PROTOCOL

Above-ground biomass survey for projects that aim to reduce greenhouse gas emissions from deforestation and forest degradation

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Table of Contents

Introduction

To generate emissions reduction credits avoided deforestation projects must create real, measurable and long-term benefits related to the mitigation of climate change, and must be additional to the baseline scenario that would occur in the absence of the project activity[1]. It is therefore necessary to determine carbon stocks at project inception, and the predicted change in carbon stocks in the absence of project activity. This protocol describes the methods to estimate the carbon stocks in biomass at project inception. Since it is not possible to measure every tree in the project area, a sampling approach is necessary. The choices and assumptions made during sampling must be transparent, and contribute to a conservative estimate of carbon stocks[2]. It is also important that the cost of sampling, and required expertise, do not exceed those which can be supplied by the project. The methodology described ensures that sampling provides a robust estimate of baseline carbon stocks, with minimal reliance on external resources and expertise.

Methods

To quantify the carbon stocks at the start of the project it is necessary to:

1. define project boundaries and stratify the project area;
2. determine the carbon pools to be measured;
3. carry out the biomass survey; and
4. calculate the carbon stocks per hectare for each stratum.

Defining project boundaries and strata

For each project site the boundaries of the project area should be determined using maps and remote sensing data for the local area. Carbon stocks are likely to be related to:

- land use;
- vegetation species;
- slope;
- drainage;
- disturbance history;
- age of vegetation; and
- proximity to settlement.

It is therefore necessary to establish separate biomass estimates for strata which differ in their carbon stocks. Information for determining strata can be derived from satellite imagery, aerial photographs, maps of vegetation, soils and topography. The areas under each stratum should be determined before sampling is carried out.

Determining the carbon pools to be measured

The carbon pools that could be assessed as part of a biomass survey include: aboveground biomass in trees, non-tree vegetation, leaf litter, and deadwood; and belowground biomass in roots and soil organic matter. Quantifying all of these carbon pools is likely to be time consuming and expensive, and may not provide sufficient information to justify the cost. If a carbon pool is expected to increase by only a small amount relative to the overall rate of change, and if the pool will not decrease as a result of project activities, it can make sense to exclude that pool from the baseline[3], especially if its quantification is costly.

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1 Kyoto protocol, Article 12.5b,c http://unfccc.int/kyoto_protocol/items/2830.php

2 Marrakesh accords http://unfccc.int/cop7/documents/accords_draft.pdf

3 http://unfccc.int/cop9/

The biomass stored in trees and their roots are likely to be the main carbon pools in avoided deforestation projects. The carbon stored in leaf-litter and dead wood are likely to be maintained or increased by avoided deforestation projects, but leaf litter is time consuming to quantify and is unlikely to constitute a large proportion of the total carbon pool and it may therefore be excluded from the baseline. The effects of deforestation on non-tree vegetation are less certain but are unlikely to constitute a large proportion of the total carbon pool, so non-tree vegetation may be excluded from the baseline. The carbon stored in soils is expected to increase, but the cost associated with recording the carbon in soil usually prevents their inclusion in the baseline. The biomass survey will therefore concentrate on above- and below-ground tree biomass, coarse woody debris (i.e. large pieces of dead wood), and necromass (i.e. dead trees).

Carrying out the baseline survey

An estimate of the total carbon stored in the project area is obtained from an average of a predetermined number of sample plots distributed throughout the project area. For the estimate to be robust the mean from individual samples must be close to the reality for the entire area (an accurate estimate), and the variance among individual samples should be relatively small (so the estimate is precise). Nested sample plots are an efficient method for sampling trees of different sizes (see Figure 1). Coarse woody debris is surveyed along 20 m transects running north to south, and east to west, through the centre of each plot.

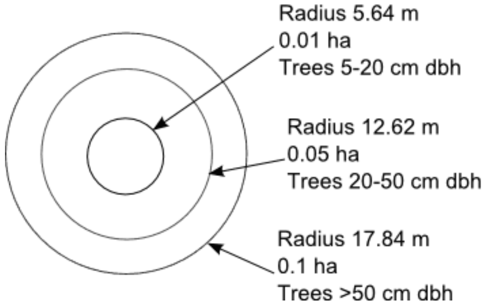

Figure 1. Diagram of nested plots for sampling trees of different sizes.

The total number of plots necessary to ensure 95% confidence that the estimated carbon stock in each strata is accurate, with a precision of 20%, should be determined from an initial survey of around 10 plots in each stratum[4]. It is essential that plot locations are determined without bias, but it is also important that they are accessible to the survey teams. The plot locations within each stratum should therefore be determined either by selecting coordinates at random, or by selecting a path or road within the stratum at random, determining a random distance along the path using a random number generator, deciding which side of the path the plot will be located using a coin toss, and a distance from the path using a random number generator.

