eccm
Part of the Camco Group

PROTOCOL

Baseline survey for agroforestry projects

12 May 2008

Version 1.0

Contact details:

Nicholas Berry
Forest Carbon Consultant
Tel: +44 (0)131 666 5073
Fax: +44 (0)131 666 5055
Email: nicholas.berry@esd.co.uk

The Edinburgh Centre for Carbon Management
Part of the Camco Group
Tower Mains Studios, 18F Liberton Brae, Edinburgh, EH16 6AE

CONTENTS

1 Introduction

To generate emissions reduction credits agroforestry 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] (Figure 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. 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 baseline 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.

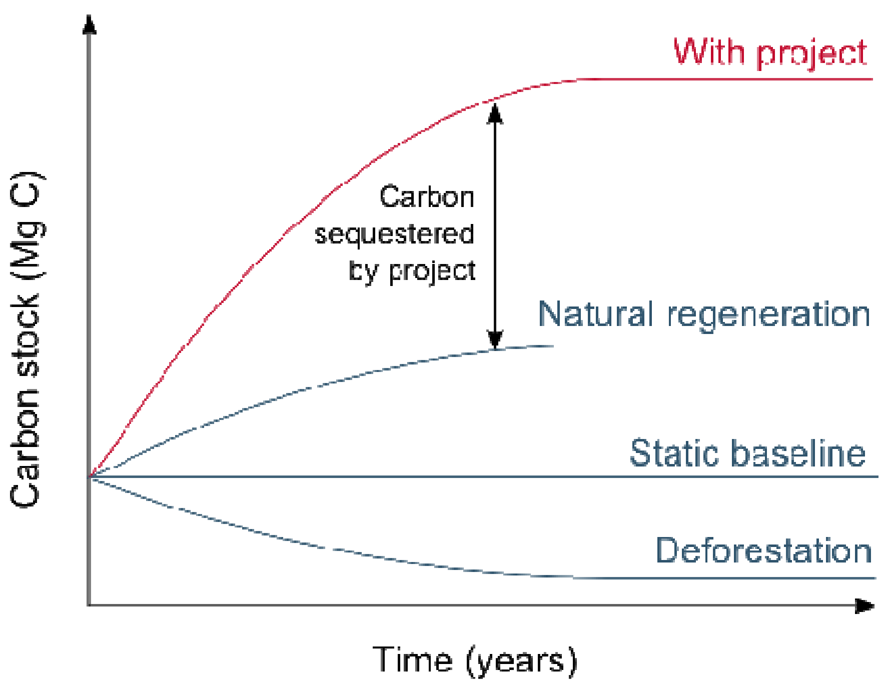

Figure 1. The carbon offset by the project is equal to the difference between the carbon sequestered by the project, and the baseline. A static baseline applies to projects where the current land use is unlikely to change in the absence of project activities (for example for planting agroforestry trees on agricultural land). If carbon would be accumulated in the absence of project activities the baseline will have to account for this natural regeneration. If deforestation is expected in the absence of intervention in the project area, a reduction in carbon stocks with time is the appropriate baseline against which to record carbon sequestration[3].

---

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 For information on determining baselines involving deforestation see the ECCM report "*Determining baselines for avoided deforestation projects*"

2 Methods

To quantify the baseline carbon stocks 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 baseline survey; and
4. calculate the baseline for each stratum.

2.1 Defining project boundaries and strata

For each farm that will carry out agroforestry activities, the boundaries of the project area should be determined. Maps of the local area should be obtained from the ministry of environment or web based sources[4], and the location of the farms marked using GPS and/or local features. Hand-drawn maps of each farm should be developed by farmers with boundaries described with GPS and/or features on the map. If boundary maps have not been produced for the farms visited during the baseline survey, this must be completed before sampling is carried out.

