Partnerships for Forests

Catalysing investments in forests and sustainable land use

Partnerships for Forests forest carbon assessment methodology

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Contents

Acknowledgements

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Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
AGB	Above Ground Biomass
AoI	Area of Interest
BAU	Business as Usual
BGB	Below Ground Biomass
CO2	Carbon Dioxide
EX-ACT	EX-Ante Carbon balance Tool
FAO	Food and Agriculture Organization of the United Nations
FP	Forest Partnership
GFW	Global Forest Watch
GHG	Green-House Gases
GIS	Geographic Information Systems/Science
ICF	International Climate Fund
IPCC	Intergovernmental Panel on Climate Change
KML	Keyhole Mark-up Language
NFD	National Forest Definition
P4F FCA	Partnerships for Forests Forest Carbon Assessment
USAID	United States Agency for International Development

1.   Introduction

The Partnerships for Forests (P4F) carbon assessment (FCA) methodology provides an approach for estimating the greenhouse gas (GHG) emission impact of Forest Partnerships (FPs) supported by P4F. This methodology is designed around the following principles:

- Rapid, desk based and cost efficient of the performance of FPs and related GHG emission reductions;
- Use of existing global, but spatially explicit products (Global Forest Change, pantropical biomass maps, global soil maps) to derive tier 2 and tier 3 activity data and emission factors;
- Application and combination of existing tools and guidance to produce a consistent, transparent and reproducible GHG emission reduction estimate for all FPs;
- Applicable across a range of intervention types in tropical forest landscapes.

P4F was established in recognition of the role of forests and reducing deforestation in tackling the climate crisis; the FCA enables P4F to understand its impact across its diverse portfolio. P4F FCA methodology is a monitoring and evaluation tool that produces rapid estimates. The results of the P4F FCA can be support reporting, decision making and adaptive management at programme portfolio and individual project levels. The FCA may support other forest carbon programs who want to estimate their GHG impacts for reporting to donors, development financing institutions or green funds. In addition to reporting projected impact, the FCA can be used to support decision making as it provides indication of observed performance.

P4F does not aim to generate emission reduction certificates and this methodology is not suitable to produce GHG estimates with a sufficient accuracy required by such financing instruments. There are established methodologies and organisations for such work for example, Verified Carbon Standard, Gold Standard, and the FCPF Methodological Framework.

The FCA methodology is aligned with the ICF KPI6 guidelines[1] and is consistent with IPCC good practice guideline. The P4F approach and methodology has been validated as fit for purpose by independent external consultants with extensive experience on conducting and reviewing forest carbon projects.

This document provides a stepwise guide for following the approach used by P4F in conducting a forest carbon assessment (herein referred to as the P4F forest carbon assessment approach or P4F FCA) for both projected (ex-ante) and observed (ex-post) carbon impacts. The methodology leverages a suite of existing open source tools and datasets including QGIS, Global Forest Watch, and the FAO EX-ACT[2] tool. This guide is intended for use by technical personnel with a basic knowledge of GIS – users should be able to open a shapefile in QGIS or equivalent software and perform basic operations such as changing the Coordinate Reference System and buffering. Extracting location specific parameter values for different carbon pools requires specialist proprietary software (e.g. Ecometrica[3]) or more advanced skills in raster data handling in desk-based GIS software. The guide will also be useful as an overview guide for those with less technical experience but that have a basic understanding of what GIS systems are and in principle how they work.

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[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/813595/KPI-6-net-change-greenhouse-gas-emissions.pdf
[2] http://www.fao.org/tc/exact/ex-act-home/en/
[3] https://ecometrica.com/

2. High level summary

The scope of a P4F FCA is to estimate carbon balance from change in forest cover only – of course there lots of other sources of emissions but deforestation is generally the largest source of emission for many commodities and it is the focus of P4F. There are two separate methodologies for calculating the carbon emissions from deforestation and carbon sequestration from reforestation. In addition, separate methodologies are used for calculating projected (ex-ante) versus observed (ex-post) emissions and sequestration.

The **ex-ante** assessment is the projected net balance in tonnes of CO_2 equivalent for intervention areas (referred to in P4F as Forest Partnerships or FPs) following the projected completion of the intervention in question, compared to the "Business As Usual" (BAU) scenario without the intervention, that result from the change to forest cover in the area in question. The basic steps of the **ex-ante assessment** are as follows:

1. Establish the boundaries of the area of interest (AoI).
2. Establish a reference area.
3. Establish the counterfactual baseline (the baseline should reflect the situation in the AoI without the intervention) based average forest loss of the reference area, without the consideration of trends.
4. Estimate the expected change in tree cover as a result of the intervention, relative to the baseline counterfactual.
5. Estimate the net change in Green House Gas (GHG) emissions based on emission factors (EFs) and the difference between expected tree cover change in the area of interest as a result of the intervention compared to tree cover change under BAU.
6. Establish a weighting of results for the degree of probability of the intervention being successful at curbing BAU trends.

The **ex-post** assessment is the observed net balance in tonnes of CO_2 equivalent for intervention areas (Forest Partnerships or FPs) following the actual completion of the intervention in question, compared to "Business As Usual" (BAU) scenario (based on a reference area) as a result of change to forest cover in the area in question. The basic steps of the **ex-post assessment** are as follows:

1. Establish the boundaries of the area of interest.
2. Establish a reference area.
3. Define the assessment period.
4. Establish the counterfactual based on observed rates of deforestation in the reference area during the assessment period.
5. Estimate the expected tree cover in the area of interest based on observed rates in the reference area.
6. Establish the observed rate of deforestation in the area of interest.
7. Estimate the net change in GHG emissions based on emission factors and the difference between expected tree cover change in the area of interest compared to the observed tree cover change in that area.
8. Establish a weighting of results for the degree of probability of the intervention being successful at curbing BAU trends.

