GUIDANCE G

Yield Estimation

Version 1

RAINFOREST ALLIANCE

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Document Name:		**Document Code:**	**Version:**
Guidance G: Yield Estimation		SA-G-SD-8-V1	1
Date of first publication:	**Date of revision:**	**Valid From:**	**Expires by:**
March 31, 2021	N/A	March 31, 2021	Until further notice
Developed by:		**Approved by:**	
Rainforest Alliance Department Standards and Assurance		Director of Standards and Assurance	
Linked to:			
SA-S-SD-1-V1.1 Rainforest Alliance 2020 Sustainable Agriculture Standard, Farm requirements (1.2.10, 2.1.1, 2.1.2)			
Replaces:			
N/A			
Applicable to:			
Farm Certificate Holders			
Country/Region:			
All			
Crop:		**Type of Certification:**	
All crops in the scope of the Rainforest Alliance certification system; please see Certification Rules.		Farm Certification	

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1. INTRODUCTION

Accurate estimation of crop yields is important for the agronomic, entrepreneurial, and environmental benefits of the farm. Reliable harvest estimation enables producers and group managers to become better farm managers, helps guide in adopting sound agricultural practices, and brings transparency to the supply chain. In addition, having accurate numbers on certified volumes is essential for the credibility of Rainforest Alliance's certification program and traceability system.

This guidance covers different commodity crops and production contexts. Basic principles are described to enable more accurate yield estimates while acknowledging that different and more detailed approaches (methodologies) are possible and currently being practiced in some contexts.

Accurate volume estimates enable producers to:
Better manage production

- Estimate how much input (e.g. fertilizers, pesticide) is needed.
- Have a better understanding of the management of the farm.
- Observe the impact of better farming practices and optimization of productivity.

Better manage market relationships

- Estimate the supply of certified product for the coming year.
- Increase the trust between producer and buyer, by more accurately indicating how much produce will be available for sale.

Better manage livelihoods

- Accurately estimate income to better management of household finances.
- Increase the possibility of access to loans/credits from financial institutions.

Requirement 2.1.1 states that The estimated volume for the upcoming certification year is determined annually based on a credible methodology applied by group or farm management. In addition, for group management, at every certification cycle internal inspectors visit a representative sample of group members and estimate the crop yield based on a credible methodology.

After the annual audit conducted by a Certification Body, which verifies the estimated crop yield and volumes as well as the credibility of the methodology used, the group enters the estimated volumes in the Rainforest Alliance traceability system, allowing groups to sell their certified product to buyers.

After verification of the volumes during the external audit, the Group reports the total volume harvested in the traceability system. The group compares the real harvest with the volume estimates to check that the estimation methodology is realistic.

To ensure a credible methodology is used is it is always essential to:Test the methodology.

- Train the users.
- Verify that the estimation reflects what is observed in the field.
- Continuously monitor production and those factors affecting it (pests and diseases, weather conditions).
- At the end of the certification year, compare the estimation with the real harvested volume.
- For each new certification year, compare the estimated volume with previous harvests.
- Measure using the metric system (kilograms or Kgs) or hectare (ha).

This yield estimation guidance refers to the implementation of standard requirements 1.2.10 as this indicates the production areas, and 2.1.1 and 2.1.2.

2. SELECTING A GOOD SAMPLE TO ESTIMATE YIELD

The crop yield is the volume of crop grown per unit of land area or per plant in a year. Depending on the crop, the yield can be determined using different product types (e.g. green coffee/parchment, green leaves/made tea).

Commodity crop	Field estimation	Sub-product in Rainforest Alliance Traceability System	Measurement unit
Coffee	Cherries	Cherries, parchment, green coffee	Kg
Cocoa	Dry cocoa beans	Dry cocoa beans	Kg
Tea	Green leaves	Made tea	Kg

Monoculture

In the case of crops grown in monoculture, the spacing between plants is generally the same across the whole plot. In these cases, the volume estimation can be made by multiplying the farmer's certified crop area with an average yield estimate of the farmer's plots:

Image of Calculation 1: Estimated Certfied Volume per Group Member with Monoculture

Diversified farming systems

In diversified farming systems, the total certified volume cannot be calculated by working with the full production acreage. Therefore it is estimated based on the production per tree or bush. The total certified volume is then calculated by multiplying the number of trees/bushes with the average yield estimate per tree/bush.

