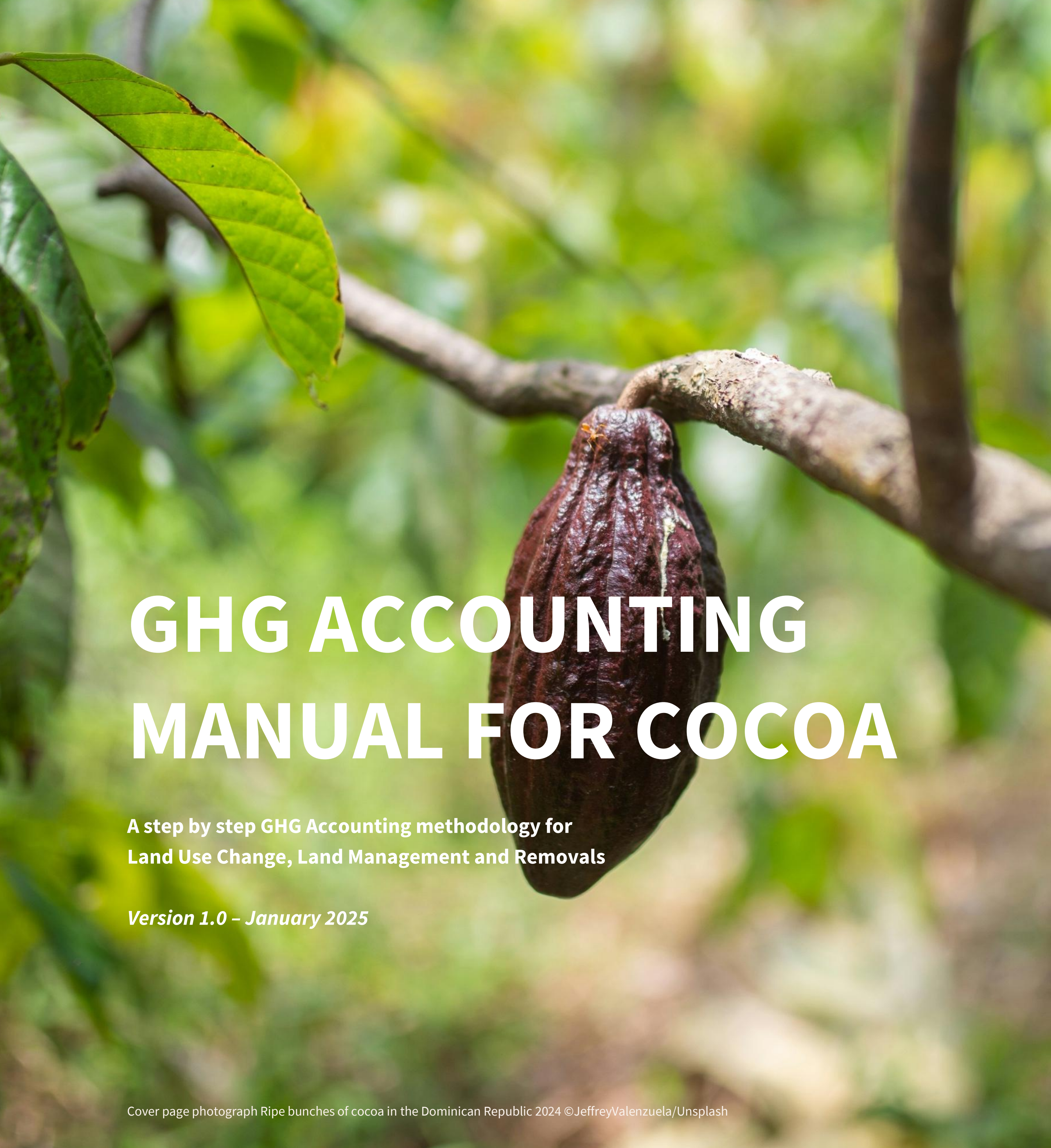

GHG ACCOUNTING MANUAL FOR COCOA

A step by step GHG Accounting methodology for Land Use Change, Land Management and Removals

Version 1.0 – January 2025

Cover page photograph Ripe bunches of cocoa in the Dominican Republic 2024 ©JeffreyValenzuela/Unsplash

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Abbreviations

AGB	Above Ground Biomass
APV	Actual procurement volume
BAU	Business As Usual
BF	Buffered Fraction
BGB	Below Ground Biomass
C	Carbon
CF	Corporate Footprint
CIAT	International Center for Tropical Agriculture
CFA	Cool Farm Alliance
CoC	Chain of Custody
CO_2	Carbon Dioxide
DBH	Diameter at Breast Height
dLUC	Direct Land Use Change
DOM	Dead Organic Matter
EF	Emission Factor
EPV	Estimated production volume
FAOSTAT	Food and Agriculture Organization Statistics
GFW	Global Forest Watch
GHG	Greenhouse Gas
GHGP-LSRG (draft)	GHG Protocol Land Sector and Removals Guidance (September 2022 draft)
IP	Identity Preserved
IPCC	Intergovernmental Panel on Climate Change
jdLUC	Jurisdictional Land Use Change
LM	Land management
LMU	Land Management Unit
LUC	Land Use Change
R	Removals
RF	Removals Factor
sLUC	Statistical Land Use Change
SBT	Science Based Target
SBTi	Science Based Target initiative
SOC	Soil Organic Carbon
tCO_2e	Tonnes (t) of carbon dioxide (CO_2) equivalent (e)
TCL	Tree cover loss

TMF	Tropical Moist Forest
UAV	Unmanned Aerial Vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard
WFLDB	World Food LCA Database
WCF	World Cocoa Foundation

1. Introduction

As the cocoa sector advances toward achieving its climate targets, this step-by-step manual provides clear guidance to help companies in the sector conduct accurate and aligned greenhouse gas (GHG) accounting and reporting. The manual defines **traceability** recommendations as well as step by step accounting guidance for **land use change** (LUC) emissions, **land management** (LM) emissions, and **removals** (R). The manual also outlines additional guidance for example on **rebaselining** corporate footprints.

The manual describes the steps to arrive at LUC, LM and removals values per plot area (a plot is an area of land where cocoa cultivation takes places), and then describes how to consider conversion and allocation to translate emission and removals values per plot area to a kilogram or tonne of cocoa product (Section 9). Depending on what and how a company is reporting they may need the emissions and removals per the total area (e.g. the full sourcing area of a trader) or per kilogram or tonne of cocoa product (e.g. if only a portion of the volume from a sourcing area is purchased).

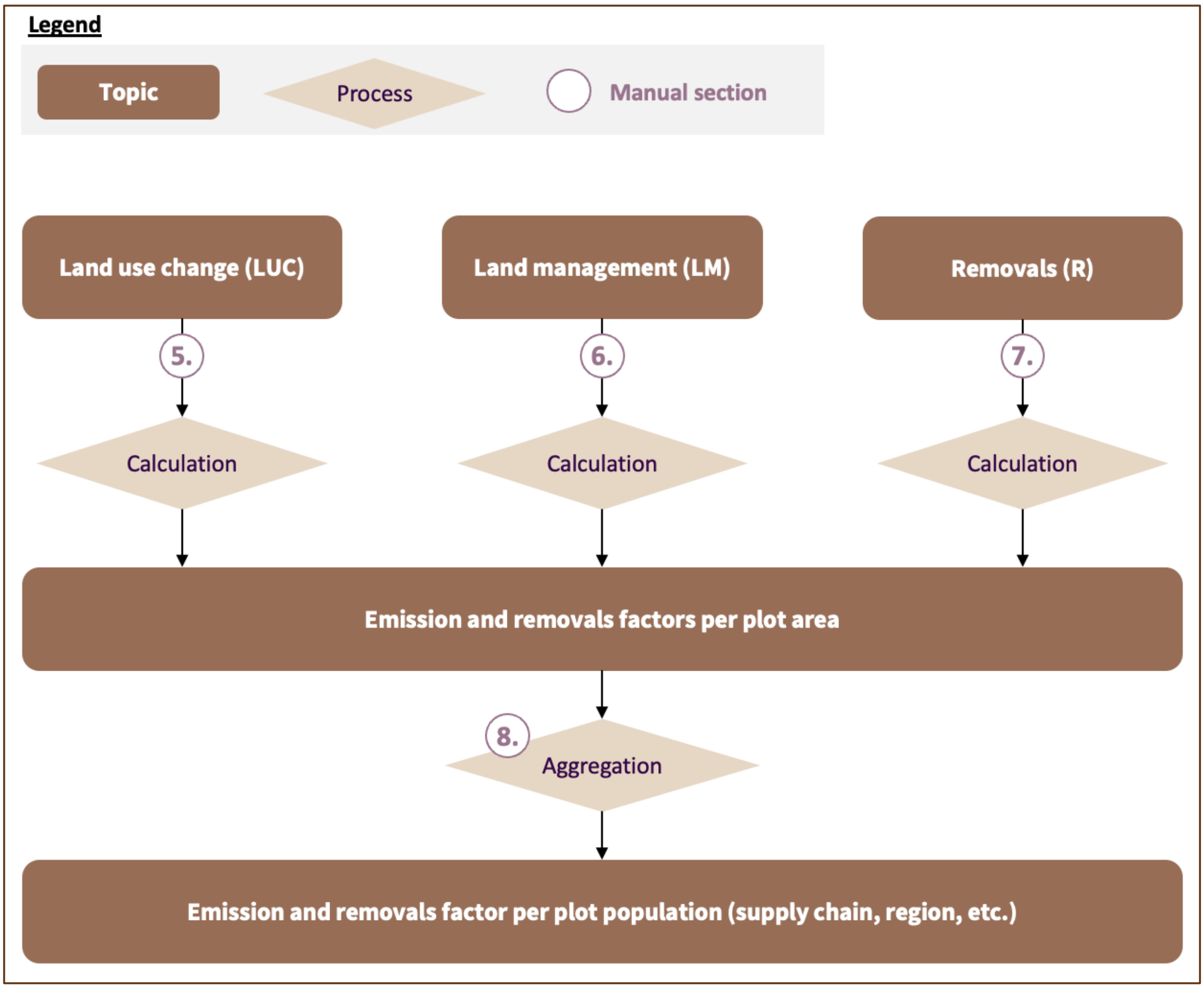


Figure 1. Schematic of the framework described by the manual. First, methods for emissions and removals are described to obtain estimates per plot area, and then the approach to obtain the emission or removal factor (i.e. $kgCO_2/kg$ cocoa) that represents cocoa sourcing from a plot population (i.e. a group of plots) is described.

To ensure alignment among companies and comparability of results, the manual provides the following for each key topic:

Minimum requirements (required by the GHG Protocol): These are requirements that the cocoa sector must follow in order to align with the Greenhouse Gas Protocol Land Sector and Removals Guidance (GHGP-LSRG draft).

Recommended requirements: Suggestions that are not explicitly required by the GHGP-LSRG (draft) but are highly recommended to support in alignment with the minimum requirements. When the GHGP-LSRG (draft) lacks clear guidance, these recommendations provide complementary approaches and, in some cases, these go beyond the minimum requirements.

Additional practices: These are alternatives to the recommendations that would also be appropriate and support alignment with the minimum requirements.

When following the manual, ensure to document the approach used to calculate the GHG emissions and removals and which requirements were followed. While this document aims to build on the GHGP-LSRG (draft), it extends beyond it by providing detailed and concrete recommendations to enable step by step guidance.

This guidance is based on Quantis' interpretation of best practices as outlined in the GHGP-LSRG (draft) released in September 2022. As the final version of the GHG Protocol has not been published at the time of writing this manual, it is important to note that the final guidance may require amendments to certain methodological aspects presented here.

The requirements follow key principles aimed at establishing a methodology that is highly:

1) **Feasible:** *Accessible to companies in the cocoa sector for example through publicly available data and tools without requiring excessive resources or expertise.*
2) **Transparent:** *Enables disclosure of sources and methods*.
3) **Accurate:** *Aims to provide best-in-class accurate accounting methods.*
4) **Conservative:** *Avoids underestimating emissions and overestimating removals.*
5) **Aligned:** *Strives for alignment across companies and when relevant with non-sector specific standards mainly the GHGP-LSRG (draft), and Science Based Targets guidelines.*

This manual gives instructions on how to proceed when using both primary data and secondary data. The GHG Protocol defines primary data as "Data from specific activities within a company's value chain"; in this manual we extend this definition to describe any **data collected outside of established databases to increase the precision of the calculation of a plot**, including data relevant to certain activity that is outside of the company's value chain. It should be noted that this use of the term is broader than its typical meaning in the scientific community, where "primary data" specifically refers to data collected directly on the ground.

2. Traceability

In the manual, traceability refers to the ability to demonstrate a **chain of custody (CoC) model. A CoC model describes the approach taken to demonstrate the physical (or administrative) link between the GHG attribute (emissions or removals value) and a specific volume of agricultural good**.

To enable credible supply chain-specific claims, certifiers have developed various CoC models.

Relevant CoC models are:

- Identity Preservation
- Segregation
- Batch-level mass balance
- Site-level mass balance
- Group-level mass balance

Definitions for the chains of custody are detailed by ISEAL[1]. An update of ISEAL definitions should be expected in later 2024.

A certificate, credit (e.g. book and claim), or GHG attribute calculation that is not tied to one of the above CoC models likely does not have a traceability system as there is no chain of custody.

Accounting requirements that balance credibility and feasibility are (at the time of writing this manual) under discussion by various NGOs and platforms guiding corporate GHG accounting. The current GHGP-LSRG (draft) has an open question related to the level of traceability required for removals accounting (Box 8.3 Open Question #3). The key question revolves around whether it is feasible to establish physical traceability to the land management unit or sourcing region while ensuring appropriate safeguards are in place. This document does not provide guidance on what is required for policy compliance, e.g. EUDR, but provides guidance on scope 3 accounting based on the current draft.

Minimum requirement (required by the GHG Protocol): Document and disclose the chain of custody model (or lack thereof) when reporting any plot-specific emission or removals estimates (e.g. dLUC or removals accounting on a specific plot).

Recommended requirements: Ensure chain of custody is in place when making product specific claims (e.g. per kilogram or tonne of cocoa bean or chocolate) in relation to emissions or removals documented on specific plot(s).

[1] At the time of writing this manual the 2016 version was used: https://www.isealalliance.org/get-involved/resources/iseal-guidance-chain-custody-models-and-definitions

Recommended requirements: If there is no chain of custody in place, calculate the average emissions value for a plot population that represents the entire sourcing region. For example, the average emission should include all identifiable plots (or a region) and not only plots with projects or interventions. Reporting emission and removals from specific plots with projects or interventions would require a chain of custody model.

To fulfill the minimum requirement, obtain the CoC information directly from a supplier or certifier. If there is no existing documentation, work to create and document a credible system by considering the following steps:

1) Contact the site-specific plot manager (e.g. the manager of the plot of land relevant for the dLUC or removals calculation).
2) Ensure that the volume purchased is tied to a volume tracking system that provides evidence that the physical volume of good with a GHG attribute flows into the supply chain of a reporting company in a given time period (i.e. reconciliation period of less than a year). Compare if this volume tracking system matches an established CoC model (e.g. group-level mass balance).
3) Confirm documentation of the physical sites where the volume of beans or cocoa products is transferred, such as from a plot to a processing facility.
4) Confirm that values sold outside the supply chain (e.g., to another trader) are being tracked.
5) Confirm that infiltrated volumes from other locations without the assessed GHG attributes are being tracked.
6) Confirm the GHG reporting for the purchased volume does not exceed the volume produced from the plot, and verify through contracts that no other company at the same level in the supply chain has reported on the same volume.
7) Confirm the allocation method of emissions and removals from the plot to the specific purchased good, and that emissions and removals originate from the same plot(s) and follow the same allocation.
8) Confirm the primary data used by the reporting company to calculate the conversion of cocoa into relevant purchased ingredients or products (e.g., liquor, powder, cake, butter, etc.). (See Section 9. Allocation and Conversion)

If any of the above steps cannot be fulfilled, it is likely there is no CoC in place, or the CoC in place is weak.

3. Plot Area & Cocoa Volume

3.1 Plot Area Definition

When companies collect plot location data, it often comes in different formats and captures various elements of the agricultural production system. For instance, locations might be logged as point coordinates recorded at the farmer's house or provided as polygons that encompass other commodities, access roads, and additional features. Keep in mind that a single farm may consist of multiple plot locations that are associated with one farmer. This manual does not offer specific guidance on how to improve and harmonize the collection of plot areas by farmers.

In this manual, we use the term **plot** to describe the location of cocoa cultivation.

A plot is a spatially coherent physical area that can either represent

(I) A spatially continuous cocoa cultivation area

(II) A spatially continuous land management or agricultural system where cocoa cultivation is integrated

Definition point II solves two major issues:

- Inclusion of adjacent lands that are not actively cultivated for removals projects (and therefore also considered in emissions estimates).
- Inclusion of non-cultivated areas on polygons or plot areas (e.g. a farm or some other land management area). Due to the diversity of ways cocoa is grown and plots are defined, it frequently occurs that a plot includes non-cultivated areas.

This definition is aligned with the current GHGP-LSRG (draft) definition of land management unit (LMU) in Section 8.2.3.

Recommended requirement: If it is possible to visually determine or calculate cocoa cultivation areas, to avoid drawing large boundaries beyond cocoa cultivation systems, it is recommended that the considered adjacent land area does not exceed the cultivated area (see Section 7.2 Adjacent lands). Exceptions can be made when justified by the local context (e.g., the Brazilian Forest code).

The manual uses the term **plot population** to describe a group of plots. A group of plots may be a sourcing region, a cocoa shed, cooperative, or some other relevant spatial area depending on how they were identified.

Recommended requirement: Assess land use change, land management, and removals on the same defined plot area(s). It is not acceptable to assess emissions and removals on different plots or plot sections (to represent a single cocoa cultivation system).

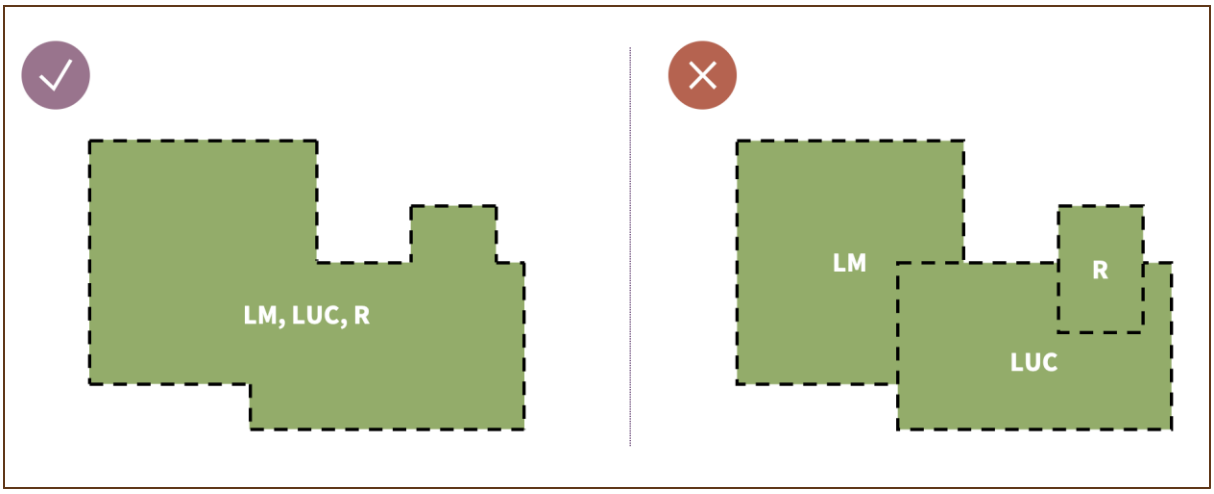


Figure 2: Recommended (left) and not recommended (right) way to define the plot land management unit (LMU)

3.2 Cocoa Volume Definition

The cocoa volumes purchased by a company do not always match the total volume produced by a list of plots. For instance, a farmer might sell to multiple companies (side-selling), meaning the company is acquiring less than the farmer's total production. Consequently, it is essential to differentiate between two types of volumes in the calculations.

Calculations for emission factors and footprints distinguish between

(I) Estimated plot's production volume (EPV)
(II) Actual procurement volume (APV)

The EPV (kg cocoa / plot area) is the total amount of cocoa produced on a given cocoa plot to be valorized, regardless of who it is sold to. Losses on field should be excluded from this amount. Dividing the emissions and removals over the plot by the EPV results in the emission or removals factor (RF) per kilogram (kg) or tonne of cocoa.

The APV (kg cocoa / plot population) is the amount of cocoa that a company sources from a given plot population (where often the per plot procured volume is unknown). Multiplying the APV by the emission or removals factor per kg of cocoa relevant for the plot population estimates the total cocoa impact of the purchases from the plot population.

3.3 Estimated production volume and yield

In theory, EPV should be derived from primary yield data collected through farmer surveys.

Recommended requirement: Due to annual yield variations, primary yield data need to be calculated as a rolling average over 3 years. During the initial 1 or 2 years of data collection, the data from only these 1 or 2 years can be used with caution (i.e., comparing to secondary data, making sure to check for outliers) until a full 3 years of data is available.

The use of a 3-years average for the EPV of each individual plot is needed because crop yields vary annually depending on a variety of factors such as the weather conditions, plant disease, and the management practices. Considering an average allows to smooth out any variations in yield that are not a stable trend through time (e.g. due to improved management), while still enabling to see and account for yield improvements over time.

In practice, companies in the cocoa sector have concerns that farmer declarations of yield are biased (e.g. over-estimated). To know if the yield provided by the farmer is within a reasonable range, it can be compared with default yield data coming from secondary sources, Table 1 provides estimated ranges of yield per country based on the World Food LCA Database (WFLDB). The archetypes are explained in the Appendix in Table 13.

If your sourcing country is not in Table 1, calculate the yield based on country-level FAOSTAT crop data:

1) Go to https://www.fao.org/faostat/en/#data/QCL
2) Under the ribbon "Countries" select your sourcing countries
3) Under the ribbon "Elements" select "Yield"
4) Under the ribbon "Items", select "Cocoa beans"
5) Under the ribbon "Years", select all years in a time frame 5 years prior to your assessment year (e.g., if your assessment year is 2022 select years 2017-2021)
6) Select "Download data"
7) Calculate the average yield over the last 5 years to use in your assessment. Note that no granularity on archetypes is available in FAOSTAT.

Table 1: Cocoa yields and their shares in the production mix from WFLDB version 3.10.

Country (kg/ha)	Low input	Medium input	Extreme high input	Agro-forestry	Improved practices	Production mix (%) | Average yield
Brazil	-	800	2000	450	-	-, 48%, 30%, 22%, - | 1083
Cameroon	450	-	-	400	600	37%, -, -, 56%, 7% | 433
Ecuador	-	800	2500	450	-	-, 52%, 33%, 15%, - | 1309
Ghana	600	-	-	550	750	39%, -, -, 36%, 25% | 620
Indonesia	-	650	1500	450	-	-, 43%, 39%, 18%, - | 946
Ivory Coast	500	-	-	450	650	51%, -, -, 36%, 13% | 502

Additional practice: If reported yield via farmer survey exceeds the values in Table 1, consider replacing with the yield value in the table that best represents the given plot, unless there is clear evidence of the accuracy of the reported value.

4. Sampling Design

Sampling is when a selected portion of plots are used to represent a larger group of plots. This section gives recommendations on choosing a relevant sample to represent a plot population for land management and removals. For land management, sampling is accepted. For removals, sampling is acceptable when extrapolating results for the same project type on different farms, e.g. the regional climate, tree types (species or varieties), tree density, and tree age are similar. No sampling and extrapolation are recommended for dLUC as the purpose of sampling is to diminish data collection requirements and for dLUC once the polygons are in-hand the data processing is highly automated.

Note that data collection is a resource intensive process that might not be necessary to do every year. The appropriate frequency for monitoring the evolution of land management practices will depend on whether improvement practices are actively being implemented, and the timeline of those practices (short-term or long-term). For example, in areas where an improvement program is underway, tracking changes annually may be necessary. In other areas, reassessing the population every five years might be sufficient. It is the company's responsibility to establish a data collection plan that aligns with their specific context.

4.1 Decision on the type of sampling

Recommended requirement: Perform random sampling in the population of plots to be represented (e.g. a farmer group, a supply shed, a jurisdiction, a country, etc.). Identify all relevant cocoa plots, assign them with a unique identifier, and then use a random values generator to identify which plots to collect data from.

Additional practice: Perform stratified sampling within a larger plot population.

4.1.1 Random sampling

Random sampling refers to randomly selecting a subset of the total population of cocoa plots that are being represented in the reporting, so that each plot has an equal probability of being chosen. This approach aims to ensure that the sample represents the entire population of plots without bias (e.g. selection of best performers).

When performing random sampling, companies need to ensure they are not applying bias when choosing the farms to sample from, and that they truly select them at random over the population of interest (e.g. representing the full scope 3, or a farmer group etc.). The plot population can be a farmer group, a supply shed, a jurisdiction, a country, etc. When reporting based on primary data, companies cannot choose a specific farmer group, supply shed, jurisdiction, or country to represent a larger population of plots (e.g. multiple farmer groups, or multiple countries).

4.1.2 Stratified sampling

When a plot population has large variation in GHG performance, a company may want to improve the insights gained from sampling and perform calculations that represent a sub-population of plots with specific characteristics.

Stratified sampling divides the total population of sourcing plots into distinct subgroups (i.e., strata) based on pre-defined characteristics, and then randomly selects plots from each strata. This helps to ensure that the sample accurately reflects the diversity within the strata sub-population of cocoa plots. By using stratified sampling, data collection captures important variations across different types of plots, providing more comprehensive and reliable insights.

When a company chooses to perform stratified sampling, the archetypes established will depend on the company's need and knowledge of the specific characteristics of the plot population to stratify. This knowledge will likely be limited at first and increase over time with the repetition of the data collection and assessment exercise.

When defining strata based on practices or geophysical characteristics, the following elements can be considered, as they are likely to influence the farm's performance and impact:

- Altitude
- Rainfall conditions
- Agroforestry practices
- Shade-grown or not
- Plot size
- Quantities of fertilizer inputs
- Type of residue management

It is possible for a company to split the total plot population into sub-groups that are representative of specific supply sheds, farmer programs or some other kind of group, instead of archetypes defined based on the farm practices and geophysical characteristics of the plot. In this case, if the calculation of GHG attributes for a larger population is based on an extrapolation of the sub-groups it is important to ensure the full plot population is assigned to a given strata and all strata are considered and weighted appropriately when estimating the GHG attributes of the larger plot population.

Keep in mind any traceability requirements when making claims that link any specific strata to a physical volume of cocoa being sold or reported on (see Section 2).

4.2 Definition of the number of samples

Recommended requirement: When performing a random sampling, choose a sample size that is statistically representative for the total population size, with a confidence level of minimum 90% and margin of error of maximum 10%. For removals in particular, the GHGP Land Sector and

Removals Guidance indicates that a choice of a confidence level lower than 95% must be justified by the robustness of the data and method used.

Additional practice: When performing stratified sampling, choose a sample size that is statistically representative for the population size of each subgroup, with a confidence level of minimum 90% and margin of error of maximum 10%. For removals in particular, the choice of a confidence level lower than 95% must be justified by the robustness of the data and method used.