3. Limitations

The P4F FCA has a specific scope and use case as outlined in the introduction. The inherent design creates limitations in the accuracy of the results; desk-based assessments approximate what is happening on the ground. When estimating forest carbon impact from avoided deforestation the counterfactual used can significantly change the results. The P4F FCA uses a counterfactual of average loss over a 10-year period in the reference area to preserve the rapidity of the assessment (see section below for definition of the reference area). In some locations, average loss disguises more recent trends and future trends could have a different pattern. In addition, the assessment of tree cover change does not consider tree cover gain.

The P4F FCA does not cover ex-post assessments of reforestation.

Basic limitations specific to components of the P4F FCA are outlined in section below.

4.   Resources required

The following resources are required to undertake a P4F forest carbon assessment.

4.1.   Geospatial digital files

Geospatial files are required in order to conduct the analysis. The methodology uses spatial data to generate location specific parameters, in order to generate these data, the specific location must be defined in a geospatial file (e.g. Shapefile or Keyhole Mark-up Language (KML)).

1.   Area of interest (AoI)

The AoI is the boundary of the area of land that is subject to a written land use management plan, agreement or contract where sustainable land use management activities are expected to achieve avoided deforestation and/or reforestation. The project partner should provide a geospatial digital file (e.g. Shapefile or KML) of the AoI.

2.   Reference area (RA)

Methodologies to determine reference areas differ in their requirements (see Annex 1). The reference area definition used by P4F is aligned with the Verified Carbon Standard (VM0015)[4]. The reference area is created by 'buffering' the AoI using QGIS. The size of the reference area depends on the size of the AoI:

- If the AoI is less than 100,000 hectares in area the reference area is 30x the AoI
- If the AoI is greater than 100,000 hectares in area the reference area is 6x the AoI

4.2.   EX-ACT tool

The Food and Agriculture Organisation's (FAO) EX-ACT tool is an Excel based tool with a series of formula and default data for calculating the estimated carbon stock changes from a range of land use changes. There are many different carbon calculators and tools for land use-based projects. They vary in scope, complexity and format. The FAO EX-ACT tool was selected because of its simplicity and flexibility. The tool includes modules for calculating carbon benefit of both avoided deforestation and reforestation projects using a large set of different parameters compiled by the Intergovernmental Panel on Climate Change (IPCC). The tool uses geographically specific parameters based on the region and biome selected by the user. This data can be overridden with location specific data (e.g. EFs calculated based on Tier 3 data from the specific project location).

4.3.   National Forest Definition (NFD)

The IPCC Good Practice Guidelines (IPCC GPP) [5] recommend considering the national forest definition. Many countries developed a national forest definition in terms of i) tree cover ii) tree height and iii) minimum area, within the ranges allowed by the Marrakesh Accords. The P4F FCA assesses forest area and its change with respect to the national forest definition (i.e. canopy cover threshold) (see annex 2).

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[4] https://verra.org/methodology/vm0015-methodology-for-avoided-unplanned-deforestation-v1-1/
[5] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

4.4. GIS software

The P4F FCA uses desk-based and web-based GIS software for a range of tasks including editing shapefiles and generating location-specific data.

- **QGIS or similar:** QGIS is an open-source desk-based GIS software. The tool can be used for data management, manipulation, interrogation, and analysis.
- **Global Forest Watch:** GFW is a web-based GIS tool. The tool can be used to display and analyse a selection of pre-defined spatial datasets. The types of analysis e.g. number of hectares of forest in a selected area, are predefined. The analysis can also be done offline using a desk-based GIS software but requires a higher level of GIS expertise.

4.5. Key datasets

The key datasets used in P4F FCA analysis are outlined below. The datasets are global to ensure coverage and consistency between projects; however, they do contain geographical variations in accuracy. The methodology is dataset independent so other datasets can be used where appropriate.

4.5.1. Global Forest Change[6] (Hansen et al., 2013)

About: This dataset is the result of a time-series analysis of Landsat images characterizing global forest extent and change from 2000 through 2018 with 30-meter resolution.

Limitations: 1. Tree cover is defined by vegetation greater than 5 meters in height. The dataset captures canopy cover from 0 to 100 percent and as such the dataset captures plantation forest and perennial crops such as palm oil as well as natural forest cover. 2. Tree cover loss includes loss from natural causes such as storms and fires and captures land management as well as land use change, for example, timber harvest from plantation forest.3. The dataset has variable accuracy in different parts of the world.

4.5.2. Pantropical Above Ground Biomass[7] (Baccini et al 2012)

About: This dataset was produced using a combination of remote sensing and field data. The field data was taken between 2008 and 2010. The end dataset, published in 2012, shows live Above Ground Biomass at a resolution of 500m.

Limitations: 1. The 500m resolution is lower than the tree cover dataset so estimates of AGB in areas of tree cover may include other land use types. 2. The dataset was published in 2012 using data from as early as 2008. Areas that have been degraded since 2008 will not reflect the present-day biomass. Areas lost since present day will not be counted although the difference in resolution between the tree cover dataset and the AGB could mean estimates of AGB could be higher than present day values. 3. The dataset is an interpolation of samples; the coverage of the samples will range geographically so it's likely there will be geographical variability in the accuracy.

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[6] https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.6.html
[7] Baccini A et al 2012 Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps Nat. Clim. Chang. 2 182–5

4.5.3. Soil carbon

About: This dataset is based on International Soil Reference and Information Centre data[8]. Data for the upper 30cm of soil was combined in this dataset[9] as recommended in IPCC Best Practice. The datasets were produced using 150,000 soil profiles and remote sensing-based data. The dataset was published in 2017 and has a resolution of 250meters.