Image of Calculation 2: Estimated Certfied Volume per Producer Group with number of Trees/Bushes

Whether the volume estimation per producer is done based on the production per tree/bush or on the production per certified area (yield), the Group management can eventually multiply the average certified volume of a representative sample of group members for the total number of group members:

Image of Calculation 3: Estimated Certfied Volume per Producer Group by represeative sample

A key aspect of obtaining an accurate estimation at a group level is a good methodology to select a representative sample of group members. Here you can find the basic steps to select a good sample:

1. **Choose the sample size.**
The sample size may depend on the total production acreage and on its homogeneity. In more diverse areas the sample size needs to be larger to have a proper representation of the area. The sample size may cover 5% to 10% of the total area.

2. **Choose the group members to be included.**
When preparing a sample of group members, include the following elements at a minimum:
   - Producers representing higher and lower yields per hectare in the group of farmers based on previous yield estimates and actual volumes, if this information is available.
   - Producers with smaller and larger areas.
   - Producers covering the different geographical and climatic characteristics in the certified area.
   - If posssibe, select producers who made accurate yield estimations in earlier years, provided their acreage is large enough to represent the whole area.

It is better not to include the following:
   - Producers who recorded significant differences between estimated yield and previous year harvest as this suggests their yield estimation was not accurate
   - Producers who had non-conformities related to volume estimation as ttheir information may not accurate or reliable.

These groups of producers should first be taught how to make an accurate yield estimation, which is checked during the internal inspection.

3. **Implement the yield estimation methodology with the sample of farmers.**
This is done using the methods laid out in the chapters below.

3. ACCURATE YIELD ESTIMATION

The accuracy of the certified volume relies on two parameters: the yield per area or per tree/bush and the certified area. The basic factors determining the yield are the following:

- The number of all the farm plots,
- The location and size of the farm plots to determine the certified area of the farm (often measured with GPS devices),
- The number and age of the plants,
- The plant spacing,
- The type of varieties/cultivars used.

When determining the certified area, use a GPS tool that is widely available and considered a reliable method when used well (see Annex). It allows for more accurate and consistent data collection than estimating locations or areas using paper maps or a compass and distance measurements.

In several countries, governmental bodies issue official land titles indicating the size of the farm. These officially recognized documents are also considered a reliable method to determine the size of the certified area per producer. Group management should nevertheless verify during the internal inspections that the farm has not been split or sold since the official land title was issued.

The accuracy of the yield depends on many factors including environmental conditions and agronomic practices implemented by the producers. Whichever methodology is used, the final estimation should be adjusted based on the following information:

- If available, local average or potential yield of the area, for comparison purposes (e.g. provided by departments of Agriculture, extension services et cetera)
- Integrated pest management (IPM) practices implemented.
- Soil fertility and soil nutrient management.
- Sanitary status of the crop (pest and disease pressure and their management).
- Cropping system (intercropping or monocropping – the density of the certified crop will affect the yields).
- Agricultural practices (level of pruning, weed management, irrigation, etc.).
- Climate conditions and precipitation (rainfall) pattern.
- Labor input.
- Method of harvesting.
- Quality of the harvested product requirements, e.g. for tea: two leaves and a bud or three leaves and a budetc For coffee or only ripe/mixed/dried cherries.

These aspects of crop production have a significant impact on crop yield. This is one of the reasons explaining the substantial variation that occurs between countries, regions, farms, and even within farms. A careful assessment of each of these parameters should eventually be translated into better estimations of crop production.

For groups, to increase the accuracy of the estimates Rainforest Alliance encourages the following methodologies to be used:

- Digitalized and centralized archive with all the relevant information (see later in this guidance).
- Historical database of harvested volumes for each of the farm plots, possibly also in digital format. Among other purposes, this is to triangulate a plantation's records with local crop yield estimations made by local research institutes and/or extensionists.
- Maps.

