cover	1968	0	Y	Y
S14	Cocoa - Medium tree cover	1967	0	Y	Y
S15	Cocoa - Medium tree cover	1967	0	Y	Y
S19	Fallow	1965	0	Y	Y
S8	Cocoa - High tree cover	1960	0	Y	Y

S9	Cocoa - Low tree cover	1960	0	Y	Y
849	Cocoa - Low tree cover	1948	2008	N	N
989	Permanent crop	? (before 2010)	2016	N	N
1255	Permanent crop	? (before 2009)	2016	N	N
T12	Fallow	? (before 2015)	2015	P	P
1226	Fallow	? (before 2014)	2014	P	P
1418	Cocoa - High tree cover	? (before 2001)	2014	N	N
1459	Cocoa - High tree cover	? (before 1988)	2014	N	N
1308	Permanent crop	? (before 2013)	2013	P	P
880	Cocoa - High tree cover	? (before 1993)	2010	N	N
754	Cocoa - High tree cover	? (before 2003)	2009	N	N
Ad03	Permanent crop	? (before 2000)	2009	N	N
675	Cocoa - High tree cover	? (before 1993)	2009	N	N
860	Secondary forest	? (before 2000)	2008	N	N
869	Cocoa - High tree cover	? (before 1993)	2008	N	N
1414	Cocoa - High tree cover	? (before 1988)	2008	N	N
T3	Secondary forest	? (before 2004)	0	P	P
Ad01	Cocoa - High tree cover	? (before 2000)	0	Y	Y
Ad05	Secondary forest	? (before 2000)	0	Y	Y
S26	Secondary forest	? (before 2000)	0	Y	Y
T25	Secondary forest	? (before 2000)	0	Y	Y
Ad06	Cocoa - High tree cover	? (before 1998)	0	Y	Y
S34	Fallow	? (before 1998)	0	y	y
T28	Fallow	? (before 1998)	0	Y	Y
S29	Annual crop	? (before 1978)	0	Y	Y
607	Permanent crop	?	2014	P	P
770	Cocoa - High tree cover	?	2016	P	P
990	Annual crop	?	2017	P	P
1034	Fallow	?	2017	P	P
1059	Fallow	?	2016	P	P
1327	Cocoa - High tree cover	?	2013	P	P
Ad04	Permanent crop	?	0	P	P
Ad07	Permanent crop	?	0	P	P

Results of the comparison between the declared deforestation years and the GFW data

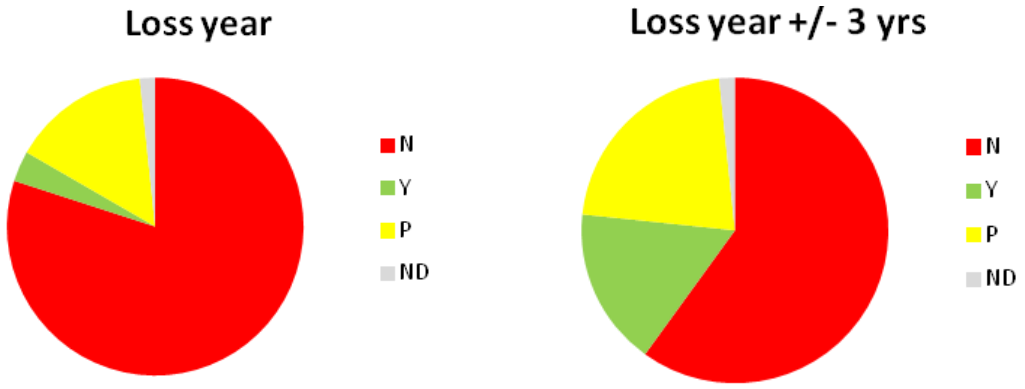
The results are summarized by the following graphs:



Summary of the results of the comparison between the declared deforestation years and the GFW data

The results show that GFW data is wrong about one-half of the time. Considering the period of +/- 3 years around the declared date, the results are better, but false in 1/3 of the situations (36 out of 106).

It is more interesting to analyze how GFW describes recent changes. To do this, we focus on plots deforested between 2001 and 2017, for which deforestation should have been identified by GFW data and on plots with tree cover loss identifies by GFW data (n=60).



Summary of the results of the comparison between the declared deforestation years and the GFW data, only for plots deforested between 2001 and 2017 and plots with tree cover loss according to GFW data

Most of GFW's information on tree cover loss between 2011 and 2017 is contradicted by information collected in the field. Even considering a period of 6 years (+/- 3 years around the date indicated by GFW), GFW data is contradicted in almost half of the cases.

The following graphs focus on the plots deforested between 2001 and 2017, according to the producers:Here again, on the central issue of the present evaluation (to identify actual deforestation events), the GFW data are wrong in the majority of cases.

As shown by the graphs, GFW data do not correspond to the reality of the field in most cases: deforestation events are not identified, while tree cover losses identified by GFW are not verified in the field.

Considering all the limits already identified during the pre-assessment (low images resolution, automatic classification process necessarily generating errors, high spatial heterogeneity of Ivorian landscapes and high variability of spectral signatures of land uses) and in view of the empirical results presented above,

Exchanges took place with Rainforest Alliance on the opportunity to consider not only a single pixel of the GFW map but a larger number of pixels. To conduct this analysis, the exact polygons of the plot boundaries are needed, while we only collected one location per plot. Indeed, Ivorian landscapes are very heterogeneous and cultivated areas include many patches whose dates of cultivation can be very different. Without knowing the boundaries of the plots, the integration of pixels around the known waypoint would include in most cases pixels of other farm / non farm parcels. The GPS survey of parcel boundaries is a feasible exercise, but longer than the exercise we did in the field. Indeed, it implies to exchange with the producer to explain to him that we seek the delimitation of the entire surface corresponding to its description and to follow it along the limits.

Since the objective of the field mission was to visit a sufficient number of plots for statistical analysis, this option was not chosen. It could be an area for further investigation.

4.3. Biophysical characteristics of cocoa stands

In order to assess whether the characteristics of cocoa plots can inform the auditors on the presence or absence of recent deforestation, the cocoa plot observations (n=52) are classified into three categories, based on descriptions from landowners: deforested between 2001 and 2017; deforested 2008 and 2017; non deforested or deforested before 2001 .

The following table summarizes the characteristics observed for each category.

	Deforested 2001-2017, as reported by the producer (n=23)				Deforested 2008-2017, as reported by the producer (n=15)				Non deforested or deforested before 2001, as reported by the producer (n=29)			
	Mean	**Min**	**Max**	**CV**	**Mean**	**Min**	**Max**	**CV**	**Mean**	**Min**	**Max**	**CV**
Nb of strata	2,1	1	3	25%	2,1	1	3	28%	1,9	1	3	32%
Height of tree stratum (m)	19,2	6	40	53%	18,1	6	40	58%	21,0	5	40	61%
Height of cocoa stratum (m)	3,7	1,2	6	36%	3,6	1,2	6	44%	5,2	3	7	19%
Cover of tree stratum	8%	1%	20%	81%	9%	1%	20%	64%	4%	1%	20%	104%
Cover of cocoa stratum	46%	5%	100%	66%	46%	5%	100%	74%	47%	20%	90%	32%
Cover of other stratum	4%	0%	30%	226%	5%	0%	30%	209%	0%	0%	5%	329%
Density of cocoa (number/ha)	2 191	370	5 200	53%	2 336	370	5 200	57%	1 488	700	2 250	26%
Basal area of trees (m²/ha)	2,1	0	4,5	65%	2,1	0	4	61%	1,1	0	3	74%
Basal area of cocoa (m²/ha)	4,5	0	9	173%	3,9	0	9	208%	8,0	4	13	200%
Herbaceous cover	43%	0%	100%	83%	39%	0%	100%	101%	36%	0%	90%	70%
Stumps (nb in a 20m radius circle)	4,3	0	20	99%	5,1	0	20	98%	1,1	0	5	134%
Diameter of stumps (cm)	31,3	15	50	35%	28,9	15	50	34%	37,9	20	80	42%
State of stumps	**Intact**	**Interm.**	**Rotten**		**Intact**	**Interm.**	**Rotten**		**Intact**	**Interm.**	**Rotten**	
	0%	43%	57%		0%	43%	57%		0%	31%	69%	
Humus	**Thin**	**Thick**	**Absent**		**Thin**	**Thick**	**Absent**		**Thin**	**Thick**	**Absent**	
	13%	0%	87%		13%	0%	87%		17%	0%	83%	
Soil organic matter	**High**	**Average**	**Low**		**High**	**Average**	**Low**		**High**	**Average**	**Low**	
	19%	29%	52%		21%	36%	43%		31%	62%	8%	
Soil texture	**Compact**	**Average**	**Loose**		**Compact**	**Average**	**Loose**		**Compact**	**Average**	**Loose**	
	62%	24%	14%		57%	21%	21%		45%	27%	27%	

Biophysical characteristics of cocoa plots

With this data, statistical tests are not conducted, but some subtle differences can be observed between the cocoa plots planted recently on forests and cocoa not planted on forests/planted before 2001 on forests:

- For recently planted cocoa, cocoa trees have lower basal area and lower height than on cocoa plots established pre-2001, but have higher density (stems / ha). The percent cover of the cocoa stratum is about the same between recently planted and pre-2001 cocoa (about 50% cover).
- For recently planted cocoa, the percent cover and basal area of the overstory tree stratum are relatively low (9% and 2 m²/ ha), but higher than that of the cocoa plots pre-2001 (4% and 1.1 m²/ ha).
- The herbaceous cover is higher in cocoa plots recently planted on forests,
- More tree stumps can be found in cocoa plots recently planted on forests than cocoa pre-2001 (5.1 vs 1.1), but stumps are smaller, and the quantity of organic matter in the soil is lower,
- Herbaceous cover, total number of vegetative strata, soil depth, and soil texture are similar across all plots.