Limitations: 1. The 250m resolution is lower than the tree cover dataset so estimates of soil carbon in areas of tree cover may include other land use types. 2. The dataset is an interpolation of samples; the coverage of the samples will range geographically so it is likely there will be geographical variability in the accuracy.

4.6. Effectiveness tool

About: The effectiveness tool is part of a P4F created set of Excel based tools used to generate data on tree cover under different scenarios. The effectiveness tool uses questions adapted from USAID's Agriculture, Forestry and Other Land Use (AFOLU) carbon calculator[10]. That carbon calculator draws on the Verified Carbon Standard risk framework[11] to estimate what the overall effectiveness of an intervention will be on tree cover in a landscape. The tool allows to assess the risk of non-permanence of forestry based (and hence reversible) emission reductions. Its application allows to determine a discount factor applied to FP's GHG emission reduction estimates.

Limitations: The effectiveness tool is a set of nine questions based on a broad understanding of deforestation risk factors, the analysis and discount to 'effectiveness' is not context specific.

4.7. Scenario calculator

The 'Scenario calculator' is another P4F Excel based tool. This tool is used to generate data on tree cover under different scenarios. Data generated using spatial datasets and the methods described in this document are entered into this tool. There are two scenario calculators, one for ex-ante and one for ex-post assessments.

5. Estimating emission reductions from Avoided Deforestation

This section covers how to generate the data required to run avoided deforestation assessments using the P4F FCA. Three key pieces of data need to be generated estimating tree cover under different scenarios. The approach for generating this data differs between ex-ante and ex-post assessments and is explained below.

5.1. Estimate tree cover under different scenarios

5.1.1. Ex-ante assessments

Ex-ante assessments are projections of expected impact on forest carbon. This section describes how to generate data for tree cover at present day, under Business as Usual (BAU) and under the project scenario. The data generated can be adjusted according to the length of the projection (i.e. the number of years). The P4F Scenario tool contains the formula set out below and generates the parameters on tree cover based on user input. The process assumes use of Global

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[8] Hengl, T., Mendes de Jesus, J., Heuvelink, G. B.M., Ruiperez Gonzalez, M., Kilibarda, M. et al. (2017) SoilGrids250m: global gridded soil information based on Machine Learning. PLoS ONE 12(2): e0169748. doi:10.1371/journal.pone.0169748

[9] Gumbricht, T; Román-Cuesta, R.M.; Verchot, L.V.; Herold, M.; Wittmann, F; Householder, E.; Herold, N.; Murdiyarso, D., 2017, "Tropical and Subtropical Wetlands Distribution version 2", https://doi.org/10.17528/CIFOR/DATA.00058, Center for International Forestry Research (CIFOR), V1; World Organic Carbon Stocks for the Upper 30 cm.7z

[10] http://afolucarbon.org/static/documents/AFOLU-C-Calculator-Series_Effectiveness_Guide.pdf

[11] http://verra.org/wp-content/uploads/2018/03/Tool-for-AFOLU-Non-Permanence-Risk-Analysis-and-Buffer-Determination.pdf

Forest Change (Hansen et al., 2013) data and the relevant national forest definition, adjustments may be needed if using another dataset.

5.1.1.1 Determine tree cover present day

Calculate tree cover at present day[12] in the Area of Interest (AoI).

1. Calculate tree cover at present day
   a. Estimate tree cover in the year 2000 in the AoI.
   b. Estimate the total tree cover loss from 2001 to most recent loss year ('present day', PD)
   c. Subtract the tree cover loss total from tree cover in the year 2000

$$TC_{AOI\ PD} = TC_{AOI\ 2000} - \sum_{2001}^{PD} TL_{AOI,n}$$

Equation (1)

Where:

$TC_{AOI\ PD}$ =   Tree cover in the AoI at present day, in ha

$TC_{AOI\ 2000}$ =   Tree cover in the AoI in the year 2000, in ha

$TL_{AoI,n}$ =   Tree cover loss in the AoI, in year n, in ha/yr.

PD =   Year at present day

Box 1 – Method for estimating forest area for 'present day' using Global Forest Watch

1. Upload shapefile with boundary of AOI or RA on the GFW**Error! Bookmark not defined.** *Analysis* tool > " Draw or upload shape" box;
2. Select the *Tree Cover* (TC) and *Tree Cover Loss* (TCL) datasets;
3. Set the following parameters:
   i. forest canopy density of the Country's national forest definition (e.g. >10%);
   ii. the *Tree Cover* base year of 2000;
   iii. the *Tree Cover Loss* period, 2001 to most recent loss year ('present day').
4. Run the *Analysis* tool to quantify forest area (i.e. *Tree Cover*) in the base year and forest area loss (i.e. *Tree Cover Loss*) to present day;
5. Subtract the hectares of *Tree Cover Loss* from the *Tree Cover* in the base year to estimate the forest area (i.e. *Tree Cover*) for the specific year.

Note: this method may underestimate forest area as forest gain is not accounted for.

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[12] Global Forest Change (Hansen et al., 2013) data is updated annually. However, there is a lag of one year in the data availability with data for the previous year published in late quarter 1, early quarter 2 e.g. data from 2018 is published in March 2019.

5.1.1.2 Estimate tree cover under the BAU scenario

Tree cover under BAU is estimated using a reference area (RA) and reference period (RP). Following best practice[13], a reference period of 10 years prior to the start date is used. Once a BAU annual rate is established this can be used to produce estimates of forest loss for different projection periods. The projection period can be adjusted based on timelines relevant to a given project. In the case of P4F the timelines are to the end of the programme (2023) and 20 years to capture impact over the lifetime of the project – this period is based on FAO good practice recommendations[14]. The relevant national forest definition should be used at each step.