4. HOW TO IMPROVE YOUR CERTIFIED VOLUME ESTIMATES

Although the process for estimating yield and volume may involve different persons within the group or farm management, it is important for one person to have an overview of the whole process to make sure the methodology is well implemented and that data, observations, and learnings are not lost. This person should have a good understanding of crop production, be literate and comfortable with numbers.

The person responsible for the yield and volume estimation process should be responsible for implementing the steps shown in the image below.

Although this process can imply responsibilities for different persons within the Group or farm management, it is important for one person to have an overview of the whole process to make sure the methodology is well implemented and that data, observations, and learnings are not lost. This person should have a good understanding of crop production, be literate and comfortable with numbers.

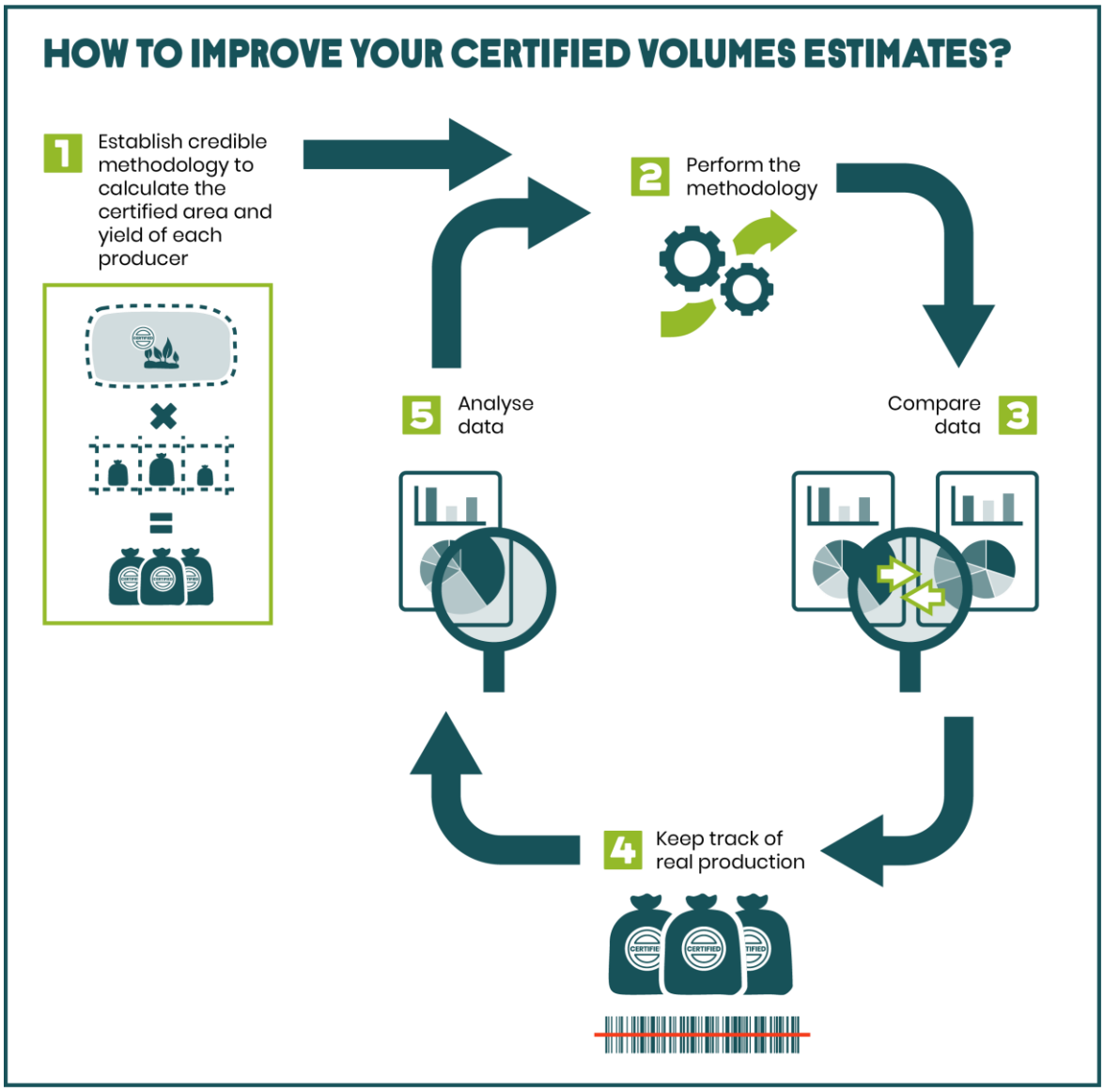

Image 1: How to improve your certified volume estimates

The steps in image 1 are described in more detail here:

1. Establish a credible methodology to calculate the certified area and yield of each producer
2. Perform the methodology:
    a. Test the methodology
    b. Train the person(s) responsible for estimating the volumes
    c. Calculate the volume for a representative sample of farm units and farms
3. Compare the Data
   Cross-check the certified volume of each producer with previous year(s) harvest, total sales of the producer and internal inspection reports (requirement 1.4.1).Take into account risks that might influence volume estimates. This can include supply chain risks: risks that influence the accuracy of your data could be in the collection centers in your supply chain or in multi-certification of your group members
1. Keep track of the real production
   Set up a system to verify real production. This can be done for example by regular checks with a representative number of producers to gather information on the status of the crop and the quantities produced.
2. Analyse the data
   After the harvest season, real production needs to be compared to the estimated production. If discrepancies between the two are found:
    - Identify the cause of the differences and, Put in place measures to prevent such differences occurring. This can include improving your methodology (step 1) and training your internal inspector (step 1)
    - Modify the estimated certified volume on your list of group members (2.1.1) for the new certification cycle.

5. ACCURATE YIELD ESTIMATES FOR COCOA

The yield and volume estimation methodology explained below is time sensitive. Group/farm management should first assess the best months to implement the methodology. Since this method is based on pod counting, the best time is right before the beginning of the harvest when the pods are not too small and may therefore never reach maturity as this would lead to an inaccurate estimate.

After assessing the best months to carry out the methodology, and after determining the certified area either with a GPS tool (polygon) or with recognized official documents, yield and volumes estimates are calculated as follows:

Step 1: productive cocoa tree density on sampled farms

This first step of determining productive tree density (number of productive trees per hectare) can be done on each group member's farm. Alternatively it can be calculated for a representative sample of farms (eg for the square root number of all group members). The average number of productive trees per hectare for these sampled farms is then calculated and applied to all group members. *The explanations below are based on a sampled number of farmers:*

Productive tree density can be determined based on the sample area(s). For this, one or more area of 10 meters by 10 meters (100m^2) is defined on a representative part of each sampled farm.

If the farm is not homogeneous, as a general guide the sample area should not be in areas where there is no production such as:

a. Newly planted fields.
b. Abandoned fields

When calculating the overall yield, the area of fields with no production should be left out.

In each of the sample areas, the number of productive trees is then counted. If more than one sample area is defined, the average number of productive trees per sample area is calculated.

This counting will result in the number of productive trees per 100m^2. This figure then needs to be multiplied by 100 to obtain the density of productive trees per hectare.

Image of Calculation 4: Productive tree density on sampled farms

Step 2: productive tree density for the whole group

Once the average number of productive trees per hectare is determined for each sampled farm, the average of all these sampled farms can be calculated to obtain the average productive tree density for the whole group.

Image of Calculation 5: Average number of productive trees for the whole group

N.B: The density range at which the productivity of the fields will be optimized is 800 to about 1,300 cocoa trees per hectare (assuming the farm is not intercropped with other crops). Below this range, producers are not making the best use of the space in their fields and are encouraged to renovate their fields. If above this range, the cocoa trees enter into competition with each other for resources (light, nutrients, water), and the probability of diseases increases. Producers are encouraged to remove some of their trees to fall back into the best tree density range.

Steps 3 and 4: pod counting on productive trees for each group member

Once the tree density has been determined and applied to all group members, pods on productive trees need to be counted to then determine the estimated yield and volume. The pod count is done on the farm of each group member on a representative number of adjacent productive trees. The number of trees on which to count the pods is based on the productive tree density for the whole group divided by 100 (the result represents the number of productive trees that would be found on a 10m by 10m sample area).