The confidence level for random sampling is based on the current GHGP-LSRG (draft). For removals, it is specified for that "companies should use a 95% confidence interval or greater to represent uncertainty, but may justify other confidence levels based on the underlying data, methods, carbon pools or other relevant factors" (part 1, p98), so the requirements above align with this rigorous approach. When the sampling is not relative to removal activities, the GHGP-LSRG (draft) is more tolerant, stating in part 2, p58 that "where no uncertainty ranges are provided by IPCC national inventory guidance, companies may apply an uncertainty range of ±90% the estimate provided." Using a 95% confidence interval instead of 90%, when possible, increases the required sample size and, consequently, the costs of the data collection campaign.

An online sampling tool can be used to calculate the appropriate sample size[2] according to the confidence level desired and size of the population.

Steps can be taken to ensure the sampling plan is adequate and the sample size is large enough:

- Planning for data collection as much as possible (e.g., getting good visibility on the total plot population, letting the farmers know to expect data collection and when).
- Oversampling to create a buffer in case some farms fail to provide data, or provide data of insufficient quality and need to be excluded.
- Allocating a contingency budget to fund a second round of data collection, if necessary (e.g. in the event that too many farms provide unreliable data).

[2] Examples of online sample size calculators which can be used:
https://www.qualtrics.com/blog/calculating-sample-size/
https://www.surveymonkey.com/mp/sample-size-calculator/

5. Land Use Change Emissions of a Plot

5.1 Introduction to LUC metrics and satellite data

5.1.1 LUC metrics

Land use change can be quantified based on satellite images, with statistical data, e.g. at country level, or with a hybrid of data sources. The most common types of LUC metrics are described in the Appendix.

The recommended approach for the cocoa sector is dLUC (direct land use change) for direct supply where plot information is known and jdLUC (jurisdictional direct land use change) when plot data is not available but there is traceability to the supply shed or country level and a cocoa mask exists for these cocoa growing areas. dLUC and jdLUC can be used together within the same region where plot information exists for part of the supply chain (e.g., direct supply) and plot information does not exist for other parts of the supply chain (e.g., indirect supply chain), if the supply shed(s) are known and a cocoa mask exists. Figure 3 illustrates that dLUC should be applied when plot locations are known and, ideally, when there is traceability between the plot locations and the procured cocoa.

When neither plot level nor supply shed data exists, a form of sLUC (statistical land use change either at subnational, national or global level) should be used. sLUC provides land use change inferred from "top down" FAO statistics of crop production and land use. As such, the methods and interpretation of sLUC differ from dLUC and jdLUC and therefore these metrics should not be compared. sLUC is considered a risk assessment metric, which companies generally use prior to performing dLUC to understand where the greatest risks of LUC occur and for which commodities. Even when companies have traceability and perform dLUC or jdLUC, they are encouraged to also assess sLUC to consider the broader context of LUC in the region. In this case, the calculated sLUC will not be reported in the corporate inventory. sLUC methods are not included as part of this manual (unlike dLUC and jdLUC) as the values can be easily obtained from databases (ecoinvent, World Food LCA database, agribalyse, etc.).

5.1.2 Satellite data and the CIAT study

In this manual, satellite data refers to satellite images that have already been classified (i.e., transformed from a picture of wave signatures to something interpretable for the end user like crop occurrence or land use). Satellite data offers value for calculating dLUC, jdLUC, and sLUC, and for evaluating compliance of a plot and can be publicly or commercially available. Publicly available satellite data is often transparent, easily accessible, and covers large areas of the globe. However, publicly available data with global or supra-regional coverage can have a lower accuracy than datasets that have been calibrated on a local context (e.g., at sub-provincial level in a specific biome or agroforestry setting). Users need to be aware of the limitations of the data they use, whether publicly available, or commercial. Companies should do their due diligence to get the highest quality data, report the accuracy of the data they are using, and consider approaches that might enhance the accuracy of their data such as mosaicking (combining the best available data of each region, considering this might decrease data consistency across regions) or using multiple data sources in the same region (see e.g. WHISP[3]).

WCF is committed to continuously improving satellite data quality. WCF and CIAT rated the quality of multiple datasets and platforms to better understand their strengths and limitations (pending publication). The study assessed four distinct types of datasets for different analytical purposes:

- **Land cover data** for the year 2020
- **Carbon/Biomass data**
- **Carbon removal data**, focusing on remote sensed tree height
- **Platforms** providing out-of-the-box analyses based on these datasets

For all datasets, a thorough evaluation was conducted using over 50 metrics spanning the following quality themes:

- **Accuracy:** tests the reliability of the datasets.
- **Completeness:** evaluates whether the datasets and platforms provide adequate coverage in terms of geographic scope, temporal resolution, and data granularity.
- **Data Management:** measures the quality of the metadata and data management practices associated with datasets. FAIR principles, metadata quality, and long-term accessibility.
- **Inclusiveness**: measures how well the land cover datasets represent vulnerable and smallholder communities within cocoa-growing regions.

In total, more than 20 datasets and 4 platforms were tested, including one commercial solution. Among these, three datasets discussed in this manual were assessed: The Tree Cover Loss (TCL) layer based on Hansen et al., 2013, the Forest GHG Emissions layer based on Harris et al., 2021, and the Tropical Moist Forest layer (TMF) based on Vancutsem et al,. 2021. The assessment aimed to evaluate the datasets' suitability for various use cases, including compliance with zero-deforestation regulations and GHG accounting. Land cover data accuracy was evaluated quantitatively, while carbon/biomass and tree height data were assessed qualitatively using associated scientific publications.

The land cover assessment tested the datasets ability to identify key land cover types, including shaded and non-shaded cocoa plantations, forests, forest regrowth, non-forest natural lands, and other land types. Nearly 700 locations were selected using stratified random sampling and independently reviewed with high-resolution imagery by trained human interpreters. Validation metrics such as precision, recall, and overall accuracy were computed for all classes.

Based on the results, the study provides the following recommendations for compliance and GHG accounting:

1. **Compliance with Deforestation-Free Regulations/Certifications**
   For compliance purposes, the study emphasizes the need for detailed baselines of forest and cocoa locations at specific cutoff dates. Publicly available global datasets, such as

[3] https://www.forestdatapartnership.org/news-events/supporting-eudr-compliance-with-whisp

TCL and TMF layers, have performed poorly in this context. However, they offer strengths such as comprehensive documentation, hosting on reputable platforms for transparency and accessibility, and the use of standardized methodologies that ensure consistency and comparability across regions. Nevertheless, given their performance, they are not recommended for compliance analysis. Instead, the study advocates for the use of locally tailored datasets, which offer higher precision, especially in complex landscapes like cocoa-growing regions. To enhance accuracy and fill data gaps, the study recommends either a mosaicking approach (combining the best available data for each region, recognizing that this may reduce consistency across regions) or leveraging multiple data sources within the same region (e.g., WHISP).

2. **GHG Accounting**
   GHG accounting requires datasets with consistent, long-term time series. While few datasets meet this criterion, the study identifies the Global Forest Carbon Fluxes (2001–2023) dataset as the most comprehensive publicly available resource for carbon flux analysis and the preferred choice for public data-reliant studies. However, the dataset's dependence on TCL as a forest cover and loss baseline raises challenges in complex landscapes, such as cocoa-growing regions in Côte d'Ivoire and Ghana, necessitating cautious use in these areas. Additionally, the dataset's lack of year-specific forest loss or gain data requires integration with external sources, such as TCL, to achieve temporal specificity. This integration should be approached carefully, given the limitations of the TCL dataset highlighted in this study.

   Understanding the limitations, this manual adopts CIAT's conclusion that the Global Forest Carbon Fluxes (2001–2023) dataset is the preferred publicly available option for companies' GHG accounting - for those companies who choose to use public data instead of commercial data. Additionally, it extends the methodology used for the Global Forest Carbon Fluxes dataset to the TMF layer, as CIAT's independent validation demonstrated that TMF has higher precision than TCL in Côte d'Ivoire and Ghana.

5.1.3 Licensing of data sources

Please note that the datasets suggested to calculate dLUC and jdLUC in this manual have individual types of licensing and need for citation. Make sure to check this before using these datasets.

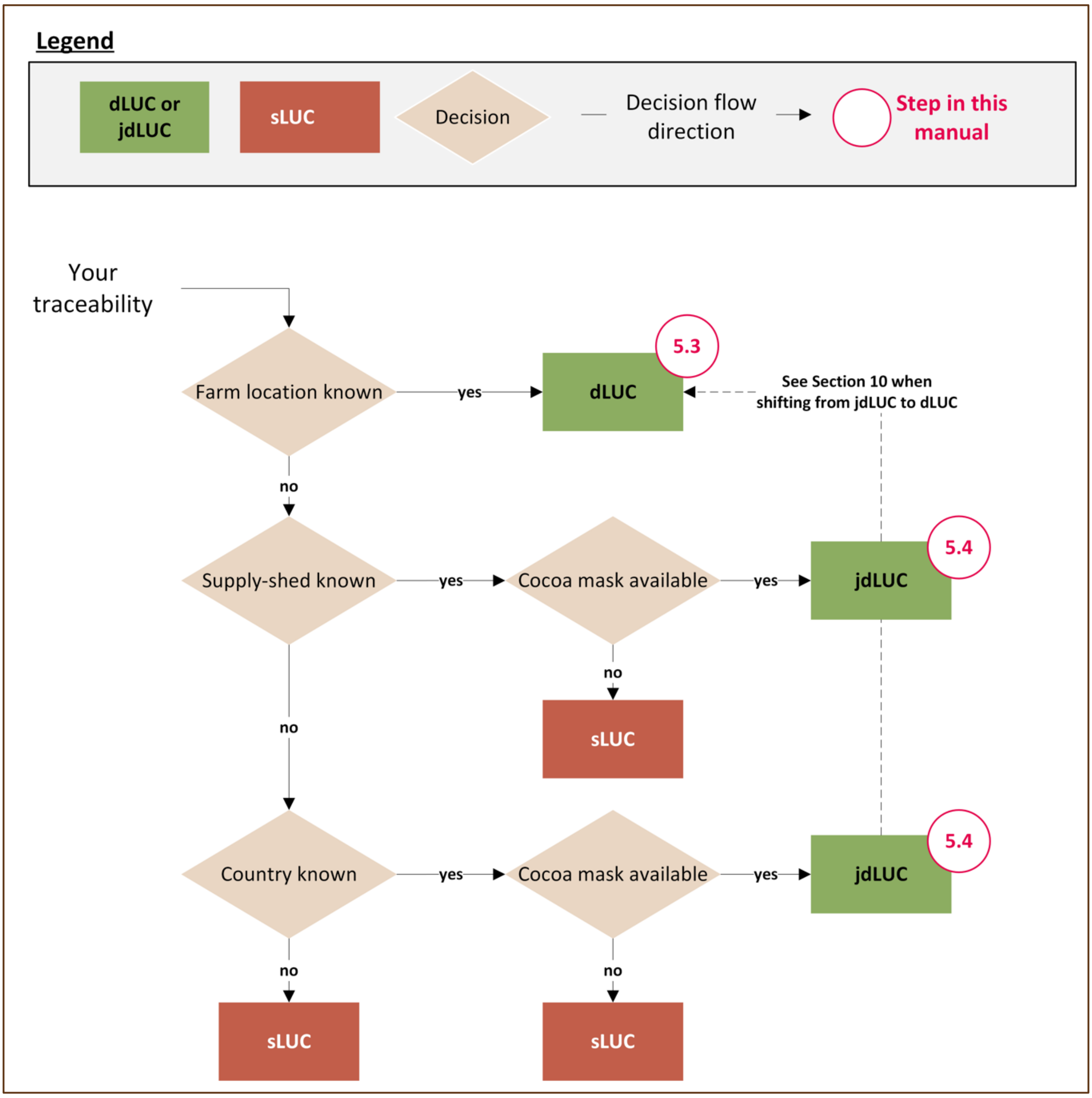


Figure 3: LUC hierarchy showing which LUC metric should be used depending on the level of traceability.

5.2 dLUC flowchart

Recommended requirement: All the steps described in this section are recommended requirements if a company is choosing to perform dLUC.

The steps to calculate direct land use change (dLUC) emissions are shown in Figure 4. The number of the step, which is described in detail further below, is indicated as a boxed number. This workflow describes geospatial processing which can be implemented with different tools.

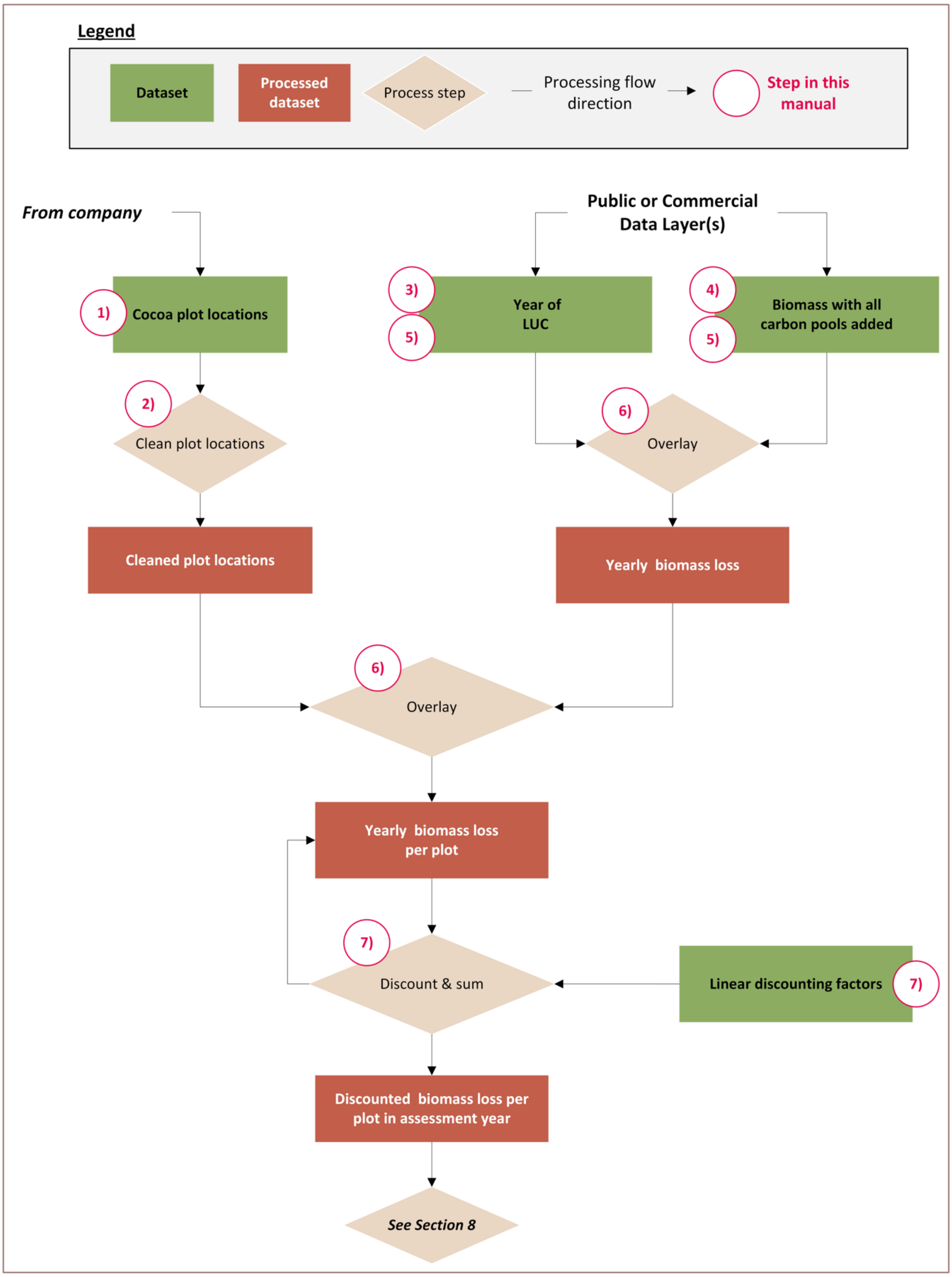


Figure 4: Processing steps of dLUC EF calculation. Steps 5 and 6 appear multiple times since they include relevant sub-steps.

More information can be found in the Appendix. Common LUC and geospatial terminology can be found in Table 14. The advantages and limitations of the most common tools are also outlined in Table 16. Finally, where relevant, the rational of the methodological choices are discussed in Table 17.

5.3 dLUC step by step

Recommended requirement: All the steps described in this section are recommended requirements if a company is choosing to perform dLUC.

This methodology explains the dLUC calculation in 8 steps. The GHGP-LSRG (draft) does not describe dLUC steps in detail. To the best of our knowledge, all steps defined in the manual are aligned with the GHGP-LSRG (draft). Companies may choose whether to use commercial datasets or those publicly available referred to in this manual. For steps 3 and 4 (LUC and biomass data) this manual follows the recommendation of the CIAT work for those that choose to use public datasets.

Please note that the datasets suggested here have individual types of licensing and needs for citation. Make sure to confirm and align with each dataset's licensing and citation needs (and any other legal intellectual property issue) before using them.

1) **Collect plot locations:**
   a. Work with your suppliers, cooperatives, or other third-parties to collect plot locations in your supply chain.
   b. Prioritize data quality (I – highest quality, V – lowest quality):
      I. Polygons outlining cocoa cultivation area (and removal areas adjacent to cocoa cultivation if relevant);
      II. Point locations ideally "in the middle" (center) of the cocoa cultivation area with size of cultivation area indicated;
      III. Point locations ideally "in the middle" (center) of the cocoa cultivation area without size of cultivation area indicated;
      IV. Polygons encompassing other production systems (e.g., cattle) or farm infrastructure (e.g., houses, streets);
      V. Points not in the middle of cocoa cultivation area and without size of cultivation area indicated.

2) **Clean plot locations:**
   a. **Outliers**: Identify and discard outlier polygons and points through visual inspection or code. Note the number of outliers for future improvement in data collection. Outliers include plots in the middle of cities or oceans. Other methods may be used to identify outliers (for example excluding plots identified with data quality IV or V as listed above). Note outlier polygons for future improvement in data collection.
   b. **Invalid polygons:** Identify and fix or discard invalid polygons (e.g., bowtie polygons which intersect themselves). Note invalid polygons for future improvement in data collection.
   c. **Points**: Buffer point locations with a circle with the size of the plot area collected in your location data collection. Resort to the values in the Appendix if you did not collect the plot area information. Prioritize point locations in the next data collection to be collected as polygons.

d. **Overlap**: Quantify all overlaps (between polygons, between buffered points, and between polygons with buffered points). Note overlaps for future improvement and visually inspect which regions might be specifically prone to overlaps. Given that it is difficult to pinpoint the reason overlaps occur (different plot collection protocols between farmer organization/suppliers, government rules on measuring land tenure, etc.), the LUC emissions should be calculated on all collected plot locations (after steps **2a.** to **2c.**). Although LUC emissions seem to be double counted on overlapping areas, so is the estimated production volume used to calculate the LUC EF. Therefore, the double counting does not necessarily lead to a systematic under- or overestimation.

Steps 3 & 4 – Option A: Forest GHG Emissions

3) Download and process Hansen Tree Cover Loss layer:

a. Go to https://storage.googleapis.com/earthenginepartners-hansen/GFC-2023-v1.11/download.html.

b. Download latest Hansen data containing the information:

  i. Tree cover in the year 2000;

  ii. Year of tree cover loss (needed for linear discounting later on).

4) Download and process Forest GHG Emissions layer:

a. Go to https://data.globalforestwatch.org/datasets/gfw::forest-greenhouse-gas-emissions/about.

b. Download latest Forest GHG Emissions (Gibbs et al., 2024) data containing the info:

  i. Biomass lost considering all carbon pools in $MgCO_2e$/pixel (without tree cover density threshold).

c. Mask the Forest GHG Emissions with **>10%** tree cover in the year 2000 (data from step **3)b.i.**) to be considered as LUC. **Warning:** CIAT tested the tree cover dataset for the year 2020 and found that using a threshold of >10% tree cover does not accurately distinguish forests from cocoa plantations. This is also likely the case for the year 2000, Users should exercise caution when applying this threshold and consider the limitations of this dataset in separating these land cover types.

d. Mask the Forest GHG Emissions with **<10%** tree cover in the year 2000 (data from step **3)b.i.**). Consider only the emissions occurring in your most recent year of your assessment period and classify them as land management (see Section 6 for details and implications).

Steps 3 & 4 – Option B: Tropical Moist Forest and GFW layers

3) Download and process Tropical Moist Forest (TMF) data

a. Go to https://forobs.jrc.ec.europa.eu/TMF/data.

b. Download the TMF layers based on Vancutsem et al., 2021, containing:

  i. Deforestation year;

  ii. Degradation year.

c. Use the TMF deforestation class to assess LUC and the TMF degradation class to assess LM only in the most recent year of your assessment period (not to be linearly discounted). The implications of this methodological choice are outlined in Table 2.

Table 2: Distinction between LUC and land management (LM) with the available TMF classes.

LUC	LM	Implications
TMF deforestation (conversion of undisturbed or degraded forest to another land cover type lasting longer than 2.5 years)	**TMF degradation** (temporary disturbance occurring on tree canopy cover for less than 2.5 years). See Section 6 on how to account for LM emissions)	• Note that approximating LM with degradation has not been extensively tested up to today • Potential underestimation of LUC in recent 3 years. • TMF updates the split of degradation and deforestation every year for the previous 3 years, potentially leading to data changes and need for rebaselining. • TMF focuses on moist forests, potentially not capturing other types of forests • **Warning:** Although the TMF dataset demonstrated better accuracy than the tree cover dataset, CIAT's analysis revealed that it still has limitations in accurately distinguishing forests from cocoa plantations in 2020. This is also likely the case for the year 2000, Users should be mindful of these constraints when using the TMF deforestation and degradation classes for their assessments.

4) Download and process GFW Above Ground Biomass (ABG) data

Note: the following steps have not been piloted as such in a project.

a. Go to https://data.globalforestwatch.org/datasets/e4bdbe8d6d8d4e32ace7d36a4aec7b93_0/explore?location=0.162491%2C0.000000%2C1.75.

b. Download the Above Ground Biomass (AGB) layer from the year 2000.

c. Add other carbon pools to AGB layer from step **2** (following the Forest GHG Emissions methodology):

   i. Below ground biomass based on Huang et al., 2020: https://figshare.com/articles/dataset/Supporting_data_and_code_for_A_global_map_of_root_biomass_across_the_world_s_forests/12199637/1?file=22432460 (obtain AGB:BGB ratio from the files "pergridarea_agb.nc" and "pergridarea_bgb.nc";

   ii. Dead organic matter based on UNFCCC, 2013, as a fraction of AGB based on a conservative estimate of 7% (Table 20 in the Appendix);

   iii. Soil organic carbon based on Hengl et al., 2017. Select the link which best fits your workflow depending on GIS tool you use: https://files.isric.org/soilgrids/latest/data/ocs/ocs_0-30cm_mean/ for downloading tiles from repository (tool agnostic), https://maps.isric.org/mapserv?map=/map/ocs.map for QGIS or ArcGIS, or https://code.earthengine.google.com/?asset=projects/soilgrids-isric/ocs_mean for Earth Engine;

iv. Peatland degradation based on the IPCC Wetlands supplement (IPCC, 2014) and Xu et al., 2017
   1. Go to https://archive.researchdata.leeds.ac.uk/251/ ;
   2. Download peatmap shapefile of your sourcing country;
   3. Intersect your cleaned plot locations from step **2** with the peatmap you just downloaded to obtain peatland specifically on your plot locations;
   4. Assign the value of 61 tCO_2e/ha/year (IPCC Wetlands supplement, see Table 17 in the Appendix for more details) to all TCL pixels that fall within the peatlands on your plot locations.

Transform all biomass values that are not in CO_2e to CO_2e by multiplying biomass with 0.47 (IPCC, 2006. Table 4.3) and multiplying with 44/12 (stochiometric ratio of CO_2 to carbon).

*Note: The following steps **5, 6, 7** and **8** are applicable for both Options A and B.*

5) Download and process grassland data

Note: this approach has not yet been widely adapted in the industry due to the recency of the data subsequently suggested to use.

a. Go to https://stac.openlandmap.org/?.language=en.
b. Download dataset with name "Global Pasture Watch: Annual grassland class and extent maps at 30-m spatial resolution" for 20 years prior to your assessment year based on Parente et al., 2024.
c. For every pair of neighboring years, check at pixel level if the land use class "Natural/semi-natural grassland" (pixel value = 2) changed to "Cultivated grassland" (pixel value = 1) or "Other land" (pixel value = 0).
d. Assign the more recent year of the neighboring year to the pixel which changed and assume a carbon stock loss of 44 tCO_2e/ha tCO_2e/ha based on moving from natural to severely degraded grassland (IPCC 2019, Table 6.2).

*Note: In steps **6** and **7**, you will calculate biomass loss and linearly discounted emissions **per plot**. This is likely too granular to be included in your corporate footprint. In addition, the uncertainty of the data (both plot locations and satellite images) is too high to allow reliable decision making at plot level (e.g., evaluating the performance of a single farmer without ground truthing). The aggregation of plot-level results to a level suitable for your corporate footprint is outlined in Section 8.*

6) Calculate biomass loss for every year per plot:

Biomass loss from tree cover/forest

a. Make sure the satellite images from step **3** (year of LUC) and step **4** (biomass loss from tree cover/forest) align, so every biomass pixel overlaps with a year-of-LUC pixel.

b. Overlay your plots from step **2** with the processed LUC data from step **3** and biomass data from step **4**.
c. Count only the part of the pixel that overlaps with the plot (pixel-bound approach).
d. Sum the biomass for each year of LUC, which gives you the biomass lost for every year per plot during your assessment period (you can achieve this by using a grouped zonal histogram where you group on the year of LUC).

Biomass loss from grassland

e. Make sure the satellite images from step **3** (year of LUC) and step **5** (biomass loss from grassland) align, so every biomass pixel overlaps with a year-of-LUC pixel.
f. Overlay your plots from step **2** with the processed LUC data from step **3** and biomass data from step **5**.
g. Follow steps **6)c.** and **6)d.** with the processed data you obtained from step **6)f.**, then continue to step **6)h.**

Bringing biomass losses together

h. Sum the yearly biomass loss from tree cover/forest (step **6)d.**) and grassland (step **6)g.** for every year.

*Note: The following steps **7** and **8** and further steps in Section 8 do not require spatial processing anymore. Therefore, you can export your results from your GIS software to continue in Excel, R, or Python, or any other language of your choice, which is usually easier than doing these steps in a GIS software.*

7) Calculate linearly discounted biomass loss in assessment year per plot:

a. Multiply your biomass loss for every year with the corresponding value in Table 3 (see Equation 1).
b. Sum up the linearly discounted emission on every plot to obtain the total linearly discounted CO_2e-emissions per plot.

Equation 1: Linear discounting of yearly biomass loss.

$$\boldsymbol{BML_{LD,plot}} = \sum_{i=1}^{20} \boldsymbol{BML_i} * \boldsymbol{LDF_i}$$

with
$\boldsymbol{BML_{LD,plot}}$: *Linearly discounted biomass loss of one plot*
$\boldsymbol{i}$: *Year in assessment period*
$\boldsymbol{BML_i}$: *Biomass loss in year i*
$\boldsymbol{LDF_i}$: *Linear discounting factor of year i (see* Table 3*)*

Table 3: Linear discounting factors relative to the assessment year (AY) and with an example of AY=2023.