1. Calculate annual loss rate in RA in the last 10 years
    a. Estimate tree cover in the year 2000 in the reference area
    b. Estimate the tree cover at the start of the BAU reference period (11 years previous to present day).
        i. Sum tree cover loss in the year 2001 to one year previous to BAU reference period start. Subtract tree cover loss during this period from tree cover in the year 2000

$$TC_{RA\ RP\ start} = TC_{RA\ 2000} - \sum_{2001}^{RP_{start-1}} TL_{RA,n}$$

Equation (2)

Where:

$TC_{RA\ RP\ start}$ =   Tree cover in the reference area at start of the reference period, in ha

$TC_{RA\ 2000}$ =   Tree cover in the reference area, in the year 2000, in ha

$TL_{RA,n}$ =   Tree cover loss in the reference area, in year n, in ha/yr

RP_{start} =   Year at the start of the reference period

    c. Estimated tree cover at the end of the reference period
        i. Estimate the tree cover loss during the reference period (total sum loss in the 10 years pervious to present day)
        ii. Subtract tree cover loss during the reference period from tree cover at start of the reference period

$$TC_{RA\ RP\ end} = TC_{RA\ RP\ start} - \sum_{RP_{start}}^{RP_{end}} TL_{RA,n}$$

Equation (3)

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[13] FCPF (2016), Methodological Framework, FCPF Carbon Fund, Revised Version, World Bank, Washington, USA;

[14] http://www.fao.org/fileadmin/templates/ex_act/pdf/EX-ACT_quick_guidance.pdf

Where:

$TC_{RA\,RP\,end}$ =   Tree cover in the reference area at the end of the reference period, in ha

$TC_{RA\,RP\,start}$ =   Tree cover in the reference area at start of the reference period, in ha

$TL_{RA,n}$ =   Tree cover loss in the reference area, in year n, in ha/yr

RP_{start} =   Year at the start of the reference period

RP_{end} =   Year at the end of the reference period

d. Calculate BAU deforestation rate
  i. Calculate the annual loss rate based on area lost during the reference period using a compound rate

$$Def_{RA\,projected} = \left(\frac{TC_{RA\,end}}{TC_{RA\,start}}\right)^{\frac{1}{RP}} \times -1 \qquad \text{Equation (4)}$$

Where:

$Def_{RA\,projected}$ =   Projected business as usual deforestation rate, in % per year

$TC_{RA\,end}$ =   Tree cover in the reference area at the end of the reference period, in ha

$TC_{RA\,2000}$ =   Tree cover in the reference area, in the year 2000, in ha

RP =   Number of years of the reference period

Box 2 – Method for estimating tree cover loss for the BAU reference period using Global Forest Watch

1. Upload shapefile with boundary of AOI or RA on the GFW**Error! Bookmark not defined.** *Analysis* tool > " Draw or upload shape" box;
2. Select the *Tree Cover* (TC) and *Tree Cover Loss* (TCL) datasets;
3. Set the following parameters:
   i. forest canopy density of the Country's national forest definition (e.g. >10%);
   ii. the *Tree Cover* base year of 2000;
   iii. the *Tree Cover Loss* prior to BAU reference period; 2001 to one year previous to BAU reference period start i.e. 11 years ago with a 10 year reference period.
4. Run the *Analysis* tool to quantify forest area (i.e. *Tree Cover*) in the base year and forest area loss (i.e. *Tree Cover Loss*) to present day;
5. Subtract the hectares of *Tree Cover Loss* from the *Tree Cover* in the base year to estimate the forest area (i.e. *Tree Cover*) for the start of the reference period.
6. Repeat the above steps. At step 3.iii set the *Tree Cover Loss* parameter to select data between one year previous to BAU reference period start i.e. 11 years ago with a 10 year reference period, and present day.

Note: this method may underestimate forest area as forest gain is not accounted for.

2. Calculate tree cover under BAU

The BAU rate of loss calculated from the reference area is used as the baseline. The BAU rate is applied to the present-day tree cover in the AoI to calculate projected remaining tree cover under a BAU scenario.

   a. Estimate the expected tree cover loss in the AoI using the BAU rate to adjust the area of remaining tree cover by the end of the chosen projection period. The AoI should lose a percentage area equivalent to the BAU rate each year during the projection period.
   b. Estimate remaining tree cover in the AoI under BAU at the end of the projection period by subtracting expected loss under BAU from present day tree cover in the AoI.

$$TC_{AoI\ BAU} = TC_{AOI\ PD} \times \left(1 - Def_{BAU\ projected}\right)^t$$

<div align="right">Equation (5)</div>

Where:

$TC_{AOI\ BAU}$	=	Projected area of tree cover remaining under the BAU scenario in the AoI interest, in ha
$TC_{AOI\ PD}$	=	Tree cover in the AoI at present day, in ha
$Def_{BAU\ projected}$	=	Projected business as usual deforestation rate, in % per year
t	=	Time, projection period, in years

5.1.1.3 Estimate tree cover under the project scenario

The project activities should reduce the likelihood of deforestation occurring in the AoI. The 'effectiveness' of the activities at reducing the risk of deforestation depends on the number, nature and degree of implementation of those activities.

