TROFACO
Tropical Farmer Connect

CO_2 removal

by planting of tropical trees

Methodology and Standard (Volume 1)

(Edition 2024/01)

Contents

Volume 2 of the TROFACO methodology and standard describes how TROFACO verifies the amounts of CO_2 taken up by individual trees and by plantings.

It is available below.

INTRODUCTION

TROFACO plants trees in tropical areas, together with landholders there. And TROFACO also gives advice and document planting by others, if they follow our standards.

TROFACO's guiding values are:

Benefits must go to those that suffer most from global heating: Communities in tropical areas.

Maximum transparency between the beneficiaries and the sponsors of climate action must be provided.

Highest possible effectiveness is maintained through a robust, simple and no-nonsense approach.

Here we present how we do to ensure permanency of the climate action, that the activities are **additional** and the climate benefits are claimed only once.

1.1 Basics:

- TROFACO always plants on land that is *previously forested and currently without trees*
- TROFACO always plants on land that is *identified by local communities or other landowners*
- TROFACO always plants on land that is *not used for household farming* and we prefer plantings managed as agroforestry, if the landholders agree.
- TROFACO plants trees based on *written agreements* with each landholder and confirmed by relevant authorities.
- The TROFACO standard provides financial encouragement 'along the way' in proportion to how well the landholder takes care of the trees.
- TROFACO follows up on each planting by regular, physical visits.
- TROFACO, in working with communities, builds long-term relationships with the communities and the national partner(s) and authorities working in the same communities.

IN-CONTRY NATIONAL PARTNERS

TROFACO carefully screens partners' organizations, i.e. track record, financial management, staff management, technical capacity, relations to authorities etc. TROFACO does that before entering any long-term collaboration and also 'along the way'[1]

1. TROFACO conducts testing of new partners. TROFACO pays for one or two minor plantings and then monitors how these are doing. TROFACO, on this basis, have rejected some potential partners and maintained those that consistently perform.
2. With our trusted partners, TROFACO continues the deepening of collaboration. This is through expansion, joint inspections and joint planning for the way ahead.
3. TROFACO staff follows up in the field, through regular working visits to planting sites and tree-hosting communities and for identification of new potential locations and/or partners. This involves both in-country staff and staff from Denmark.
4. These same principles also apply when working with commercial farms in our countries of operation.

[1] (TROFACO have a screening note for new national partners. May be provided on request)