Year	AY-20	AY-19	AY-18	AY-17	AY-16	AY-15	AY-14
Example	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*

Factor	**0.25%**	**0.75%**	**1.25%**	**1.75%**	**2.25%**	**2.75%**	**3.25%**
Year	AY-13	AY-12	AY-11	AY-10	AY-9	AY-8	AY-7
Example	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Factor	**3.75%**	**4.25%**	**4.75%**	**5.25%**	**5.75%**	**6.25%**	**6.75%**
Year	AY-6	AY-5	AY-4	AY-3	AY-2	AY-1	AY
Example	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
Factor	**7.25%**	**7.75%**	**8.25%**	**8.75%**	**9.25%**	**9.75%**	**N/A**

8) Optional: Account for deforestation-free verification

Satellite images can sometimes show LUC on already established cocoa plots, even if they are verified deforestation and conversion free (vDCF), if e.g. different datasets are used for GHG accounting and compliance assessments. This apparent LUC can be, for example, due to pruning, which would technically be classified as land management in the context of GHG accounting. LUC emissions on vDCF plots after the DCF cutoff date can also send confusing signals to stakeholders that interpret LUC assessments.

This challenge of LUC showing up on vDCF plots can be addressed by reclassifying LUC to LM emissions on plots that are vDCF after the cutoff date specified and if the vDCF certificate respects the following rules:

- **Ecosystems**: Consider conversion of primary and secondary forest (following FAO forest definition) as well as conversion of other relevant ecosystems like grassland and peatland;
- **Cutoff date**: Clear definition of cut-off date;
- **Verification**: Satellite monitoring at spatial resolution 30x30m (preferably 10x10m or less) since cutoff date to verify DCF status (at least annually) and/or ground truthing through field visits;
- **Scale**: Verification must happen at **plot** level.[4]

However, keep the following limitations in mind:

- Common field practices that can be classified as LM instead of LUC are (list is non-exhaustive):
  - Tree pruning
  - Replanting
  - Cutting trees in areas not classified as forest according to the FAO definitions
- Supplier mapping and related traceability to plots information can be inaccurate. Before reclassifying LUC emissions on vDCF plots as LM after the cutoff date specified, ensure that your plot locations *accurately* represent the cocoa cultivation fields. Issues that come with imprecise plot locations and therefore LUC being detected on vDCF plots are:

[4] Note: If your DCF status has been implemented at a sourcing area level, there is a risk that DCF monitoring may detect deforestation and conversion events in non-productive areas between supplier farms and plots. In such cases, you should consider refining your approach from a sourcing region to a plot-level analysis before contemplating the reclassification of LUC emissions as land management emissions.

a. In a smallholder (SH) context, forest encroachment could technically be classified as a deforestation event linked to the company's value chain. As such this scenario could lead to two outcomes:
    i. The deforestation event must be accounted for if it occurs on adjacent lands controlled by supplying SH which can no longer be considered vDCF.
    ii. The deforestation is occurring outside of the supply chain and therefore does not need to be accounted for or reclassified as LM-related emissions.
b. Supplier concession may include undeveloped land areas. Even if the supplier has been granted a vDCF status, remaining forests and natural ecosystems within the supplier's concession may still be at risk. Deforestation or conversion alerts occurring in undeveloped concession areas **should not be** reclassified as LM activities.

Supplier mapping and traceability data often suffer from inaccuracies and lack robust delineation of plot boundaries. Combined with the limitations of satellite monitoring, this makes the conditions required to reclassify LUC alerts as LM activities difficult to meet. Therefore, companies should apply vDCF *very carefully* to their GHG LUC accounting. Only if a company is confident in the accuracy of plot locations and that the LUC occurring on vDCF plots aligns with the specified field practices should the company reclassify incorrectly identified LUC emissions as LM activities.

5.4 Jurisdictional dLUC flowchart step by step

Recommended requirement: All the steps described in this section are recommended requirements if a company is choosing to perform jdLUC.

The processing steps to calculate jurisdictional direct land use change (jdLUC) emissions are shown in
Figure 5. jdLUC provides information on LUC for all cocoa area (identified with satellite imagery) within a jurisdictional region (subnational or national). The number of each calculation step, which is described in detail further below, is indicated as a boxed number. This workflow describes geospatial processing which can be implemented with different tools.

More information on common LUC and geospatial terminology can be found in the Appendix - Table 14. The advantages and limitations of the most common tools are outlined in Table 16. Finally, where relevant, the rationale of the methodological choices is discussed in Table 17.

Note that jdLUC can be either (1) calculated over all plots identified by the satellite image cocoa mask, or (2) just over the plots that are not in your direct supply chain/known sourcing. Option two shows the jdLUC average of the unknown sourcing without bias from your known sourcing. However, this might not accurately represent your cocoa supply if there is leakage from your direct supply chain into the indirect supply chain. If you are not sure about potential leakage, calculate the jdLUC as described in (1) over all plots.

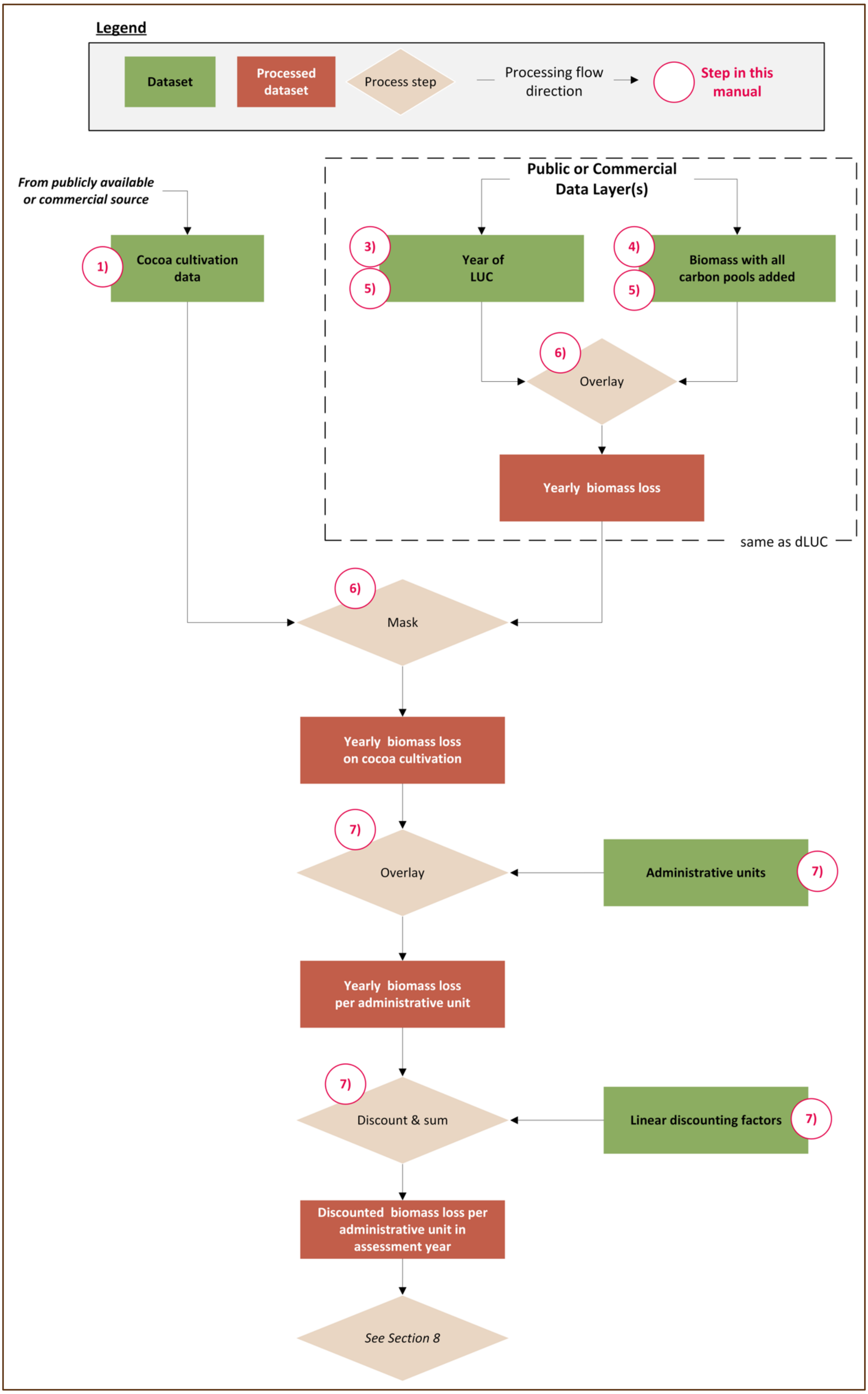


Figure 5: Processing steps of jdLUC EF calculation. Steps 6 and 7 appear multiple times since they consist of relevant sub-steps.

5.5 Jurisdictional dLUC step by step

Recommended requirement: All the steps described in this section are recommended requirements if a company is choosing to perform jdLUC.

This methodology explains the jdLUC calculation in 7 steps and is based on the dLUC step by step explanation. Where dLUC is intended for plot locations in a company's direct supply chain, jurisdictional dLUC is based on cocoa cultivation areas (i.e., from a cocoa map layer in a region or country) in a company's indirect supply chain (i.e., not supply chain specific). Like for dLUC, the GHGP-LSRG (draft) does not describe jdLUC steps in detail. To the best of our knowledge, all steps in the manual are aligned with the current GHGP-LSRG (draft). Please note that the datasets suggested here have individual types of licensing and need for citation. Make sure to check this before using these datasets.

1) **Download and process the cocoa cultivation data** (if deciding to use public data or use a proprietary layer from a commercial data provider of your choice)
    a. For Ghana and Ivory Coast in the years 2019-2021:
        i. Go to https://www.research-collection.ethz.ch/handle/20.500.11850/654400;
        ii. Download the cocoa cultivation map (covering Ghana and Ivory Coast) based on Kalischek et al., 2023 containing the following information:
            - Probability of cocoa cultivation in a 10x10m pixel;
        iii. Select only pixels that have a probability >=65% of being cocoa (as recommended by the authors);
        iv. Mention in your methodological report that this map is valid between 2019-2021 (the algorithm was trained on that time period). A limitation of this map is that it is currently only available for one point in time and does not capture cocoa grown since 2021 (expansion).
    b. For other origins and years:
        i. For Cameroon, work is ongoing to map the cocoa cultivation area[5].
        ii. For other origins and years, the data of Kalischek et al., 2023, is not available. Future work could consist of WCF and its members to either adapt the code of Kalischeck et al., 2023 by collaboration with a consultancy, university, or by engaging with a commercial data provider and making the mask available to all WCF members.
        iii. If ii) is not feasible, approximate the cocoa cultivation extent during your assessment year with the cocoa cultivation extent from the closest available year.

[5] https://www.fao.org/in-action/sepal/news-and-events/news/detail/mapping-the-path-to-sustainable-cocoa--fao-and-eu-launch-the-cartography-of-cocoa-and-forest-impacts-project-in-cameroon-(cocafori)/en [25.10.2024]

c. Mask out/exclude all cocoa cultivation pixels that fall within the polygons from your company on which you calculate the dLUC assessment. This step can be skipped if there is leakage from dLUC polygons, meaning that cocoa purchased in indirect supply chains is possibly coming from within a polygon where dLUC was assessed.

2) **Download the FAO Global Administrative Units (GAUL) layer:**
   a. Go to https://gadm.org/data.html;
   b. Download the data.

3) **Download and process year of LUC layer:**
   a. Follow step **3** from **Section dLUC step by step**.

4) **Download and process biomass layer:**
   a. Follow step **4** from **Section dLUC step by step**.

5) **Download and process grassland data:**
   b. Follow step **5** from **Section dLUC step by step**.

6) **Calculate biomass loss for every year on cocoa cultivation area country or subnational level:**
   c. Follow step 6 from **Section dLUC step by step**, but instead of your plot locations use the data from step **1)c.** so you only consider emissions occurring on cocoa cultivation area.
   a. Group the biomass loss by year of LUC, e.g. through a grouped histogram or grouped zonal statistics, where your grouping criterion is the year of LUC, within the subnational units from the administrative units layer form step **2**.

7) **Calculate linearly discounted biomass loss in assessment year per administrative unit:**
   a. Follow step **7.a.** from the **Section dLUC step by step**.
   b. Sum up the linearly discounted emissions for every administrative unit to obtain the total linearly discounted CO_2e-emissions per administrative unit.

6. Land Management Emissions of a Plot

In order to quantify land management emissions, companies can choose whether they want to use primary or secondary data, depending on their needs. If they choose to use primary data, the requirements described in Section 6.1 need to be met to ensure sufficient data quality. The decision to use primary or secondary data should be guided by the type of emission factor (EF) the company requires for its claims or reporting, as well as its access to and resources for primary data collection.

How to choose between selecting primary or secondary EFs?

- Primary EFs are helpful to track change through time in relation to implementation of more sustainable practices that influence several management factors (e.g. yield, fertilizer, energy amount etc.). To generate primary EFs for land management, it is essential to engage farm managers --either directly or through a 3rd party-- to obtain permission to use their data and to reward and incentivize the collection and fair sharing of on-the-ground information from the plots (production volumes, yields, etc.). A sampling of the total plot population can be performed in order to reduce the resource investment needed to perform the data collection (see Section 4).
- Secondary EFs (i.e. from a database) are sufficient for GHG accounting purposes, where there is no intention of claiming progress through the implementation of programs and other actions and there is no engagement with the farmer.

6.1 Primary activity data collection

Companies are free to choose a preferred method to collect primary activity data (e.g., survey, remote sensing), keeping in mind some data parameters are more important than others in the calculation of cocoa land management emissions.

Table 4 : Data parameters for primary data collection, their unit, and their importance in the calculation of GHG emissions for cocoa. Note: N is for nitrogen, P is for phosphorous, K is for potassium; for units kg is kilogram, ha is hectare, L is liter, MJ is Mega Joule, kWh is kilowatt hour, p is "pieces" or number.

Parameter	Unit	Importance
Cocoa plot Estimated Production Volume (EPV) (or yield kg/ha)	kg	**High**
Cocoa plot area	ha	**High**
Quantities of N mineral fertilizers applied to the cocoa plot	kg	**High**
Quantities and types of organic fertilizers applied to the cocoa plot	kg	**High**

Residue management method(s)	-	High
Quantity of cocoa residues (from pruning and by-products) managed with each method	kg	Medium
Quantity of agroforestry tree pruning residues managed with each method	kg	Medium
Number of agroforestry trees removed per species, corresponding DBH and plan to replant	p, cm, -	Medium
Number of agroforestry trees per species and size present in baseline year	p, cm, -	Medium
Quantity of energy used (diesel, gasoline, electricity, etc.)	L, MJ or kWh	Medium
Quantities of P and K mineral fertilizers applied to the cocoa plot	kg	Medium
Information on specific agricultural practices: intercropping, agroforestry, etc.	-	Medium
Type and quantity of pesticides used	kg	Low
Number of cocoa trees on the plot and lifetime of the trees	p	Low

Recommended requirement: For a land management emission factor to be considered a "primary EF", the following activity data that are of high importance to the emission calculation need to be primary data:

- Cocoa plot estimated production volume (EPV) (or yield kg/ha);
- Cocoa plot area quantities of N mineral fertilizers applied to the cocoa plot;
- Quantities and types of organic fertilizers applied to the cocoa plot;
- Residue management method.

For cocoa plot EPV (Section 3.2), the data should be the average of the last 3 years, as described in Section 3.3.

Recommended requirement: Medium to low importance land management data (Table 4) also need to be considered to have a complete inventory and should be collected on field as much as possible. However, they are not as impactful to the EF as the high priority parameters, therefore if the collection of primary data for these parameters is too complex, secondary data from a standard (e.g. ecoinvent, World Food LCA Database) or reputable (e.g. Control Union, agronomist fact sheets) sources can be used instead.

Recommended requirement: To ensure data are representative of the reporting period, the time period for primary data collection should be clearly documented.

Recommended requirement: Secondary data from a certification scheme cannot be used to replace the collection of primary data or to claim a primary EF (unless the certifier provides justification that the data shared are primary data following the recommended requirements in this section).

When updating a primary EF over the years, new primary data should be collected for all of the high importance parameters, to ensure representativeness of the evolution over time.

6.1.1 Fertilizers

There are 3 main types of nutrients provided by fertilizers: nitrogen (N), phosphate (P) and potassium (K). N fertilization leads to direct field emissions of N2O, a potent GHG, whereas P and K do not lead to field GHG emissions (but do have some production emissions). Therefore, it is of high importance for a carbon footprint calculation to know the amount of N applied as mineral fertilizers and of organic fertilizers (which also contain N). This is reflected in the importance given to these different parameters in Table 4. Note that urea, although it is an organic compound, also contains nitrogen which should be considered in the total quantity of N mineral fertilizer if applied.

Recommended requirement: Due to large fertilizer variations between plots, fertilizer data need to be plot specific.

Possible types of organic fertilizers include liquid manure, solid manure, compost. The minimum N concentration in organic fertilizers given in Table 5 can be considered.

Table 5: Minimum N content in organic fertilizers

Fertilizer type	N content (kg N/kg product)	Source
Liquid manure, from cattle	0.0046	Flisch et al 2009
Liquid manure, from swine	0.006	
Solid manure, from cattle	0.0051	
Solid manure, from horse	0.0068	

Solid manure, from sheep	0.008	
Solid manure, from swine	0.0078	
Poultry manure, dried	0.027	
Poultry manure, fresh	0.021	
Compost	0.014	Ecoinvent 3.10 (market for compost, GLO)

6.1.2 Pruning and husking residues

Cocoa cultivation generates three types of residues that must be considered when assessing GHG emissions related to land management:

- Cocoa tree pruning residues
- Agroforestry tree pruning residues
- Pod husk residues

Residue management is typically one of the largest contributors to GHG emissions associated with land management in cocoa cultivation.

It should be noted that husks and shells are sometimes revalorized instead of being disposed of on the cocoa farm. In this case, they can be considered co-products instead of residues, with an allocation made following the guidance in Section 9. However, if the prices of the revalorized parts are not known, or if there are other reasons to not consider them co-products, they can be excluded from the scope. In this case, their exclusion should be specified, but they don't need to be reported as co-products nor as residue emissions.

Depending on how they are handled, residues lead to different types and amounts of direct emissions, which can be very significant. Therefore, it is important to collect primary data on the residue management methods and quantities.

Recommended requirement: Due to large residue management variations between plots, residue management data need to either be plot specific, or established by an expert for the region of the plot.

Different residue management methods include spreading residues out on the fields, composting them in an unmanaged way (e.g., leaving them in an unattended pile to decompose), composting them in a managed way (e.g., turning them and tending to them regularly, or bringing them to an industrial composting facility), and burning them.

Although quantities of residues have a large influence on GHG emissions, they are often not quantified by the farmers. Therefore, the use of primary data for this parameter is not required, however it is strongly advised, if available.

If primary data on the quantities of residues are not available, the secondary data provided in Appendix XII can be used instead. Appendix XII also provides data on GHG emissions per residue management type.

6.1.3 Agroforestry tree cutting

Recommended requirement: When there are agroforestry trees on the plot that are not part of a removals program, consider their loss as land management emissions, following the guidelines in this section.

Agroforestry tree cutting leads to a loss of biomass, and therefore needs to be accounted for. There are several cases that should be taken into consideration:

- The trees removed were part of a removals program: their loss should not be accounted for in Land Management. Instead, it should be considered as reversals, and accounted for following the guidance in Section 7.3.2 Monitoring & reversal
- The trees removed were not part of the removals program and will be replanted in the next cocoa system life cycle and have a DBH of less than 35cm: their loss doesn't need to be accounted for as emissions or reversals.
- The trees removed were not part of a removals program, but they were more than 35 cm DBH: their removal represents a significant impact on the carbon accounting so their loss should be reported as land management emissions, regardless of whether they will be replanted or not.

In the last case, several options are possible to quantify the emissions associated with the loss of the trees:

- If the company is doing a dLUC assessment using the TCL layer, the data of biomass loss captured by that layer for the area corresponding to the cocoa plot can be used as a first estimation.
- The generic allometric equation provided in Appendix X along with tree species-specific wood density can be used to estimate the biomass loss. If the trees removed were part of a removals program please refer to section 7.
- The tables of tree biomass provided in IPCC 2019 chapter 4 can be used when it is not related to a removals program.

6.1.4 Using TCL data to identify biomass loss

If the company is doing a dLUC assessment using the TCL layer and identifies biomass losses on agricultural land on some of the cocoa plots considered, this needs to be taken into account. It will be considered either as land management emissions or as reversals, depending on whether there are removals projects happening on the plots.

When the TCL happens on plots that are part of removals projects, follow the guidance in Section 7.3.2 Monitoring & reversal, to count them as reversals.

When the TCL happens on plots that are not part of removals projects, follow these steps:

- Consider only the results for the plots in your data collection sample and discard the rest. Since the sample is representative of the entire population, analyzing only the sample plots is sufficient, as the average results from the sample should accurately reflect those of the total population.
- For the plots in your sample, reconcile the results of the TCL layer with those obtained through data collection on the ground.
    a. If there is no indication of tree cut or hard pruning in the data collected, but the TCL layer shows a biomass loss, apply the TCL value as a conservative approach.
    b. If the data collected indicates that trees have been cut, refer to Section 6.1.3 to know if they should be accounted for as land management or not. If they should be accounted for as land management, you can choose whether to use directly the value from the TCL layer or to calculate the biomass loss using allometric equations or IPCC 2019 equations.
    c. If the data collected indicated hard pruning but no tree cutting, do not consider biomass loss. Instead, only consider emissions from residue management according to the treatment type as detailed in Section 6.1.2.

6.1.5 Intercropping

Recommended requirement: If there is intercropping on the cocoa plot with subsistence crops, attribute the whole plot's emissions to the cocoa (conservative approach). If there is intercropping with crops traded on international market, an economic allocation of the plot's impacts can be performed between the crops produced.

When performing an allocation for intercropping, some flows should be allocated entirely to the cocoa and some should be allocated between the different crops cultivated together. The allocation should always be economic. This process should be used for intercropping with all types of crops, whether cocoa is the primary or a secondary crop on the given plot.

Even in the case when an allocation between the different crops is performed, the impacts of the following parameters should be allocated entirely to the cocoa:

- Residues from pod husks
- Cocoa tree seedling

The impacts of all other flows (i.e., fertilizers, pesticides, energy use for irrigation and fertilization) should be allocated between the different crops following a consistent economic allocation key. Guidance on how to calculate the allocation key as well as further guidance on allocation for intercropping, not specific to land management parameters, can be found in Section 9).

6.2 Step by step GHG calculations

Recommended requirement: All the steps described in this section are recommended requirements.

Step by step framework for land management emissions accounting:

1) Choose if primary or secondary data will be collected according to the requirements and recommendations in this chapter of the manual.
2) If secondary data are to be collected, ensure the database entry matches the procured product as closely as possible (location of sourcing, land management practices, type of product etc.).
3) If primary data will be collected, identify plot area to sample e.g. for the full group of plots or based on random sampling described in Section 3 when representing a large group of plots.
4) Disclose CoC information linking the physical cocoa products from the plot where data are collected to the procurement of the reporting company's supply chain (Section 2).
5) Collect primary data on parameters of high importance and if possible medium and low importance parameters (see Table 4) and complement as necessary with reputable secondary data sources (e.g. FAO, WFLDB, farm auditors, agronomists, etc.). Take care when mixing primary and secondary data when the activity in question effects multiple aspects of land management (e.g. yield and fertilizer application). For example, primary data on fertilizer cannot be mixed with secondary data on yield because fertilizer activities influence yield. Similarly, primary data on residue management can be mixed with secondary data on yield and fertilizer only when the residue management technique does not influence the amount of fertilizer applied (and thus yield) on the plot.
6) Calculate separately direct field emissions from fertilizer and residues, based on their quantities and types. This is typically done using values and equations provided by the IPCC tier 1 and tends to be pre-programmed into a GHG calculator tool (e.g. Cool Farm Tool, Quantis' eQosphere Custom, etc.). If available, IPCC Tier 2 or Tier 3 methodology should be preferred to IPCC Tier I. If an IPCC Tier 3 methodology is used, a document reporting its validation should be provided. Additionally, the equations used for these calculations should be included in the documentation of the tool being used.
7) Calculate background emissions from fertilizer production and any other activities where primary data were collected (e.g. energy production). This is done by taking an existing EF (e.g. kg CO_2eq/kg of fertilizer applied as N) and multiplying it by the information collected on the quantity of the activity on the plot (kg of fertilizer applied as N).
8) Sum the results of direct and background emissions to obtain the total land management emissions of the plot.

Complement with secondary data

When completing a primary EF with secondary data for the parameters that are of medium or low importance, the quantities should be adapted accordingly. For example, in the WFLDB datasets the quantities of inputs correspond to a surface area of 1 ha, and to a production volume indicated in the output of the dataset. Therefore, when completing a primary EF with secondary data from a WFLDB dataset, a choice must be made to scale the amount either by the surface area or by the production volume.

The table below gives guidance on how to scale each parameter. The scaling is not always done to the same parameter, because for most inputs the quantities are applied by the farmers on an area basis, regardless of whether the production volume turns out to be high or low, whereas for by-product residues (e.g. husk) the amount will be directly linked to the quantity of bean output.

Parameter	Scaling to apply
Quantity of pruning residues	Plot area
Quantity of by-product residues	EPV
Quantity of energy used (diesel, gasoline, electricity, etc.)	Plot area
Quantities of P and K mineral fertilizers applied to the cocoa plot	Plot area
Number of cocoa trees on the plot	Plot area
Quantity of pesticides used	Plot area

7. Removals on a plot

7.1 Step by step removals accounting

To reach 1.5-degree climate targets, consensus science demonstrates a need for steep GHG emission reductions and a need to go beyond business as usual (BAU) to drawdown additional CO_2 out of the atmosphere through photosynthesis and sequester it on land (Roe et al. 2019). Reducing GHG emissions by restoring natural lands as well as agroforestry and improved soil carbon sequestration in agriculture (including the addition of biochar) are key levers of action that the cocoa and agricultural sectors can promote and be counted under "removals."

In this section the step-by-step workflow as well as requirements and recommendations for corporate accounting of removals on cocoa plots are described to be aligned with the GHGP-LSRG (draft).

Minimum requirement: All the steps described in this section are minimum requirements.

Step by step framework for removals accounting

1) Identify and define the plot area where a removals project takes place. The plot area shall include cocoa cultivation and can include "adjacent lands" (Section 7.2).
2) Verify the removals project has taken place (i.e. remote sensing, photos, boots-on-the-ground), preferably through a third party. Check permanence and additionality of the project (Section 7.3). While ensuring additionality is important for meeting climate targets and establishing credibility (Section 7.3), it is not explicitly required under the GHGP-LSRG (draft). Companies may choose not to apply additionality criteria in their removals accounting. The steps that follow are applicable regardless of whether additionality is considered or not.
3) Disclose CoC information linking the physical cocoa products from the plot where the project occurs to the procurement of the reporting company's supply chain (Section 2) (i.e., identity preservation, segregation, batch-level mass balance, site-level mass balance, or group-level mass balance CoC).
4) Estimate the emissions from land management (Section 6) and land use change (Section 5) on the same plot area and using the same assumptions (e.g., allocation).
5) Ensure relevant carbon stocks are calculated and reported separately by carbon pool (above ground, below ground, soil organic carbon, and dead organic matter) (Section 7.4).
6) Select and document the quantification approach (e.g. model-based) and specific model used (e.g. specific tree allometric equation) for the chosen carbon pool (e.g. tree biomass or soil). For tree biomass, choose an allometric equation suitable for estimating agroforestry tree biomass, ensuring it aligns with the species and country-specific context (Section 7.4 and Annex X). Future work should focus on creating a list of

validated equations that match tree type (species), region, and management system (i.e. shade intensity) which are all key parameters that influence tree growth.