1. Establish the effectiveness of the project by completing the 'Effectiveness tool' (see section 3). Effectiveness is expressed as a percentage.
2. Adjust the BAU rate by 'effectiveness' of the intervention activities in the project.
   a. Use the effectiveness percentage to adjust the BAU percentage rate e.g. BAU rate of 2% and an effectiveness of 90% = adjusted rate of 0.2%, 10% of the original rate.

$$Def_{BAU\ adjusted} = Def_{BAU\ projected} \times Effectiveness$$

<div align="right">Equation (6)</div>

Where:

$Def_{BAU\ adjusted}$	=	Adjusted business as usual deforestation rate, in % per year
$Def_{BAU\ projected}$	=	Projected business as usual deforestation rate, in % per year
$Effectiveness$	=	'Effectiveness' of the intervention activities, %

3. Calculate the projected tree cover loss using the adjusted BAU rate
   a. Estimate the expected tree cover loss in the AoI using the adjusted BAU rate to calculate the remaining tree cover by the end of the chosen projection period. The AoI should lose a percentage area equivalent to the BAU rate each year during the projection period.

$$TC_{AoI\ projected} = TC_{AOI\ PD} \times \left(1 - Def_{BAU\ adjusted}\right)^{t}$$

Equation (7)

Where:

$TC_{AOI\ projected}$ $=$ Projected remaining tree cover in the AoI, in ha

$TC_{AOI\ PD}$ $=$ Tree cover in the AoI at present day, in ha

$Def_{BAU\ adjusted}$ $=$ Adjusted business as usual deforestation rate, in % per year

t $=$ Time, projection period, in years

5.1.2. Ex-post assessment of actual tree cover change

Ex-post assessments are estimates of observed impact on forest carbon. This section describes how to generate data for tree cover at the start of the assessment period, the expected tree cover in the AoI under the BAU scenario and the observed tree cover in the AoI. The data generated can be adjusted according to the length of the assessment period (number of years). The P4F Scenario tool contains the formula set out this section and generates the parameters on tree cover based on user input. The steps assume the use of Global Forest Change (Hansen et al., 2013) data, adjustments may be needed if using another dataset.

5.1.2.1 Define the Assessment Period

The Assessment Period (AP) is the period over which emission reductions from the project will be assessed e.g. from the project start date to the year when the assessment is carried out. In the case of P4F the assessment period starts 6 months after the grant agreement is signed to allow for lag between funding being granted and impact of the funding being seen on the ground through activities. If Global Forest Change (Hansen et al., 2013) data is being used then the reference period must be a minimum of one year as this is the smallest unit of time available.

5.1.2.2 Determine tree cover in the AoI at start of assessment period

1. Calculate tree cover at start of the assessment period (AP) in the AoI.
   a. Estimate tree cover in the year 2000 in the AoI
   b. Estimate the total tree cover loss from 2001 to start date (year) of assessment period
   c. Subtract the tree cover loss total from tree cover in the year 2000

$$TC_{AOI\ start} = TC_{AOI\ 2000} - \sum_{2001}^{AP_{start}-1} TL_{AoI,n}$$

Equation (8)

Where:

$TC_{AOI\ start}$ =   Tree cover in the AoI at the start of the assessment period, in ha

$TC_{AOI\ 2000}$ =   Tree cover in the AoI in the year 2000, in ha

$TL_{AoI,n}$ =   Tree cover loss in the AoI, in year n, in ha/yr

AP_{start} =   Year at start of the assessment period

5.1.2.3 Tree cover expected in the AoI by end of assessment period (BAU)

1. Calculate observed reference area (RA) deforestation annual percentage loss rate during the assessment period (AP).

   a. Calculate the tree cover at the start of the assessment period in the reference area

      i. Estimate tree cover in the year 2000 in the reference area
      ii. Estimate the total tree cover loss from 2001 to start date (year) of assessment period
      iii. Subtract the tree cover loss total from tree cover in the year 2000

$$TC_{RA\ AP\ start} = TC_{RA\ 2000} - \sum_{2001}^{AP_{start}-1} TL_{RA,n}$$

Equation (9)

Where:

$TC_{RA\ AP\ start}$ =   Tree cover in the reference area, at the start of the assessment period, in ha

$TC_{RA\ 2000}$ =   Tree cover in the reference area, in the year 2000, in ha

$TL_{RA,n}$ =   Tree cover loss in the reference area, in year n, in ha/yr

AP_{start} =   Year at start of the assessment period

b. Calculate the observed remaining tree cover in the reference area at the end of the assessment period.

$$TC_{RA\ AP\ end} = TC_{RA\ AP\ Start} - \sum_{AP_{start}}^{AP_{end}} TL_{RA,n}$$

Equation (10)

Where:

$TC_{RA\ AP\ end}$ = Tree cover in the reference area, at the end of the assessment period, in ha

$TC_{RA\ AP\ start}$ = Tree cover in the reference area, at the start of the assessment period, in ha

$TL_{RA,n}$ = Tree cover loss in the reference area, in year n, in ha/yr

AP_{start} = Year at the start of the assessment period

AP_{end} = Year at the end of the assessment period

c. Estimate the observed annual deforestation rate in the reference area as a proportion of the observed tree cover loss in the reference area during the assessment period.

$$Def_{RA\ observed} = -1 \times \left(\frac{TC_{RA\ AP\ end}}{TC_{RA\ AP\ start}}\right)^{\frac{1}{AP}} \times -1$$

Equation (11)

Where:

$Def_{RA\ observed}$ = Observed deforestation rate in the reference area, in % per year

$TC_{RA\ AP\ end}$ = Tree cover in the reference area, at the end of the assessment period, in ha

$TC_{RA\ AP\ start}$ = Tree cover in the reference area, at the start of the assessment period, in ha

AP = Number of years of the assessment period

2. Calculate expected loss in the AoI during the assessment period (AP) based on observed loss rate in the reference area (RA).

a. Estimate the expected tree cover loss in the AoI by using the observed loss rate in the reference area during the assessment period. The AoI should lose a percentage area equivalent to the BAU rate each year during the assessment period.

$$TC_{AOI\ expected} = TC_{AOI\ start} \times \left(1 - Def_{BAU\ projected}\right)^t \qquad \text{Equation (12)}$$

Where:

$TC_{AOI\ expected}$	=	Expected tree cover in the AoI, at the end of the assessment period, in ha
$TC_{AOI\ start}$	=	Tree cover in the AoI, at the start of the assessment period, in ha
$Def_{RA\ observed}$	=	Observed deforestation rate in the reference area, in % per year
t	=	Number of years of the assessment period