IDENTIFICATION OF LAND ON WHICH TO PLANT

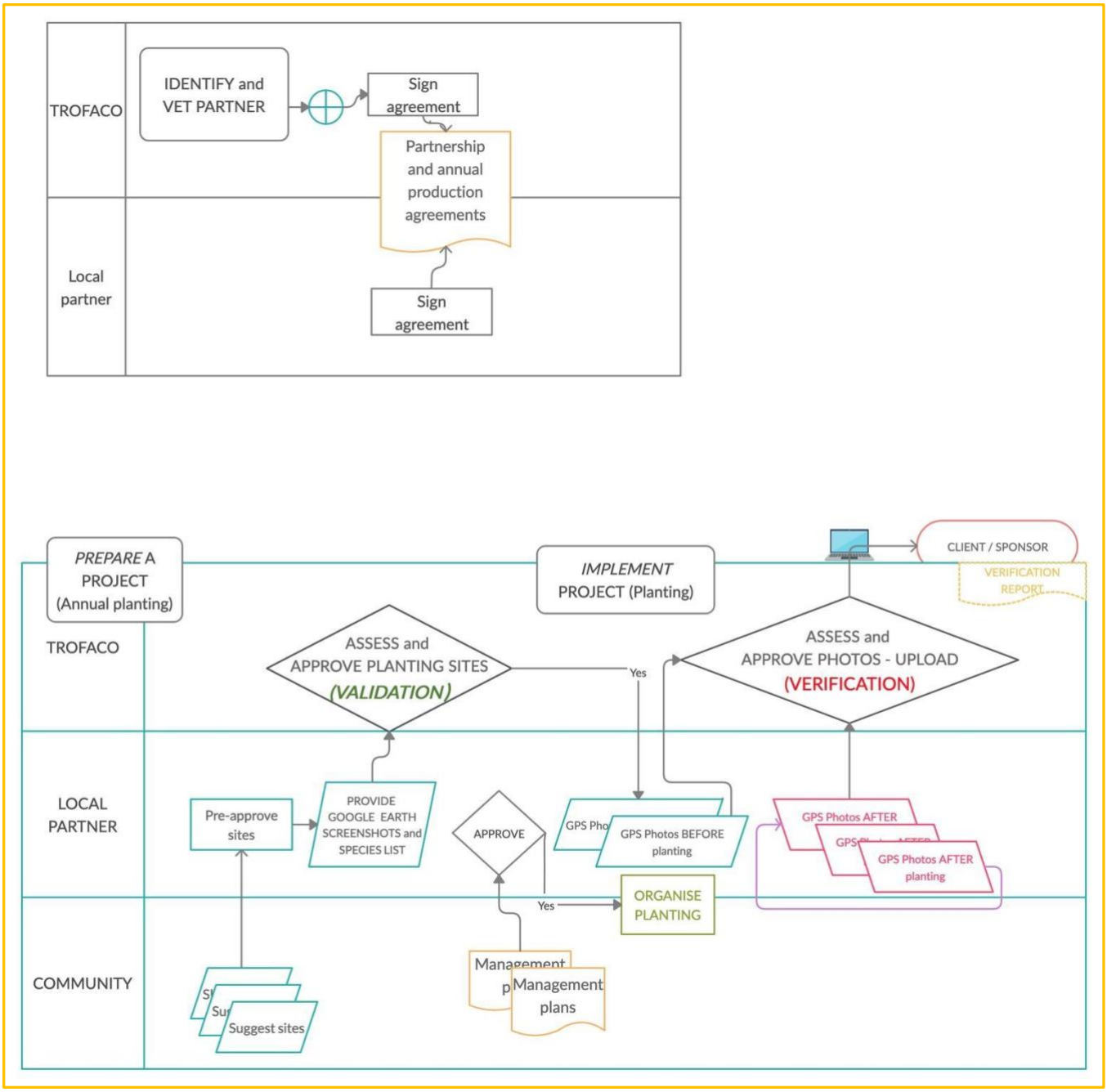
1.2 Principles

TROFACO plants only on land with secure ownership, confirmed by government and institutional powers. These may be for example a cadastral office or education department (formal), a clan leader or a church (informal).

1) TROFACO works with local partners who themselves have considerable power or influence. For example, in Uganda TROFACO and its national NGO partner (Community Integrated Development Initiatives - CIDI) have a joint agreement with the Buganda Kingdom and farmers' associations or similar.
2) TROFACO only works on land that is bare of trees and not used for farming. First step in identifying a planting site is for the partner to produce a screenshot of the location from Google Earth or a recent satellite image. This is approved (or rejected if there is existing or recently removed tree cover) by TROFACO.
3) The local communities suggest which land to plant on. TROFACO's local partners then check suitability and land management. It that is OK. they recommend to TROFACO.

1.3 Receiving suggestions

The national partner, or a TROFACO client, suggests new planting areas. TROFACO inspects the area for security of the land rights, absence of forest on the land, and its current use. TROFACO also meets the farmers in the area, to assess their commitment and spot potential disagreement in the community, which could be about land rights, the distribution of the trees or other.



A figure depicting major elements of the management of tree plantings sponsored through or verified by TROFACO.