The centre of each plot should be marked with a buried iron stake, so that it can be relocated with a metal detector at a later date. Each plot should be assigned a unique number, and the following information should be recorded:

- location;
- latitude and longitude, using GPS and/or a map;
- elevation in m, using an altimeter and/or a map.

Each stem within the plot should be assigned a unique number, and the following information should be recorded:

- distance from plot centre, using a tape measure or laser rangefinder;

4 Pearson et al. (2005)

- the compass bearing to the plot centre, in degrees;
- the diameter of the stem 1.3 m above ground level (a stick marked at 1.3 m can be useful for determining the correct height to make the measurements). Be aware of the correct way to measure trees with non-standard stems (see Figure 2). Record the value in cm to one decimal place (i.e. 10.2 cm);
- the point at which the dbh measurement was made (in m above ground level)
- the height of the tree, measured directly for smaller trees, or with a clinometer or laser hypsometer for larger trees. Record the value in m to one decimal place (i.e. 3.4 m); and
- the condition of the tree (i.e. dead or alive)

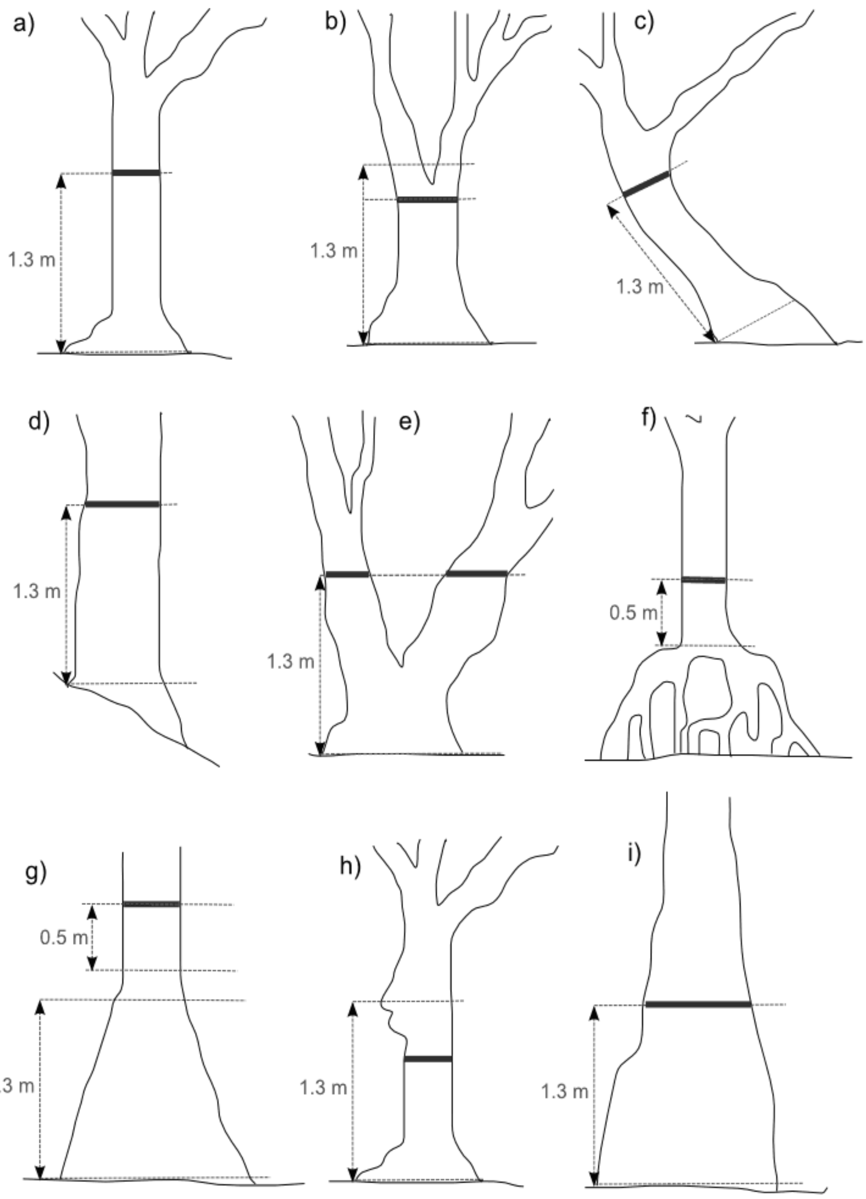

Figure 2. To determine the point of measurement for trees: a) Whenever possible record dbh at 1.3 m height b) if the tree is forked at or below 1.3 m, measure just below the fork point; c) if the tree is leaning, make sure the tape measure is wrapped around the tree according the tree's natural angle (instead of parallel to the ground); d) if the tree is on a slope measure record measure 1.3 m on the uphill side; e) if it is not possible to measure below the fork point, measure as two trees; f) if the tree has stilt roots, measure 50 cm above the highest stilt root; g) if the tree is

buttressed at 1.3 m, measure 50 cm above the top of the buttress; h) if the tree is deformed at 1.3 m, measure 2 cm below the deformity; i) if the tree is fluted for its entire height, measure at 1.3 m If the tree has fallen but is still alive (if there are green leaves present) measure the dbh as if it was standing). Pass the tape under any vines or roots on the stem.