Of the 53 cocoa plots for which we know the previous land use (clearing before or after 2001), 47 were planted on forest or fallows of more than 10 years. Among the 6 others, 4 were planted on old cocoa or coffee. The 2 remaining were planted on young cocoa plantations (planted in 2002 on forests) cleared by the agents of the SODEFOR in the Téné classified forest. According to our field survey, in the areas visited (mainly Tiassalé and Soubré, because we had little information on the LU history of cocoa plots in the Bianouan area), **cocoa is systematically planted on the forest**.

ID	Year of plantation	Previous LU
FC3	2008	Cocoa
FC4	2008	Cocoa
T13	2002	Fallow 15 years
748	2003	Intact forest
S7	2003	Intact forest
S4	2004	Fallow (10 years)
T26	2004	Ancient fallow (30 years)
T4	2006	Intact forest
T9	2006	Fallow (20-30 years)
S3	2007	Intact forest
812	2009	Fallow / abandoned coffee
S5	2009	Fallow (25 years)
FC2	2010	Intact forest
T1	2010	Intact forest
T24	2010	Fallow (10 years)
T5	2010	Fallow (10 years)
T7	2010	Fallow >15 years
T8	2010	Forest (30 years)
T20	2012	Intact forest
T21	2012	Fallow 24 years
T16	2014	Fallow (10-15 years)
S13	2015	Forest
T11	2016	Fallow
T17	2016	Fallow (10-15 years)
T19	2017	Ancient fallow
T27	2018	Very degraded forest
811	1998	Intact forest

ID	Year of plantation	Previous LU
849	2000	Coffee
1263	1998	Intact forest
FC1	2000	Intact forest
S1	1983	Intact forest
S10	1978	Intact forest
S11	1978	Intact forest
S12	1978	Intact forest
S14	1967	Intact forest
S15	1967	Intact forest
S16	1977	Intact forest
S17	1978	Intact forest
S2	1977	Intact forest
S22	1983	Intact forest
S23	1979	Intact forest
S27	1973	Intact forest
S30	1980	Intact forest
S33	1983	Intact forest
S6	1983	Intact forest
S8	1960	Intact forest
S9	1960	Intact forest
T10	2004	Cocoa
T14	2010	Cocoa
T15	1982	Intact forest
T22	1972	Intact forest
T29	1968	Intact forest
T30	1993	Intact forest

Year of plantation and previous land uses for 53 plots for which we know the cultural history

4.4. Test of additional satellite images

As a detailed deforestation risk protocol cannot rely solely on GFW data, we tested two other sources of data:

- Google Earth, which is a very easy tool to use and has the advantage of proposing to visualize satellite images of the same zone on several dates. The resolution and date range of images in Google Earth depends on the location.
- Sentinel 2 data, which are the most accurate free accessible data. Sentinel 2 images are up to 10 meter resolution and from 2015-now date range.

4.4.1. Google Earth images

In Google Earth, we try to "spot" the "deforestation" events of the 36 plots of our sample where the "deforestation" occurred between 2001 and 2017. The identification here of potential tree cover loss in Google Earth is done by visually comparing the satellite photos at two dates: before and after the deforestation event. The loss of tree cover is evaluated by eye, without any particular procedure.

Unfortunately, the images are only available for the years 2012 and 2013 in most areas. For this reason, we were able to assess deforestation only for plots T8 and T20 (see Annex IV).

ID	Year of deforestation (as reported by landowner)	Range of Google Earth images	Year of tree cover loss (Google Earth)
FC3	2002	2011-2016	
FC4	2002	2011-2016	
T13	2002	2011-2012	
748	2003	2013	
S7	2003	2013-2015	
S4	2004	2013-2015	
T26	2004	2012	
1421	2006	2013	
T4	2006	2012	
T9	2006	2011-2012	
S3	2007	2013-2015	
812	2009	2013	
S5	2009	2013-2015	
T6	2009	2011-2012	
FC2	2010	2011-2016	
T1	2010	2012	
T24	2010	2011-2012	
T5	2010	2011-2012	
T7	2010	2011-2012	
T8	2010	2011-2012	2012
S21	2012	2013-2015	
T20	2012	2012	2012
T21	2012	2012	
1409	2014	2013	
T16	2014	2012	
S13	2015	2013-2015	
T2	2015	2012	
1332	2016	2013	

1426	2016	2012-2013	
T11	2016	2011-2012	
T17	2016	2012	
1427	2017	2013	
T19	2017	2012	
Mine	2018	2014-2017	
S20	2018	2013-2015	
T27	2018	2012	

Google Earth images available and deforestation events spotted

Here, tree cover loss was identified with Google Earth for the two points, potentially confirming the "deforestation" as described by the landowner. The use of Google Earth seems interesting but is limited by the low availability of images on different dates. In addition, the low resolution of the 2011 images does not allow interpretation.

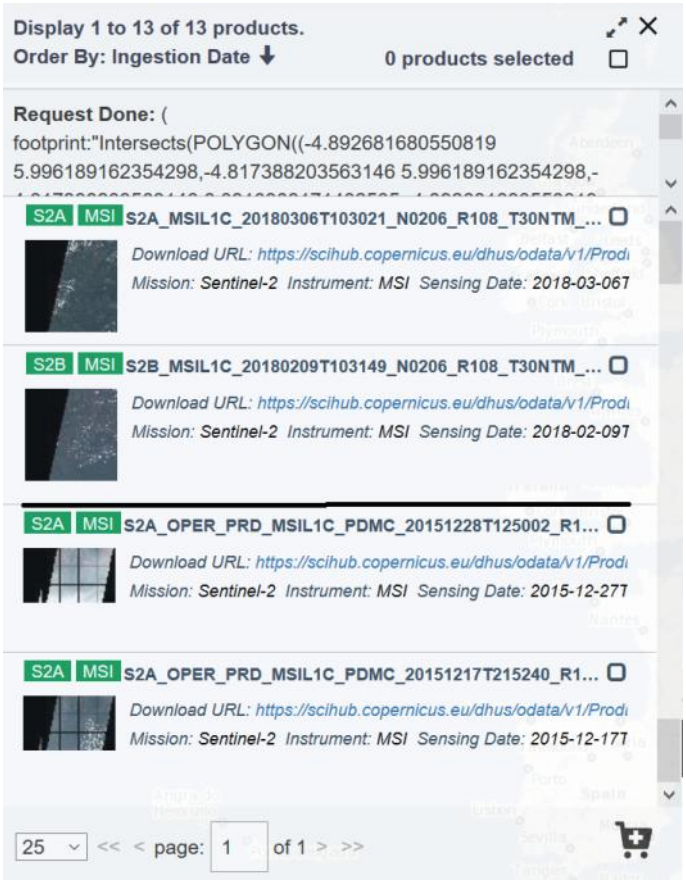
It is likely that in the future, the amount of images will increase. The availability of high-resolution images for 2013 is a positive point for Rainforest Alliance auditors to assess the land use situation for 2014, the base year for compliance with critical criterion 2.2.

4.4.2.Sentinel 2 images

Sentinel data were downloaded on https://scihub.copernicus.eu/dhus/#/home. The tool allows looking for data corresponding to the area and period of interest. The exercise was conducted for the area of Tiassalé, where the survey identified the largest number of recent deforested plots.

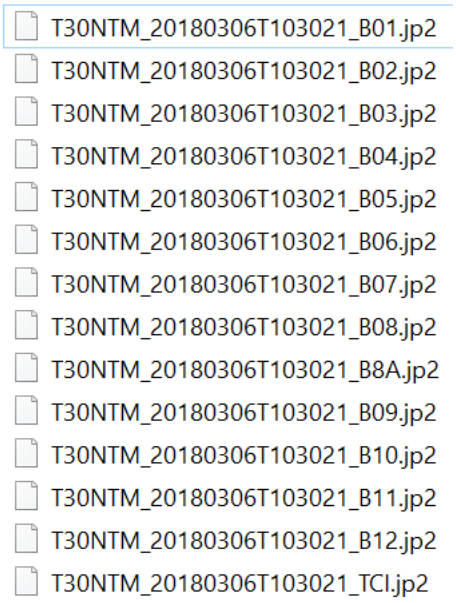
We looked for Sentinel 2 data between 2013 and 2018, with low cloud coverage (<10%)[4]. The most recent image is from 06/03/2018, while the oldest is from 17/12/2015.

[4] The following request can be pasted in the searching tool in order to find the same results : (footprint:"Intersects(POLYGON((-4.892681680550819 5.996189162354298,-4.817388203563146 5.996189162354298,-4.817388203563146 6.0910308171402505,-4.892681680550819 6.0910308171402505,-4.892681680550819 5.996189162354298)))") AND (beginPosition:[2013-01-01T00:00:00.000Z TO 2018-11-26T23:59:59.999Z] AND endPosition:[2013-01-01T00:00:00.000Z TO 2018-11-26T23:59:59.999Z]) AND ((platformname:Sentinel-2 AND cloudcoverpercentage:[0 TO 10]))



Extract of the result for the request to identify Sentinel images for a specific area and period

The downloaded data contains 13 - 14 image files.