1.4 Management of the planting and seedling survival

i. Communities / schools/ religious institutions are the local project owners. They are committed to tree planting, also for their own benefits, but without funds from

TROFACO they cannot afford the planting. The plantings are thus clearly ***additional***. Communities choose trees that are useful for them. Benefits come as fruits, leaves for animal fodder or medicine from the trees, as well as the value of the timber, when the trees are mature[2]. So, project owners and communities protect the trees. TROFACO only accepts indigenous species.

ii. TROFACO and partners operate a CO_2 fund, which will with a few years' intervals pay out rewards to the communities when trees are thriving after intervals decided by the fund board. This is one element in ***permanence*** and works towards trees becoming more like a short-term crop in the minds and economic considerations of the farmers.

iii. The local formal and informal governance structures that are agreeing and supporting the plantings include:

- 'Commune' (or similar-level government) and district governments, relevant departments. This may be education department for schools, environment, land management or others.
- Where relevant, these groups are key in the management: Farmers groups/associations/cooperatives, school management, churches, temples etc.

iv. Management agreements: At local level all parties (community or local institution, National NGO partner, local formal authorities) sign agreements and management plans. These stipulate; Trees cannot be touched for 20 or 25 years and the project owner (the landowner, where the trees are standing) is responsible for replanting trees, which may die [3] . This is one element in ***permanence***.

TROFACO avoids planting large stands of valuable trees in places where corrupt business people/officials and/ or armed groups may steal the timber or the land right. Theft or death of seedlings are dealt with by the landowner, who is obliged in their management agreement to replant missing seedlings.

UNIQUE DOCUMENTATION

Basic principles in TROFACOs documentation are: Every customer or sponsor receives information from the planting site(s) sponsored. The information is in the form of:

[2] Landowners are allowed to fell timber trees when they mature after at least 20 or 25 years, but they are obliged to plant new ones after felling. This is one element in **permanence**.

[3] TROFACO can provide examples of such plans, on request.

i. Images from the planting site. The images are taken at agreed intervals. The images are shown on TROFACOs website (trees.trofaco.org) under each planting site. Sponsors receive a certificate with a link to the planting site and can also search the website using their name or the number of their certificate and this way get to the relevant planting site(s).
    - Each image has a timestamp, which is shown on the website, so anybody can see *when* the image was taken.
    - Each image also contains GPS metadata. This is used to *place* the image onto a Google Earth or satellite image, shown on the website for each planting site. Each image, when displayed on users' screen will also show its GPS coordinates.

ii. Reports beyond the images: If desired, and agreed in contract w. TROFACO, each sponsor may also receive reports from the relevant site(s). It will report in relation to the Sustainable Development Goals and can emphasize specific aspects, as agreed.

iii. CO_2 capture measurements. If desired, e.g. for green accounting of a company or an institution, TROFACO can do detailed measurements of the trees and calculate the amount of CO_2 absorbed (sequestered) in any group of trees. (See TROFACO standard Volume 2)

And all of this above is no more complicated than a sponsor can do additional verification. TROFACO is welcoming visits from sponsors and partners and TROFACO can support visits to the particular planting(s) and the communities taking care of them. TROFACO can also support measurements of the trees if a CO_2 calculation/accounting is desired. Sponsors or partners can for example send their auditor if they need an audited CO_2 account, by an independent.

Each planting site, as presented on TROFACO's website, contains a list of which trees are planted and how many of each. Together with this is presented how many trees each customer has paid for with customer name and certificate ID. This way the number of planted trees, and the number paid for are presented together. This makes multiple selling of the same CO2 impossible

NO DOUBLE COUNTING

TROFACO's national partner works closely with the relevant national authority for the Implementation of the Paris Agreement, and reports any planting that is used for supplying CO2 credits to meet targets under the Paris Accord (of December 2021, COP 21)[4]. This avoids what is termed ***double counting*** under the Accord.

[4] Not all countries in which TROFACO operates have functioning implementation of the Paris Accord, such as a monitoring and reporting system.

TREE RESERVE

TROFACO maintains and continuously renews a reserve of 20% extra trees, to cover possible losses due to natural disasters, or other causes.