5.1.2.4   Tree cover observed in the AoI at end of assessment period

1.   Calculate observed remaining tree cover in the AoI

$$TC_{AOI\ observed} = TC_{AOI\ 2000} - \sum_{2001}^{PD} TL_{AoI,n} \qquad \text{Equation (13)}$$

Where:

$TC_{AOI\ observed}$	=	Observed tree cover in the AoI, at present day, in ha
$TC_{AOI\ 2000}$	=	Tree cover in the AoI, in the year 2000, in ha
$TL_{AOI,n}$	=	Tree cover loss in the AoI, in year n, in ha/yr
PD	=	Year at present day

5.2.   Calculated location specific carbon pool values

Location specific parameters on carbon pools can be extracted from spatial datasets, location specific parameters (IPCC Tier 2) are more representative of true values than the default parameters (IPCC Tier 1) in the Ex-ACT tool.

1.   Above Ground Biomass

Calculate average tonnes of carbon per hectare for forest in AoI can be calculated using a 'cross query' between the tree cover data and AGB dataset using GIS. The value must then be converted from biomass to carbon.

   a.   Establish the coverage (location and number of hectares) of tree cover in the AoI in the year of interest
   b.   Extract data from the AGB dataset where it overlaps with the tree cover
   c.   Sum the total AGB (tonnes) and divide by the number of hectares of forest
   d.   Covert to tonnes of Carbon per hectare by multiplying the average AGB by 0.49.

2.   Soil carbon

Calculate average tonnes of carbon per hectare for forest in AoI can be calculated using a 'cross query' between the tree cover data and soil carbon dataset using.

   a.   Establish the coverage (location and number of hectares) of tree cover in the AoI
   b.   Extract data from the soil carbon dataset where it overlaps with the tree cover
   c.   Sum the total soil carbon (tonnes) and divide by the number of hectares of forest

5.3. Run the carbon balance calculations in EX-ACT

Detailed guidance can be found on the FAO ex-act website[15]. A summary of the process is outline below.

Complete the Description tab: This must be completed so the tools can automatically select which eco-regional specific parameters to use.

Implementation period: The implementation period is how long the activities planned (that reduce the risk of deforestation) take to reach full operationalisation on the total area of interest.

Capitalisation period: The capitalisation period is the total time (number of years) where the project is fully operational. Based on a 20-year lifetime the capitalisation period is 20 – (implementation period).

Complete module 2.1: Deforestation in the Land Use Change Tab

    a. Set the final use land use after deforestation. Assume 'annual crop' unless evidence suggests otherwise. Selecting annual crop allows assumes deforestation is occurring for conversion to other land use and is more conservative than assuming the land will be deserted after it's deforested i.e. 'degraded land'.
    b. Enter 'forest area' under different scenarios

Ex-ante assessment: Enter the key data calculated on tree cover for ex-ante assessments (section 4.1.1) into the relevant fields in the tool.

    a. Tree cover present day (TC $_{AOI\ PD}$) = 'Start'
    b. Tree cover BAU (TC $_{AOI\ BAU}$) = 'Without'
    c. Tree cover project scenario (TC $_{AOI\ projected}$) = 'With'

Ex-post assessment: Enter the key data calculated on tree cover for ex-post assessments into the relevant fields in the tool

    a. Tree cover at start of assessment period (TC$_{AOI\ start}$) = 'Start'
    b. Tree cover expected by end of assessment period (TC $_{AOI\ expected}$) = 'Without'
    c. Tree cover observed at end of assessment period (TC $_{AOI\ observed}$) = 'With'

Override default parameters with location specific data

    a. Click on the 'Tier 2' button under the table in module 2.1
    b. Enter the location specific AGB (tC/Ha) and soil data (tC/Ha) in to relevant fields in the tier 2 table

6. Reforestation

This section covers how to generate the data required to run reforestation P4F FCA. Reforestation assessments require an estimate of how much forest will be restored as a result of the project and under BAU without the project. The type of tree cover and forest resulting from the reforestation should also be determined so the correct Tier 1 parameters can be used. The methodology below covers how to calculate species specific IPCC Tier 2 parameters for Above and Below ground carbon, Tier 1 data must be used for other carbon pools.

The approach for generating this data is the same for ex-ante and ex-post assessments. Ex-post assessments for reforestation projects require data that the planned reforestation schedule occurred and achieved the intended

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[15] http://www.fao.org/tc/exact/ex-act-home/en/

hectarage and canopy cover. P4F currently does not conduct ex-post assessments for reforestation projects due to lack of open source high resolution data that is capable of capturing tree growth.

6.1.   Estimate tree cover under different scenarios

1. Identify where reforestation will take place. Project developer/grantee should provide a shapefile indicating the total project area and locations where reforestation will take place.

2. Assess whether activities will qualify as reforestation. Using GFW, QGIS or similar assess whether the reforestation areas qualify as non-forest, the reforestation areas should qualify as non-forest at present day and up to five years before the project start date i.e. have not been deforested in the last five years. This analysis shall consider the national forest definition in terms minimum tree cover threshold.

3. Gather data on the number of hectares planted (based on the shapefile) and species planted (information to be provided by project developer/grantee).

4. Assess whether the planting regime will achieve canopy cover (country specific national forest definition) necessary to constitute reforestation (based on information provided by project team).

The above procedure assures, that P4F does not provide grants for reforestation of areas which were recently deforested or reforestation of areas which already qualify as forest.