Image of Calculation 6: Productive trees to do the pod count on each farm

The pods on this number of sampled productive trees are then counted on the farm of each group member:

Tree	Number of pods per productive tree
Tree 1	
Tree 2	
Tree 3	
Tree 4	
Tree …	
Tree …	
TOTAL NUMBER OF PODS ON SAMPLED PRODUCTIVE TREES:	

It is not recommended to include very small pods (called cherelles – about 5cm long) in the counting as their probability of reaching maturity is relatively low. If the pod counting is done once most pods have reached maturity, it is important to ask the producer about the relative quantity of cocoa harvested in the last few weeks to include this volume in the estimation.

Steps 5 and 6: calculating the estimated cocoa yield

Once the pods on the sampled productive trees have been counted, the cocoa yield can be estimated.

The number of pods per tree is first determined based on the sum of the number of pods counted on the sampled productive trees:

Image of Calculation 7: Average number of pods per productive tree

The average number of pods per tree is then used to calculate the average cocoa bean production per tree, knowing that on average, one pod is equivalent to 0.04kg of cocoa beans:

Image of Calculation 8: Average number of pods per productive tree

Finally, the cocoa bean production per tree is multiplied by the tree density per hectare to obtain the yield:

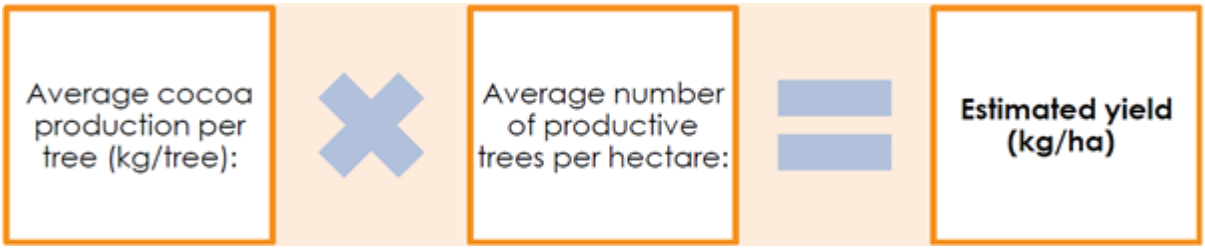

Image of Calculation 9: Estimated yields

Step 7: calculating the estimated volume and adjusting for local conditions

As the last step, the yield per hectare is multiplied by the total certified area to obtain the estimated volume and then adjusted based on the factors mentioned in chapter 3 of this document.

Image of Calculation 10: Average number of cooca beans produced

For example, with no pest and disease control (such as little to no pruning and/or weeding, or removal of infested pods), it can be expected that part of the pods will be lost, and hence, need to be deducted from the overall annual estimated volume.

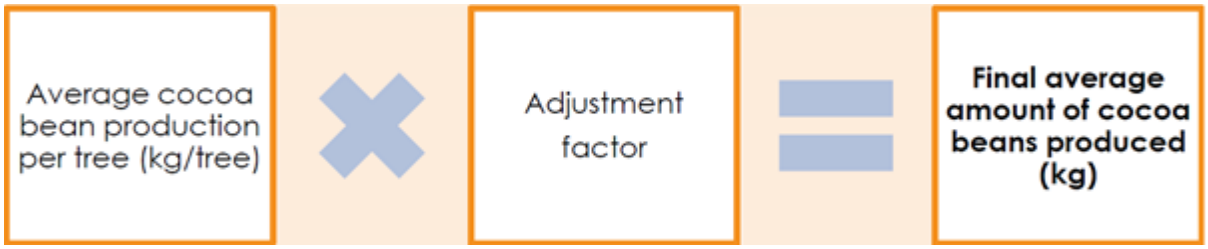

Image of Calculation 11: Final amount of cocoa beans produced

Steps 3 to 7 can also be done with a representative sample of producers (ideally, on the same sample area used for estimating the tree density – Step 1), and then extrapolated to other group members who have similar farming conditions. It is particularly important in this case to compare and adjust the value of the extrapolated estimated volume based on the field observations by the internal inspectors and the previous year's production information.

Using an Adoption Observation-based methodology for yield estimation in cocoa

For cocoa, a method of yield estimation is the method of Adoption Observation. Certificate holders are encouraged to make use of this method when possible. The method is briefly described below.