THIRD PARTY VERIFICATION

The TROFACO standard has developed a third party verification protocol in collaboration with Copenhagen University , Section for Global Development and its experts on tropical forestry. It can be applied by any entity agreed between the client and TROFACO

The protocol covers tree survival, measured CO_2 uptake and its documentation, and may also include socio-economic aspects of the plantings. It is available on request.

PHOTOS for ILLUSTRATION

June. 2023: Two-year old Chucrasia ('Indian mahogany') and Asian Teak , planted on land of Bui Van Thu, in Van Ho, Lai Cai province, Vietnam. The land was forest until some 20 years ago.

2019: Meeting in the Kigazi Tukwatirewamu Forest Group whose members plant and maintain TROFACO sponsored trees. Minziiro Hills, Rakai, Uganda

Dec. 2022: Children at Preah Theat Primary School, Prey Veng, Cambodia playing among nine-year old Cassia planted for TROFACO.

TROFACO
Tropical Farmer Connect

Verification of CO_2 removal by a planting of trees

Methodology and Standard (Volume 2)

(Edition 2023/08)

TABLE OF CONTENTS

Volume 1 of the TROFACO methodology and standard describes how TROFACO plans and collaborate with a host community about a preparing and managing a planting.

It is available on request.

1 INTRODUCTION

Knowing the amount of carbon in trees is a key element in measuring and documenting the effectiveness of any tree-based Climate offsets or Carbon Dioxide Removal.

TROFACO takes a hands-on approach to this: Trees are real, they can be measured in a very physical sense and the survival of a stand can be assessed by on-site counts.

1. The CO_2 in an individual tree:

Here the methodology applies a standard method used to calculate timber volumes in commercial forestry. Then the method is applied in translating timber volume into CO_2 absorbed and stored as biological carbohydrates (celluloses, lignin etc.) in the wood.

Below in section 3, it is described how this information is applied to estimate the total amount of CO_2 captured in a stand of trees, i.e., a planting site.

2 THE SIZE OF INDIVIDUAL TREES

2. Required measurements

The method requires only two field-based measures: The height (**H**) of the tree and the Diameter at Breast Height (**DBH**) of the trunk or stem[5]. These are transformed into a cylindrical shape by the formula $\mathbf{H \times DBH^2 \times \pi / 4}$.

Taking the two measurements is not always straightforward: How, for example, is the DBH measured? That is simple in a plantation on flat ground with trees each of which one has only one stem/trunk. Here a tape measure is applied to measure the circumference of the trees at DBH. The circumference measured by the tape is the converted to diameter (DBH) by dividing by **π** (i.e. 3.14).

When the trees are small, their height may be measured by a measuring stick. When the trees are larger, the land is flat and each tree easily visible, one can use a dedicated app on a smartphone. It can do the trigonometry. This however is not possible in a close stand of trees, as the lines of sight are blocked.

When the trees get so big the canopies close, a drone flying at the level of the tree-tops may be applied. The drone reports very accurately how high it is flying above the ground and thereby also the tree height.

3 CALCULATING THE CARBON IN ONE TREE

3. The formula

In order to calculate the amount of carbon stored in the cylinder described above, we move on to estimate its dry biomass, followed by a calculation of the amount of solid carbon stored in that biomass and then convert the carbon in the biomass into atmospheric CO_2 that the tree has captured from the atmosphere and stored in the biomass:

The above ground (dry) biomass (AGB) of a standing tree – represented by the cylinder - is calculated using the equation[6]:

$$AGB = H * DBH^2 * \pi / 4 * d * f$$

Where **H** is the height of the tree, **DBH** is the 'Diameter at Breast Height'.

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[5] Breast height is defined as 1,42 m

[6] From 'Forest mensuration' (Anthony van Laar and Alparslan Akca, Springer 2007)

π /4 'translates' the square (DBH^2) to a circle, as the trunk of the tree is circular in cross-section. Further, **d** is the wood density. This is variable among tree-species and partly by their growing conditions, i.e., some wood is heavier than other. Values for many species can be found in databases.