7) Collect the required input data for the selected quantification approach. For example, if focusing on tree biomass, this includes data such as DBH, height, or age, which can be gathered through manual "boots on the ground" sampling on plots (Section 7.4) or potentially through remote sensing (Section 7.7).
8) Calibrate quantification approaches (e.g., DNDC soil model, tree allometric equations, remote sensing models), to align with region-specific climate, ecology, land use, and management practices. Once calibrated, validate the models by comparing their outputs to a separate dataset of measured values. This validation process is essential to ensure accuracy, assess performance, and define the level of uncertainty in the estimates (Section 7.4).
9) Translate tree-based carbon calculation to plot-level removals estimate (Section 7.5)
10) Estimate the plot's carbon stock in the year before the reporting year (i.e. y-1) for the removals project by following the carbon stock quantification requirements for agroforestry or a soil organic carbon (SOC) or biochar methodology (not covered in this manual). Note that the carbon stock for the year prior to the reporting year can be zero or near zero, such as in the case of tree planting projects where trees are planted during the reporting year (i.e., the project baseline is 0). However, if additionality is not considered (i.e., a company is counting removals from pre-existing trees) and the baseline is not zero, the baseline carbon stock must be estimated and subtracted from the project's carbon stock to determine the net change. In this case, the baseline carbon stock includes all newly planted, previously planted, or naturally present biomass.
11) Using the same method (i.e. using same model, considering the same area) as in the previous step, estimate the plot's carbon stock in the reporting year (y).
12) Subtract the plot's project carbon stock from the reporting year from the previous year, y – (y-1), to obtain the net loss or gain in carbon stock. If annual measurements are not feasible, the GHGP-LSRG (draft) allows for annualized reporting over longer monitoring periods (i.e. divide the stock-difference between the monitoring years by the time period, e.g. 5 years). If annualizing, emissions and removals must be attributed to the year when they occur.
13) Ensure any carbon stock in kg or tonne of carbon are multiplied by 44/12 (molecular weight ratio between CO_2:C) to arrive at removed CO_2.
14) Loss of carbon stock shall be reported as a reversal. Gains in carbon stock can be reported under removals when requirements are met.
15) Apply buffer pool concept (minimum buffer of 20%, recommended buffer of 50% or more) (Section 7.6).

7.2 Adjacent lands

Adjacent lands (i.e. lands bordering or surrounding cocoa cultivation) can be key areas to promote carbon removals, biodiversity conservation and potentially additional income for farmers. The land area for removals reporting must be the same land area also for emissions reporting in order to align with the GHGP-LSRG (draft) concept of land management unit (LMU) and requirements for consistent accounting principles. Internal working sessions with the GHG Protocol indicate that the concept of adjacent lands is likely to be included; however, it will be necessary to await the final draft to confirm the definition and accounting requirements. Current understanding of the draft requires that the defined plot area contains both the cocoa cultivation and if relevant any adjacent lands where removals projects may take place.

Minimum requirement: If adjacent lands are considered for removals, this area must also be considered in the calculation of land management emissions and land use change emissions associated with the cocoa cultivation.

Recommended requirement: To avoid drawing boundaries beyond cocoa cultivation systems, only consider adjacent land area for a removals project that does not exceed the cultivated area. For example, if the cultivated area of a plot is one hectare, the adjacent land is no more than one hectare, and thus the full plot area is two hectares. This is a safeguard and can be revisited with evidence or rational to consider a larger area.

Recommended requirement: Take care when calculating yield and production volume when adjacent areas are included that are not cultivating cocoa. Yield typically represents the production on one hectare of cultivation area, but as required by the GHG Protocol, the emissions and removals for the full plot area shall be considered when allocating to mass of cocoa bean or product. Thereby the emissions and RF for the full area are divided by the estimated production volume (EPV) which is the volume of cocoa produced on the cultivated area.

7.3 Assurance of permanence and additionality

Permanency and additionality are key principles in ensuring carbon removals contribute effectively to climate goals. Permanency ensures long-term storage of carbon, while additionality focuses on achieving carbon sequestration beyond business-as-usual practices. In this manual, the minimum requirement for reporting carbon removals is to meet the principle of permanency as stated by the GHGP-LSRG (draft). While additionality is highly encouraged, companies may choose not to adhere to this principle as it is not explicitly required in the GHGP-LSRG (draft).

7.3.1 Documentation

Minimum requirement: Ensure there is verification and documentation that the removals project has taken place (i.e. remote sensing, boots-on-the-ground). I.e. receipts for agroforestry trees do not document the agroforestry trees have been planted.

Minimum requirement: Following a GHG Protocol LSRG (draft) requirement, removals are reported in the reporting year when the net carbon stock increase occurs in carbon pools relevant to a company's value chain. Any removal that has been claimed that has not been monitored within 5 years must be reported as a reversal. As such, documentation of previously reported removals should be verified.

7.3.2 Monitoring & reversal

Minimum requirement: Have a system that 1) keeps track of all reported removals for a company (including past reporting) for each carbon pool, 2) keeps track of the buffer pool and 3) any reversals that are subtracted from the buffer pool or otherwise need to be reported.

Recommended requirement: Removals are tracked in a database or registry including information on right-to-report (i.e. sign-off by farm manager), CoC, location, indication of the year in which the removal was reported, and when it was last monitored.

Minimum requirement: A plan is in place to monitor at least every 5 years to ensure any claimed removals are still in place (i.e. trees have not been removed), and if the previously reported removals are no longer detectable by the monitoring, they are reported as reversed or deducted from the buffer pool.

Recommended requirement: Mortality rate is typically the highest in the first years of planting. Therefore, it is suggested to check the survival rate one year after planting for all removals projects that include tree planting.

Recommended requirement: Ensure the buffer pool is also monitored (see Section 7.6).

7.3.3 Additionality and carbon in cocoa and perennial trees

Additionality is the concept that an action goes beyond business as usual (BAU). Additionality is not explicitly required under the GHGP-LSRG (draft) for removals. Companies may choose to follow the minimum requirements of the GHGP-LSRG (draft) by considering the growth of pre-existing agroforestry trees as removals, however this disregards the concept of additionality. While additionality is recommended and explained here, a consensus amongst the cocoa sector has not been made regarding the additionality principle. This is partially because, regardless of whether pre-existing agroforestry trees are included under removals, any emissions from these trees must still be monitored and reported. It is important to note that the monitoring requirements for removals demand greater effort and caution to ensure accuracy and avoid overestimation. Including pre-existing trees requires additional resources to estimate and monitor both project-related growth and pre-existing carbon stocks. The arguments in favor of considering additionality are described below.

Demonstrating additionality and putting projects in place that go above and beyond BAU is important for building public trust and enhancing the credibility of a removals project. Existing methodologies, such as the VCS (Verra, 2023), also call for only considering newly planted trees. Pre-existing trees--whether remnants of a forest, natural growth or previous agroforestry interventions-- that already contribute to existing carbon stocks are excluded. Furthermore, climate science demonstrating the need for removals to reach 1.5-degree targets is specifically referring to beyond BAU scenarios.

In most scenarios, the carbon stock of cocoa trees, as with any perennial crop, should not be included in a removals assessment, as it is considered BAU. Additionally, planting cocoa trees and other perennial crops-- such as agroforestry systems instead of monoculture, replacing annual crops, or restoring degraded land-- is already accounted for in LUC. Including this in removals assessment could result in double counting.

The scenarios under which carbon stock in cocoa trees and other perennial crops may be included (provided they follow all other requirements) would be when the average carbon stock on the land is planned to be increased through improved agroforestry management practices. Such practices may include measures that reduce tree mortality, lowering pruning intensities, or chipping and spreading pruning residues of cocoa trees on the soil.

It is also crucial for cocoa companies to remember that, under GHG Protocol guidelines, reversals accounting is required. This means that if the carbon stock in cocoa trees is accounted for, any carbon loss must also be reported as a reversal when the trees reach their economic maximum and are removed.[6]

A counterpoint to including additionality, is that companies, whether they follow the additionality principle or not, will still need to monitor baseline carbon pools to ensure that pre-existing trees (i.e. previously planted, newly planted and naturally present or re-growth) are maintained (see section 6.1.3 on land management emissions from agroforestry trees). Furthermore, parties in the accounting debate do not fully agree on the use of additionality, as it might seem to disincentivize early adopters. By not considering additionality, companies will likely be able to claim more removals than if they had considered additionality.

Recommended requirement: Unless there is a gain in average carbon stock on a parcel of land (e.g. due to changing from monoculture to agroforestry, from annual to perennial agriculture, or

[6] Unless the trees themselves become biochar; however, rules for accounting this have not yet been clarified and this is not yet an industry practice

restoring degraded land) the carbon in cocoa trees and other perennials shall be excluded from removals accounting as they are not intended to be permanent and may not go beyond BAU (i.e. are not additional).

Recommended requirement: Removals projects should be additions. For the sake of this manual, additionality can mean going beyond BAU (e.g. installing shade, windscreens, biodiversity corridors alongside farms, hedge), or can mean qualifying as "additional" according to a carbon credit methodology.

Recommended requirement: Regardless of whether companies consider additionality for removals, they must incentivize the retention of pre-existing trees on the land through mechanisms such as payments for tree survival, regardless of planting date, to prevent their unintended removal. This is particularly important in mature agroforestry systems optimized for shade and cocoa yield, where opportunities for additional removals may be limited. Maintaining existing trees is critical to avoid land management emissions or reversals, and companies are encouraged to monitor the survival and performance of previously planted agroforestry trees.

Understanding your agroforestry system during the baseline year is crucial, especially for existing systems. In particular, it is important to assess the agroforestry pool by carrying out an inventory, which includes for example the number, size, and location of trees (see Table 4). This assessment applies regardless of whether additionality is considered, and is essential for two main reasons:

1. To calculate your company's carbon stock baseline accurately (see Section 7.1, Step 10)
2. To establish monitoring processes for existing agroforestry trees, given their critical role in carbon stock building and providing social, economic, and environmental benefits.

7.4 Carbon stock calculation for agroforestry

This section details the calculation of carbon (C) stock in agroforestry when using allometric equations that approximate the C stock in a tree based on its "allometry" (i.e. shape and size). Allometric equations are usually a multiplicative or exponential equation that require the input parameters of age, height, and/or diameter at breast height (DBH) of a tree. Allometric equations can also be coupled with remote sensing information to calculate C stock. However, newly planted agroforestry trees under existing cocoa canopies are often difficult to detect remotely in their early years.

Minimum requirement: Publicly document (e.g. in a word file with the date and reference to the removals project) the methodology and process used for the C stock calculation for agroforestry. Annex XI provides a full list of recommended data to disclose.

7.4.1 Carbon pools

Focusing on AGB, where removals have the highest potential, measurement is more feasible, and uncertainties can be better quantified, is recommended, while assuming zero for BGB, SOC, and DOM in the absence of primary data or calibrated models. The logic and supporting arguments for this recommendation are presented below.

Evidence suggests the highest removals potential for cocoa is through increased tree biomass from planting shade species, rather than through soil organic carbon gain (Blaser et al. 2017). Although not included in this manual due to the lack of evidence of materiality for cocoa, companies are welcome to develop SOC calculation methods (e.g. based on the FAO LEAP) aligned with GHG Protocol to include SOC as removals. Furthermore, biochar is an emerging topic of interest which may help increase carbon stocks in soils. Soil sampling can be used to estimate changes in SOC resulting from any management practice, including biochar application. However, models such as DNDC are currently not calibrated to accurately estimate SOC changes for these practices. Although not included in this manual, companies are welcome to develop methods aligned with GHG Protocol to include biochar in their removals accounting. In the case of removals reporting via SOC or biochar, any relevant requirements and recommendations in this manual are still valid (i.e. monitoring, etc.).

Estimating belowground biomass (BGB) is labor-intensive and impractical. Root-to-shoot ratios, commonly used as proxies, are subject to significant uncertainty due to their variability across tree sizes, biomes, environmental conditions, and management practices (e.g., pruning and fertilizer input), as well as the calculation methods themselves. Additionally, root-to-shoot ratios are frequently derived from smaller trees, as they are easier to excavate; however, smaller trees typically exhibit higher root-to-shoot ratios than larger trees, leading to potential biases in biomass estimation (Huang et al., 2021).

Regarding dead organic matter (DOM), dead trees are most likely removed from the farm for use as fuel or other purposes, which do not contribute to building carbon stock on the farm. Litter may either be burned or left on the ground. If left on the ground, it decomposes and becomes part of the short-term carbon cycle or contributes to the soil organic carbon pool (Ledo et al., 2018).

Minimum requirement: Report all carbon pools separately.

Minimum requirement: Calculate C stock in agroforestry trees (AGB) through choosing appropriate allometric equations that match the species and conditions (see Table 18 Annex XI).

Minimum requirement: Assume soil organic carbon (SOC) removals are equal to 0 unless soil sampling or adequately calibrated and validated soil modeling demonstrate otherwise.

Recommended requirement: Assume dead organic matter (DOM) removals are equal to 0.

Recommended requirement: The preferred approach for estimating removals through below ground biomass (BGB) is to assume they are equal to 0, following the conservative principle. However, the GHGP-LSRG (draft) permits the use of root-to-shoot ratios. When applying root-to-shoot ratios first prioritize specificity (i.e. species- and region- specific ratios) and in second instance generic ratios specific to the region or growing conditions, e.g. as outlined in on step **4.d.i.** in **Option B** in the Section dLUC step by step.

7.4.2 Primary and secondary data

Primary data are generally data collected from the removals plot. Remote sensing can or cannot be considered as primary data depending on how the data are collected and processed. In this manual, "primary data" mainly refers to data from 'boots on the ground sampling' (i.e. direct measurements). It is assumed when GHG Protocol refers to primary data it can include remote sensing.

Minimum requirement: Use primary data (or remote sensing data) on DBH and height to estimate removals at least once every five years.

Additional practice: The number of trees planted must be based on primary data. If using secondary data or estimates on DBH and height within the first 5 years while collecting primary data (i.e., as an interim approach) ensure that: i) the data is sourced from the same species, region, and growing conditions and ii) conservative estimates are reported and justified. Once primary data becomes available, no later than year 5, implement a clear protocol to identify and report any necessary reversals in case the initial removals estimation based on secondary data were overestimated.

7.4.3 Calibration and validation of biomass allometric equations

Model calibration are essential steps in ensuring that the models used for estimating carbon stocks in cocoa agroforestry systems are accurate and reliable. Calibration involves adjusting the parameters of an equation to better reflect the local growing conditions and species. Model validation, on the other hand, evaluates the performance of the calibrated model by comparing its outputs to a separate dataset of measured values. This process also quantifies the uncertainty associated with the model.

This section provides a high-level overview of the process for selecting, calibrating and validating allometric equations. For detailed technical guidance on the calibration, validation and uncertainty assessments of allometric equations, refer to established methodologies and relevant references (e.g. Picard et al 2012, GHG Protocol Policy and Action Standard 2014, Cifuentes et al. 2015, Walker et al 2016, Jucker et al. 2017, Moreira et al. 2021).

As an initial step, prior to model calibration and validation, it should be verified whether an existing allometric equation has been previously developed and calibrated to similar species, regional-specific climate, ecology, and land management practices. Existing allometric equations can be identified through scientific literature.

Minimum requirement: Biomass carbon stocks can be measured through use of either ground-based measurements of tree diameter and height or destructive biomass sampling techniques. Companies should report internationally recognized peer-reviewed publication or protocols of allometric equations, inventory methods or destructive biomass sampling protocols applied to measure biomass carbon stock on relevant lands or strata.

Recommended requirement: A set of assessed equations is provided in Annex X and can serve as a starting point. If the target species is not listed in the Annex, a generic equation that includes wood density for species specificity can be used.

Minimum requirement: Document and quantify the uncertainty of biomass estimates. Ensure that within 5 years validation and calibration (see step by step below) of the model has been performed if it has not been already performed by the model creators and the model is being applied for the same species and region (or geospatial conditions, e.g. climate zone). Take care when using a model that has not been validated or calibrated to be conservative and disclose this.

Recommended requirement: The selected allometric equation must be verified for appropriateness (see Annex for appropriateness criteria), and its applicability can be confirmed through limited destructive sampling within the sourcing region and performing statistical tests

(Walker et al. 2016). This is a cost-effective approach compared to developing and creating a new allometric equation, as it requires significantly fewer sample trees. If an existing peer-reviewed allometric equation has been validated and demonstrated to accurately estimate biomass (e.g., within a 95% confidence interval) under local conditions, recalibration of the model may not be necessary. This is contingent on the validation process being thorough, well-documented, and including a quantification of uncertainties. When significant discrepancies arise—particularly overestimations—between predicted biomass and measured biomass (i.e. more than 5%), it is recommended to collect additional field data to re-calibrate the equation (here, re-calibration refers to adjusting an equation previously calibrated to similar growing conditions but not specific to the study) or to develop a new one.

Recommended requirement: Validate (internally or via a third party) the model estimates against measured values and evaluate the model performance through statistical analysis. As best practice follow the step by step guide below.

Step by step guide to validation and calibration (Figure 6)

1) **Collect raw data:** Document all the input and output variables in the allometric or growth equation (i.e. C in biomass, age and DBH). Specify the sampling design employed for data collection (e.g. stratified, random). Collect data on all input and output variables (note to collect C in biomass destructive or semi-destructive sampling and measurement in a laboratory is required), the age, and DBH. For tree biomass, it is recommended to do this for at least 6 different trees at 3 different ages or sizes (18 samples total). For more detailed guidance on sampling size related to tree biomass allometric equations, refer to (Piccard et al. 2012, Walker et al. 2016). A specific protocol for calibration is not provided in this manual.
2) **Split dataset (randomly):** Define independent datasets for calibration and validation, e.g. with 6 samples for validation and 12 for calibration. Keep in mind that fewer samples increase the likelihood of validation failure.
3) **Validate**: Use the validation dataset to assess the model's estimates and determine the adequacy of the model by performing statistical analysis (e.g. coefficient of determination R2, Root Mean Square Error RMSE and Mean Bias Error MBE).
4) **Report uncertainty**: From the validation, report the uncertainty (e.g. through error propagation or Monte Carlo analysis).
5) **Refine model (or increase sampling):** If the validation fails and the model produces highly biased estimates (e.g., the relationship between measured and predicted biomass significantly deviates from a 1:1 relationship, or the residuals are not evenly distributed around zero), consider collecting additional field data or refining the allometric model using the calibration dataset to better fit local conditions.
6) **Iterate:** Refine model as needed, e.g. if the model overestimates by 5%.

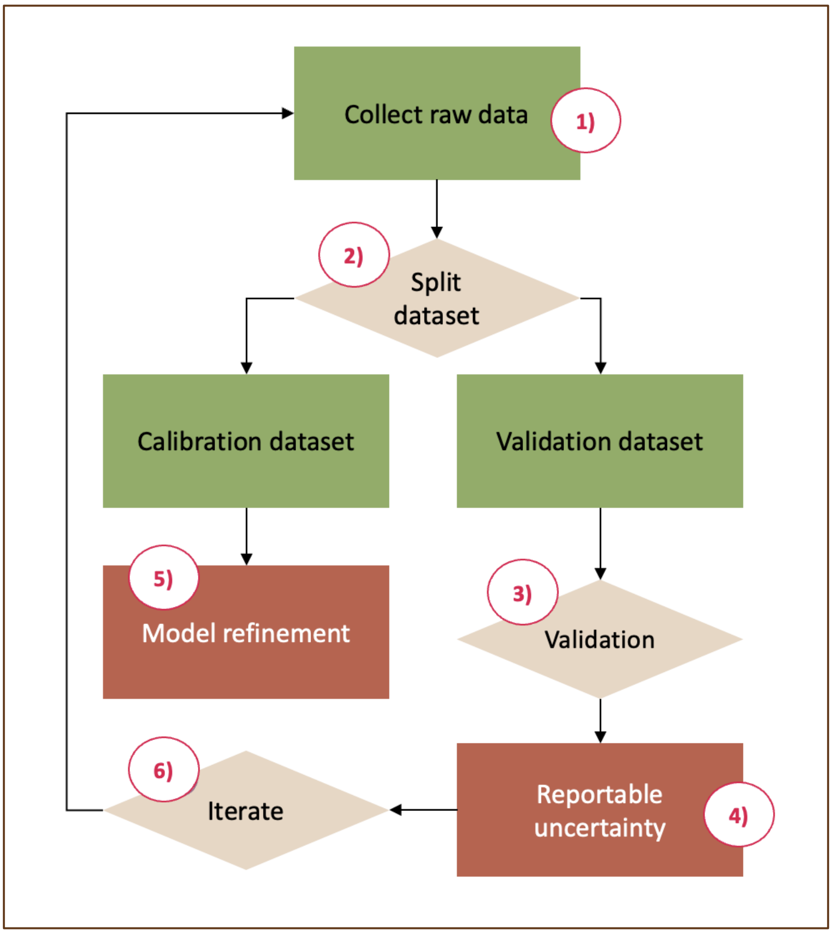


Figure 6: Workflow to validate and calibrate growth and allometric equations

7.5 Translating tree carbon to plot-level removals

To calculate plot-level removals, the final **agroforestry tree** density at maturity—different from the initial planting density—should be factored into the calculation for each species and then multiplied by the carbon content (refer to Section 7.4). Remote sensing techniques, such as satellite imagery, LiDAR, and drones, can support identifying and estimating the remaining number of trees, though their effectiveness varies. Satellites are best for broad-scale monitoring but struggle to detect individual trees in dense canopies, while aircraft and drones equipped with high-resolution cameras or LiDAR excel at precise, tree-level assessments. To ensure accuracy, remote sensing outputs must be coupled with on-the-ground sampling for validation and reliability in estimating tree density and carbon stock.

Other factors that can be used to estimate the final number of remaining trees required to calculate the carbon stock at the plot level, related to planted agroforestry trees, include:

Mortality rate

Mortality rates and planned thinning (i.e. removal of trees due to management) should be used to estimate the number of agroforestry trees remaining for the removals accounting. Monitoring is particularly crucial in the first year, when mortality is highest, and should continue for five years to track changes for each species. As a reminder, removals must be monitored continuously to ensure permanency. While on-the-ground inventory is essential in the early years—since remote sensing cannot accurately detect the mortality of young trees—it becomes less intensive over time. As the trees mature, remote sensing can be increasingly relied upon to monitor mortality.

Management

For agroforestry tree species where farmers prune to limit crown expansion and reduce competition with cocoa, it is recommended to account for the impact of pruning in the carbon stock calculation. This can be done by adjusting the estimates to reflect potential reductions in carbon stock, ensuring the calculations remain conservative. Alternatively, if pruning emissions are already included in land management emissions, no additional adjustments may be required.

Additional Safeguards

Companies may opt to add other relevant safeguards or safety factors for anticipated reversals, drawing on their expertise and field observations (e.g., the likelihood and extent of wood fuel use by the local community).

Minimum requirement: Provide justification of how removal estimates are not overestimated.

7.6 Buffer pool

Buffer pools were not a GHGP-LSRG (draft) requirement but are likely to appear in the final draft in 2025. All requirements in this section are thus preliminary placeholders before the GHGP-LSRG (draft) is published in final form.

A buffer pool is a reserved amount of removals that are not reported and are intended to safeguard a company's claims and ensure coverage for any future reversals that need to be reported. Cocoa companies agree they should maintain a buffer pool to safeguard against future reversal risks. A buffer pool does not replace the need to monitor, and buffer pools also need to be monitored (see Section 7.3). Buffer pools can consist of separate physical reserves which are not reported as removals or portions of reported removals that are accounted for but not reported.

Minimum requirement: The method for assessing the buffer pool is documented and follows the same requirements and calculation method for reported removals, including for monitoring.

Minimum requirement: The amount of buffer set aside is documented.

Minimum requirement: Detected reversals in or outside of the buffer pool diminish a buffer pool and there shall be documentation when a reversal is detected and it is deducted from a buffer pool. Reversals deducted from a buffer pool do not need to be reported.

Minimum requirement: Like reported removals, the buffer pool shall also be monitored (every 5 years). If monitoring ceases for both the buffer and the removals the full amount of reported removal shall be considered as reversed. If monitoring shows that a buffer pool has been damaged such that reversal of the buffer has occurred, it does not need to be reported as a reversal, but it shall be documented that the buffer pool is diminished. Any reported removals that are reversed in excess of the buffer pool need to be reported; e.g. if the project is fully reversed and the buffer is fully reversed the project is no longer buffered and must be fully accounted for as reversed.

Recommended requirement: A safer buffer pool option when considering tree planting (agroforestry, etc.) is creating a physically separate buffer pool which covers 100% of the reported removals such that a reversal would never have to be reported, assuming the buffer pool remains intact, is monitored, and is not itself reversed.

<u>Step by step to set a buffer pool:</u>

Recommended requirement: Engage a 3rd party or perform a risk assessment that takes into account tree mortality (which includes seedling death and risk of wildfire, and could consider if the trees are planted with intention to cut e.g. for firewood) to set the buffer pool.

Recommended requirement 1) for a buffer pool method: Adjust reported values to reserve a buffer pool (i.e. take the buffer pool from the project carbon pool) of 20%.

1) Calculate the project removals following the same requirements and calculation method for reported removals, including for monitoring.
2) Multiply by the buffer pool fraction e.g. 20% to obtain the reserved buffer amount.
3) Multiply by 1 – (buffer pool fraction) to obtain the reportable amount.

Example: A project has removed 100 tonnes of CO_2 with a buffer of 20% taken from the project.

- *100 tonnes of CO_2 removed * 20% = 20 tonnes of CO_2 reserved as buffer*
- *100 tonnes of CO_2 removed * (1-20%) = 80 tonnes of CO_2 reportable.*

Recommended requirement 2) for a buffer pool method: Reserve a separate carbon pool as a buffer pool (i.e. report the full project and reserve a separate project).

1) Calculate the project removals following the same requirements and calculation method for reported removals, including for monitoring.
2) Multiply by the buffer pool fraction to obtain the reserve amount.
3) Secure another project that is equal to the reserve amount that has not been and will not be reported.

Example: A project has removed 100 tonnes of CO_2 with a buffer of 20% from another project.

- *100 tonnes of CO_2 removed * 20% = 20 tonnes of CO_2 removal reserved as buffer*
- *100 tonnes of CO_2 is reported*
  - *A project in another location is verified to have 20 tonnes of CO_2 removal reserved as buffer that is not reported*

7.7 Integrating remote sensing data

Estimating biomass in agroforestry systems has traditionally depended on both destructive and non-destructive methods, which are often labor-intensive, costly, and challenging to scale. Remote sensing-- a model-based approach using data from technology like drones-- offers a scalable, cost-effective alternative for assessing annual carbon stock changes. Recently, accessible datasets have enhanced AGB estimation, e.g. in cocoa agroforestry systems (Lammoglia et al 2024). Allometric equations, which use tree height and crown dimensions (variables measurable through remote sensing), have been developed to estimate DBH and AGB (Asigbaase et al. 2023, Blaser et al. 2018, Jucker et al. 2016, Tiralla et al. 2013, see Annex X).