Example of the 14 files constituting a Sentinel image

Files whose names end with B02, B03 and B04 correspond to the blue, green and red bands, while the file whose name ends with TCI corresponds to a True Color Image[5], composed by the blue, green

[5] https://www.sentinel-hub.com/eoproducts/true-color

and red bands. This file is to be used for visual interpretation. When this file does not exist, a true color image can be created by following tutorial instructions available on the Internet[6].

We used these images to identify deforested plots between 2015 and 2018. In order to conduct the exercise in an objective manner, we conducted it without reminding us the actual dates of deforestation. The images for 2015 and 2018 covering the plots on which we identified deforestation, as well as those on which we should have identified deforestation, are in Annex V.

Similar with the process for Google Earth images, As for images in Google Earth, the identification of tree cover loss with Sentinal images is done by visually comparing the satellite photos at two dates.

ID	Tree cover loss 2015-2018 (based on Sentinel)	Year of deforestation (as reported by landowner)	Result
T1	No	2010	
T2	No	2015	Not spotted
T3	No	None	
T4	No	2006	
T5	No	2010	
T6	No	2009	
T7	No	2010	
T8	No	2010	
T9	No	2006	
T10	No	None	
T11	Yes	2016	Spotted
T12	Yes	2014 or 2015	Spotted
T13	No	2002	
T14	No	None	
T15	No	None	
T16	No	2014	
T17	Yes	2016	Spotted
T18	No	None	
T19	No	2017	Not spotted
T20	No	2012	
T21	No	2012	
T22	No	None	
T23	No	None	
T24	No	2010	
T25	No	None	
T26	No	2004	
T27	No	2018	Not spotted
T28	No	None	
T29	No	None	
T30	No	None	

Results of the deforestation identification exercise on the basis of Sentinel images

3/6 of plots deforested were detected with the help of Sentinel 2 images. T2 (deforested in 2015) and T27 (deforested in 2018) were not identified as deforested during the period, probably because of the dates on which the images were acquired (17/12/2015 and 06/03/2018).

[6] For example: https://www.youtube.com/watch?v=5c7-KJoPle0

T19, deforested in 2017, should have been identified as deforested. This means that the visual interpretation of these images is not 100% reliable.

5. Recommendations for a deforestation assessment protocol

5.1. Desktop assessment

The complementary use of Google Earth and Sentinel images could allow pre-identification of sites that have probably been deforested.

This implies to know in advance the location of the plots to visit.

The tools provide a good basis for the years 2013 and 2015, which is a good thing considering that Rainforest Alliance uses 2014 as a reference year.

As the availability of satellite images increases, especially with the Sentinel 2 program, it is hoped that the availability of images for audits will improve.

The visual interpretation of these images and the generation of true color images under GIS could require some training of the auditors. The data collected as part of this study, as well as others, could be mobilized for these training exercises.

This method is not 100% reliable, and it must be completed by field surveys (see next chapter).

The interpretation of satellite data could also be mobilized after the field collection phase, in order to verify the data collected, or in the case the location of the plots is not known before the field phase. In fact, it is easier to identify deforestation when having an idea of the cocoa planting dates.

5.2. Field assessment

Based on the assessment of the field data collected during the study, the following parameters seem interesting. They can give evidence about the presence or absence of deforestation, but do not allow being categorical. We believe that the questions should be asked in the order indicated so the conversation is not directly engaged on the issue of deforestation.

➔ **Questions to ask to the producer**

- **Age of cocoa trees**. *Obvious but important. If cocoa trees are old, there cannot have been recent deforestation (but there could still be removal of shade cover). An auditor with the ability to determine cocoa age would be an asset for the assessment.*
- **Dates of stand replacement**. *Old cocoa trees can be replaced by new ones. If the producer indicates a date, we can think that he planted on a former cocoa farm.*
- **Did the producer plant yam before the cocoa and if yes, during which year?** *Yam cultivation requires very good fertility, which can be found on forest soils. In general, it is planted on forest clearing or old fallow. Many producers told us that they planted yam just after deforestation and before cocoa.*

➔ **Biophysical data to collect**

If the author cannot estimate the age of cocoa trees, some parameters may give information: young plots young plots are characterized by **low heights** and **mean diameters**[7] and **high densities** and **cover** (see Annex VI).

As shown above, deforested plots have a **higher number of tree stumps**. However, the decomposition of the stumps is fast. In addition, some trees may be left in plots for several years before being cut or falling naturally. Only a high number of large stumps, **greater than 4 in a radius of 20 m**, can be an interesting evidence.

We do not recommend collecting information on the herbaceous cover and soil organic matter, as these parameters showed little difference between recently deforested and other cocoa plots; the estimation of these parameters is also subjective and highly dependent on the data collector.

[7] Calculated as √[4*(basal area*10000/density)/π))

Annex I – Field mission schedule

	AM	PM	Night
Mon. 22/10	Travel to Kétésso/Bianouan	Inventories in the Kétésso/Bianoun area	Kétésso or Bianouan
Tue. 23/10	Inventories in the Kétésso/Bianouan area	Inventories in the Kétésso/Bianouan area	Bianouan
Wed. 24/10	Inventories in the Bianouan area	Inventories in the Bianouan area	Bianouan
Thu. 25/10	Inventories in the Songan area	Inventories in the Songan area + travel to Abidjan	Abidjan
Fri. 26/10	Travel to Soubré	Travel to Soubré	Soubré
Sat. 27/10	Inventories in the Soubré area	Inventories in the Soubré area	Soubré
Sun. 28/10	Inventories in the Soubré area	Inventories in the Soubré area	Soubré
Mon. 29/10	Travel to Tiassalé	Inventories in the Tiassalé area	Tiassalé
Tue. 30/10	Inventories in the Tiassalé area	Inventories in the Tiassalé area	Tiassalé
Wed. 31/10	Inventories in the Tiassalé area	Travel to Abidjan	Flight to Paris

Annex II – Field form

Date		Time		Name		Land use	

ID		Producer's name		Producer's tel.	

Area (ha)	Fertility of the plot	State of local forests
	□ Good □ Average □ Bad	□ Intact □ Relatively well conserved □ Degraded □ Very degraded □ No forests

Tools used for clearing		Use of fertilizers	Regeneration of cocoa trees
□ Chainsaw □ Axe	□ machete □ No clearing	□ Organic □ Chemical □ No	□ Frequent □ Rare □ No

First year cultivated (any crop)		First grower	□ Himself □ Other : □ A parent □ Do not know

Vegetation before first cultivation		
□ Relatively well conserved forest	□ Very degraded forest	□ Other :
□ Degraded forest	□ Grassland	□ Do not know

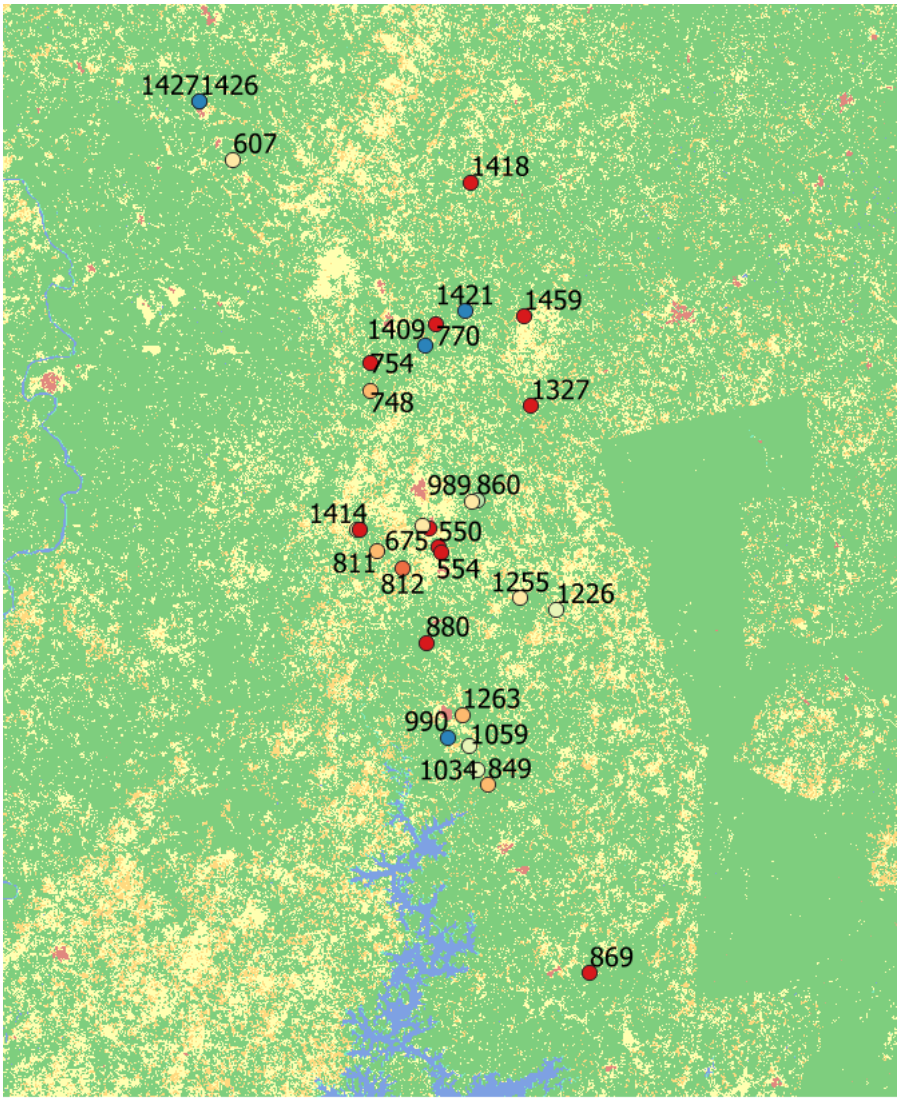
1st cocoa plant. year		Vegetation before cocoa		Years of major cocoa replant.	