6.2.   Calculated location specific carbon pool values

1. Calculate species specific Above Ground Biomass (AGB) based on species specific parameters[16].

$$AGB_{AA} = MAI \times BWD \times BEF$$

Equation (14)

Where:

AGB_{AA}	=	Above Ground Biomass (annual accumulation)
MAI	=	Mean Annual Increase (m^3 / Ha / yr)
BWD	=	Basic Wood Density
BEF	=	Biomass Expansion Factor

2. Calculate species specific Below Ground Biomass (BGB) based on species specific parameters.

$$BGB_{AA} = AGB_{AA} \times RS$$

Equation (15)

Where:

BGB_{AA}	=	Below Ground Biomass (annual accumulation)

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[16] Look up tables for species specific parameters values can be found in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Chapter 4

| AGB_{AA} | = | Above Ground Biomass (annual accumulation) |
| RS | = | Root to Shoot ratio |

6.3. Run the carbon balance calculations in EX-ACT

Detailed guidance can be found on the FAO ex-act website. A summary of the process is outline below.

Complete the Description tab: This must be completed so the tools can automatically select which eco-regional specific parameters to use.

Implementation period: The implementation period is how long the activities planned (that reduce the risk of deforestation) take to reach full operationalisation on the total area of interest.

Capitalisation period: The capitalisation period is the total time (number of years) where the project is fully operational. Based on a 20-year lifetime the capitalisation period is 20 (implementation period).

Complete module 2.2 Afforestation and Reforestation in the Land Use Change Tab

a. Select the most relevant forest type in 'Type of vegetation that will be planted'. The selection in the description tab and the selection made in this field determine the default data for the carbon pools used in the formula. The methodology described in this document only calculates Above and Below ground carbon, the two largest carbon pools. However, there are three additional carbon pools that are factored into the equation so it's important the most appropriate parameters are used.

b. Set the previous land use. Previous land use can be established using freely accessible spatial datasets. The nature of the previous land use can also be set in the Ex-act tool, for example, if the previous land use if 'Grassland' the condition (Initial State) can be disclosed in the Module 4 'Glasslands', the carbon benefit of reforestation on severely degraded is greater than reforesting on non-degraded land.

Enter the data on tree cover with and without the project

Override default data (IPCC Tier 1) for the growth parameters with species specific data (Tier 2)

a. Click on the 'Tier 2' button under the table in module 2.1

b. Use the data generated in section 5.2 to override the default data for the relevant carbon pools.

7. Collate the results

Emission reductions are calculated by the Ex-act tool based on user input. The results of the assessment can be found in the 'Results' tab. Projected impact is based on net balance measured in tonnes of CO_2 equivalent over the projection (ex-ante) or assessment (ex-post) period.

8. Probability adjust the results

The initial results of the assessment are based on the project implementing all the planned activities on the whole area of interest. Complete success in this regard may not be the case, therefore a probability adjustment should be made to adjust the assessments based on the probability of complete success being the case.

8.1. Probability adjustments for 2023 projections

P4F staff working most closely with each project are asked to provide a percentage of the project area that is expected to be under 'full implementation' by 2023 ('Active' area). This is based on the maturity of the project, capacity of the partners and expected ease of operations during the period of interest. This percentage is used to adjust the total projected result and is the probability adjustment.

8.2. Probability adjustments for 20-year projections

No adjustments are made to individual projects on the 20-year horizon. An adjustment is made at the portfolio level instead, the total of all projects is discounted by fifty percent. The justification for this is that all projects should have reached full implementation on the total area of interest, however, it is also expected that a number of projects will fail on a 20-year horizon, a fifty percent failure rate was chosen to ensure a conservative estimate and due to the inherent uncertainty of land use over such a time period.

9. Reporting

The results of the P4F carbon assessments are reported annually following ICF KPI6 requirements. The results are updated as new projects are added and projects mature, updated results are reported through a range of P4F reporting channels.

In addition to reporting the results of the assessments are used at 'decision gates' in P4F's approval process to support decision making processes and portfolio development. The results of the assessments at the individual and portfolio level support P4F in managing resources and the programme portfolio to deliver maximum outcomes and impact, where carbon emissions reductions are a key part. As the programme matures opportunities will arise for using the results as a tool to help understand which of our forest partnership models for forests and sustainable land use are most effective at delivering different kinds of outcomes and impact (include carbon) and why. Programmes and funds with similar objectives to P4F may also benefit from adopting a similar carbon assessment methodology and rapid assessment approach.

10. Further information

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Annex 1

Extent of Reference Area

There are three VCS methodologies, and two Plan Vivo methodologies that employ an analysis of deforestation in a Reference Area (or 'reference region') to determine baseline deforestation for a project area exposed to the risk of unplanned deforestation and forest degradation (see Table). All methodologies include the requirement that the Reference Area is representative of the future trajectory of the project area in the absence of project activities. The methodologies differ in their requirements for the extent of the region, and whether the project area is included or excluded from the Reference Area. All of the methodologies have further requirements to ensure that the reference region is well matched to the project area with respect to:

   i.   agents and drivers of deforestation;
   ii.   landscape configuration and ecological conditions; and
   iii.   socio-economic and cultural conditions.

The minimum extent requirements for Reference Areas apply to areas that meet those requirements. Defining a Reference Area that meets the VCS or Plan Vivo methodology requirements therefore requires detailed spatial analysis of all these factors.