While remote sensing provides significant advantages (e.g. cost-effectiveness and scalability), it should not be viewed as a quick-fix solution for removals estimation. Achieving reliable and accurate biomass estimates still requires careful calibration, high-quality validation data, and well-structured methodologies to support and refine remote sensing outputs.

Minimum requirement: Remote sensing measurements for primary data and ongoing storage monitoring must be calibrated with on the ground inventory data, recalibrated every five years, and include uncertainty assessments.

Recommended requirement: Select the data collection method that best aligns with the study's specific analysis needs, optimizing for both cost-effectiveness and data precision. For example, in light-to-moderately shaded agroforestry systems, drone-based photogrammetry may offer a more cost-effective alternative to LiDAR (Moreira et al. 2021).

Recommended requirement: When selecting a data provider, request a sample dataset or pilot project to confirm it meets the needs, prioritize providers with agroforestry experience, and ensure the data format aligns with your reporting requirements. Work closely with the provider from the beginning to tailor updates and measurements to the specific project, adopting a hands-on approach that improves accuracy and relevance in removal estimations. Where possible, ask for a third-party accuracy assessment to validate the data's reliability.

Recommended requirement: When remote sensing data is obtained from a data service, ensure all relevant information is included, as detailed in Annex XI. This should include data sources, methods for combining remote sensing and ground data, specific models or algorithms used, and an uncertainty analysis in accordance with calibration and uncertainty guidelines.

The following example focuses on the use of aerial remote sensing through drones (unmanned aerial vehicles, UAVs), which are advancing and increasingly utilized in cocoa agroforestry (Lammoglia et al., 2024; Moreira et al., 2021). Drones are generally more suitable than satellite remote sensing for measuring tree height and canopy structure due to their higher resolution and ability to easily map individual trees. Their capability to integrate LiDAR or photogrammetry to derive 3D models of tree and forest structure provides the level of detail required for accurate removal estimations. Nevertheless, companies can choose alternative approaches based on their specific needs, resources, and study characteristics (e.g. combining drone data for detailed areas with satellite data for broader landscape analysis).

Example of Step by step process for drone-based imagery acquisition:

1) **Define biomass estimation model:** Select an allometric equation that has been calibrated and validated for the species and site conditions, or develop a new equation (e.g., relating AGB and DBH, see Annex X).

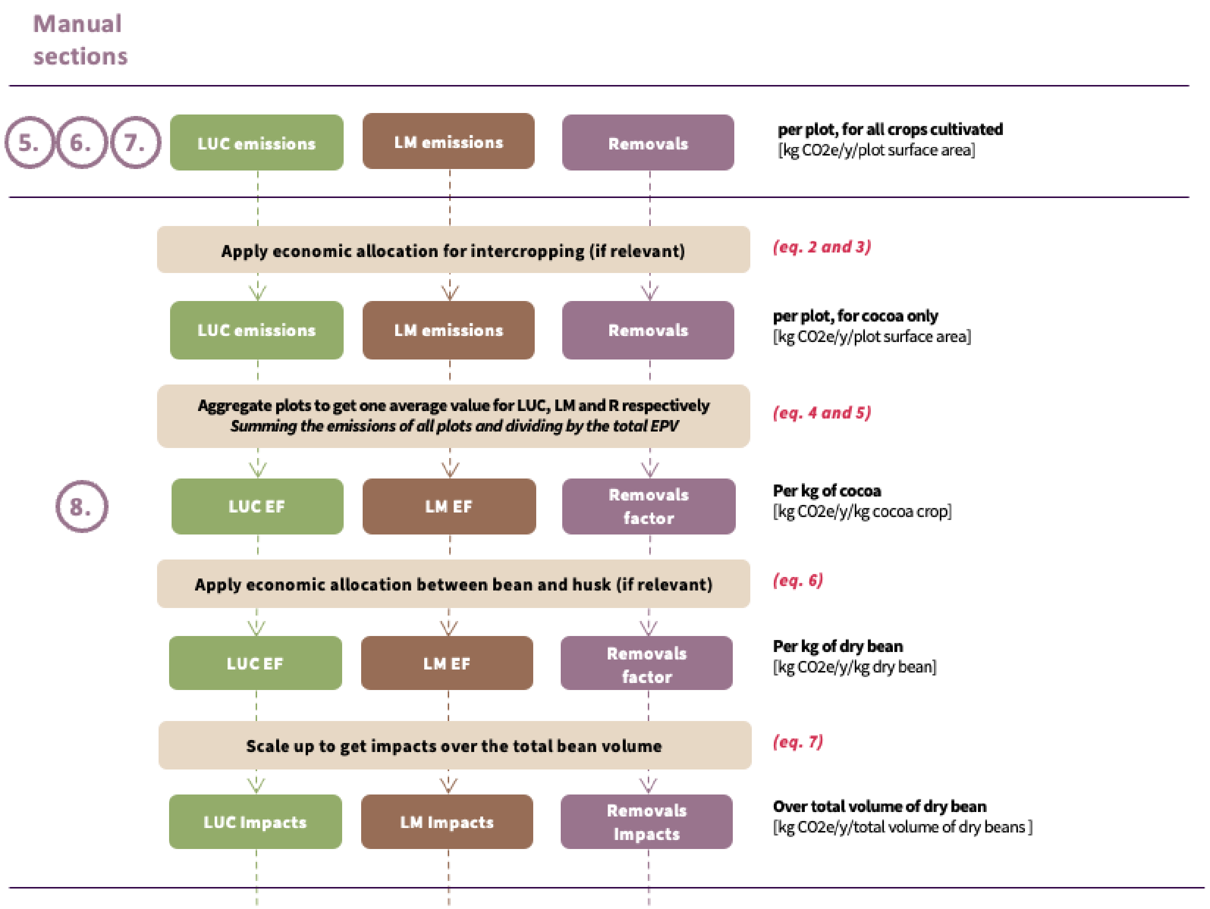
2) **Collect field measurements to validate remote sensing data** (e.g. H, DBH, crown diameter) for non-cocoa and cocoa trees.
3) **Design drone survey and settings** (e.g. timing, spatial coverage, flight altitude, interval between images, sampling design, number of images per flight, camera angle, image overlap, ground sampling distance).
4) **Execute planned flights.**
5) **Process drone-derived data and calculate variables** (e.g. use a processing software to derive tree height and crown dimensions).
6) **Convert remote-sensed measurements into biomass estimates**: Use calculated variables derived from drone images (e.g. tree height and crown diameter) to estimate DBH. Input the DBH and other relevant variables (e.g. specific wood density) into the selected allometric equation from Step 1 to calculate AGB.

7) **Validate and Calibration**: compare AGB estimates derived from airborne sensors (e.g., drone) and data processing with those obtained from field measurements. Adjust the model as needed to improve estimates, which may include fine-tuning drone configuration.
8) **Uncertainty assessments:** Apply statistical analysis to measure the precision of AGB estimates.
9) **Translate results into carbon stocks** at the plot level.

8. Emissions and removals per unit of cocoa: Results Aggregation, Allocation and Extrapolation

Each of the **Sections Land Use Change, Land Management, and Removals** showed how to calculate CO_2 emissions and removals, per plot. This section shows how to handle allocation in the case of intercropping, how to move from emissions or removals per plot to emission factors (EF) and removal factors (RF) per kilogram of cocoa, then aggregate or extrapolate to the impact per a population (or group) of plots. This group could define a “cocoa shed” or “sourcing region” or “jurisdiction” depending on how the plots have been identified. As mentioned in the Section 3, LUC is calculated on all plots and all calculations for LM and Removals should have been conducted on the same sample of plots, representing the same plot population.

Figure 7 summarizes all the steps described in this section and the following, with references to the equations in which each step is detailed and the dimension of the quantity obtained at the end.



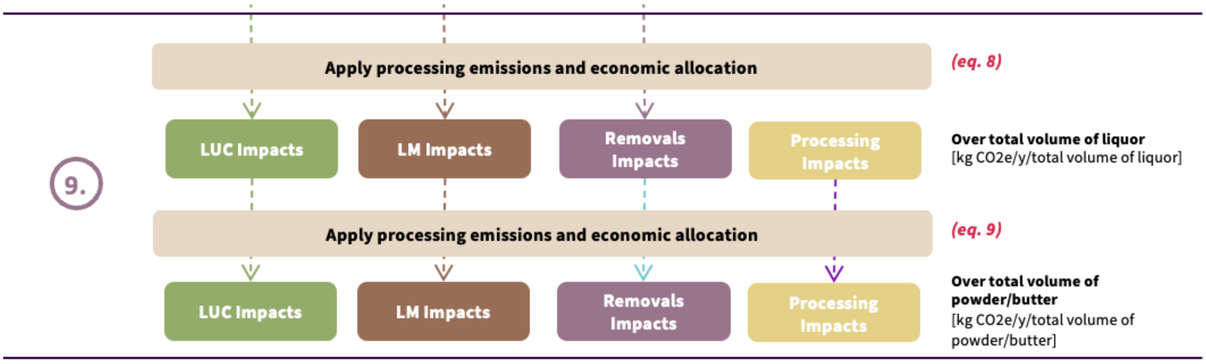


Figure 7: Summary of the different steps described in Sections 8 and 9

1) Calculate the emissions and removals allocated to cocoa on a given crop when there is intercropping:

If there is intercropping on the cocoa plots, there are 2 possible options, as outlined in the LM section:

- **Allocating all the plot emissions and removals to the cocoa**. This is the more conservative approach, and should be followed in the case of subsistence crops.
- **Doing an economic allocation of the plot emissions and removals among the different crops cultivated on the plot.** This can be relevant if the other crops cultivated alongside cocoa are traded on the international market.

If the second option is chosen, the same allocation factor should be used for all three impact components (LUC, LM and Removals). It would be incorrect to apply an impact allocation between crops for emissions but to allocate all the benefits of removals to the cocoa crop.

The allocation should be economic, and the factors will be dependent on the prices of the dry cocoa beans and of the other commodities sold at the farm gate. The allocation factors should be calculated as described in box Equation 2.

Equation 2: Economic allocation factors in the case of intercropping

$$(a.)\quad Factor_{cocoa} = \frac{Price_{cocoa} * EPV_{cocoa}}{Price_{cocoa} * EPV_{cocoa} + \sum_{i=1}^{n} Price_{other\ crop\ i} * EPV_{other\ crop\ i}}$$

$$(b.)\quad Factor_{other\ crop\ j} = \frac{Price_{other\ crop\ j} * EPV_{other\ crop\ j}}{Price_{cocoa} * EPV_{cocoa} + \sum_{i=1}^{n} Price_{other\ crop\ i} * EPV_{other\ crop\ i}}$$

with

$Factor_{cocoa}$: allocation factor for cocoa (dimensionless)

$Factor_{other\ crop\ j}$: allocation factor(s) for the other crop(s) cultivated alongside cocoa (dimensionless)

$Price_{cocoa}$: price of cocoa beans, in $

$\boldsymbol{Price_{crop\ j}}$: price of the other crop(s) sold, in $
$\boldsymbol{EPV_{cocoa}}$: estimated production volume of cocoa, in kg/y/plot surface area
$\boldsymbol{EPV_{crop\ j}}$: estimated production volume of the other crop(s) sold, in kg/y/plot surface area
$\boldsymbol{n}$: number of other crop(s) sold
$\boldsymbol{i, j}$: *plots in reporting unit*

The factors should then be applied to the LUC emissions, to the removals and to all LM flows as described in Equation 3 except those attributable solely to cocoa (i.e., cocoa residues and cocoa trees).

Equation 3: Calculation of LUC EF (a.), LM EF (b.) and RF (c.) per plot

$$(a.)\quad LUC\ Emissions_{cocoa,AY,i} = Factor_{cocoa} * LUC\ Emissions_{all\ crops,AY,i}$$

$$(b.)\quad LM\ Emissions_{cocoa,AY,i} = Factor_{cocoa} * \left(LM\ Emissions_{all\ crops,AY,i} - LM\ Emissions_{cocoa\ residues,AY,i} - LM\ Emissions_{cocoa\ trees,AY,i}\right) + LM\ Emissions_{cocoa\ residues,AY,i} + LM\ Emissions_{cocoa\ trees,AY,i}$$

$$(c.)\quad Removals_{cocoa,AY,i} = Factor_{cocoa} * Removals_{all\ crops,AY,i}$$

with
$\boldsymbol{LUC\ Emissions_{all\ crops,AY,i}}$: *LUC emissions of plot i in assessment year over the whole plot area, unallocated, in kg CO_2e/plot surface area*
$\boldsymbol{LM\ Emissions_{all\ crops,AY,i}}$: *LM emissions of plot i in assessment year over the whole plot area, unallocated, in kg CO_2e/plot surface area*
$\boldsymbol{Removals_{all\ crops,AY,i}}$: *Removals of plot i in assessment year over the whole plot area, unallocated, in kg CO_2e/plot surface area*
$\boldsymbol{LUC\ Emissions_{cocoa,AY,i}}$: *LUC emissions of plot i allocated to cocoa in assessment year over the whole plot area, in kg CO_2e/plot surface area*
$\boldsymbol{LM\ Emissions_{cocoa,AY,i}}$: *LM emissions of plot i allocated to cocoa in assessment year over the whole plot area, in kg CO_2e/plot surface area*
$\boldsymbol{Removals_{cocoa,AY,i}}$: *Removals of plot i allocated to cocoa in assessment year over the whole plot area, in kg CO_2e/plot surface area*
$\boldsymbol{i}$: *plot in reporting unit*
AY: *Assessment year*

2) Calculate the average emissions and RF per kg of cocoa crop:

Note: If using a secondary emission factor for LM from a database, this is likely already the emissions factor (EF) per kg of cocoa, so this section is not relevant.

Note: If the cocoa husks or any other parts of the pod are valorized (i.e. sold or given economic value) the term crop refers here to all harvested parts that are valorized. Otherwise, it refers to only the dry beans.

a. Sum up the plot CO_2e emissions, or removals, of all the plots in your sample (if you performed sampling) or population.
b. Sum up the plots' crop estimated production volumes (EPVs)[7] in your sample (if you performed sampling) or population. For LUC, you might not have the crop EPVs of each of the plots.
    1) When crop EPVs are missing, take the yield from primary data collection if available, or from the WFLDB (see
    Table 1) representing the plot population.
    2) Multiply the yield with each plot area to calculate the EPVs.
    3) Sum the EPVs to obtain the EPV per plot population.
c. Divide the sum of the plot CO_2e emission and removals **1a** separately by the sum of the plot EPVs from step **1b** (see Equation 4a. for LUC and Equation 4b. for LM). You now have an LM EF, a LUC EF, and a RF providing the emissions and removals per kilogram of cocoa crop.

Equation 4: Calculation of average LUC EF (a.), LM EF (b.) and RF (c.) for the plot population

$$(a.)\quad LUC\ EF_{AY,PP} = \frac{\sum_{i=1}^{n} LUC\ Emissions_{cocoa,AY,i}}{\sum_{i=1}^{n} cocoa\ EPV_i}$$

$$(b.)\quad LM\ EF_{AY,PP} = \frac{\sum_{i=1}^{n} LM\ Emissions_{cocoa,AY,i}}{\sum_{i=1}^{n} cocoa\ EPV_i}$$

$$(c.)\quad RF_{AY,PP} = \frac{\sum_{i=1}^{n} Removals_{cocoa,AY,i}}{\sum_{i=1}^{n} cocoa\ EPV_i}$$

with
$LUC\ EF_{AY,PP}$ *: Average LM EF in assessment year over plot population, in kg CO_2e/y/kg of cocoa crop*
$LM\ EF_{AY,PP}$*: Average LUC EF in assessment year over plot population, in kg CO_2e/y/kg of cocoa crop*
$RF_{AY,PP}$*: Average removal factor in assessment year over plot population, in kg CO_2e/y/kg of cocoa crop*
$cocoa\ EPV$ *: Estimated production volume of the cocoa crop on a given plot, in kg of cocoa crop*
i*: plot in reporting unit*
n*: number of plots in reporting unit*
***AY:** Assessment year*
***PP:** Plot population*

If a stratified sampling has been performed, the steps a., b., and c. need to be done for each

[7] EPV is the estimated production volume of a plot, not the procured volume from a plot.

separate archetype. The outcome will be one EF or RF for each archetype. To get the EF or RF representative of the company's sourcing from the region, calculate the average of the archetype EFs or RFs weighted by the APV of each archetype described in Equation 5.

Equation 5: Calculation of APV-weighted average LM EF and RF in plot population from different archetypes

$$(a.)\ LM\ EF_{AY,PP} = \frac{\sum_{i=1}^{n}(LM\ EF_{AY,i} * APV_i)}{\sum_{i=1}^{n} APV_i}$$

$$(b.)\ RF_{AY,PP} = \frac{\sum_{i=1}^{n}(RF_{AY,i} * APV_i)}{\sum_{i=1}^{n} APV_i}$$

with
$LM\ EF_{AY,PP}$ *: Procurement volume weighted average LM EF in assessment year over plot population, in kg* CO_2*e/y/kg of cocoa crop*
$RF_{AY,PP}$ *: Procurement volume weighted average in assessment year over plot population, in kg* CO_2*e/y/kg of cocoa crop*
APV *: Actual procurement volume of crop, in kg of cocoa crop*
i*: archetype in plot population*
n*: number of archetypes in plot population*
AY: *Assessment year*
PP: *Plot population*

3) Allocate between beans and husk (optional, if relevant)

If the cocoa pod husks from the plot population are valorized, this needs to be reflected by allocating the cocoa EF between the beans and the husks. If the husks are not valorized, they need to be accounted for as LM residues, as described in Section 6.1.

The allocation should be done by taking the total EF of the crop (beans and husks) and applying to it the ratio of the weight of husks over beans, and the average prices of husks and husks, as described in Equation 6.

Equation 6: Calculation of the emissions and RF of cocoa beans and husks from a plot population

$$(a.)\ LUC\ EF_{AY,PP,beans} = LUC\ EF_{AY,PP} * \frac{Price_{beans}}{Price_{beans} + r * Price_{husks}}$$

$$(b.)\ LUC\ EF_{AY,PP,husks} = LUC\ EF_{AY,PP} * \frac{r * Price_{husks}}{Price_{beans} + r * Price_{husks}}$$

$$(c.)\ LM\ EF_{AY,PP,beans} = LM\ EF_{AY,PP} * \frac{Price_{beans}}{Price_{beans} + r * Price_{husks}}$$

$$(d.)\ LM\ EF_{AY,PP,husks} = LM\ EF_{AY,PP} * \frac{r * Price_{husks}}{Price_{beans} + r * Price_{husks}}$$

$$(e.)\ \boldsymbol{RF_{AY,PP,beans} = RF_{AY,PP} * \frac{Price_{beans}}{Price_{beans} + r * Price_{husks}}}$$

$$(f.)\ \boldsymbol{RF_{AY,PP,husks} = RF_{AY,PP} * \frac{r * Price_{husks}}{Price_{beans} + r * Price_{husks}}}$$

with

$\boldsymbol{LUC\ EF_{AY,PP,beans}}$: *LUC EF of the cocoa beans in assessment year in plot population, in kg CO_2e/y/kg of cocoa beans*

$\boldsymbol{LUC\ EF_{AY,PP,husks}}$: *LUC EF of the cocoa husks in assessment year in plot population, in kg CO_2e /y/kg of cocoa husks*

$\boldsymbol{LUC\ EF_{AY,PP}}$: *Total LUC EF of the cocoa (beans and husks) in assessment year in plot population, in kg CO_2e /y/kg of cocoa crop*

$\boldsymbol{LM\ EF_{AY,PP,beans}}$: *LM EF of the cocoa beans in assessment year in plot population, in kg CO_2e /y/kg of cocoa beans*

$\boldsymbol{LM\ EF_{AY,PP,husks}}$: *LM EF of the cocoa husks in assessment year in plot population, in kg CO_2e /y/kg of cocoa husks*

$\boldsymbol{LM\ EF_{AY,PP}}$: *Total LM EF of the cocoa (beans and husks) in assessment year in plot population, in kg CO_2e /y/kg of cocoa crop*

$\boldsymbol{RF_{AY,PP,beans}}$: *RF of the cocoa beans in assessment year in plot population, in kg CO_2e /y/kg of cocoa beans*

$\boldsymbol{RF_{AY,PP,husks}}$: *RF of the cocoa husks in assessment year in plot population, in kg CO_2e /y/kg of cocoa husks*

$\boldsymbol{RF_{AY,PP}}$: *Total RF of the cocoa (beans and husks) in assessment year in plot population, in kg CO_2e /y/kg of cocoa crop*

$\boldsymbol{Price_{beans}}$: *Price of cocoa beans*
$\boldsymbol{Price_{husks}}$: *Price of cocoa husks*
r: *weight ratio of cocoa husks over beans*
AY: *Assessment year*
PP: *Plot population*

4) Calculate the CO_2e impact of your plot population in your portfolio:

a. Collect the actual procurement volumes (APVs) of dry cocoa beans per plot population in your portfolio.
b. Multiply the emission or removal factors from step **1)** or **2)** with the APVs as defined in Section 3.2 for each plot population (see Equation 7).

Equation 7: Calculation of impacts of cocoa dry beans from the plot population

$$(a.)\ \boldsymbol{LUC\ Impacts_{AY,PP} = LUC\ EF_{AY,PP} * APV_{PP}}$$
$$(b.)\ \boldsymbol{LM\ Impacts_{AY,PP} = LM\ EF_{AY,PP} * APV_{PP}}$$
$$(c.)\ \boldsymbol{Removal\ Impacts_{AY,PP} = RF_{AY,PP} * APV_{PP}}$$

with

$\boldsymbol{LUC\ Impacts_{AY,PP}}$: *LM total impact of the procured volume in assessment year over plot population, in kg CO_2e /y/total volume of dry beans*

$\boldsymbol{LM\ Impacts_{AY,PP}}$: *LUC total impact of the procured volume in assessment year over plot population, in kg CO_2e /y/total volume of dry beans*
$\boldsymbol{Removal\ Impacts_{AY,PP}}$: *Removals total impact of the procured volume in assessment year over plot population, in kg CO_2e /y/total volume of dry beans*
$\boldsymbol{APV}$: *Actual procurement volume*
AY: *Assessment year*
PP: *Plot population*

If the cocoa husks are valorized, apply equations 5 with the EF and APV for beans and husks directly to get their specific impacts.

9. Processing, allocation and conversion for cocoa derivatives

This section describes how to go from the emission and removals estimated per dry bean, to emissions and removals attributable to cocoa derivatives.

When dry cocoa beans are processed, they are first separated between shells and liquor, and the allocation rationale for this first step is described in Section A. Then the liquor can be processed into butter and powder, and the allocation rationale for this second step is described in Section B.

At each step, there are processing impacts to account for as well as an allocation or conversion from the input product to the output product(s).

Table 6 gives a summary of the default secondary data to use for conversion and allocation of derivatives in the case when primary data is unavailable. A conversion to dry bean equivalent (BEQ) is also included in the table; this is done by taking the inverse of the yield. More details on the references and the calculations are given in the respective sub-sections below.

Table 6: Default secondary data for cocoa derivatives conversion and allocation

Product	Yield (kg output product / kg input product)	Price ($/kg product)	Allocation factor (%)	Dry bean equivalent (BEQ) (kg allocated dry bean / kg product)
Liquor	0.8	3.53	95%	1.19
Shells	0.2	0.7	5%	0.25
Powder	0.55	2.34	35%	0.75
Butter	0.45	5.29	65%	1.71

When a process yields different co-products with some of them leaving the company's value chain (e.g., shells being transformed into biochar), the company can decide not to perform allocation, and instead to attribute all emissions and removals to the cocoa products used by the company. In this case, the company must make sure that:

- the same scope is indeed considered for both emissions and removals (same area and quantity of product);
- the party buying or using the co-product is not claiming the associated removals, to avoid double counting.

A. From dry beans to liquor and shells

Processing

Processing the dry beans into liquor requires energy, which should be accounted for at this stage, as well as transport from the factory to the plant. Moreover, if shells are not valorized, the impacts of their processing or waste treatment should be calculated and added to the other parts of the impact. For this, data on the treatment applied to the shells should be collected at plant.

If no primary data on the quantity of energy use, transport and shell by-products are collected, the secondary data in Table 7 can be used.

Table 7: Minimum secondary data on dry bean processing

Parameter	Quantity	Source
Electricity, grid, low voltage	0.220 kWh / kg beans	WLFDB 3.10 – Cocoa liquor, at plant Half of the amount is taken, as the dataset also includes energy for processing into powder and butter.
Heat, district or industrial	0.185 kWh / kg beans	WLFDB 3.10 – Cocoa liquor, at plant Half of the amount is taken, as the dataset also includes energy for processing into powder and butter.
Transport	200 km	WLFDB 3.10 – Cocoa liquor, at plant
Shell	0.11 kg shell / kg beans	Vergara-Mendoza et al. 2022 - Table S1

Yield and economic allocation

When cocoa shells are valorized at the plant, this should be reflected by attributing part of the cocoa plot's GHG emissions (and removals) to the shells. This is done by taking the cocoa bean emissions calculated in Section 8 and applying an economic allocation using the following parameters:

- the weight ratio of shells to liquor and;
- the shell and liquor prices.

The formulas to apply are described in Equation 8.