The method can result in a robust yield estimate but using it requires proper training first. Further guidance on the use of this method will be available on the Rainforest Alliance Learning Network through https://learn.ra.org/.

The development of Adoption Observations was supported by Mars Wrigley as a way to observe farm practices and conditions which are correlated with prevailing yields.

This methodology involves two main steps:

Step 1: Plotting:
When starting to work with Adoption Observation for the first time, the farm is divided into ''homogeneous plots.'' These are parts of a farm where the conditions of the trees are the same and where the trees all need the same interventions to reach a high yield. A plot may be indicated on a paper map or, better, on a digital map. Often digital maps for the whole farm exist, in which case only the boundaries between plots within the farm need to be added. If a whole farm is homogeneous only one plot is indicated for the whole area of the farm.

Step 2: Collecting Adoption Observation information:
The observer visits a plot and makes 14 observations against specific criteria:
Plant material,

1. Plant Material, Genetics
2. Tree Age
3. Tree Density
4. Tree Health
5. Debilitating Disease
6. Pruning
7. Pest, Disease and Sanitation

8. Weeding
9. Harvesting
10. Shade
11. Physical Condition of Farm Land
12. Soil Health
13. Formulations for Fertilizer and Organic Nutrient Replenishment
14. Fertilizer and Organic Nutrient Application

The 14 observations are categorized as Good/Bad or Good/Medium/Bad depending on the observation. The system starts with an assumption that an ideal targeted yield potential of 1.5 or 2.0mt cocoa per year per hectare can be reached.

- Every observation that is rated Good will support the target yield potential to be achieved.
- Observations rated Medium or Bad will reduce the potential by a certain percentage depending on their severity.

The final estimated yield on a plot is derived from reducing the potential for every intervention that scores less than Good and the yield for the whole plantation is determined by adding up the volumes of all plots.

1. ACCURATE YIELD ESTIMATES FOR COFFEE

After having mapped the area, Certificate Holders can make yield estimates by taking the following steps per group member. This methodology can be used when cherries are present in the field.

If there is more than one harvest per year, yield estimates take into account all harvests.

Step 1: Tree counting to calculate coffee plant density
Count the productive trees in one hectare. See Annex 1 for an example of the methodology. In this example, there are 1500 trees/hectare.

Step 2: Make a sample
In one plot, draw a transect/imaginary line. This transect has to go through representative areas of the farm in terms of variety and age of trees and soil quality. On this line, identify three points where there is a good diversity of yields. At each point, choose five representative trees in terms of yield and go through the next steps.

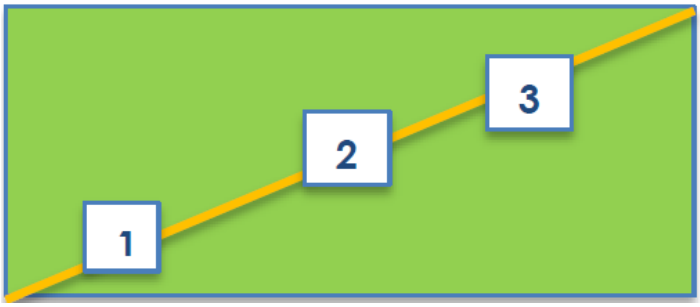

IMAGE OF TRANSECT LINE 1

Step 3: Count branches and cherries

Counting should take place during harvest time. For each tree, count the number of branches and write it down. Afterward, choose four average size branches in four directions, count all cherries on the branches and calculate the average. Once you have the number of cherries per branch and the number of branches per tree, you can calculate the number of cherries per tree. Complete the following table:

Tree number	Number of branches (Filled in by farmer/ technical staff)	Number of cherries on one branch (Filled in by farmer/ technical staff)	Number of cherries per tree = number of cherries per branch * number of branches per tree (Filled in by farmer/ technical staff)
1	30	20	30 * 20 = 600
2	50	60	50 * 60 = 3 000
3	45	45	45 * 45 = 2 000
4	45	40	45 * 40 = 1 800
5	32	25	32 * 25 = 800
6	55	65	55 * 65 = 3 600
7	40	10	40 * 10 = 400
8	50	50	50 * 50 = 2 500
9	37	40	37 * 40 = 1 500
10	46	50	46 * 50 = 2 300
11	30	33	30 * 33 = 1 000
12	75	60	75 * 60 = 4 500
13	50	60	50 * 60 = 3 000
14	45	45	45 * 45 = 2 000
15	50	28	50 * 28 = 1 400
Average number of cherries per tree = 2030 cherries/tree			

Step 4: Yield estimate

To determine the weight of green coffee per tree, do the following calculation.