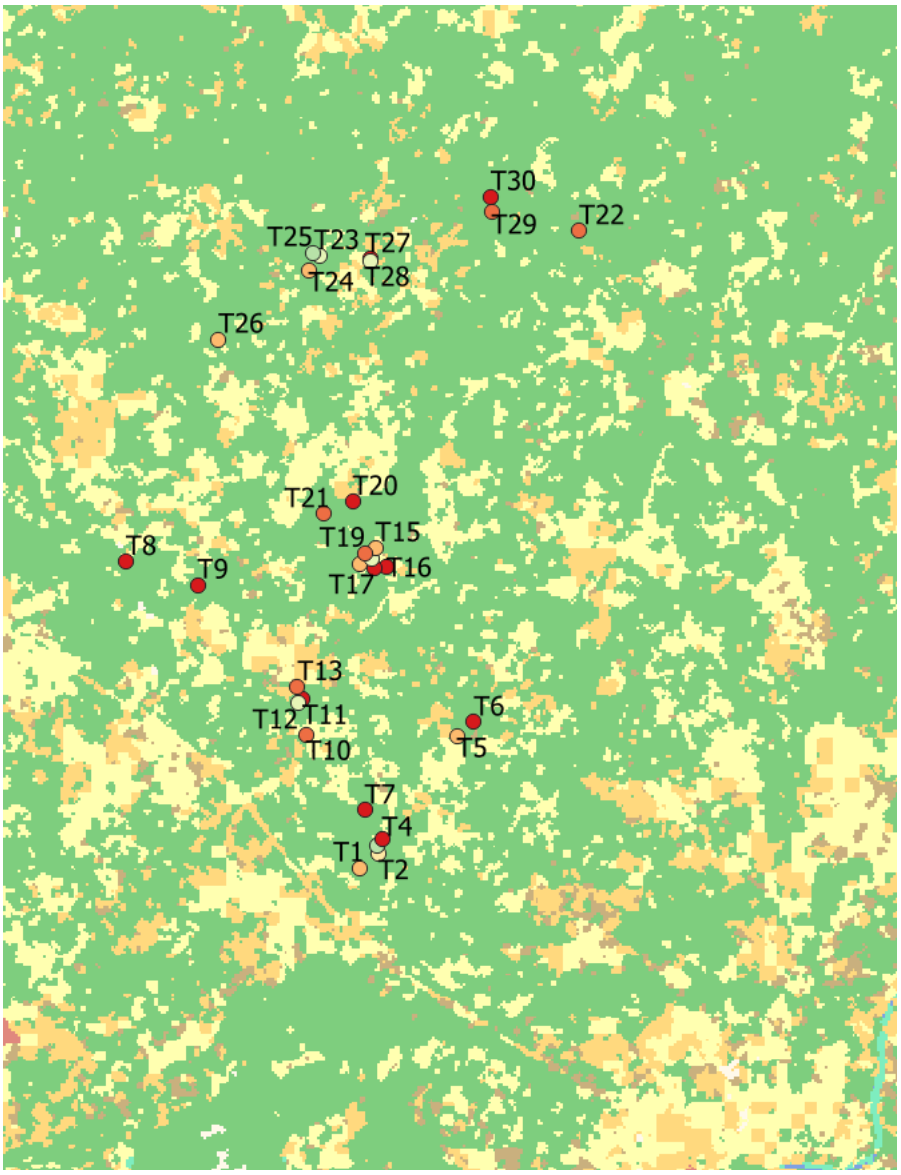
Ligneous stratum	Height (m)		Basal area (m²)	Cover (%)	Density	Varieties/species (and %)
1 (highest)		Cocoa				
		Forest trees				
		Shrubs				
2 (middle)		Cocoa				
		Forest trees				
		Shrubs				
3 (lowest)		Cocoa				
		Forest trees				
		Shrubs				

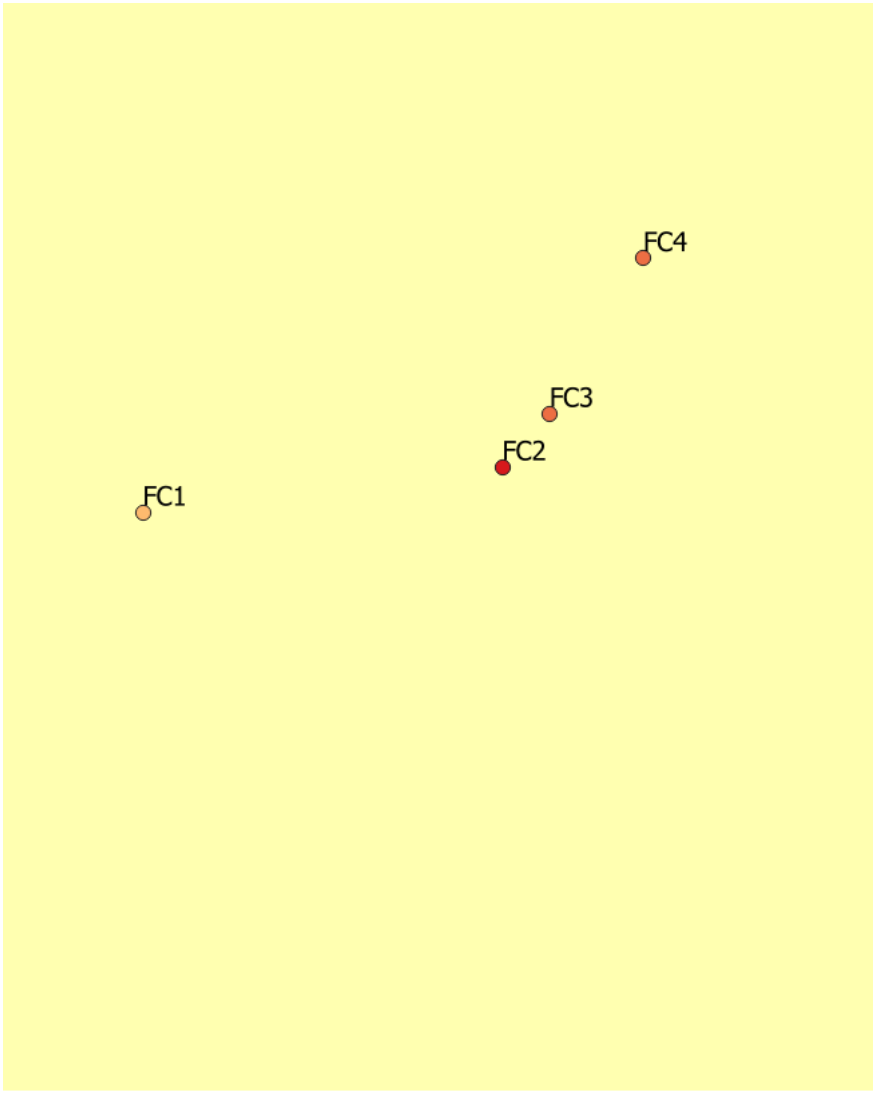
Tree stumps within 20 meters	State of the stumps	Humus	Herbaceous stratum (% of cover)
	□ Intact □ Intermediate □ Rotten	□ Thick □ Thin □ Almost absent	