Equation 8: Calculation of the respective impacts of cocoa liquor and shells from a plot population

$$(a.)\, LUC\ Impacts_{AY,PP,liquor} = LUC\ Impacts_{AY,PP,beans} * \frac{Price_{liquor}}{Price_{liquor} + r * Price_{shells}}$$

$$(b.)LUC\ Impacts_{AY,PP,shells} = LUC\ Impacts_{AY,PP,beans} * \frac{r * Price_{shells}}{Price_{liquor} + r * Price_{shells}}$$

$$(c.)LM\ Impacts_{AY,PP,liquor} = LM\ Impacts_{AY,PP,beans} * \frac{Price_{liquor}}{Price_{liquor} + r * Price_{shells}}$$

$$(d.)LM\ Impacts_{AY,PP,shells} = LM\ Impacts_{AY,PP,beans} * \frac{r * Price_{shells}}{Price_{liquor} + r * Price_{shells}}$$

$$(e.)Removal\ Impacts_{AY,PP,liquor} = Removal\ Impacts_{AY,PP,beans} * \frac{Price_{liquor}}{Price_{liquor} + r * Price_{shells}}$$

$$(f.)Removal\ Impacts_{AY,PP,shells} = Removal\ Impacts_{AY,PP,beans} * \frac{r * Price_{shells}}{Price_{liquor} + r * Price_{shells}}$$

$$(g.)Processing\ Impacts_{AY,liquor} = Processing\ Impacts\ _{AY,beans} * \frac{Price_{liquor}}{Price_{liquor} + r * Price_{shells}}$$

$$(h.)Processing\ Impacts_{AY,shells} = LM\ Impacts_{AY,beans} * \frac{r * Price_{shells}}{Price_{liquor} + r * Price_{shells}}$$

with
$LUC\ Impacts_{AY,PP,liquor}$: *LUC impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*
$LUC\ Impacts_{AY,PP,shells}$: *LUC impacts of the cocoa shells in assessment year over plot population, in kg CO_2e /y/total volume of shells*
$LUC\ Impacts_{AY,PP,beans}$: *LUC impacts of the cocoa beans in assessment year over plot population, in kg CO_2e /y/total volume of beans*

$LM\ Impacts_{AY,PP,liquor}$: *LM impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*
$LM\ Impacts_{AY,PP,shells}$: *LM impacts of the cocoa shells in assessment year over plot population, in kg CO_2e /y/total volume of shells*
$LM\ Impacts_{AY,PP,beans}$: *LM impacts of the cocoa beans in assessment year over plot population, in kg CO_2e /y/total volume of beans*

$Removal\ Impacts_{AY,PP,liquor}$: *Removal impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*
$Removal\ Impacts_{AY,PP,shells}$: *Removal impacts of the cocoa shells in assessment year over plot population, in kg CO_2e /y/total volume of shells*
$Removal\ Impacts_{AY,PP,beans}$: *Removal impacts of the cocoa beans in assessment year over plot population, in kg CO_2e /y/total volume of beans*

$\textit{\textbf{Processing Impacts}}_{AY,liquor}$: *Impacts of the processing of the total dry beans volume in assessment year that is allocated to the liquor, in kg CO_2e /y/total volume of liquor*
$\textit{\textbf{Processing Impacts}}_{AY,shells}$: *Impacts of the processing of the total dry beans volume in assessment year that is allocated to the shells, in kg CO_2e /y/total volume of shells*
$\textit{\textbf{Processing Impacts}}_{AY,beans\ transformation}$: *Impacts of the processing of the total dry beans volume in assessment year, unallocated, in kg CO_2e /y/total volume of beans*

$\textit{\textbf{Price}}_{liquor}$: *Price of cocoa liquor, in $*
$\textit{\textbf{Price}}_{shells}$: *Price of cocoa shells, in $*
r: *weight ratio of cocoa shells over liquor*
AY: *Assessment year*
PP: *Plot population*

If no primary data on the yield of shells versus liquor at plant is collected, the following secondary data from Rojas et al. 2021 can be considered: 1'000 kg of beans yields, 200 kg of shells and 800 kg of liquor. This leads to a ratio of 0.25 kg shells / kg liquor.

If no primary data on the difference in economic value between shells and liquor is collected, the following secondary data from FAOSTAT averaged over the years 2018-2022 can be considered:

- 0.70 $ / kg shells
- 3.53 $ / kg liquor

B. From liquor to powder and butter

Processing

Processing the liquor beans into powder and butter requires energy, which should be accounted for at this stage. If no primary data on the quantity of energy use is collected, the secondary data in Table 8 can be used.

Table 8: Minimum secondary data on liquor processing

Parameter	Quantity	Source
Electricity, grid, low voltage	0.220 kWh / kg beans	WLFDB 3.10 – Cocoa liquor, at plant Half of the amount is taken, as the dataset also includes energy for processing into powder and butter.
Heat, district or industrial	0.185 kWh / kg beans	WLFDB 3.10 – Cocoa liquor, at plant Half of the amount is taken, as the dataset also includes energy for processing into powder and butter.

Yield and economic allocation

When the commodity procured is powder or butter, the impacts of the transformation should be added, and the overall impacts need to be split between these commodities. This is done by taking the cocoa liquor impacts calculated in part A and applying the following parameters:

- the weight ratio of butter to powder;
- the butter and powder prices.

The formulas to apply are described in box Equation 9.

Equation 9: Calculation of the respective impacts of cocoa powder and butter from a plot population

$$(a.)\ \textit{LUC Impacts}_{AY,PP,powder} = \textit{LUC Impacts}_{AY,PP,liquor} * \frac{Price_{powder}}{Price_{powder} + r * Price_{butter}}$$

$$(b.)\ \textit{LUC Impacts}_{AY,PP,butter} = \textit{LUC Impacts}_{AY,PP,liquor} * \frac{r * Price_{butter}}{Price_{powder} + r * Price_{butter}}$$

$$(c.)\ \textit{LM Impacts}_{AY,PP,powder} = \textit{LM Impacts}_{AY,PP,liquor} * \frac{Price_{powder}}{Price_{powder} + r * Price_{butter}}$$

$$(d.)\ \textit{LM Impacts}_{AY,PP,butter} = \textit{LM Impacts}_{AY,PP,liquor} * \frac{r * Price_{butter}}{Price_{powder} + r * Price_{butter}}$$

$$(e.)\ \textit{Removal Impacts}_{AY,PP,powder} = \textit{Removal Impacts}_{AY,PP,liquor} * \frac{Price_{powder}}{Price_{powder} + r * Price_{butter}}$$

$$(f.)\ \textit{Removal Impacts}_{AY,PP,butter} = \textit{Removal Impacts}_{AY,PP,liquor} * \frac{r * Price_{butter}}{Price_{powder} + r * Price_{butter}}$$

$$(g.)\textit{Processing Impacts}_{AY,powder} = \textit{Processing Impacts}_{AY,liquor\ transformation} * \frac{Price_{liquor}}{Price_{liquor} + r * Price_{shells}}$$

$$(h.)\textit{Processing Impacts}_{AY,butter} = \textit{LM Impacts}_{AY,liquor\ transformation} * \frac{r * Price_{shells}}{Price_{liquor} + r * Price_{shells}}$$

with

$\boldsymbol{LUC\ Impacts_{AY,PP,powder}}$: *LUC impacts of the cocoa powder in assessment year over plot population, in kg CO_2e /y/total volume of powder*
$\boldsymbol{LUC\ Impacts_{AY,PP,butter}}$: *LUC impacts of the cocoa butter in assessment year over plot population, in kg CO_2e /y/total volume of butter*
$\boldsymbol{LUC\ Impacts_{AY,PP,liquor}}$: *LUC impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*

$\boldsymbol{LM\ Impacts_{AY,PP,powder}}$: *LM impacts of the cocoa powder in assessment year over plot population, in kg CO_2e /y/total volume of powder*
$\boldsymbol{LM\ Impacts_{AY,PP,butter}}$: *LM impacts of the cocoa butter in assessment year over plot population, in kg CO_2e /y/total volume of butter*
$\boldsymbol{LM\ Impacts_{AY,PP,liquor}}$: *LM impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*

$\boldsymbol{Removal\ Impacts_{AY,PP,powder}}$: *Removal impacts of the cocoa powder in assessment year over plot population, in kg CO_2e /y/total volume of powder*
$\boldsymbol{Removal\ Impacts_{AY,PP,butter}}$: *Removal impacts of the cocoa butter in assessment year over plot population, in kg CO_2e /y/total volume of butter*
$\boldsymbol{Removal\ Impacts_{AY,PP,liquor}}$: *Removal impacts of the cocoa liquor in assessment year over plot population, in kg CO_2e /y/total volume of liquor*

$\boldsymbol{Processing\ Impacts_{AY,powder}}$: *Impacts of the processing of the total liquor volume in assessment year that is allocated to the powder, in kg CO_2e /y/total volume of powder*
$\boldsymbol{Processing\ Impacts_{AY,butter}}$: *Impacts of the processing of the total liquor volume in assessment year that is allocated to the butter, in kg CO_2e /y/total volume of butter*
$\boldsymbol{Processing\ Impacts_{AY,liquor\ transformation}}$: *Impacts of the processing of the total liquor volume in assessment year, unallocated, in kg CO_2e /y/total volume of liquor*

$\boldsymbol{Price_{powder}}$: *Price of cocoa powder, in $*
$\boldsymbol{Price_{butter}}$: *Price of cocoa butter, in $*
r: *weight ratio of cocoa butter over powder*
AY: *Assessment year*
PP: *Plot population*

If no primary data on the yield of butter versus powder at plant is collected, the following secondary data from Beg et al. 2017 can be considered: 1'000 kg of liquor yields 450 kg of butter and 550 kg of powder. This leads to a ratio of 0.82 kg butter / kg powder.

If no primary data on the difference in economic value between butter and powder is collected, the following secondary data from FAOSTAT averaged over the years 2018-2022 can be considered:

- 5.29 $ / kg butter
- 2.34 $ / kg powder

10. Rebaselining & Tracking Progress

Rebaselining a corporate footprint (CF) refers to when a base year's corporate footprint e.g. used towards the Science Based Target initiative (SBTi) needs to be re-estimated to track progress through time and compare with future years' corporate footprints. The key need when rebaselining is to differentiate progress towards climate targets from methodological or data changes that affect the calculation but do not reflect actual improvements in emissions or removals. Subsequently, general rebaselining practices are explained, followed by examples specific to cocoa.

1) Distinguish between progress and methodological change

a. Document any changes in data and/or methodology between the base year and current reporting year.

b. Check Table 9 to distinguish between progress methodological change. Color coding in the table helps qualify the change. Note that although the distinction between active and passive progress in a rebaselining is not necessarily needed, it is recommended to make a distinction when communicating about progress, e.g., in your corporate sustainability report.

   I. **Active progress**[1]: Actively driven progress through corporate activity.
   → Report progress.

   II. **Passive progress**[2]: Progress driven outside of corporate activity (e.g. new regulation).
   → Report progress, but use caution with company-specific claims

   III. **Data changes**[3]: Data changes, e.g. switching from secondary to primary data.
   → Do not count as progress.

   IV. **Methodological changes**[4]: Method changes, e.g. in a background database or software.[8]
   → Do not count as progress.

   V. **Entangled changes**[5]: Real improvements and method improvements that occur simultaneously.
   → Do not count as progress until dis-entangling.

c. See Table 10 and Table 11 for specific examples in cocoa carbon accounting.

[8] Switching from jdLUC to dLUC is not considered a methodological change.

Table 9: Distinction between progress and methodological change. The color indicates the type of change as described in the manual. Note that although most guidelines do not require to distinguish between active and passive, it is recommended to distinguish when you communicate about progress, e.g. in your corporate sustainability report.

	PROGRESS Improvement by sustainability initiatives	**METHODOLOGICAL CHANGE** And potential combination with progress
ACTIVE Under the influence of company	**Corporate driven** • Improved residue management[1] • Reduced fertilizers while stabilizing yield[1] • Stabilized supply base and thus out-growing LUC legacy[1] • Changes in product portfolio or reformulation e.g. replacing cocoa[1] • Reduced logistic emissions[1] • Switch to renewable energy[1]	**Corporate driven** • Increase granularity of dataset[3] • Move from secondary to primary data[3] • Move from sLUC to dLUC or from sLUC to jdLUC[3] (switching from jdLUC to dLUC is not a methodological change) • Change database[4] • Change of recycling benefit[4] • Fix a mistake[4]
PASSIVE Outside the influence of company	**Externally driven** •Supplier change to renewable energy[2] •New regulations affecting N_2O emissions of suppliers[2]	**Externally driven** • Change of GWP for methane by IPCC[4] • Method change by suppliers[4]
BACKGROUND DATABASE CHANGE Outside the influence of company	**Data updates reflecting real change** • New electricity mixes[5] • New technologies[5] • Improved inventories[5]	**Data updates due to method** • New allocation[5] • Improved inventories[5] • Redefined markets[5]

Table 10: Common cases and examples of methodological changes within cocoa carbon accounting

Methodological change	**Realistic, hypothetical example for cocoa**	**Driver**
Improved precision and granularity of dataset	Switching from default data to precise satellite imagery	Reporting corporate or supplier
Moving from proxy dataset to primary data	Improving land management data through field survey	
New allocation rule	Changing how impact is allocated to banana intercropping	
Fixing a bug/mistake	Linear discounting applied the wrong way	
Any method change by a supplier	Supplier switching from GFW to Starling for LUC calculation	Suppliers
Change in background data	Ecoinvent updates the transport component of fertilizer to the field or a different database is selected	Database providers

Table 11: Common cases and examples of actions leading to progress within cocoa carbon accounting

Key actions	Example for cocoa	Trigger
Stabilize supply base	dLUC reduced from X to Y tCO_2e/tCocoa	Reporting corporate or supplier
Reduce agrochemical use while maintaining productivity	X% less fertilizer was used while productivity was maintained or improved	
Close yield gap	Residue management to control disease spread increased yield by X%. Yield is one of the most important levers for impact reduction. If yield is boosted through agrochemical application, it could increase impact.	
Improve residue management	X% less emissions through applying passive aeration and vermiculture	
Evolve product formulation and portfolio	Sourcing X% less cocoa and replacing with a lower impacting product	

2) Account for newly available data

a. Work towards collecting more granular data where relevant.

b. Check which of the 4 cases in Table 12 applies to the new data you collected.

I. Cases **(A)** and **(C)**: When you or a supplier recently increased their data granularity, that data can be back cast to the base year if evidence allows.

II. Cases **(B)** and **(D)**: If a change in supplier occurs, the performance of the new supplier will need to be compared to how the former supplier performed in the past. Therefore, the performance of the former supplier in the past will need to be reconstructed.

Table 12: Cases when more granular data becomes available

Recent data…	Change of data availability within your supplier or physical farms	Change of physical farms/change between suppliers
…became available and past data are not available	**(A) Back casting with best available proxy** Use the best available data and assumptions to identify what has been improved since the base year. ***Example*** *You have increased data granularity on traceability.*	**(B) Reconstruct supplier performance with proxy** Reconstruct how your former supplier performed in the past (e.g., your base year) by benchmarking with a national average in e.g., your base year. ***Example*** *A new supplier has data about their process and traceability in 2023, while former supplier had no transparent and granular data.*

… became available and past data are available	**(C) Back casting with actual data** You have collected data about your supplier, or they can provide information about improvements since the base year. ***Example*** *You got info from a supplier in 2023 about plot locations and can make sure those plots were already in your sourcing portfolio in the base year.*	**(D) Reconstruct supplier performance with actual data** If the new supplier can provide past data, assess to which extent they can be valid for the former supplier you switched away from. ***Example*** *You decide to switch to a supplier that can provide farm-level traceability.*

3) Check if you need to rebaseline

a. If a change of data and/or methodology leads to a change of less than 5% over your cocoa impact, you do not need to rebaseline. This is the maximum recommended, and companies can choose to enforce a lower percent. Otherwise, go to step **4)**.

4) Check if rebaselining affects your targets

a. If rebaselining does not affect your targets e.g. it does not influence a %-reduction, you have two options:
   I. Submit to SBTi your updated baseline and targets at the same time as the mandatory target review (e.g. 5 years from last submission).
   II. Submit to SBTi your updated baseline and targets immediately. This option has more administrative tasks and is thereby not recommended.

b. If rebaselining affects your targets, you should resubmit both updated baseline and targets as soon as they are assessed.

Glossary

Terms (A-Z)	Definitions
Above Ground Biomass (AGB)	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage[9]
Assurance	The level of confidence that the inventory and report are complete, accurate, consistent, transparent, relevant, and without material misstatements[10]
Below Ground Biomass (BGB)	The total mass of living roots below the soil surface
Carbon Pools	Stores of carbon, including above-ground biomass, below-ground biomass, soil organic carbon, and dead organic matter
Cabon Stock	The mass of carbon contained in a carbon pool at a given time. For example, tonnes of biomass carbon on forest lands or tonnes of carbon in building materials[10]
Carbon storage	The process of maintaining carbon dioxide or carbon in a pool for a period of time[10]
Chain of Custody (CoC)	The custodial sequence that occurs as ownership or control of the material supply is transferred from one custodian to another in the supply chain[11]
Dead organic matter (DOM) carbon pool	Carbon in non-living organisms or other non-fossil organic compounds two mm in size or greater. Includes dead wood and litter carbon pools[10]
Direct Land use change (dLUC)	Emissions (primarily from carbon stock losses) due to recent (previous 20 years or more) land conversion directly on the area of land that a company owns/controls or on specific lands in the company's value chain [10]
Emissions	The release of a greenhouse gas into the atmosphere[10]
Forest degradation	The reduction in a forest's ability to perform ecosystem services, such as carbon storage and water regulation, due to natural and anthropogenic changes[12]
Identity Preservation (IP)	An IP model ensures that certified product from a certified site is kept separate from other sources. If used through the whole supply chain, it allows certified products to be uniquely traced through the production process from a production site and batch (sustainability certificate holder) to the last point of transformation or labelling of a product (or use of a claim)[11]
Intercropping	Cultivating multiple crops in the same area simultaneously
Life Cycle Inventory (LCI)	A dataset detailing the environmental inputs and outputs of a system
Land use change (LUC)	Change from one land use (e.g., forest) to another (e.g., cocoa)

[9] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

[10] https://ghgprotocol.org/land-sector-and-removals-guidance

[11] https://www.isealalliance.org/get-involved/resources/iseal-guidance-chain-custody-models-and-definitions

[12] https://research.wri.org/gfr/key-terms-definitions

Mass Balance	An overarching term for various slightly different types of chain of custody models which involve balancing volume reconciliation. In the mass balance model, the volume of certified product entering the operation is controlled and an equivalent volume of product leaving the operations can be sold as certified[11]
Plot	A plot is a spatially coherent physical area that can either represent 1) a spatially continuous cocoa cultivation area, 2) a spatially continuous land management or agricultural system where cocoa cultivation is integrated
Removal	The transfer of a greenhouse gas from the atmosphere to storage within a pool. Removals can be from biogenic or technological sinks and stored in land-based, product or geologic carbon pools[10]
Reversal	An emission from a carbon pool that stores carbon associated with a removal that was previously reported by the reporting company[10]
Science Based Target (SBT)	International famework for setting greenhouse gas reduction targets
Secondary data	Data that is not from specific activities within a company's value chain
Segregation	CoC model ensuring that a certified product is kept separate from non-certified sources through each stage of the supply chain, allowing assurance that the ingredients within a particular product originate from certified sources, though it may not be possible to identify which molecule came from which certified source[11]
Soil carbon pool	Carbon in soil minerals and organic matter less than 2 mm in size. Includes mineral soil organic carbon, organic soil organic carbon and soil inorganic carbon pools[10]
Soil organic matter	The portion of organic residues in soil in various stages of decay. Despite being a small part of the soil matrix, the presence of SOM contributes significantly to soil health[10]
Soil organic carbon (SOC)	The carbon stored in soil as part of organic matter
Supply shed	A geographic area from which a company sources its products.
Traceability	The ability to verify the history, location, or application of an item by means of documented recorded identification[11]
Tree cover	All vegetation greater than five meters in height and may take the form of natural forests or plantations across a range of canopy densities. Unless otherwise specified, the Global Forest Review uses greater than 30 percent tree canopy density for calculations[12]
Tree cover loss (TCL)	The removal or mortality of tree cover, which can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. As such, loss does not equate to deforestation[12]
Yield	The amount of crop produced per unit area

References

Aabeyir, R., Adu-Bredu, S., Agyare, W. A., & Weir, M. J. C. (2020). Allometric models for estimating aboveground biomass in the tropical woodlands of Ghana, West Africa. *Forest Ecosystems*, *7, 41*. https://doi.org/10.1186/s40663-020-00250-3

IPCC. (2023) *AR6 Synthesis Report: Climate Change 2023 —* IPCC. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

Blaser, W. J., Oppong, J., Hart, S. P., Landolt, J., Yeboah, E., & Six, J. (2018). Climate-smart sustainable agriculture in low-to-intermediate shade agroforests. *Nature Sustainability*, *1*(5), 234–239. https://doi.org/10.1038/s41893-018-0062-8

Blaser, W. J., Oppong, J., Yeboah, E., & Six, J. (2017). Shade trees have limited benefits for soil fertility in cocoa agroforests. *Agriculture Ecosystems & Environment*, *243*, 83–91. https://doi.org/10.1016/j.agee.2017.04.007

CLEAN DEVELOPMENT MECHANISM. (2013). *A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities*. https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v3.0.pdf

Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *In Science (Vol. 361, Issue 6407, pp. 1108–1111). American Association for the Advancement of Science (AAAS).* https://doi.org/10.1126/science.aau3445

FAOSTAT. (n.d.). https://www.fao.org/faostat/en/#data/TCL

Flisch, René & Sinaj, Sokrat & Charles, Raphaël & Richner, W.. (2009). Grundlagen für die Düngung im Acker- und Futterbau (GRUDAF). Agrarforschung. 16. 1-97

Gibbs, D. A., Rose, M., Grassi, G., Melo, J., Rossi, S., Heinrich, V., & Harris, N. L. (2024) Revised and updated geospatial monitoring of twenty-first century forest carbon fluxes, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2024-397 (in review).

Greenhouse Gas Protocol. (2014). Policy and Action Standard: An Accounting and Reporting Standard for Estimating the Greenhouse Gas Effects of Policies and Actions. World Resources Institute and World Business Council for Sustainable Development. ISBN 978-1-56973-840-5

Greenhouse Gas Protocol. (2022). Land Sector and Removals Guidance, Draft for Pilot Testing and Review, Part 1 and Part 2 https://ghgprotocol.org/land-sector-and-removals-guidance

Gumbricht, T., Roman-Cuesta, R. M., Verchot, L., Herold, M., Wittmann, F., Householder, E., Herold, N., & Murdiyarso, D. (2017). An expert system model for mapping tropical wetlands and peatlands reveals South America as the largest contributor. *Global Change Biology*, *23*(9), 3581–3599. https://doi.org/10.1111/gcb.13689

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *In Science (Vol. 342, Issue 6160, pp. 850–853). American Association for the Advancement of Science (AAAS).* https://doi.org/10.1126/science.1244693

Hengl, T., et al. (2017). SoilGrids250m: Global gridded soil information based on machine learning. *PLoS ONE*, *12*(2), e0169748. https://doi.org/10.1371/journal.pone.0169748

Huang, Y., Ciais, P., Santoro, M., Makowski, D., Chave, J., Schepaschenko, D., Goll, D. S., Yang, H., Wei, W., & Piao, S. (2020). Supporting data and code for A global map of root biomass across the world's forests (Version 1). Dataset. https://doi.org/10.6084/m9.figshare.12199637.v1

Huang, Y., Ciais, P., Santoro, M., Makowski, D., Chave, J., Schepaschenko, D., ... & Piao, S. (2021). A global map of root biomass across the world's forests. Earth System Science Data, 13(9), 4263-4274.

IPCC. (2006). IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

IPCC. (2014). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland

IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 11- N2O Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

ISEAL Guidance: Chain of custody models and definitions. (n.d.). ISEAL Alliance. https://www.isealalliance.org/get-involved/resources/iseal-guidance-chain-custody-models-and-definitions

Jara, M. C., Henry, M., et al. (2014). Guidelines for documenting and reporting tree allometric equations. *Annals of Forest Science*, *72*(6), 763–768. https://doi.org/10.1007/s13595-014-0415-z

Jucker, T., Caspersen, J., Chave, J., Antin, C., Barbier, N., Bongers, F., ... & Coomes, D. A. (2017). Allometric equations for integrating remote sensing imagery into forest monitoring programmes. *Global change biology*, 23(1), 177-190

Kalischek, N., Lang, N., Renier, C. *et al.* (2023) Cocoa plantations are associated with deforestation in Côte d'Ivoire and Ghana. *Nat Food* 4, 384–393. https://doi.org/10.1038/s43016-023-00751-8

Kazimierski,P.;Hercel,P.; Suchocki,T.;Smolin´ski,J.;Pladzyk, A.; Kardas´, D.; Łuczak, J.; Januszewicz, K. Pyrolysis of Pruning Residues from Various Types of Orchards and Pretreatment for Energetic Use of Biochar. *Materials* 2021,*14*,2969. https://doi.org/10.3390/ma14112969

Lammoglia, S. K., Akpa, Y. L., Danumah, J. H., Brou, Y. L. A., & Kassi, J. N. D. (2024). High-resolution multispectral and RGB dataset from UAV surveys of ten cocoa agroforestry typologies in Côte d'Ivoire. *Data in Brief*, 110664.

Ledo, A., Heathcote, R., Hastings, A., Smith, P., & Hillier, J. (2018). Perennial-GHG: A new generic allometric model to estimate biomass accumulation and greenhouse gas emissions in perennial food and bioenergy crops. *Environmental Modelling & Software, 102, 292-305.*

Measuring and modelling soil carbon stocks and stock changes in livestock production systems Guidelines for assessment. (n.d.). https://openknowledge.fao.org/server/api/core/bitstreams/3573cc7c-f8b0-42cc-bead-ea56c502647e/content

Miettinen, J., Shi, C. & Liew, S. C. (2016). Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. *Glob. Ecol. Conserv*. 6, 67– 78.

Beg, M.S, Ahmad S., Jan K. & Bashir K. (2017), Status, supply chain and processing of cocoa - A review, *Trends in Food Science & Technology*, Volume 66, 2017, Pages 108-116, ISSN 0924-2244, https://doi.org/10.1016/j.tifs.2017.06.007.

Moreira, B. M., Goyanes, G., Pina, P., Vassilev, O., & Heleno, S. (2021). Assessment of the influence of survey design and processing choices on the accuracy of tree diameter at breast height (DBH) measurements using UAV-based photogrammetry. Drones, 5(2), 43.

Parente, L., Sloat, L., Mesquita, V., Consoli, D., Stanimirova, R., Hengl, T., Bonannella, C., Teles, N., Wheeler, I., Ehrmann, S., Hunter, M., Ferreira, L., Mattos, A. P., Oliveira, B., Meyer, C., Şahin, M., Witjes, M., Fritz, S., Malek, Ž., & Stolle, F. (2024). Annual 30-m maps of global grassland class and extent (2000–2022) based on spatiotemporal Machine Learning. *Springer Science and Business Media LLC*. https://doi.org/10.21203/rs.3.rs-4514820/v3

Picard, N., Saint-André, L., & Henry, M. (2012). Manual for building tree volume and biomass allometric equations: from field measurement to prediction, FAO; Food and Agricultural Organization of the United Nations. https://www.fao.org/3/i3058e/i3058e.pdf

Policy and Action Standard | GHG Protocol. (2016, November 1), chapter 12, section 12.6. https://ghgprotocol.org/policy-and-action-standard

Quantis. (2022). *Credibly accounting for carbon sequestration in perennial cropping systems*. https://quantis.com/report/credibly-accounting-for-carbon-sequestration-in-perennial-cropping-systems/

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., Fricko, O., Gusti, M., Harris, N., Hasegawa, T., Hausfather, Z., Havlík, P., House, J., Nabuurs, G., Popp, A., Sánchez, M. J. S., Sanderman, J., Smith, P., Stehfest, E., & Lawrence, D. (2019). *Contribution of the land sector to a 1.5 °C world. Nature Climate Change*, 9(11), 817–828. https://doi.org/10.1038/s41558-019-0591-9

Rojas, M., Hommes, A., Heeres, H.J. et al. Physicochemical Phenomena in the Roasting of Cocoa (Theobroma cacao L.). *Food Eng Rev 14*, 509–533 (2022). https://doi.org/10.1007/s12393-021-09301-z

Schneidewind, U., Niether, W., Armengot, L., Schneider, M., Sauer, D., Heitkamp, F., & Gerold, G. (2018). *Carbon Stocks, Litterfall And Pruning Residues In Monoculture And Agroforestry Cacao Production Systems. Experimental Agriculture, 1–19.* doi:10.1017/s001447971800011x

Shoch, D., Settelmyer, S., Furniss, J., Dickson, R., Ericksen, D., Terra Carbon, Silvestrum Climate Associates, Emmer, I., Hemes, K., & ABACUS working group. (2023). VCS Methodology. In *AFFORESTATION, REFORESTATION AND REVEGETATION* (Report No. VM0047, v1.0; pp. 1–68). https://verra.org/wp-content/uploads/2023/09/VM0047_ARR_v1.0-1.pdf

Sudip Sarkar, Dipty Kumar Das. Tree Biomass And Carbon Stock Assessment In Different Agroforestry System Trees. Int J Chem Stud 2020;8(4):3858-3861. DOI: 10.22271/chemi.2020.v8.i4aw.10251

Tiralla, N., Panferov, O., & Knohl, A. (2013). Allometric relationships of frequently used shade tree species in cacao agroforestry systems in Sulawesi, Indonesia. *Agroforestry Systems*, *87*(4), 857–870. https://doi.org/10.1007/s10457-013-9602-4

Vancutsem, C., Achard, F., Pekel, J., Vieilledent, G., Carboni, S., Simonetti, D., Gallego, J., Aragão, L. E. O. C., & Nasi, R. (2021). Long-term (1990–2019) monitoring of forest cover changes in the humid tropics. *Science Advances*, *7*(10). https://doi.org/10.1126/sciadv.abe1603

Vergara-Mendoza, M.; Martínez, G.R.; Blanco-Tirado, C.; Combariza, M.Y. Mass Balance and Compositional Analysis of Biomass Outputs from Cacao Fruits. *Molecules* 2022,*27*,3717. https://doi.org/10.3390/molecules27123717

Walker, S. M., Murray, L., Tepe, T., & Winrock International. (2016). *Allometric Equation Evaluation Guidance*. https://winrock.org/wpcontent/uploads/2018/08/WinrockAllometricEquationGuidance-2016.pdf

WCF & Quantis (2023). GHG ACCOUNTING METHODS FOR COCOA PRODUCTION. A review and guidance on methodologies and tools used in accounting for greenhouse gas emissions and carbon removals. Version 1.0.