If no economically motivated (e.g. agriculture) or legally mandated (e.g. preservation) changes in landuse are expected within the lifetime of the project, the baseline can be determined from existing or historical changes in carbon stocks in the carbon pools within the project boundary[5]. Carbon stocks are likely to be related to:

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

It is therefore necessary to establish separate baseline scenarios 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.

Readily identifiable strata that could be used for baseline surveys, even in the absence of remote sensing data, are agricultural land and neglected land. The areas under each stratum should be determined for farms visited during the baseline survey, before sampling is carried out (e.g. Figure 2).

---

4 e.g. http://eusoils.jrc.it/esdb_archive/EuDASM/africa/lists/crw.htm

5 http://unfccc.int/cop9/

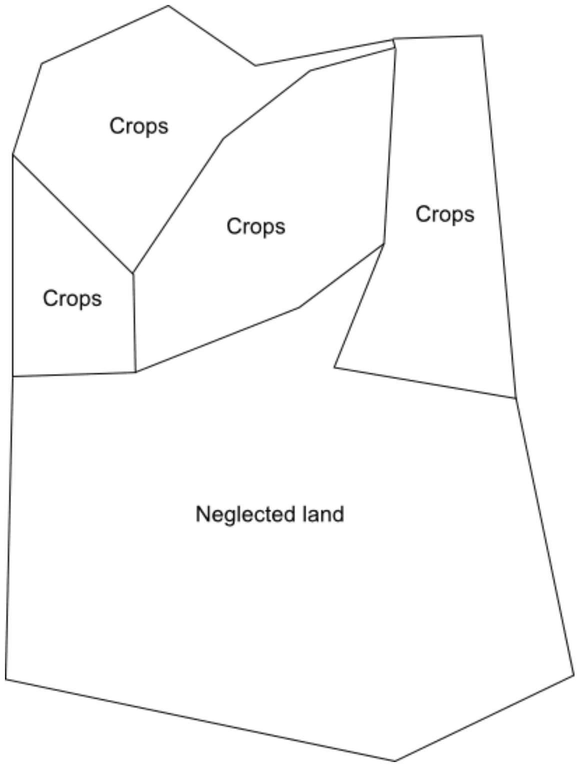

Figure 2. Example of farm map

2.2 Determining the carbon pools to be measured

The carbon pools that could be assessed as part of a baseline 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[6], especially if its quantification is costly.

- The biomass stored in trees and their roots are likely to be the main carbon pools in most areas and should be quantified in all baseline assessments.
- The carbon stored in leaf-litter and dead wood will increase as a result of agroforestry activities, but is unlikely to constitute a large proportion of the total carbon pool and is therefore excluded from the baseline.
- The effects of agroforestry plantings on non-tree vegetation are less certain but are unlikely to constitute a large proportion of the total carbon pool, so non-tree vegetation is also excluded from the baseline.
- The effects of project activities on soil organic matter are also less certain, although the carbon stored in soils is expected to increase, but the cost associated with recording the carbon in soil prevents their inclusion in the baseline.

6 http://unfccc.int/cop9/

2.3 Carrying out the baseline survey

An estimate of the total carbon stored in the project area in the absence project activities 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 3). However, if planting areas are small (≤ 0.5 ha), contain few trees, and have a known area (for example in small agricultural plots) it may be more efficient to record all trees in that area, being sure to make note of the size of the area surveyed.

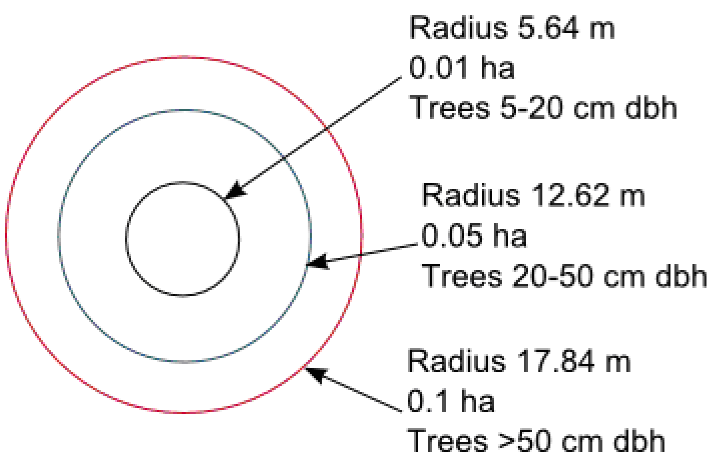

Figure 3. Diagram of nested plots for sampling trees of different sizes.