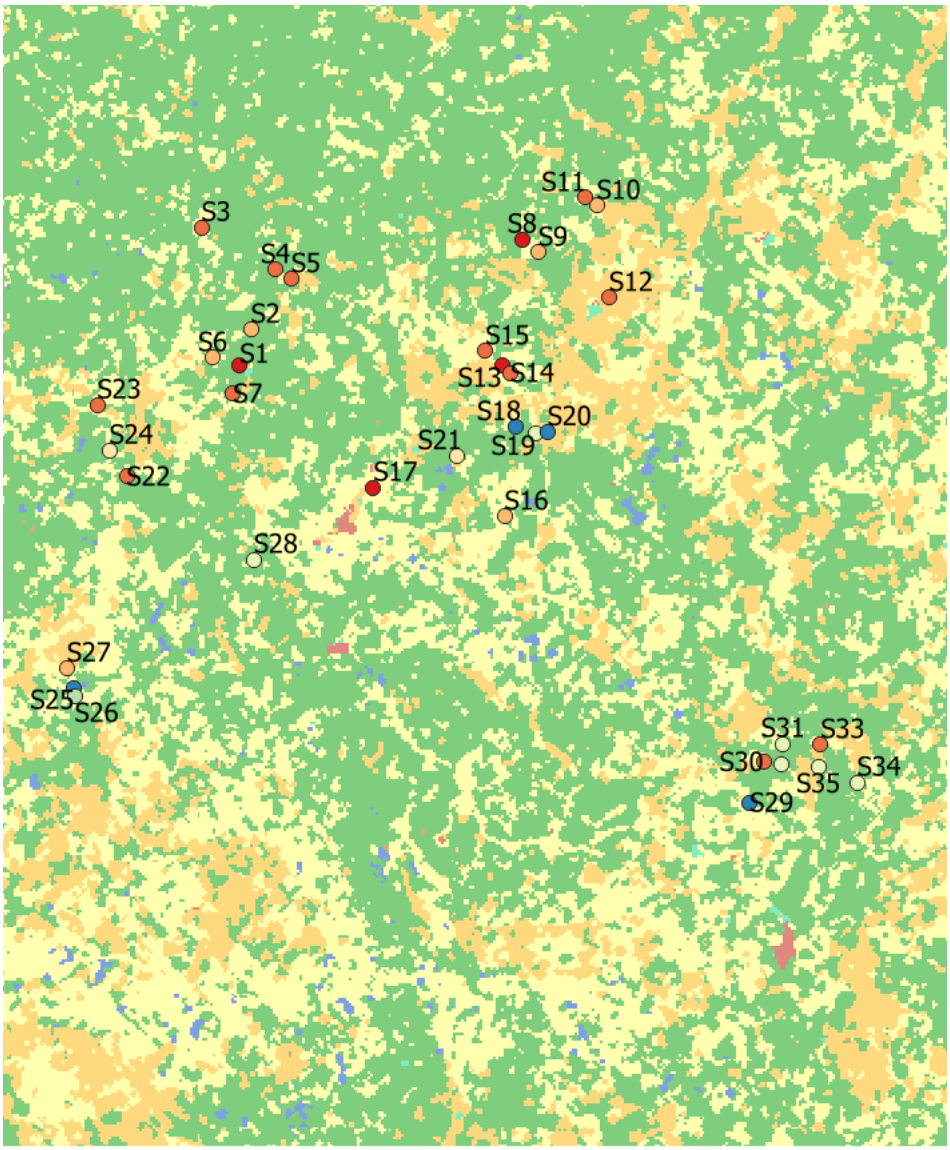
Observations

Annex III – Maps showing the distribution of land uses among the visited areas

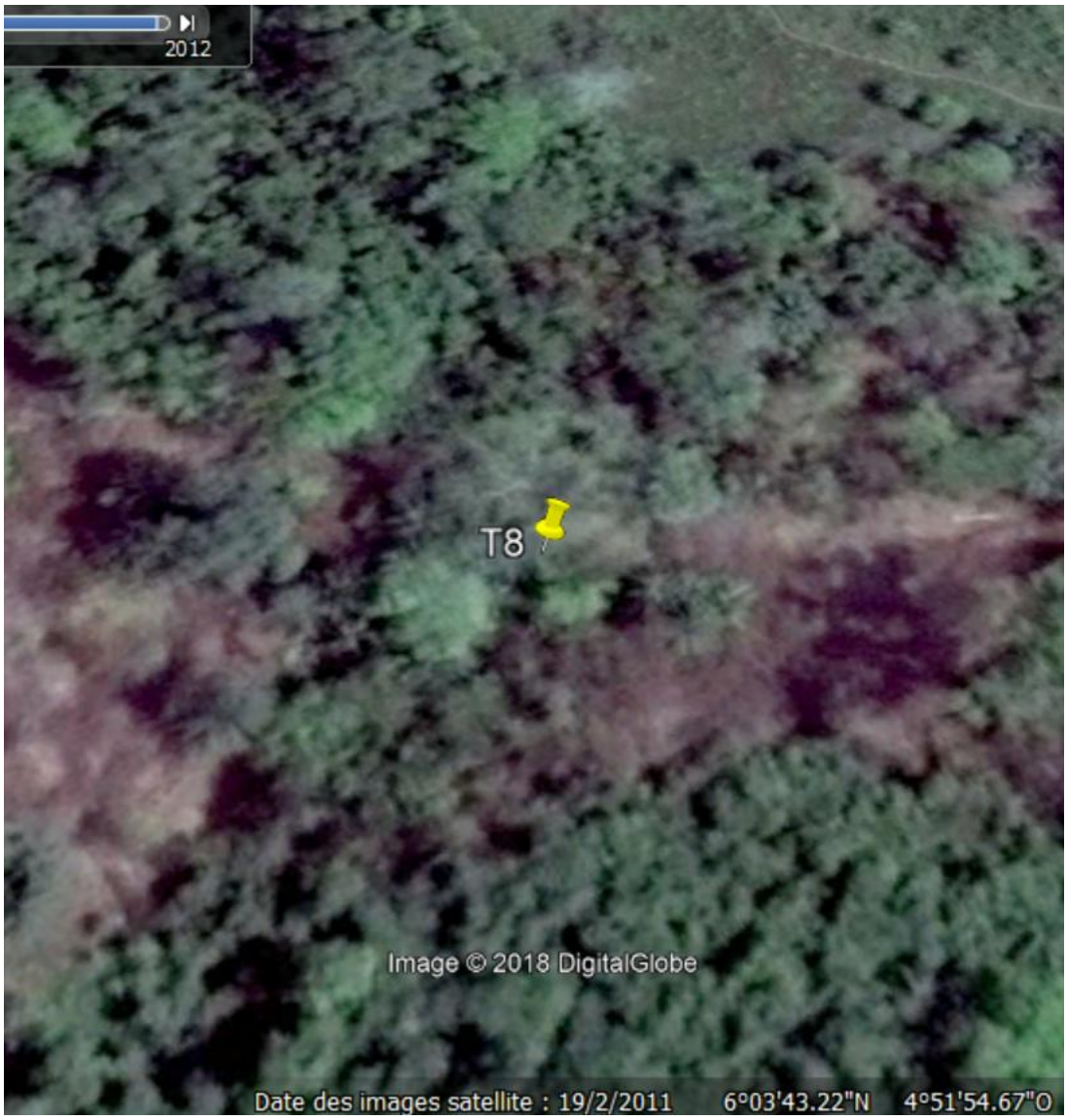


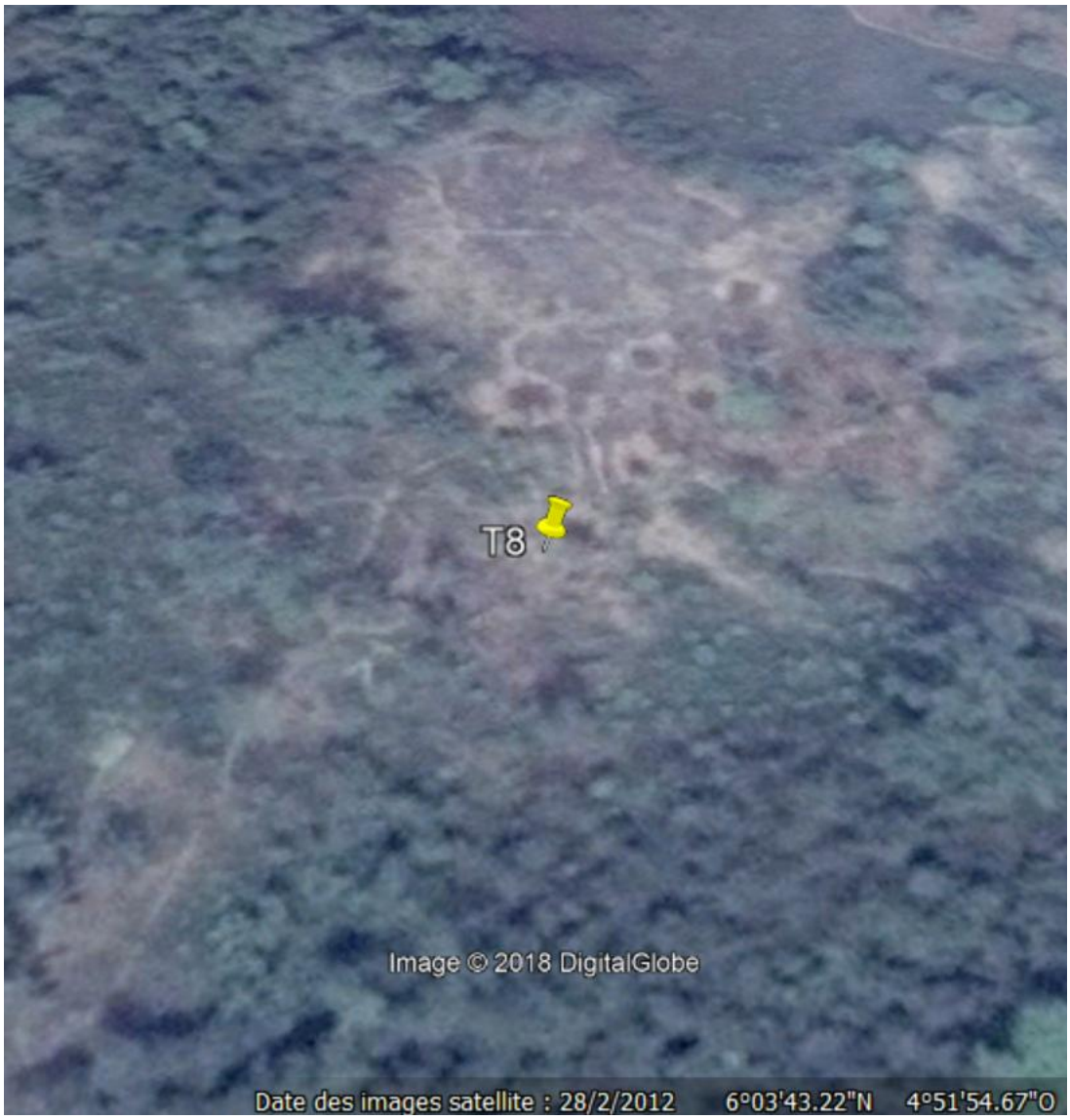

T30
T29
T22
T25
T23
T27
T24
T28
T26
T21
T20
T19
T15
T8
T9
T16
T17
T13
T12
T11
T6
T10
T5
T7
T4
T1
T2