Xu, J., Morris, P.J. and Liu, J. and Holden, J. (2017) *PEATMAP: Refining estimates of global peatland distribution based on a meta-analysis.* University of Leeds. [Dataset] https://doi.org/10.5518/252

World Agroforestry Centre (ICRAF). (2007). Global Wood Density Database. Available at: https://www.worldagroforestry.org/output/global-wood-density-database.

Annex

I. Checklist of requirements for companies

Topic	Minimum (M) and Recommended (R) requirements	Check
Traceability	**(M)** Document and disclose the chain of custody model (or lack thereof) when reporting any plot-specific emission or removals estimates (e.g. dLUC or removals accounting on a specific plot).	☐
	(R) Ensure chain of custody is in place when making product specific claims (e.g. per kilogram or tonne of cocoa bean or chocolate) in relation to emissions or removals documented on specific plot(s).	☐
	(R) If there is no chain of custody in place, calculate the average emissions value for a plot population that represents the entire sourcing region. For example, the average emission should include all identifiable plots (or a region) and not only plots with projects or interventions. Reporting emission and removals from specific plots with projects or interventions would require a chain of custody model.	☐
Plot Area & Cocoa Volume	**Plot Area Definition**	
	(R) If it is possible to visually determine or calculate cocoa cultivation areas, to avoid drawing large boundaries beyond cocoa cultivation systems, it is recommended that the considered adjacent land area does not exceed the cultivated area. Exceptions can be made when justified by the local context (e.g., the Brazilian Forest code).	☐
	(R) Assess land use change, land management, and removals on the same defined plot area(s). It is not acceptable to assess emissions and removals on different plots or plot sections (to represent a single cocoa cultivation system).	☐
	Estimated production volume and yield	
	(R) Due to annual yield variations, primary yield data need to be calculated as a rolling average over 3 years. During the initial 1 or 2 years of data collection, the data from only these 1 or 2 years can be used with caution (i.e., comparing to secondary data, making sure to check for outliers) until a full 3 years of data is available.	☐
Sampling Design	**Decision on the type of sampling**	
	(R) Perform random sampling in the population of plots to be represented (e.g. a farmer group, a supply shed, a jurisdiction, a country, etc.). Identify all relevant cocoa plots, assign them with a unique identifier, and then use a random values generator to identify which plots to collect data from.	☐
	Definition of the number of samples	
	(M) When performing a random sampling, choose a sample size that is statistically representative for the total population size, with a confidence level of minimum 90% and margin of error of maximum 10%. For removals in	☐

	particular, the GHGP Land Sector and Removals Guidance indicates that a choice of a confidence level lower than 95% must be justified by the robustness of the data and method used.	
LUC Emissions of a plot	**dLUC step by step** **(M)** All the steps described in the manual to calculate dLUC are intended to be considered Minimum requirements.	☐
	Jurisdictional dLUC step by step **(M)** All the steps described in the manual to calculate jdLUC are intended to be considered Minimum requirements.	☐
Land Management (LM) Emissions of a plot	**Activity data primary collection** **(R)** For a land management emission factor to be considered a "primary EF", the following activity data that are of high importance to the emission calculation need to be primary data: • Cocoa plot estimated production volume (EPV) (or yield kg/ha), • Cocoa plot area Quantities of N mineral fertilizers applied to the cocoa plot, • Quantities and types of organic fertilizers applied to the cocoa plot, • Residue management method. **(R)** Medium to low importance land management data (Table 4) also need to be considered to have a complete inventory and should be collected on field as much as possible. However, they are not as impactful to the EF as the high priority parameters, therefore if the collection of primary data for these parameters is too complex, secondary data from a standard (e.g. ecoinvent, World Food LCA Database) or reputable (e.g. Control Union, agronomist fact sheets) sources can be used instead. **(R)** To ensure data are representative of the reporting period, the time period for primary data collection should be clearly documented. **(R)** Secondary data from a certification scheme cannot be used to replace the collection of primary data or to claim a primary EF (unless the certifier provides justification that the data shared are primary data).	☐ ☐ ☐
	Fertilizers **(R)** Due to large fertilizer variations between plots, fertilizer data need to be plot specific.	☐
	Pruning and husking residues **(R)** Due to large residue management variations between plots, residue management data need to either be plot specific, or established by an expert for the region of the plot.	☐
	Agroforestry trees cutting **(R)** When there are agroforestry trees on the plot that are not part of a removals program, consider their loss as land management emissions.	☐

	Intercropping **(R)** If there is intercropping on the cocoa plot with subsistence crops, attribute the whole plot's emissions to the cocoa (conservative approach). If there is intercropping with crops traded on international market, an economic allocation of the plot's impacts can be performed between the crops produced.	☐
	Step by step GHG calculations **(R)** All the steps described in this manual section are intended to be considered Recommended requirements.	☐
Removals on a plot	**Removals step by step** **(M)** All the steps described in the manual to calculate Removals are intended to be considered Minimum requirements.	☐
	Adjacent lands **(M)** If adjacent lands are considered for removals, this area must also be considered in the calculation of land management emissions and land use change emissions associated with the cocoa cultivation. **(R)** To avoid drawing boundaries beyond cocoa cultivation systems, only consider adjacent land area for a removals project that does not exceed the cultivated area. For example, if the cultivated area of a plot is one hectare, the adjacent land is no more than one hectare, and thus the full plot area is two hectares. This is a safeguard and can be revisited with evidence or rational to consider a larger area. **(R)** Take care when calculating yield and production volume when adjacent areas are included that are not cultivating cocoa. Yield typically represents the production on one hectare of cultivation area, but as required by the GHG Protocol, the emissions and removals for the full plot area shall be considered when allocating to mass of cocoa bean or product. Thereby the emissions and RF for the full area are divided by the estimated production volume (EPV) which is the volume of cocoa produced on the cultivated area.	☐ ☐ ☐
	Assurance of permanence and additionality **(M)** Ensure there is verification and documentation that the removals project has taken place (i.e. remote sensing, boots-on-the-ground). I.e. receipts for agroforestry trees do not document the agroforestry trees have been planted. **(M)** Following a GHG Protocol LSRG (draft) requirement, removals are reported in the reporting year when the net carbon stock increase occurs in carbon pools relevant to a company's value chain. Any removal that has been claimed that has not been monitored within 5 years must be reported as a reversal. As such, documentation of previously reported removals should be verified.	☐ ☐

Removals on a plot (continued)	**Monitoring & reversal**	
	(M) Have a system that 1) keeps track of all reported removals for a company (including past reporting) for each carbon pool, 2) keeps track of the buffer pool and 3) any reversals that are subtracted from the buffer pool or otherwise need to be reported.	☐
	(R) Removals are tracked in a database or registry including information on right-to-report (i.e. sign-off by farm manager), CoC, location, indication of the year in which the removal was reported, and when it was last monitored.	☐
	(M) A plan is in place to monitor at least every 5 years to ensure any claimed removals are still in place (i.e. trees have not been removed), and if the previously reported removals are no longer detectable by the monitoring, they are reported as reversed or deducted from the buffer pool.	☐
	(R) Mortality rate is typically the highest in the first years of planting. Therefore, it is suggested to check the survival rate one year after planting for all removals projects that include tree planting.	☐
	(R) Ensure the buffer pool is also monitored.	☐
	Additionality and carbon in cocoa and perennial trees	
	(R) Unless there is a gain in average carbon stock on a parcel of land (e.g. due to changing from monoculture to agroforestry, from annual to perennial agriculture, or restoring degraded land) the carbon in cocoa trees and other perennials shall be excluded from.	☐
	(R) Removals projects should be additions. For the sake of this manual, additionality can mean going beyond BAU (e.g. installing shade, windscreens, biodiversity corridors alongside farms, hedge), or can mean qualifying as "additional" according to a carbon credit methodology.	☐
	(R) Regardless of whether companies consider additionality for removals, they must incentivize the retention of pre-existing trees on the land through mechanisms such as payments for tree survival, regardless of planting date, to prevent their unintended removal. This is particularly important in mature agroforestry systems optimized for shade and cocoa yield, where opportunities for additional removals may be limited. Maintaining existing trees is critical to avoid land management emissions or reversals, and companies are encouraged to monitor the survival and performance of previously planted agroforestry trees.	☐
	Carbon stock calculation for agroforestry	
	(M) Publicly document (e.g. in a word file with the date and reference to the removals project) the methodology and process used for the C stock calculation for agroforestry. Annex XI provides a full list of recommended data to disclose.	☐

Removals on a plot (continued)	**Carbon pools** **(M)** Report all carbon pools separately. **(M)** Calculate C stock in agroforestry trees (AGB) through choosing appropriate allometric equations that match the species and conditions (see Table 18 Annex XI). **(M)** Assume soil organic carbon (SOC) removals are equal to 0 unless soil sampling or adequately calibrated and validated soil modeling demonstrate otherwise. **(R)** Assume dead organic matter (DOM) removals are equal to 0. **(R)** The preferred approach for estimating removals through below ground biomass (BGB) is to assume they are equal to 0, following the conservative principle. However, the GHGP-LSRG (draft) permits the use of root-to-shoot ratios. When applying root-to-shoot ratios first prioritize specificity (i.e. species- and region- specific ratios) and in second instance generic ratios specific to the region or growing conditions, e.g. as outlined in on step 4.d.i. in Option B in the Section dLUC step by step.	☐ ☐ ☐ ☐ ☐
	Primary and secondary data **(M)** Use primary data (or remote sensing data) on DBH and height to estimate removals at least once every five years.	☐
	Calibration and validation of biomass allometric equations **(M)** Biomass carbon stocks can be measured through use of either ground-based measurements of tree diameter and height or destructive biomass sampling techniques. Companies should report internationally recognized peer-reviewed publication or protocols of allometric equations, inventory methods or destructive biomass sampling protocols applied to measure biomass carbon stock on relevant lands or strata. **(R)** A set of assessed equations is provided in Annex X and can serve as a starting point. If the target species is not listed in the Annex, a generic equation that includes wood density for species specificity can be used. **(M)** Document and quantify the uncertainty of biomass estimates. Ensure that within 5 years validation and calibration (see step by step below) of the model has been performed if it has not been already performed by the model creators and the model is being applied for the same species and region (or geospatial conditions, e.g. climate zone). Take care when using a model that has not been validated or calibrated to be conservative and disclose this. **(R)** The selected allometric equation must be verified for appropriateness (see Annex for appropriateness criteria), and its applicability can be confirmed through limited destructive sampling within the sourcing region and performing statistical tests (Walker et al. 2016). This is a cost-effective approach compared to developing and creating a new allometric equation, as it requires significantly fewer sample trees. If an existing peer-reviewed allometric equation has been validated and demonstrated to accurately estimate biomass (e.g., within a 95%	☐ ☐ ☐ ☐

Removals on a plot (continued)	confidence interval) under local conditions, recalibration of the model may not be necessary. This is contingent on the validation process being thorough, well-documented, and including a quantification of uncertainties. When significant discrepancies arise—particularly overestimations—between predicted biomass and measured biomass (i.e. more than 5%), it is recommended to collect additional field data to re-calibrate the equation (here, re-calibration refers to adjusting an equation previously calibrated to similar growing conditions but not specific to the study) or to develop a new one. **(R)** Validate (internally or via a third party) the model estimates against measured values and evaluate the model performance through statistical analysis. As best practice follow the step by step guide below.	☐
	Translating tree carbon to plot-level removals **(M)** Provide justification of how removal estimates are not overestimated.	☐
	Buffer pool **(M)** The method for assessing the buffer pool is documented and follows the same requirements and calculation method for reported removals, including for monitoring. **(M)** The amount of buffer set aside is documented. **(M)** Detected reversals in or outside of the buffer pool diminish a buffer pool and there shall be documentation when a reversal is detected and it is deducted from a buffer pool. Reversals deducted from a buffer pool do not need to be reported. **(M)** Like reported removals, the buffer pool shall also be monitored (every 5 years). If monitoring ceases for both the buffer and the removals the full amount of reported removal shall be considered as reversed. If monitoring shows that a buffer pool has been damaged such that reversal of the buffer has occurred, it does not need to be reported as a reversal, but it shall be documented that the buffer pool is diminished. Any reported removals that are reversed in excess of the buffer pool need to be reported; e.g. if the project is fully reversed and the buffer is fully reversed the project is no longer buffered and must be fully accounted for as reversed. **(R)** A safer buffer pool option when considering tree planting (agroforestry, etc.) is creating a physically separate buffer pool which covers 100% of the reported removals such that a reversal would never have to be reported, assuming the buffer pool remains intact, is monitored, and is not itself reversed.	☐ ☐ ☐ ☐ ☐
	Buffer pool step-by-step **(R)** Engage a 3rd party or perform a risk assessment that takes into account tree mortality (which includes seedling death and risk of wildfire, and could consider if the trees are planted with intention to cut e.g. for firewood) to set the buffer pool.	☐

Removals on a plot (continued)	**(R)** Recommended requirement 1) for a buffer pool method: Adjust reported values to reserve a buffer pool (i.e. take the buffer pool from the project carbon pool) of 20%. 1) Calculate the project removals following the same requirements and calculation method for reported removals, including for monitoring 2) Multiply by the buffer pool fraction e.g. 20% to obtain the reserved buffer amount 3) Multiply by 1 – (buffer pool fraction) to obtain the reportable amount **(R)** Reserve a separate carbon pool as a buffer pool (i.e. report the full project and reserve a separate project). 1) Calculate the project removals following the same requirements and calculation method for reported removals, including for monitoring 2) Multiply by the buffer pool fraction to obtain the reserve amount 3) Secure another project that is equal to the reserve amount that has not been and will not be reported	☐ ☐
	Integrating remote sensing data **(M)** Remote sensing measurements for primary data and ongoing storage monitoring must be calibrated with ground-based inventory data, recalibrated every five years, and include uncertainty assessments. **(R)** Select the data collection method that best aligns with the study's specific analysis needs, optimizing for both cost-effectiveness and data precision. For example, in light-to-moderately shaded agroforestry systems, drone-based photogrammetry may offer a more cost-effective alternative to LiDAR (Moreira et al. 2021). **(R)** When selecting a data provider, request a sample dataset or pilot project to confirm it meets the needs, prioritize providers with agroforestry experience, and ensure the data format aligns with your reporting requirements. Work closely with the provider from the beginning to tailor updates and measurements to the specific project, adopting a hands-on approach that improves accuracy and relevance in removal estimations. Where possible, ask for a third-party accuracy assessment to validate the data's reliability. **(R)** When remote sensing data is obtained from a data service, ensure all relevant information is included, as detailed in Annex XI. This should include data sources, methods for combining remote sensing and ground data, specific models or algorithms used, and an uncertainty analysis in accordance with calibration and uncertainty guidelines.	☐ ☐ ☐ ☐

II. Default yield archetypes

Table 13: Definition of archetypes used to define different yields.

Archetype	Description	Average quantity of N mineral fertilisers used
Low input	Farms with no to medium shade, which are not very organised. Many farmers use no or only little fertilisers and pesticides (here an average situation is modelled).	0 kg N / ha
Medium input	Typical cocoa farms in South America and Indonesia, which use higher fertiliser amounts compares to West Africa, but also grow more fruit/coconut/rubber or other trees in between cocoa (light to medium shade), with an economic value for the in-kind use by the farmer, and/or for sale.	63 kg N / ha
Extreme high input	Often bigger cocoa farms, which are irrigated, use improved planting material and 1 tonne or more of fertiliser per ha, apply mechanical pruning, and produce 2 tonnes or more cocoa beans per hectare.	134 kg N / ha
Agroforestry	Farms defined in a rather broad sense where a proportion of the agroforestry trees are original/native forest trees and other agroforestry trees were planted, e.g. Gliricidia. In the "agroforestry" cocoa farming archetype defined here, most trees don't have an economic value; they rather provide different ecosystem services.	0 kg N / ha
Improved practices	Farms where fertiliser and pesticide volumes applied are following official recommendations, which increases the cocoa yield by approx. 150 kg/ha.	4 kg N / ha

III. Different types of LUC

Table 14: Overview of the three most common land use change (LUC) metrics at different traceability levels.

Type of LUC	Strategic use	Required data	Strengths and limitations
Direct at farm level (dLUC)	- LUC specific to supply chains - Track interventionslt	- Plot locations - Geospatial LUC data	**Strengths** - Supply chain specific - Track progress on stable supply - Traceability required by regulations **Limitations** - Data hard to collect - No visibility on indirect LUC - Cannot be compared to or reported against sLUC when tracking progress
Jurisdictional direct at country or region (jdLUC)	- Benchmark performance - Fill traceability data gaps	- Commodity map layers - Geospatial LUC data	**Strengths** - Some visibility on indirect LUC - Track progress on supply sheds **Limitations** - Data availability limitations - Cannot be compared to or reported against sLUC when tracking progress
Statistical at country or region (sLUC)	- Identify LUC hotspots regionally - Decide where to deep-dive	- LUC data for sourcing country or region	**Strengths** - Data easier to collect - Indicates indirect LUC risk **Limitations** - Not supply-chain specific - Cannot be compared to or reported against dLUC or jdLUC when tracking progress

IV. LUC Terminology

Table 15: Common terminology used in land use change (LUC) calculations and geospatial processing.

Topic	Terminology	Explanation
Geo-coordinates	Point	Coordinate with no area, indicated through latitude and longitude
	Buffer	Area assigned to a point
	Polygon	Multiple points connected by vertices that from a shape
	Coordinate reference system (CRS)	Defining the two-dimensional, projected map relating to real places on Earth
	Plot	Single, spatially coherent cocoa cultivation area
	Farm	Legal entity belonging to farmer, possibly consisting of multiple plots
Geospatial data	Pixel	Smallest (usually quadratic) unit of an image with a color and associated value
	Image	Usually in the form of a geotiff, containing pixels which are assigned a geographic location
	Shapefile	Data format containing points or polygons, often with sidecar files containing e.g. info on CRS
	Layer	Generic term of data that is displayed on a map, like an image or a shapefile.
	Spatial resolution	Length of one side of a pixel
	Temporal resolution	Frequency and time extent image captures
	Coverage	Geographic extent to which image is available
	Layer	Image
Geospatial processing	Overlay	Superposing two data sources, e.g. satellite image with polygons
	Mask	Filtering values of an image based on a criterion, e.g. a threshold
	Zonal statistics	Statistics of a satellite image over a region/zone (e.g., a polygon)
Sourcing	Direct supply chain	You can trace your product back to the farm
	Indirect supply chain	You source from a collection point (cooperative) or from a trader and have no visibility where the cocoa was grown
	Chain of custody (CoC)	Process of tracking the movement and ownership of a product from its origin to the final consumer
Forest	Forest cover	"Forests are lands of more than 0.5 hectares, with a tree canopy cover of more than 10 percent, which are not primarily under agricultural or urban land use."[13]
	Tree cover	Presence of trees, including individual trees and tree patches, which might not qualify as a forest

[13] https://www.fao.org/4/ad665e/ad665e03.htm

Table 15 (continued): Common terminology used in land use change (LUC) calculations and geospatial processing.

Topic	Terminology	Explanation
Land use change	Land use change (LUC)	Change from one land use (e.g., forest) to another (e.g., cocoa).
	Direct LUC (dLUC)	Emissions (primarily from carbon stock losses) due to recent (previous 20 years or more) land conversion directly on the area of land that a company owns/controls or on specific lands in the company's value chain[10]
	Jurisdictional dLUC (jdLUC)	LUC that occurred to plant cocoa.
	Indirect jdLUC	jdLUC in your indirect supply chain.
	Indirect LUC (iLUC)	LUC caused by a change in supply or demand because of your cocoa sourcing.
	Deforestation	Loss of forest cover due to natural or human cause.
	Tree cover loss (TCL)	The removal or mortality of tree cover, which can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. As such, loss does not equate to deforestation[12]
Biomass	Above ground biomass (AGB)	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage[9]
	Below ground biomass (BGB)	The total mass of living plant roots below the soil surface.
	Dead organic matter (DOM)	Decaying remains of plants and animals that were once alive.
	Soil organic carbon (SOC)	The carbon stored in soil as part of organic matter
	Peatland	A type of wetland with a thick layer of accumulated dead plant material, mainly mosses, that stores a large amount of carbon.
Accounting	Emission factor (EF)	Emission intensity of product, usually in $kgCO_2e/kgProduct$.
	Assessment year (AY)	Year for which you want to calculate your emissions. Usually the same as the year of traceability data collection.
	Lookback period	Time frame during which to consider LUC before the AY, starting at AY-1, set to 20 years.
	Linear discounting	Weighted average of LUC emissions over lookback period to calculate LUC EF in assessment year, weighing LUC emissions closer to the AY more than LUC emissions further back.

V. Geospatial processing tools overview

Table 16: Overview of the most common tools used in geospatial processing. Tools evolve over time and the info provided here should be used as an initial direction for the user to do their own due diligence.

Feature	QGIS/ArcGIS	Python/R	Google Earth Engine (GEE)
Cost and Access	- QGIS is open-source and free - ArcGIS is free for non-commercial use	- Open-source and free	- Free for non-commercial use - Requires a Google account
User Friendliness	- User-friendly for GIS professionals - QGIS is open-source, ArcGIS is commercial but tends to offer more features	- Requires programming expertise - Certain geospatial libraries can be tricky to get used to	- Required programming expertise - Strict client-server separation can make error detection difficult. - Best for users with coding background (JavaScipt, Python).
Workflows Automation	- Automation requires scripting or model-building (e.g., Python, ModelBuilder)	- Highly customizable with full control over workflow automation. - Example libraries Python: Geopandas, Rasterio (Python) - Example libraries R: sf, raster	- Cloud-based, fully automated platform for large geospatial workflows. - Easy sharing and collaboration of code.
Processing Power	- Suitable for medium to large datasets, but performance may decrease with very large datasets.	- High processing power if parallelization techniques are used. - Might require cloud computation environment	- Cloud-based processing power, handles petabyte-scale datasets efficiently.
Data Storage	- Requires local storage or integration with cloud solutions.	- Requires users to manage their own storage solutions. - Can integrate with cloud services like AWS or Google Cloud.	- Cloud storage by Minimum, no local storage required. - Automatically saves outputs in the cloud with options for local download.

VI. LUC rationale on recommendations

Table 17: Overview of rational for methodological and data choices in the relevant steps of the LUC workflow.

Relevant step	Relevant substep	Rationale
1)	b.	Polygons, if collected accordingly, delineate the exact cocoa cultivation field boundaries. Points on the other hand need to be buffered, so a field shape and size needs to be assumed, which adds uncertainty.
	c.	The dLUC EF should only be calculated over farms from which you sourced in the assessment year, as this represents the impact on the environment during that year. Sometimes a delay of 1 year between assessment and data year occurs.

Table 17 (continued): Overview of rational for methodological and data choices in the LUC workflow.

Step	Substep	Rationale
	c.	The canopy cover of 10% follows the definition of the widely used FAOSTAT forest definition and follows the conservative principle, as opposed to using a 30% threshold. Note that *not* masking the Harris Global Carbon Flux layer with a forest area layer allows to pick up loss from large agroforestry trees on farms.
3) Opt. A		Using the TCL based on Hansen et al., to assign a year to the Forest GHG Emissions layer for linear discounting follows the principles of feasibility, transparency, accuracy, and alignment. Note that accuracy is defined within the use case of GHG accounting, and not within ensuring compliance with e.g., the EUDR. In addition, the data is regularly updated, globally consistent, and covers the 20 year timeframe (starting 2001) needed for a GHG Protocol aligned LUC assessment. This product has the following aspects: - Small-scale disturbances are potentially not detected at a 30x30m resolution. - Gradual disturbances are potentially not detected by the change detection algorithm. - Changes of low-density tree cover canopy might not be picked up (harder to detect change to bare soil). Excluding farmers or cooperatives is not advised solely based on this data. Include other data (ground-truthing, other satellite images like the tropical moist forest layer) to increase confidence in the results. This product does not detect all pruning. Hard pruning will likely be detected as well as loss of agroforestry trees. A comparison to the TMF layer is shown in Table 19.
4) Opt. A		Using the Forest GHG Emissions, which is based on the TCL layer (see description above) follows the principles of feasibility, transparency, accuracy, and alignment. Note that accuracy is defined within the use case of GHG accounting, and not within ensuring compliance with e.g., the EUDR. In addition, the data is regularly updated, globally consistent, and covers the 20 year timeframe (starting 2001) needed for a GHG Protocol aligned LUC assessment. This product has the following aspects[14]: - 30x30m above ground biomass map based on lidar and more than 20'000 ground-measured biomass plot. - Includes tree cover gain since 2000.