Finally, **f** is a factor for the shape of the tree, depending for example whether its trunk is straight, or it has many branches already from low above the ground and other factors. [7]

One ton of dry above-ground biomass (AGB) equals 0.5 tons of carbon (half the molecular weight of the hydrocarbons is carbon). Using this fact, we can calculate the amount of carbon stored in the AGB. Each ton of carbon equals 3.66 tons CO_2, as the molecular weight of CO_2 is 3.66 times the atomic weight of C (Carbon).

All of this leads us to the amount of CO_2 the tree has captured from the atmosphere from its time as seed till the date the measurements described in 2.1. are taken.

Many stands of trees will be mixtures of several species. For these, the TROFACO methodology prescribes that numbers of each species be counted, measurements taken on representative samples of each species and CO2 uptake calculated for each species, as they differ in wood density and sometimes also in shape.

A large Mvule (*Milicia excelsa*) in Hoima town, Uganda. Probably 80-100 years old. This tree may well have absorbed more than 50 tons CO_2e in its lifetime. Photo by TROFACO, 2019

[7] For an illustration of what 'f' is, see note towards the bottom of this methodology.

4 MOVING FROM TREE TO PLANTING SITE

The number of trees in each species in each planting site must be known and a control-count of numbers of each species must be undertaken at each verification event. For each of the accepted species for CO2 removal, available in the plantation, CO2 uptake must be calculated for a number of individual trees. This number must be significantly large to allow establishment of a mean value for CO2 uptake, for each species, with maximum of 10% standard deviation, or higher if desired by the customer.

When trees are harvested, hardwood timber will be used in furniture or timber for construction. The UNFCC (UN Framework Convention on Climate Change) recognizes timber as a 'semi-permanent sink' and says that approximately half of the CO_2e stays in the wood used for these purposes for at least 100 years. This is relevant for the ***permanence*** of the O2 emission compensation.

For each planting to be verified, the methodology prescribes the counting numbers of trees of each species. Species whose wood have short after-felling duration must be excluded from the CO2 calculation, and this must be shown in the verification report.

The ***permanence*** of the storage must be assessed also in light of potential thinning that may take place *after* any given verification of the amount of CO2 taken up. Thinning is often done two times during the planting's lifetime), each halving the number of trees. This is in order to give the remaining trees space to grow to full size. For example, a planting of 10.000 trees is expected to be thinned twice. 10000 trees, thinned by 50% twice, give us 2500 trees at maturity. So, estimates of CO2 taken up by the trees in this stand must be reduced by 75% if trees are counted before first thinning and by 50% if before second thinning. The estimated CO2 from the planting will take this thinning into account, or any other thinning/planting density format, and report on the expected CO2 considering the number of surviving trees at the time of harvest.

Other thinning schedules are often seen. They must be considered in similar fashion. (See note below)

5 AND THE 'FREE BONUS'

All of the above is about calculating CO2e of the trees, and only CO2 in the above-ground parts of the trees. (See also note on the "f" factor, below)

Actually, the roots have about 20-30% additional biomass, to the above-earth part of the tree. And the trees help re-establish a rich underground ecosystem, where the life below the ground also build up very substantial biomass[8] – meaning these organisms provide an additional 'sink' for CO_2.

[8] https://www.futurity.org/mycorrhizal-fungi-forests-1822492-2/

Furthermore, our estimate above does not include the CO_2 in the younger trees that may have been cut during thinning. In the case of timber-species, the wood from these will have been used for stakes, construction or similar, so most of their absorbed CO_2 has not been released.

Communities will leave the trees longer than 20 years, as they want to enjoy the benefits of doing so. Communities also mix several species of trees [9], and often plant crops under the trees. Both have been shown to increase CO_2 uptake in the trees and in soils.

6 THIRD PARTY VERIFICATION

A TROFACO 3rd party verification protocol has been developed in collaboration with Copenhagen University, Section for Global Development and its experts on tropical forestry.