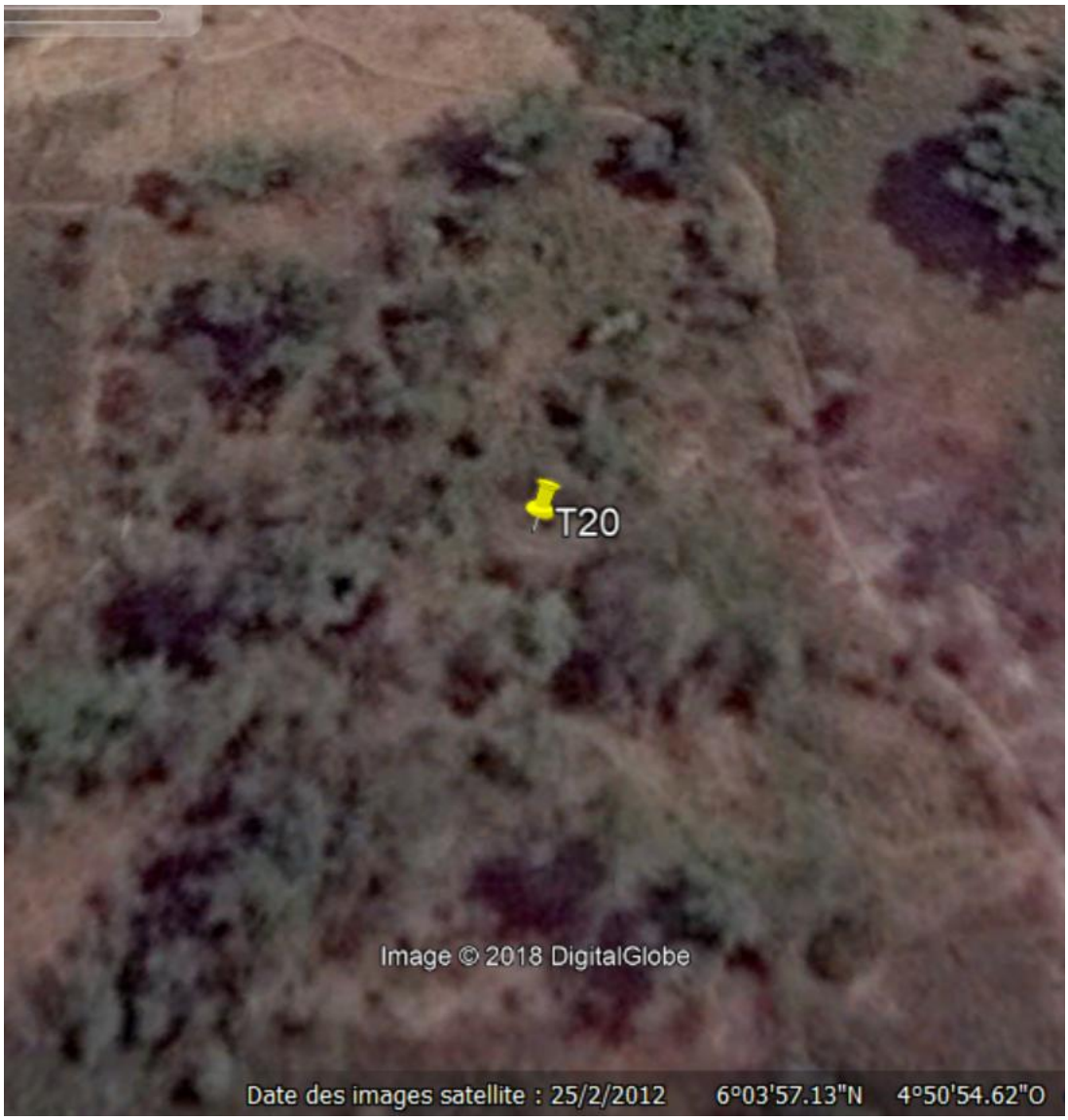

FC4
FC3
FC2
FC1

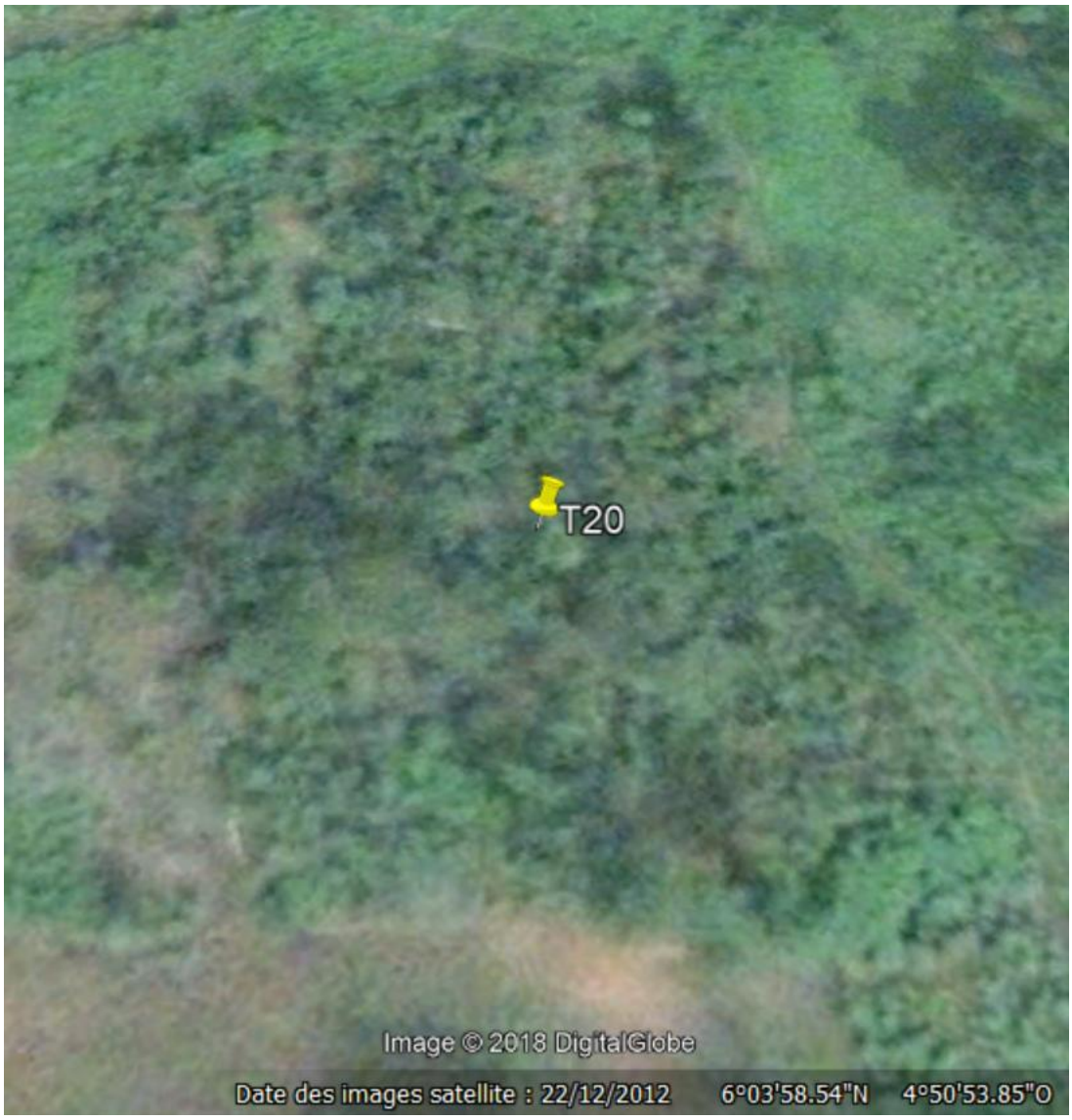

S11
S10
S3
S8
S9
S4
S5
S12
S2
S15
S6
S1
S13
S14
S23
S7
S18
S20
S24
S21
S19
S22
S17
S16
S28
S27
S25
S26
S31
S33
S30
S34
S35
S29

Annex IV – Identification of deforestation on plots T8 and T20 with the help of Google Earth