[14] https://www.researchgate.net/publication/348666331_Global_maps_of_twenty-first_century_forest_carbon_fluxes

		- Includes all other relevant carbon pools (below ground biomass, litter, soil organic carbon, peatland if TCL occurred on it) based on satellite images or region/biome-specific values. Note that peatland degradation is only considered in pixels subject to TCL. Includes loss of biomass pools adapted to drivers of loss (e.g., commodity-driven, urbanization, forestry).
3) Opt. B		Using the Tropical Moist Forest product follows the principles of feasibility, transparency, accuracy, and alignment, and allows to also be leveraged for EUDR compliance due-diligence. In addition, the data is regularly updated, globally consistent, and covers the 20 year timeframe (starting 1990) needed for a GHG Protocol aligned LUC assessment. This product[15] has the following aspects: - Maps yearly tropical moist forests extent and disturbances at a 30x30m resolution - Differentiates between degradation (disturbance shorter than 2.5 years) and deforestation (disturbance longer than 2.5 years without regrowth) - Differentiation between degradation and deforestation during past three years is based on additional criteria (e.g., disturbance intensity) and updated in the next version of the data Excluding farmers or cooperatives is not advised solely based on this data. Include other data (ground-truthing, other satellite images like the tropical moist forest layer) to increase confidence in the results. A comparison to the Hansen TCL layer is shown in Table 19.
4) Opt. B		The peatland drainage value of 61 tCO_2e/ha/year is based on the IPCC Wetlands Supplement (IPCC, 2014). For the CO_2 calculations, firstly land use category "Plantations, drained, unknown or long rotations" and climate/vegetation zone "tropical" are used to select the emission factor from Table 2.1 (EF=15tCO_2-C/ha/year). Secondly, the climate zone "Tropical" are used to select a Minimum DOC emission factor ($EF_{doc\_drained}$ tC/ha/year). Finally, both values are multiplied with the stochiometric ratio of CO_2 to carbon of 44/12 to calculate the onsite CO_2 emissions (55 tCO_2e/ha/year) and offsite emissions (3 tCO_2e/ha/year) respectively. For the CH_4 calculations, first the land use category "Forest Land and cleared Forest Land (shrubland), drained" and climate zone "tropical/subtropical" are used to select the land emission factor from Table 2.3 (EF_{land}=2.7 $kgCH_4$/ha/year). Second, the land use "All land uses involving drainage" and the climate zone "tropical" are used to select emission factor and fraction of ditches from Table 2.4 (EF_{ditch} = 2259 $kgCH_4$/ha/year and $Frac_{ditch}$ = 0.02). Finally, these three values are plugged into Equation 2.6 to calculate the annual CH_4 emissions from drained organic soils (48 kg CH_4/ha/year). For the N_2O calculations, the value from Table 2.5 for land-use category "Forest Land and cleared Forest Land (shrubland), drained" and climate zone "tropical/subtropical" are used (2.4 kgN_2O-N/ha/year). All values that are not already in CO_2 are multiplied with their respective global warming potential based in IPCC AR 6 (27 for CH_4 and 273 for N_2O) and summed up to equate to 61 tCO_2e/ha/year.
7)	a.	Linear discounting weighs LUC less the further away from the assessment year they are. This reflects that companies might not have the power to combat deforestation e.g., 15 years ago.
jdLUC step by step		

[15] https://www.globalforestwatch.org/blog/data-and-tools/how-accurate-is-accurate-enough-examining-the-glad-global-tree-cover-change-data-part-1/

1)	a.	Accuracy of Kalischek et al., 2023 is 89%. Note that other publicly available options for e.g. Ivory Coast exist (e.g., BNETD-CIGN[16] with an accuracy of 91%). However, Kalischek et al., 2023 is assumed to be an accurate and publicly available resource covering both Ghana and Ivory Coast for 2019-2021.
	c.	Threshold recommended by authors[17].
	d.	Masking out cocoa cultivation area that falls on traceable plots calculated as dLUC allows to calculate LUC emissions related only to the rest of the cocoa sourcing (sometimes referred to by industry as "indirect" supply chain). When masking out dLUC this will influence the average of the remaining plots.

[16] https://developers.google.com/earth-engine/datasets/catalog/BNETD_land_cover_v1#description [2.12.2024]

[17] https://nk.users.earthengine.app/view/cocoa-map [17.9.2024]

VII. Average cocoa plot area per country

Table 18: Average plot sizes extracted from WCF plot locations database (excluding points buffered with 4 ha). The number of plots considered in the average is indicated to estimate data quality. Note: In Brazil, the average area of a cocoa farm is significantly bigger than in other countries, suggesting that other cultivation systems are captured within the polygon outline.

Country	Average plot area [ha]	Number of plots considered [kPlots]
Brazil	67.49	9.8
Ivory Coast	2.55	751.1
Cameroon	2.36	140.2
Ecuador	4.81	29.5
Ghana	1.16	709.1
Indonesia	0.69	123.3
Nigeria	1.44	170.6
Peru	3.85	5.0
Other	4.0	N/A

VIII. Deep dive on comparison of the Tropical Moist Forest Layer (TMF) vs. the Hansen TCL

Table 19: Comparison of the University of Maryland Hansen Tree Cover Loss (TCL) product and the European Joint Research Institute Tropical Moist Forest product (JRC TMF).

	TCL	JRC TMF
Temporal coverage	2000-2022	1990-2022
Geographic coverage and extent	Global tree cover: woody vegetation with a minimum height of at least five meters at 30-meter resolution in 2000.	Tropical moist forest: closed primary and secondary forests in the humid tropics in 1990.
Definition of disturbance	Clearing of at least half of tree cover within a 30-meter pixel.	An absence of tree foliage cover within a 30-meter pixel.
Disturbance classes	All disturbances classified as tree cover loss. The length of disturbance is not considered.	Disturbances are classified as degradation if they are visible for less than 2.5 years, and deforestation if they are visible for more than 2.5 years with no vegetative regrowth over the last three years.
Methods	Classifies change using change detection metrics derived from all valid Landsat images over the present and past years. Only the first loss event that is detected is recorded.	Classifies valid single-date Landsat images and derives disturbance classes by analyzing the single-date classifications. Dynamics of disturbance events over time are recorded.
Accuracy (False negatives | False positives)	Source: GFW Blog[18] - Sub-Saharan Africa (SSA): 48% | 4% - South/Southeast Asia: 14% | 8% - Latin America: 17% | 4% Large number of false negatives in SSA suspected due so smalls-scale disturbances (<30x30m)	Source: Vancutsem et al., 2021 - Africa on forest: 4% | 8% - Africa on non-forest: 7% | 3% - Asia on forest: 7% | 13% - Asia on non-forest: 14% | 8% - South America on forest: 10% | 6% - South America on non-forest: 7% | 13%

[18] https://www.globalforestwatch.org/blog/data-and-tools/how-accurate-is-accurate-enough-examining-the-glad-global-tree-cover-change-data-part-1/ [25.10.2024]

IX. Details on Steps 3 & 4 – Option B

Table 20: Dead organic matter (DOM), consisting of dead wood and litter, as a fraction of above ground biomass (AGB), from UNFCCC, 2013.The recommended fraction to use is highlighted in bold

Climate	Elevation [m]	Precipitation [mm/year]	DOM fraction of AGB [%]
Tropical	**< 2000**	< 1000	6%
		1000 – 1600	2%
		> 1600	**7%**
	> 2000	All	8
Temperate/boreal	All	All	12

X. Selected allometric equations for estimating biomass of agroforestry trees

The most precise method to estimate total biomass is destructive sampling, where a tree is harvested, and its components are dry-weighted. Data from destructive sampling are then used to create allometric equations to model the biomass and thus carbon content of trees. The accuracy of allometric equations varies based on species, genetics, and environmental factors like climate and farming systems (e.g. shade intensity in agroforestry). Selecting or developing an equation that matches the tree population's characteristics is essential to minimize errors in biomass estimates.

Desktop research and reviews of company methodologies and previous work (WCF & Quantis 2023, CFA & Quantis 2022) revealed a gap in species-specific equations for agroforestry trees in cocoa agroforestry. WCF is working on creating a comprehensive list of validated allometric equations. In the interim, this manual recommends using established generic equations (Table 18) based on DBH, H and species-specific wood densities from known databases (ICRAF 2007). Where available, calibrated and validated species- and region-specific equations should be applied and documented per instructions in Annex XI. Table also includes recent species-specific equations that connect DBH and height with crown diameter are useful for calibrating field data with remote sensing, such as drone imagery.

Table 21 Selected allometric equations for major agroforestry tree species used in agroforestry cocoa systems for key sourcing regions. Namely, agroforestry species found in Ivory Coast, Ghana, Ecuador, Cameroon, Nigeria, Brazil, Peru and Indonesia. Selection criteria: equations were selected from peer-reviewed articles that published associated metadata and methodologies, derived from direct measurements (minimum 10 individuals, including multiple age classes), and were statistically tested and validated with provided results. As a best practice, when using a published allometric equation, it is important to always consult the original publication. The list presented here is intended for informational purposes only.

Applicable region	Equation	Species ([1]uses)	[2]Dependent variable	[2]Independent Variable	Parameters	R^2 (%)	[3]SE or RSE	[3]p-value	[4]n	Metadata of the equation	Reference *(journal)*
Ghana	$Y=m(Z^n)$	*Citrus sinensis* (2,4,6,7)	CA	DBH	m=2.71 ; n=1.30	62.9	SE=0.210	***	36	Type equation: Species and region-specific Location: Suhum (N 06° 5' and W 0° 27') in the Eastern Region of Ghana [5] Species: 11 species including *C. sinensis, E. angolense, T. ivorensis, H. floribunda, M. indica* DBH range: DBH median 26 cm Type of forest: Moist Semi-deciduous Forest Type of management: cocoa agroforestry system (ranging from 4 to over 50 years). Cocoa average age 25 years. Average farm size: 1.57 ha Average tree density (trees per ha) : agroforestry trees (113), cocoa trees (1155), fruit plant density (207) Stand structure: with variable proportions of naturally regenerated or planted forest tree	Asigbaase et al. 2023 *(Nature-Scientific Reports)*
			H	DBH	m=4.24 ; n=0.42	53.4	SE= 0.077	***	39		
			CA	H	m=4.65 ; n= 2.03	27.8	SE=0.301	**	33		
		Entandophragma angolense (1,4,7)	CA	DBH	m=2.16 ; n=1.12	66.6	SE=0.198	***	17		
			H	DBH	m=1.95 ; n=1.00	75	SE=0.145	***	17		
			CA	H	m=1.30 ; n=2.07	73.4	SE=0.159	***	17		
		Terminalia ivorensis (1)	CA	DBH	m=3.46 ; n=1.16	67	SE=0.233	***	23		
			H	DBH	m=4.35 ; n=0.54	73	SE=0.093	***	23		
			CA	H	m=3.46 ; n=1.57	46.2	SE=0.298	***	23		
		Holarrhena floribunda (1,4,8)	CA	DBH	m=2.95 ; n=1.42	60.8	SE=0.213	***	42		
			H	DBH	m=4.90 ; n=0.53	55.4	SE=0.091	***	47		
			CA	H	m=5.53 ; n=1.34	31.9	SE=0.282	***	42		
		Mangifera indica (2,3,4,7)	CA	DBH	m=1.27 ; n=1.74	87.4	SE=0.114	***	12		
			H	DBH	m=3.32 ; n=0.52	64.1	SE=0.063	**	12		
			CA	H	m=1.46 ; n=2.35	60.6	SE=0.201	**	12		

										species, fruit trees and food crops Soil type: ochrosols Methodology: Nondestructive and field measurements. Data sets collected from 84 plots (25 m x 25 m). Variables measured: circumference (with tape and at 1.3 m height), height (vertex), crown length (m), crown width (m). Total of 551 individual teres were inventoried. Species-specific allometries were fitted for at least 10 individuals.	
	$Y=a(W(DBH^2H)^b)$	Various species	AGB	DBH, H, W	a=0.0580 ; b=0.999	Adj R2=96.2			745	Type equation: generic and region specific including species-specific wood densities Location: Kintampo Municipality of Ghana, lies between latitudes 7°45′ N and 8°50′ N and longitudes 1°0′ W and 2°5′ W (23 sites) Species: 31 tree species including *Acacia sp., Albizia sp., Khaya senegalensis* and *Terminalia macroptera.* DBH and Height ranges: 5.0-48.2 cm ; 6.6-18.6 m	Aabeyir et al. 2020 *(Forest Ecosystems)*

										Type of forest: tropical West African woodlands Type of management: charcoal production Soil type: not provided Methodology: destructive sampling based on Picard et al. 2012, stratified sampling, field measurements DBH (with tape, cm), H (hypsometer, m) and wood density (g /cm3, measured per species). Coordinates of each tree harvested were also recorded.	
Indonesia	*Y=a + bX*	*Aleurites moluccana (1,7)*	H	DBH	a=3.6784 ; b=0.3101	64.3	SE(a)=1.858; SE(b)=0.050	***	23	Type equation: Species and region-specific Location: Sulawesi, Indonesia, two cacao agroforestry sites : Omu (1°17’ 6.72’’ S, 119°56’51.2’’ E, 188 m a.s.l.), Bulili (1°10’24.3’’ S, 120°5’31.7’’ E, 588 m a.s.l.) Species: *G. sepium* (dicotyledonous), *C. nucifera* (monocotyledonous), *A. moluccana* (dicotyledonous). *See article for details on*	Tiralla et al. 2013 (Agroforestry Systems)
			CR	DBH	a=1.2577 ; b=0.0898	61.3	SE(a)=0.573; SE(b)=0.016	**	23		
			CR	H	a=0.9461; b=0.2376	64.3	SE(a)=0.589; SE(b)=0.039	***	23		
			CL	DBH	a=2.4065; b=0.2673	51.0	SE(a)=2.104; SE(b)=0.057	***	23		
			CL	H	a=-1.7558; b=0.9306	92.5	SE(a)=0.877; SE(b)=00.058	***	23		
		Cocos nucifera (2,6,7,8)	TH	H	a=1.5896; b=0.4173	52.1	SE(a)=1.649; SE(b)=0.092	***	41		
			CL	H	a=-1.5896; b=0.5827	66.3	SE(a)=1.649; SE(b)=0.092	***	41		
		Gliricidia sepium (3,5)	CR	DBH	a=-1.6420; b=0.3242	98.3	SE(a)=0.300; SE(b)=0.021	***	28		

			CR	H	a=-4.6245; b=0.6947	52.7	SE(a)=3.542; SE(b)=0.329	*	28	*growth rates and patterns.* <u>DBH range (cm):</u> GS (7-44.); CN (19-41); AM (14-51) <u>Height range (m):</u> GS (7-13); CN (13-38); AM (8-25) <u>Type of management</u>: cocoa agroforestry. *G. sepium* laterally pruned after DBH=20 cm <u>Agroforestry tree density</u>: low-density (*assumed from the text)* <u>Stand structure</u>: Two-storied plantation cocoa + coconut (Omu site). Mix plantation all species + *D. zibethinus* and *P. americana* (Bulili site) <u>Soil type</u>: not provided <u>Methodology</u>: Non-destructive. Field measurements DBH (tape, cm), H (vertex, H), trunk height (vertex, m), crown length (m), & crown diameter (Kronenspiegel-Densiometer, m). The measurements cover a broad range of DBH classes but only for matured trees. Equation performance tests: correlation analysis,	
			CL	H	a=-3.0425; b=0.9436	73.8	SE(a)=1.142; SE(b)=0.110	***	28		

										Shaprio-Wilk's test (normality test) and Levene's test (homogeneity of residual variances). Validation tests based on secondary data collected from national inventory: Statistical tests used ANCOVA, test of homogeneity of slopes. Additionally, transferability tests, including "analysis of covariance" and "homogeneity of slopes", were used to assess the applicability to other cacao agroforestry systems of the region (with proper calibration and adjustment of the equation).	
Ghana, Ivory Coast, Cameroon, Nigeria, Ecuador, Peru, Brazil, Indonesia	$Y=a+b(X_1X_2^2X_3)^c$	Various species	AGB	X_1=W; X_2=DBH; X_3=H	a=0; b=0.0673 ; c=0.976	R^2 Not provided; AIC=3130	RSE=0.357	Not provided	4004	Type equation: Generic equation for pantropical regions withs species-specific wood densities. Location: across tropics and vegetation types, 58 sites Species: various DBH range (cm): 5-212 cm H range (cm): 9-44.1 (assumed from validation dataset) Type of forest: various within the pantropical region	Chave et al. 2014 *(Global Change Biology)*
					a=0. b=0.0559 ; c=1	R^2 Not provided; AIC=3211	RSE=0.361	Not provided	4004		

										with at least 50% of canopy cover Type of management: old-growth or secondary woody vegetation, excluding plantations and agroforestry systems. The rationale is lower natural variability in plant allometry. Stand structure: Various Soil type: Various Methodology: secondary data of studies with destructive sampling (58 studies published and unpublished). Variables: DBH (cm); H (m), W (g/cm^3), and AGB (dry kg). Tree harvest sum up to 4004 trees from which 1429 from Afro-tropical realm, 1794 from Latin America, 7851 from Southeast Aasia and Australia. The article has meticulously conducted various statistical analyses and model fitting procedures, ensuring all necessary steps were taken, and thoroughly documented the entire process within the paper.	

										Limitation: AGB less accurate for tree level estiamtesl. Model built for secondary forests and not agroforestry systems.	

[1] Uses: 1. Timber, 2. Food & beverages, 3. Fodder, 4. Fuelwood/Charcoal, 5. Nitrogen-fixation, 6. Essential Oils, 7. Medicinal, and 8. Other uses (adapted from Dawoe et al. 2016)

[2] CA = crown area (m2) ; CR= crown radius (m); CL=Crown length (m); DBH=diameter at breast eight 1.5 m (cm); H=tree height (m); TH= Tree trunk (m);W=wood density (g/cm^3); AGB= aboveground biomass (Dry kg)

[3] SE Standard deviation. The 95% confidence interval of the slope and intercepts are in parenthesis. *p<0.05; **p<0.01; ***p<0.001.; RSE Residual standard error

[4] n is the sample size

[5]Other species-specific allometric for *F. sur, M. regia, M. zechiana, N. Laevis, R. vomitoria, S. campanulate*

References

Aabeyir, R., Adu-Bredu, S., Agyare, W.A. et al. (2020). Allometric models for estimating aboveground biomass in the tropical woodlands of Ghana, West Africa. For. Ecosyst. 7, 41. https://doi.org/10.1186/s40663-020-00250-3

Asigbaase, M., Dawoe, E., Abugre, S. et al. Allometric relationships between stem diameter, height and crown area of associated trees of cocoa agroforests of Ghana. Sci Rep 13, 14897 (2023). https://doi.org/10.1038/s41598-023-42219-6

Chave, J., Rejou-Mechain et al.(2014). Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology, 20(10), 3177-3190. https://doi.org/10.1111/gcb.12629

Tiralla, N., Panferov, O. & Knohl, A. (2013). Allometric relationships of frequently used shade tree species in cacao agroforestry systems in Sulawesi, Indonesia. Agroforest Syst 87, 857–870. https://doi.org/10.1007/s10457-013-9602-4

XI. Guidelines for documenting allometric equations and remote sensing data acquisition

Table 22: Checklist of recommended guidelines for documenting allometric equations and remote sensing methodologies in cocoa production. This checklist is designed to support comprehensive documentation, enhance data reuse, and improve validation and reliability

Category		Information to include
Definitions and concepts		*Mandatory*
	☐	Tree species for which the equation was developed
	☐	Tree components measured (e.g. bole, crown, roots)
	☐	Type of height measurements (total, commercial)
	☐	Type of diameter measurements (point of measurement, e.g. 130 cm at breast height)
	☐	Units of measure
	☐	Definitions of variables used
Environmental conditions and growing system		*Mandatory*
	☐	Geographic coordinates (latitude and longitude) and projection system
	☐	Elevation (in m above sea level)
	☐	Climate variables: mean annual temperature (°C), mean annual precipitation (mm/year), length of dry season (in month with rainfall <100 mm)
	☐	Tree density trees per ha and species (cocoa, agroforestry trees)
	☐	Archetype (e.g. agroforestry, intercropping, light shade, intense shade, etc.,)
	☐	Cocoa plantation age
		Highly recommended
	☐	List of agroforestry trees present
	☐	Soil information (type, texture, depth)
	☐	Management practices (e.g. pruning, residue management, thinning)
	☐	Cocoa yield
	☐	Landscape characteristics (slope, aspect)
Sampling and laboratory analysis		*Mandatory*
	☐	Sampling criteria (e.g. diameter classes, species composition or guild, plot-based sampling)
	☐	Sample size
	☐	Range of values for diameter, height, wood specific gravity, tree components, etc.
	☐	Methods used in the field or in the laboratory (e.g. method used to measure wood specific gravity)
		Highly recommended
	☐	Number of replicates
	☐	Instruments used in the field or in the laboratory (e.g. laser model for tree height measurement)
	☐	Calculation procedures
Model fitting, prediction and uncertainty		*Mandatory*
	☐	Functional form of the model(s) (e.g. power, non-linear, log-log)
	☐	Model mathematical formula, including form of the error term (multiplicative versus additive)
	☐	Data transformations (if any, e.g. log transformation), Software (and version)
	☐	Statistical parameters (R^2, RSE, mean bias, at a minimum)
	☐	Parameter values and confidence intervals of the parameters

	☐	Comparative statistics (e.g. F-value, AIC, BIC, Furnival index)
Meta data	*Highly recommended*	
	☐	Data owner (contact information)
	☐	Raw data
Remote sensing specificity	*Mandatory*	
	☐	Specify remote sensing technology (e.g. optical, radar, LiDAR)
	☐	Data source/provider
	☐	Collection equipment (i.e. satellite, aircraft, drone), including model details and sensors characteristics
	☐	Measurement specifications such as survey design, temporal/spectral resolution, flight altitude, camera angle, ground sampling distance, and image overlap.
	☐	Image processing (i.e. methods, software, key parameters and projections)
	☐	Validation and calibration process, including dataset description (ground-measurements and training datasets)
	☐	Uncertainty estimates and calculation procedure
	☐	Data limitations and assumptions
	☐	Data update process and frequency
	Highly recommended	
	☐	Details on data availability and access (i.e. repository name and ownership, direct URL to data, instructions for data access and usage)

XII. Residue quantities, properties, management and emissions

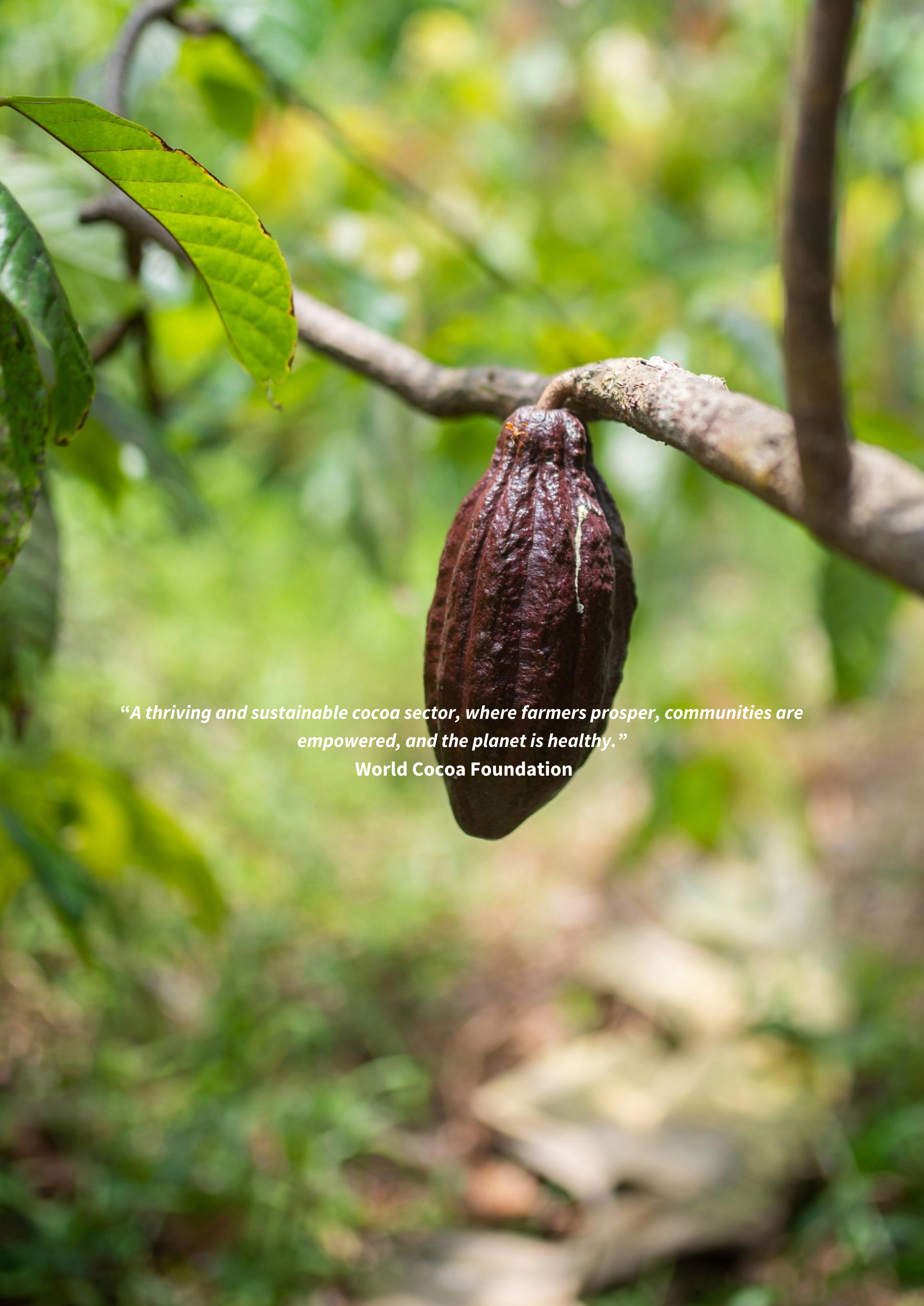
Table 23: Default quantities and properties of the different types of cocoa agricultural residues

Type	Dry Matter content	Reference	N content in DM	Reference	Mass ratio	Justification	Reference
Pruning residues	57% DM	Kazimierski et al. 2021	0.58% N in DM	Rodríguez-Espinosa et al. (2023) - Table 1 - average of the different crops	8 900 kg fresh mass / ha	The reference gives 4 different quantities of C in pruning residues per ha depending on the production scheme. For the reference quantity, the average of the 4 is taken -> 2.28 t C/ha	Schneidewind et al. 2018
						Carbon content of 0.45 kg C / kg DM	Sarkar et al 2022
Pod husk	15.4% DM	Vergara-Mendoza et al. 2022 - Table 1	5.27% N in DM	Vergara-Mendoza et al. 2022 - Table 1	3.04 kg fresh husk / kg fresh bean	-	Vergara-Mendoza et al. 2022 - Table S1

Table 24: Default carbon emissions per type of residue management

Type	EF	Reference
Spreading out on field	<u>In wet* climate</u> Direct emissions: 0.006 kg N2O-N / kg N Indirect emissions: 0.0026 kg N2O-N / kg N **-> 3.7 kg N2O-N / kg N in residues** <u>In dry* climate</u> Direct emissions: 0.005 kg N2O-N / kg N (no indirect emissions considered in dry climate) **-> 2.14 kg N2O-N / kg N in residues**	IPCC 2019 Vol4 Ch11 Table 11.1
Unmanaged compost	0.52 kg CO_2e / kg DM of residues	Ecoinvent 3.10
Managed compost	0.062 kg CO_2e / kg DM of residues	Ecoinvent 3.10
Burning	0.070 g N_2O/kg DM and 2.70 g CH_4/kg DM **-> 0.092 kg CO_2e / kg DM of residues**	IPCC 2019 Vol4 Ch2 Table 2.5, line 'Agricultural residues'

* The IPCC considers a climate wet if the precipitations go above 1'000 mm/year, and dry otherwise.



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