Methodology	Minimum area of reference region*	Project area included or exclude	Forest matching
VM0006	250,000 ha or PA, whichever is greater	Excluded	The reference region must have at least 15% forest cover at the beginning of the crediting period.
VM0007-BL-UP	PA * 7500 * PA$^{-0.7}$	Excluded	The total area of reference region must be forested at the start of the reference period.
VM0015	For projects areas with tree cover > 100,000 ha: tree cover in RA must be 5 to 7 times to that in PA For project areas with tree cover < 100,000 ha: tree cover in RA must be 20 to 40 times to that in PA	Included	At least 90% of the project area must have forest classes or vegetation types that exist in at least 90% of the rest of the reference region
PV-CFREDD	At least ten times the area of each forest stratum present within the project area at the start of the reference period	Excluded	Forest in reference area must be of the same stratum as in the project area
PV-RLDD	Reference area should normally extend approximately 20-30 km from the project intervention area in all directions	Included	Reference area should exclude forests that are significantly different from the project intervention area

* PA = extent of project area (in hectares)

Defining a Reference Area without detailed spatial analysis, is only possible if simplifying assumptions are applied; for example if it assumed that areas close to the project area are likely to affected by deforestation in the same way as the

project area in the absence of project activities. There are many cases where such as assumption would not be valid, but it does provide a simple method for defining a Reference Area that can be applied without detailed spatial analysis.

One aspect of the Reference Area that can be explored using GFW data is tree cover. The proposed approach to defining a simple Reference Area is therefore based on selecting areas close to the Project Area and applying a threshold for the area of tree cover that must be present in the Reference Area, depending on the tree cover within the Project Area. This approach avoids the potential situation where land surrounding a project area in an isolated forest fragment does not include enough forest to give a reasonable estimate of baseline deforestation. A maximum threshold as well as a minimum is included to prevent reference regions being expanded to include areas that are distant from the project area.

The suggested thresholds are aligned with the recommendations of Brown et al. (2007) that informed development of VM0007 and VM0015:

- For Projects Areas with tree cover > 100,000 ha: tree cover in the Reference Area must be 5 to 7 times that in the project area
- For Projects Areas with tree cover < 100,000 ha: tree cover in the Reference Area must be 20 to 40 times that in the project area

Baseline Approach

VCS and Plan Vivo Methodologies that use a Reference Area (or 'reference region') for estimating emission reductions from projects that avoid unplanned deforestation all make use of an ex-ante baseline that is set for a fixed period at the start of the project. This provides some certainty to projects, which is important as they depend on income from sale of emission reduction certificates for their financial viability. In reality, baseline rates of deforestation are likely to be highly variable and if projects are not reliant on the sale of emission reduction certificates, alternative baseline approaches would provide a more accurate assessment of deforestation avoided by a project.

As VCS and Plan Vivo baselines need to be set at the start of the project, they make use of historical patterns of deforestation in the a reference region to predict future deforestation in the project area in the absence of project activities. The VCS methodologies require analysis of drivers of deforestation to extrapolate historic trends, while Plan Vivo methodologies allow for a simpler linear extrapolation, similar to that employed in many national REDD+ Reference Levels.

If the aim is to assess project performance, and not to generate certified emission reductions, an alternative and more simple approach is to directly compare the deforestation that occurred within the Project Area during a period of interest, to the deforestation that occurred in the reference region over the same period. This is the approach proposed in the draft Carbon Assessment Methodology.

If there is a need to estimate potential emission reductions at the start of a project, or if it is preferable to have a baseline set for a fixed period, then approaches for determining baseline deforestation from historical trends can be added. To update the approach, it would therefore be good to consider:

1) Whether an ex-ante estimate of potential emission reductions is needed (it seems like it is); and

2) Whether it is preferable to use a fixed baseline derived from historic trends in the Reference Area to assess performance, or a real-time comparison of deforestation in the Project Area and Reference Area (as we have in the Methodology at the moment).

My suggestion would be to include the ex-ante method for estimating potential, but to maintain the real-time comparison for assessing performance. This would also get around the need to periodically update fixed baselines.

Annex 2

Country	Region	Canopy cover %	Source
Brazil	Latin America	10	https://redd.unfccc.int/files/20140606_submission_frel_brazil.pdf
Colombia	Latin America	30	https://redd.unfccc.int/files/frel_amazon_colombia_english_19_12.14_en.pdf
Peru	Latin America	30	https://redd.unfccc.int/files/2015_submission_frel_peru_en.pdf
Ghana	West and Central Africa	15	https://redd.unfccc.int/files/ghana__modified_frl_november_10_2017_clean.pdf
Liberia	West and Central Africa	30	https://www.reddplussd.org/phocadownload/Contribution%20Forest%20Definition%20Sudan_14_03_2017_2.pdf
Ivory Coast	West and Central Africa	30	https://redd.unfccc.int/files/01_01_2017_rci_nerf_version_finale.pdf
Sierra Leone	West and Central Africa	10	http://www.fao.org/3/al624E/al624E.pdf https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/3785/5%20Carbon%20Forestry%20Pre-review.pdf?sequence=3
DRC	West and Central Africa	30	https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf
Gabon	West and Central Africa	10	https://www.fs.fed.us/nrs/pubs/jrnl/2016/nrs_2016_sannier_001.pdf
Cameroon (scoping)	West and Central Africa	30	https://www.asb.cgiar.org/PDFwebdocs/CAMEROON_REALU.pdf
Nigeria (scoping)	West and Central Africa	10	https://redd.unfccc.int/files/2018_frel_submission_nigeria.pdf
Ethiopia	East Africa	20	https://www.reddcompass.org/forest-definition?fid=%2Fmgd%2F2.3.1&ver=v2
Kenya	East Africa	15	http://www.fao.org/3/a-i6014e.pdf
Tanzania	East Africa	10	https://redd.unfccc.int/files/2017_submission_frel_tanzania.pdf
Mozambique	East Africa	30	https://redd.unfccc.int/files/moz_frel_report_final.v03_03102018.pdf
Uganda (scoping)	East Africa	30	https://redd.unfccc.int/files/uganda_frel_final_version_16.01.pdf
Madagascar (scoping)	East Africa	30	https://redd.unfccc.int/files/20180528_frel_mada_modified.pdf
Indonesia	South East Asia	30	https://redd.unfccc.int/files/national_frel_for_redd__in_indonesia_2015.pdf