The protocol can be applied by any entity, which is jointly agreed by TROFACO and a client or partner.

The protocol covers CO2 uptake and its documentation, and may also include socio-economic aspects of the plantings. It is available on request.

7 IMAGES WITH GPS- AND TIME-STAMPS, PRESENTED ON GOOGLE EARTH

TROFACO has developed and operates a database to present transparent and unambiguous photographic documentation of tree stands. For further information contact TROFACO or see TROFACO standard Volume 1.

[9].

1 NOTES

1. A note on the 'f' factor in the equation used to assess biomass of a single tree

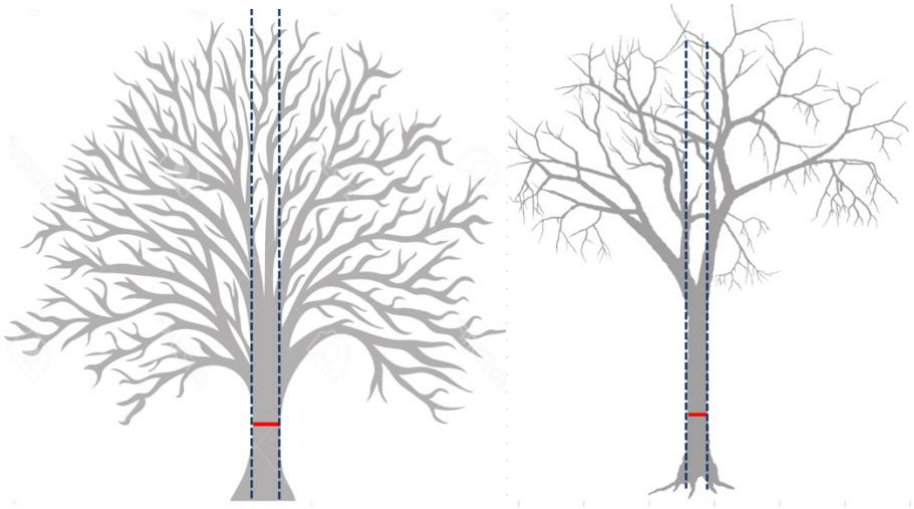
According to the source for the equation: 'Forest mensuration' by Anthony van Laar and Alparslan Akca, 'f' is defined (p. 71) as:

1.4.3 Form factors and form quotients

The *form factor* of a tree or stem is defined as stem volume, expressed as a proportion of the volume of a cylinder of the same height, with a diameter equal to the stem diameter at the selected reference point:

$$f = \frac{\text{stem volume}}{\text{cylinder volume}}$$

This emphasizes the volume of sawn timber to be obtained from the trunk of the tree, as illustrated by this figure of two typical tree-shapes:



The red line indicates DBH (Diameter at Breast Height) and the blue, vertical lines show the cylinder, which the equation calculates, if you leave out the 'f'

It becomes clear that often a large proportion of the trees will not be included in the result obtained from the equation.

This is because the equation is developed as a tool for estimating how much sawn wood (for planks and boards) that can be obtained from a tree.

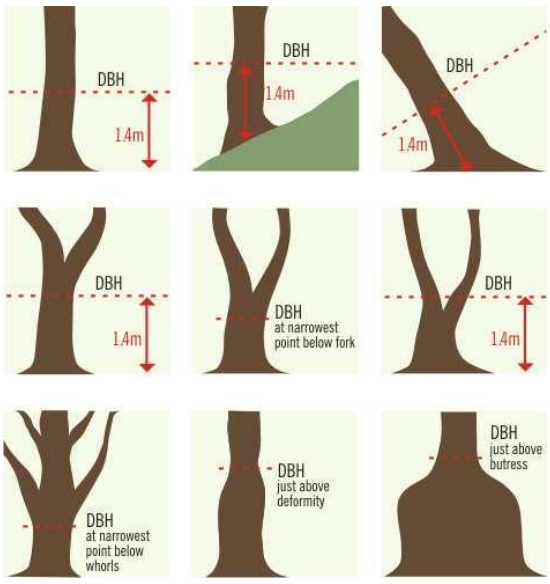
The parts of the trees being "cut-off" (by the equation) do, however, contain large amounts of CO_2 in their wood (in the form of C in celluloses, lignins etc.) How much will depend on the shape of the tree. In the example to the left, it is possibly as much as or more than what is within the 'cylinder'.