Calculating the carbon stocks per hectare for each stratum

To convert measurements of individual trees to estimates of carbon stock per hectare allometric equations, which convert measured dbh and/or height to an estimate of above ground biomass, are used. It is best to use allometric equations developed for the species and areas included in the project area, and a literature search and consultation with local universities and forestry departments should be carried out to determine the most appropriate equations to use. Some allometric equations also require information on the wood density of the species. The wood density of many species can be obtained from published sources (e.g. Brown 1997) or online databases (e.g. World Agroforestry Centre Wood Density Database[5]).

The aboveground biomass of trees in each plot is determined by adding together the values of all trees in that plot. This is done separately for trees 5-20 cm in the 0.01 ha subplot, trees 20- 50 cm in the 0.05 ha subplot, and trees >50 cm in the 0.1ha subplot. The values for each subplot are then multiplied up to give an estimate over a standard area of 1 ha ($\times$ 100 for 0.01 ha subplot, $\times$ 20 for 0.05 ha subplot, and $\times$ 10 for 0.1 ha subplot). Finally the values from all three subplots are added together to give the estimated aboveground biomass per hectare from that plot.

If locally derived relationships between above- and below-ground biomass are not available, values for belowground biomass are determined from aboveground biomass estimates with the equation[6]:

$$RBD = \exp(-1.0587 + 0.8836 \times \ln(a))$$

Where RBD is root biomass density in kg/ha, and a is aboveground biomass density in kg/ha.

The total carbon for each plot is then determined by multiplying the biomass per hectare by the proportion of biomass that is carbon. Unless a locally derived alternative is available it should be assumed that 50% of woody biomass is carbon.

The average value across all plots surveyed is then applied as the carbon stock for that strata. The total carbon stock for the project area can then be determined by multiplying the carbon stock for each stratum by the area covered by that type of forest.

Bibliography

Avery, T.E., and Burkhart, H. 2001. Forest Measurments. McGraw-Hill: UK.

Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A Primer. UN FAO Forestry Paper 134, Rome. Available online: http://www.fao.org/docrep/W4095E/W4095E00.htm

Eggleston, S. et al. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4 Agriculture,

5 http://www.worldagroforestry.org/Sea/Products/AFDbases/wd/

6 Cairns, M.A., Brown, S., Helmer, E.H. & Baumgardner, G.A. 1997. Root biomass allocation in the world's upland forests. Oecologia 111, 1-11.

Forestry and Other Land Uses. Available online: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Greenhalgh, S. et al. 2006. The Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting. World Resources Institute. Available online: http://www.wri.org/publication/land-use-land-use-change-and-forestry-guidance-greenhouse-gas-project-accounting

Houghton, J.T. et al. 1996. IPCC Guidelines for National Greenhouse Gas Inventories. Available online: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html

MacDicken, K.G. 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock. Available online: http://www.winrock.org/ecosystems/files/carbon.pdf

Pearson, T., Walker, S., and Brown, S. 2005. Sourcebook for Land Use, Land Use Change and Forestry Projects. Winrock International. Available online: http://www.winrock.org/ecosystems/files/winrock-biocarbon_fund_sourcebook-compressed.pdf

Penman, J. et al. 2003. IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. Available online: www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm

Equipment

Equipment required by each survey team includes:

- a compass
- 30 m measuring tape for demarcating plots
- a plastic or wooden stake for marking plot centre during measurement
- 5 m measuring tape for recording tree diameter
- 2 m long stick with 1.3 m marked for determining point of measurement
- maps of local area
- pencils
- record sheets
- a GPS
- a clinometer

Information requirements

1) **Maps and remote sensing data**
   a) Regional maps, remote sensing data, and GIS coverages depicting topography, rivers and streams, population centres, legal classification, and land-use and land-cover for both project areas, and for the whole country
   b) Historical remote sensing data (e.g. Landsat or SPOT) from at least 3 periods over the last 10-15 years, from regions surrounding the two project areas, and for the whole country (if available)
   c) Detailed maps, remote sensing data, and GIS depicting topography, rivers and streams, population centres, legal classification, and land-use and land-cover within both project areas

2) **Forestry data**
   a) Forest inventory data from within the project areas and areas with similar vegetation and land-

use characteristics

b) Relevant literature on carbon stocks in local forests, and other land-use types present in and around the project areas

c) Locally derived allometric equations for determining above- and/or below-ground biomass of trees

d) Local, regional, and national estimates of past rates of deforestation and forest fires

3) **Project information**

a) Existing management plans

b) Information regarding main agent groups, drivers, and underlying causes of deforestation in and around the project areas