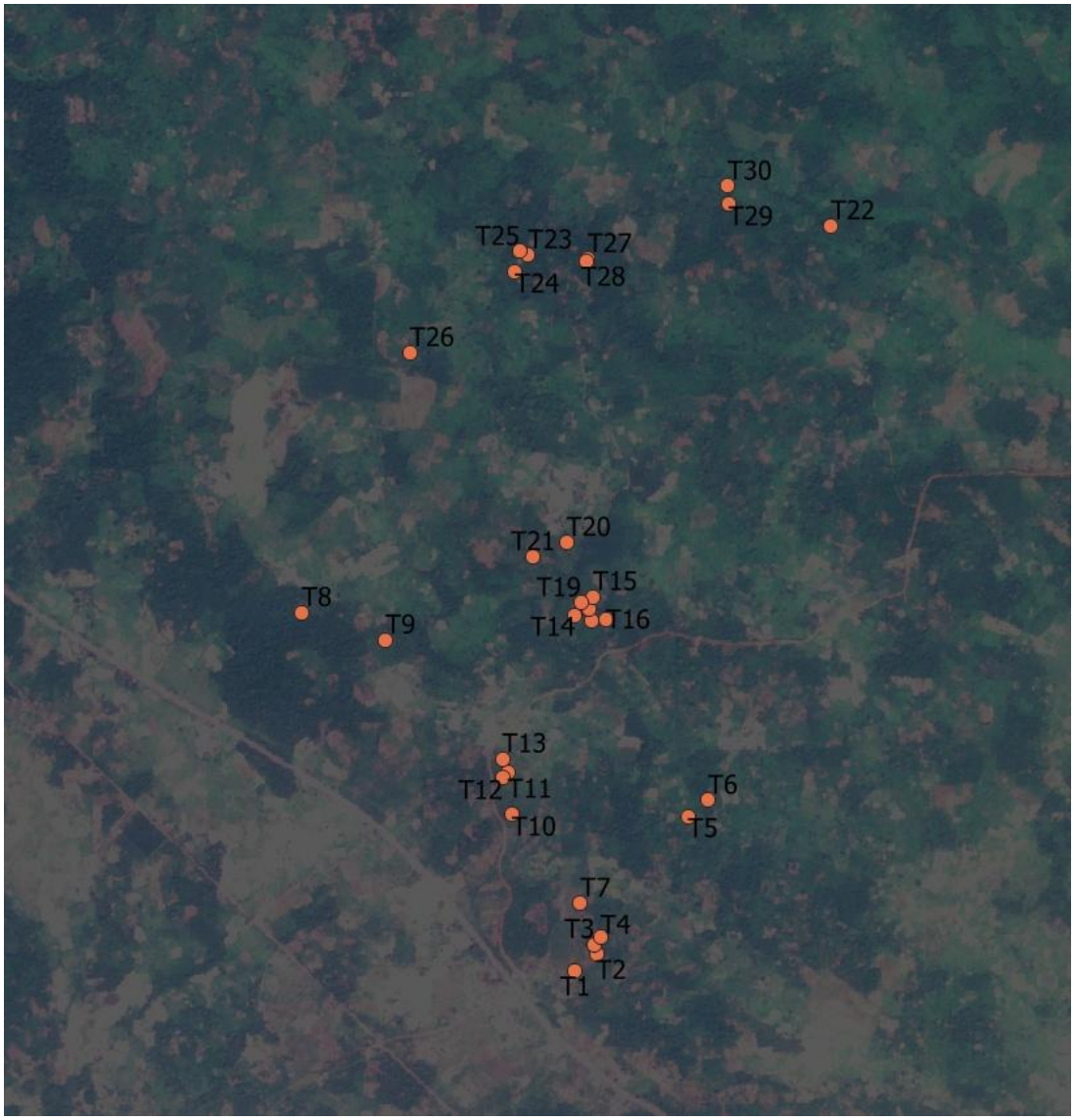

T8
Image © 2018 DigitalGlobe
Date des images satellite : 28/2/2012
6°03'43.22"N
4°51'54.67"O


T20
Image © 2018 DigitalGlobe
Date des images satellite : 25/2/2012
6°03'57.13"N
4°50'54.62"O


T20
Image © 2018 DigitalGlobe
Date des images satellite : 22/12/2012
6°03'58.54"N
4°50'53.85"O

Annex V – Sentinel 2 images for plots T2, T11, T12, T17, T19 and T27

Tiassalé area – Sentinel 2 image for 2015



Tiassalé area – Sentinel 2 image for 2018

Plot T2 – Sentinel 2 image for 2015

Plot T2 – Sentinel 2 image for 2018

Plots T11 & T12 – Sentinel 2 image for 2015

Plots T11 & T12 – Sentinel 2 image for 2018

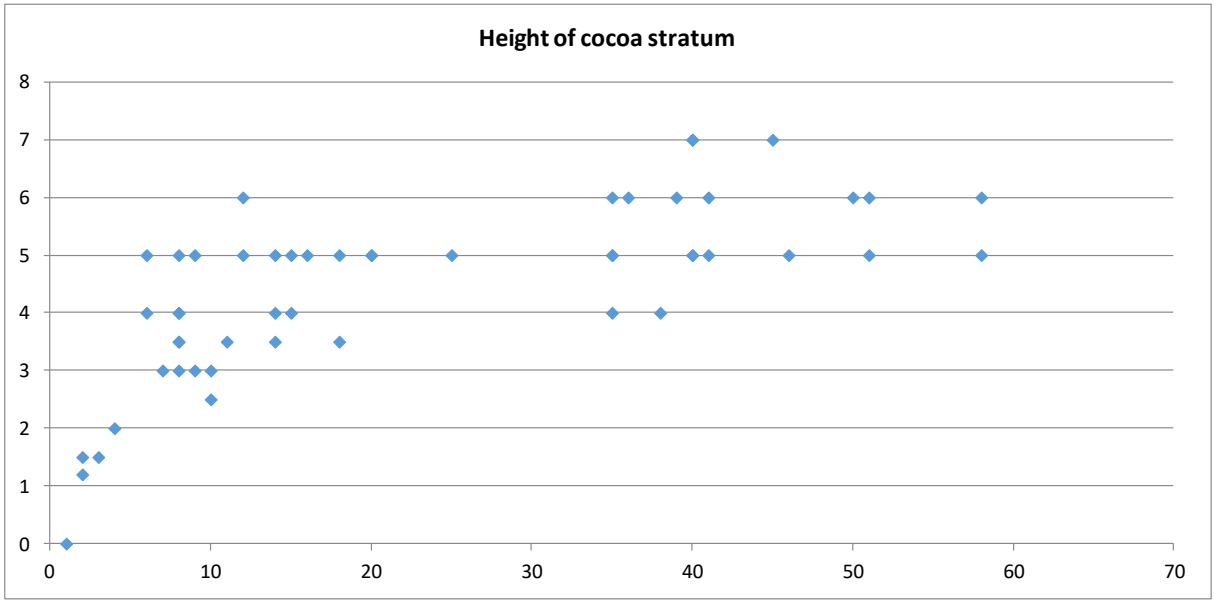
Plot T17 & T19 – Sentinel 2 image for 2015

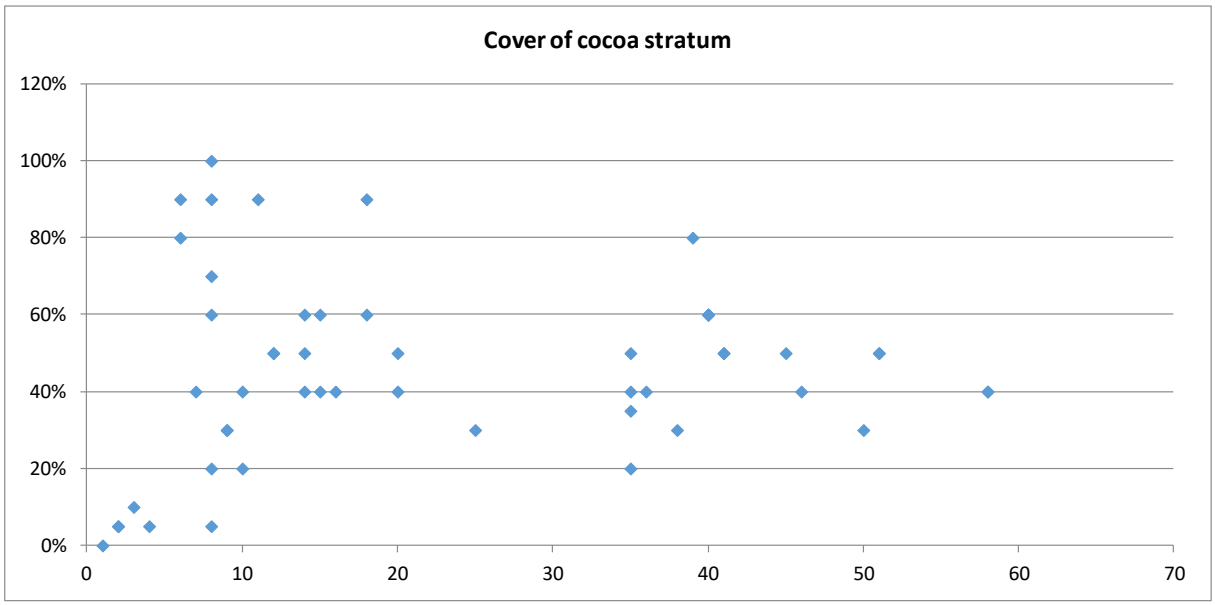
Plot T17 & T19 – Sentinel 2 image for 2018