An important question then becomes: If/when the tree is eventually felled; which parts will be used and which may be left to rot or used for firewood, both of which will simply release the CO_2 absorbed?

TROFACO has confirmation from two colleges in Uganda that provide carpenter training, that also larger tree branches will be used for construction timber,or for tools, furniture or utensils or handicraft items. This is especially for the species producing valuable hardwood.

The 'f' applied in forestry for commercial timber is always smaller than 1.0. For assessing biomass of a tree with ample space and large crown it may be prudent to use 1.0 or bigger. TROFACO however, still uses values smaller than 1.0. This means the clients gets a 'free bonus'.

2. A figure of how to measure DBH on more complicated terrains and tree shapes.



DBH measuring in different conditions (Source: Queensland Arboricultural Association)

3. An example of a thinning practice and how to account for it.

		Illustrative figures . NOT actual							
Year	Year after planting	Measured CO2 absorbed	Discounted CO2 due to later ***expected*** thinning	Discounted CO2 due to later ***actual*** thinning	Remaining trees per ha	Expected thinning	Actual thinning	Expected thinning (fraction of remaining)	Actual thinning
2022	1	10000	4000		1000	0	0	0,60	
2023	2	5000	2000		1000			0,60	
2024	3	5000	2000		1000			0,60	
2025	4	5000	2000		1000	150		0,60	
2026	5	5000	2000		850			0,60	
2027	6	5000	2353		850	150		0,53	
2028	7	5000	2353		700			0,53	
2029	8	5000	2353		700			0,53	
2030	9	5000	2857		700	150		0,43	
2031	10	5000	2857		550			0,43	
2032	11	5000	2857		550			0,43	
2033	12	5000	3636		550	150		0,27	
2034	13	5000	5000		400			0	
2035	14	5000	5000		400			0	
2036	15	5000	5000		400			0	
2037	16	5000	5000		400			0	
2038	17	5000	5000		400			0	
2039	18	5000	5000		400			0	
2040	19	5000	5000		400			0	
2041	20	5000	5000		400			0	
2042	21	5000	5000		400			0	

4. TROFACO and Biodiversity

TROFACO can monitor and document bird-diversity in tree stands. THe sound of the birds are recorded and compared (machine learning) to a database of bird songs in the area. This requires the satabse to be available. They are for some areas and are rapidly developing in others. The data are stored and can be evaluated also in the future, thus awaiting database improvements

5. A note on the best way to recreate forest

What TROFACO is doing when managing the planting of new trees, and also recommending projects we advise, is better than just planting trees. Trees are planted on previously forested land, and mixes of native trees are planted. This way the trees help to re-establish a forest ecosystem. In a key, recent (2021) paper [10] the approach we use is termed 'Livelihoods Native Forest' (A brief summary of the paper by BBC can be found here). The paper states:

[10] Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. Global Change Biol. 2021;00:1–21._wileyonlinelibrary.com/journal/gcb

In naturally forested regions that have become deforested by human activities, we propose a 'native forest approach' to Forest Landscape Restoration, to increase carbon sequestration and other ecosystem services, accelerate biodiversity recovery and generate sustainable livelihoods.

This approach emphasizes protecting and restoring native forest elements within a mosaic of land uses, which would typically include **livelihood native forest,** to maximize economic benefits to local communities while significantly increasing carbon sequestration.

TROFACO staff measuring the height of a nine-year old Cassia sponsored through TROFACO, at Preah Theat Primary school, Prey Veng, Cambodia