The first step is to calculate the average weight of cherries per tree. This can be done by weighing the counted cherries and dividing the weight by the number of cherries.
In this example we have taken 1/600kg as the weight of one cherry.

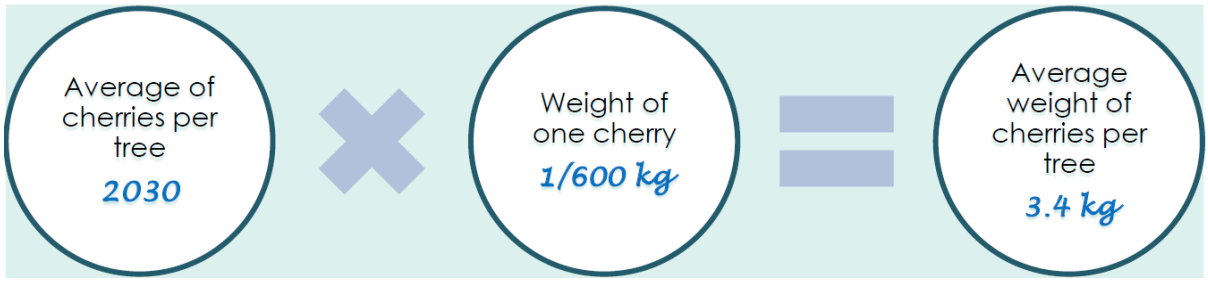

Image of Calculation 12: Average Weight of Cherries per tree

The second step is to calculate the weight of green coffee per tree by using a conversion rate of 1 to 7.7. For this example: kg of green coffee per tree = 3.4/7.7 = 0.486kg of green coffee per tree.

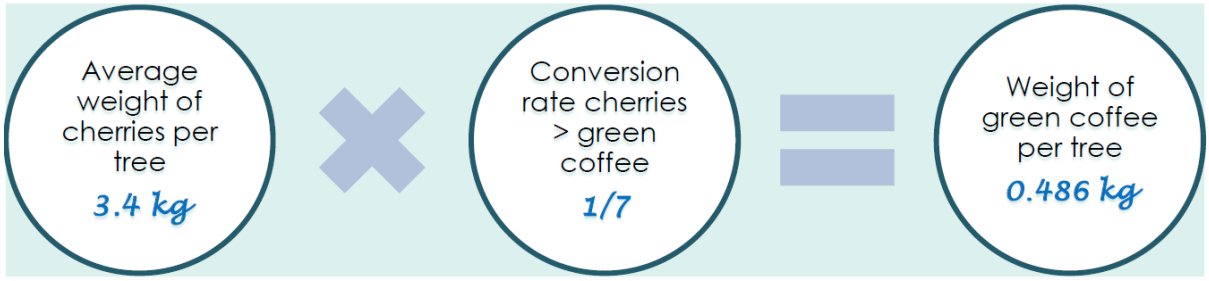

Image of Calculation 13: Weight of green coffee per tree

To have the yield estimate per hectare, multiply by the number of trees identified in Step 1:

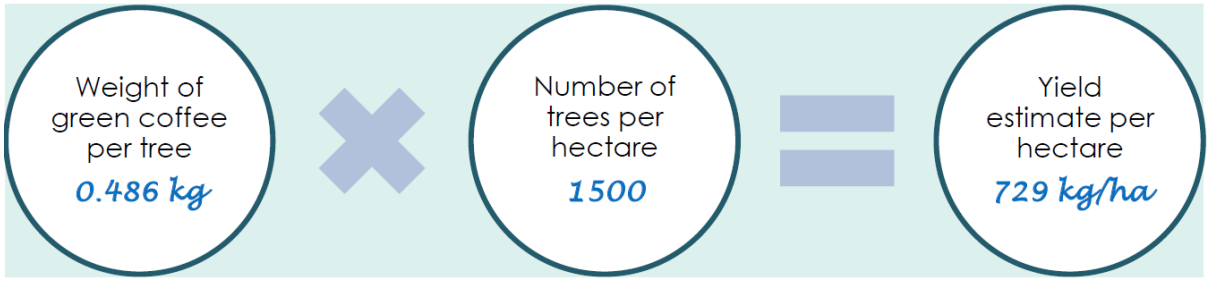

Image of Calculation 14: Yield estimate per hectare

Step 5: Volume estimation

The last step is to multiply the yield estimate and the size of the certified area to get the estimated volume.

2. ACCURATE YIELD ESTIMATES FOR TEA

Unlike the other commodities mentioned, tea is a crop that is continuously (or almost continuously) harvested throughout the year in most regions. It is also characterized by pruning cycles of 3-to-5 years of length. Production of tea varies with the year of the pruning cycle the plot is in.

The yield is calculated for the calendar year, from January to December or for 12 months depending on the financial year of each of the producing organization, e.g.July-June/April-March.

Commonly for plantations the yield is calculated in kilograms of made tea per hectare.
Small farms can also work with calculations in kilograms of green leaves per bush, which can be converted into kilograms of green leaf per hectare or acre. This can then be converted to made tea per hectare based on the conversion rates of the factory.

Yield estimations in tea are commonly based on historical data. The yield estimation is further influenced by factors including:

- Harvesting method (mechanical or hand harvesting).
- The desired quality of the harvest, e.g. two leaves and a bud or three leaves and a bud, and the number of plucking rounds/interval (varies from 1-to-4 plucking rounds/month/bush).
- Age of the tea bushes.
- Stage of the pruning cycle of the harvested bushes, pruning height and other husbandry practices including the tipping height allowed.
- Fertilization program (type and amounts of fertilizer applied, time and conditions during fertilizer application, method of application, split applications or annual, etc.).
- Field coverage with bushes (Is the whole field covered or are there gaps, e.g. because of missing bushes, shade trees, other elements within the tea field?)
- Types of clones.
- Plant spacing.
- Time between harvesting and weighing (the season also affects this, e.g. dry season vs. rainy season).

Yield estimation can be conducted by taking the following steps:

Step 1:
The yield estimation starts from the map of the farm, as per Requirement 1.2.10. This map (for small farms, also the group registry) can be used to identify areas where there might be different characteristics influencing the yield based on the aspects mentioned above.

Step 2:
For larger farmers, the yield calculation is based on the area under plantation, which will be clear from the GPS polygons, and on historical yields and further factors as mentioned above.

In very small farms where there is no consolidated plot for which the area can be calculated, yield calculation is based on the number of bushes. Count the bushes for each of the plots identified and categorized based on relevant characteristics including the pruning cycle. This is done for all established farms and plots.

Step 3:
Based on the records made at the factory level on the average productivity per bush, the producer calculates the average kilograms of production per tea bush.

Step 4:
The volumes estimate for the current season is calculated by multiplying the average kg of green leaves production per tree (Step 3) by the number of tea bushes counted in Step 2.

Step 5:
The yield estimated for each plot is added up to eventually obtain an overall volume in green leaves.

Step 6:
Green leaves are converted into made tea by using the local conversion rate.

A table with example numbers:

Plot	Area (ha)	Number of bushes (#)	Average yield per bush per pruning cycle per year (kg/bush/year)	Overall estimated volume for this plot (kg)
Plot 1	0.3	1200	1.8	1200x 1.8 =2160
Plot 2	0.6	2000	1.7	2000 x 1.7 = 3400
Plot 3				
Plot 4				
Plot …				
Plot …				

In the plantation context

For mechanical harvesting or scissor harvesting there can be added residue to the harvested produce. To take as clean as possible harvested volume data, it is suggested to weigh the volume again after cleaning, or to use a method to calculate conversion rates. It is important to note down the method for such conversion in the yield estimation methodology document.