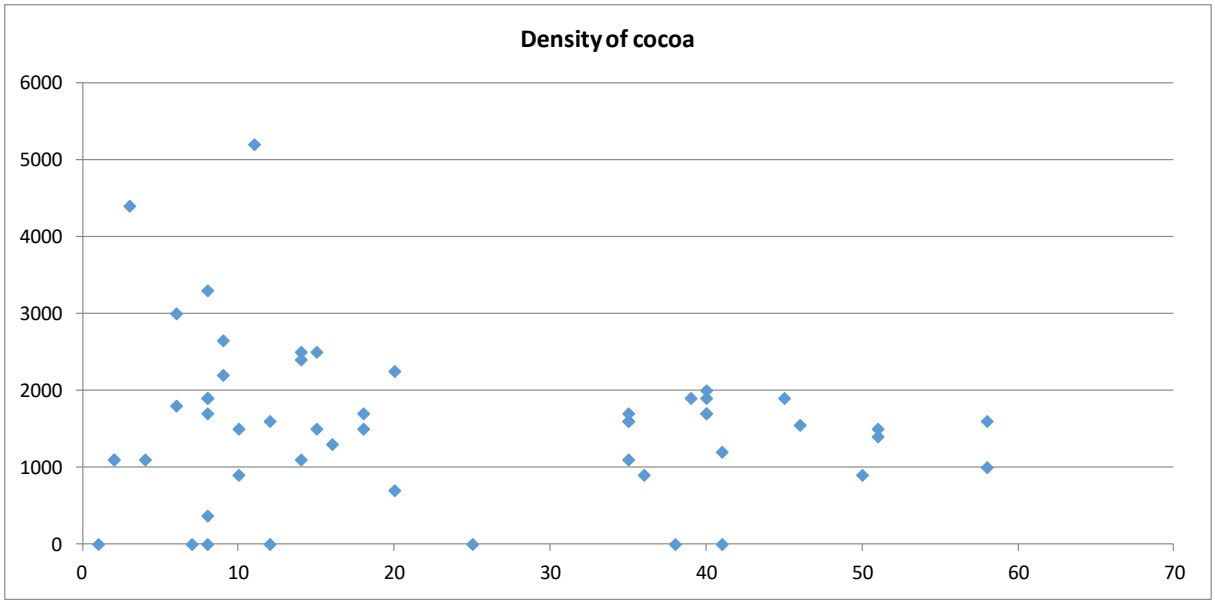
Plot T27 – Sentinel 2 image for 2015

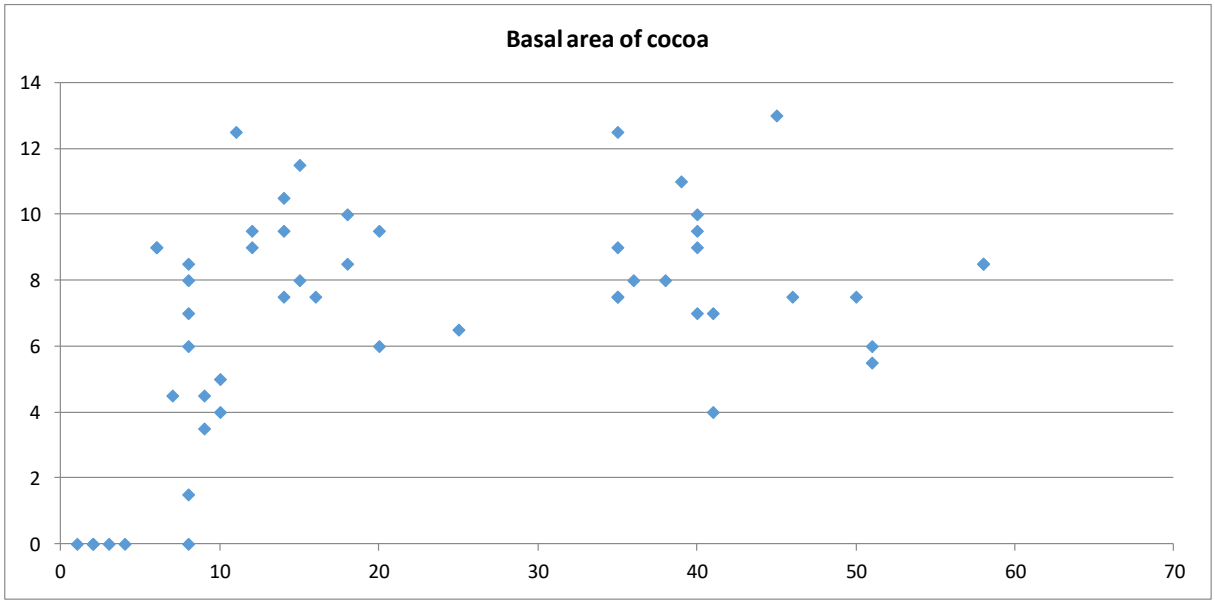
Plot T27 – Sentinel 2 image for 2018

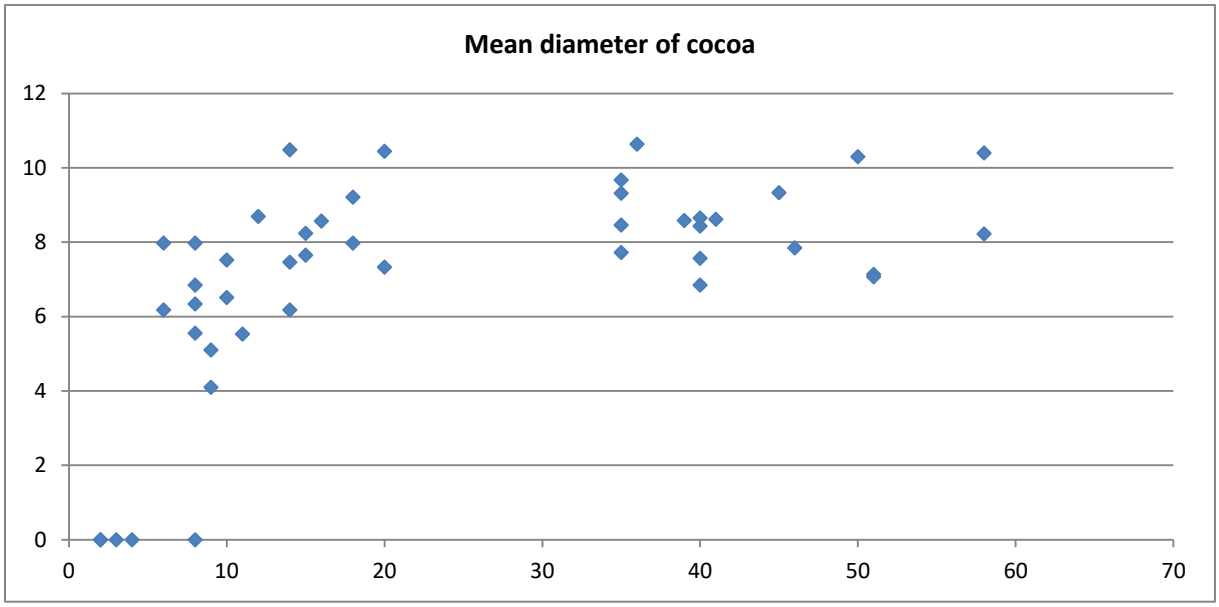
Annex VI - Characteristics of cacao plots depending on their age

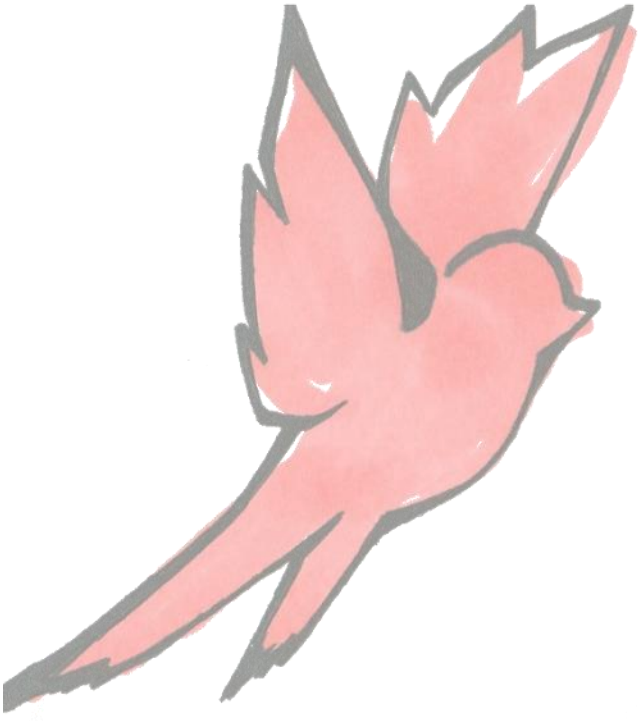





Density of cocoa
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70


Basal area of cocoa
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70


Mean diameter of cocoa
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70



December 2018

SAS SalvaTerra
6 rue de Panama
75018 Paris I France
Tél : +33 (0)6 66 49 95 31
Email : o.bouyer@salvaterra.fr
Skype : o.bouyer.salvaterra
Web : www.salvaterra.fr
Vidéo : www.salvaterra.fr/fr/video