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[7]. It is essential that plot locations are determined without bias. The farms included in the sample should therefore be determined at random (using a random number generator or milliseconds on a stop watch). For each potential planting area the first plot should be situated 20 m North and 20 m East of the Southwest corner of the planting area. Subsequent plots should be located in a regular 20 m grid until a maximum of ten plots have been surveyed (e.g. Figure 4). For large planting areas it may be appropriate for plot locations to be determined using a grid with wider spacing to ensure an even coverage of the entire area.

7 Pearson et al. (2005)

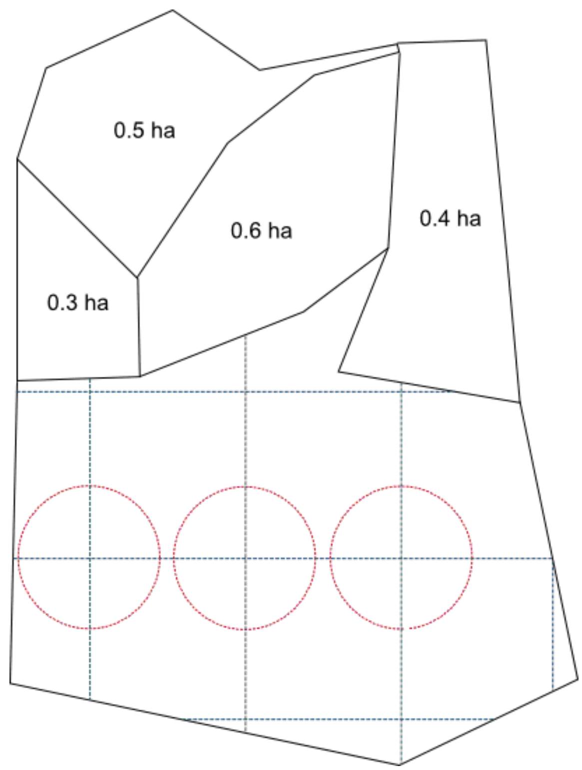

Figure 4. Sampling plan for a farm in which the small cultivated areas will have all of the trees within them sampled, while the larger area of neglected land will be sampled with nested plots located on a 20 m grid.

When measuring a plot, locate the centre point using a compass and measuring tape (or 20 m cord). Anchor one end of a measuring tape to the centre point and begin measuring trees 5-20 cm dbh within 5.64 m of the centre point, trees 20-50 cm dbh within 12.62 m of the centre point, and trees >50 cm within17.84 m of the centre point. For trees that are on the boundary only include trees with more than half of the base of their stem within the plot. Start with a tree to the North of the centre and work systematically around the circle in a clockwise direction. It helps if you mark the first tree recorded so it is clear when the entire plot has been measured.

Within each district assign each farm a unique number (e.g. F1, F2, etc.) and record:

- district;
- sector;
- latitude and longitude, using GPS and/or a map;
- elevation in m, using an altimeter and/or a map;
- precipitation in mm/yr (if known).

Within each farm assign each planting area a unique number (e.g. A1) and record:

- whether the area is neglected or agricultural land;
- whether it is likely or possible that the area would be planted with trees if there was no Plan Vivo project. Yes/No (give details of potential plantings if Yes);
- any signs of management or details from the farmer (for example fuel wood collection, dates of burning);

- soil conditions;
- the length time the area has been neglected for (for neglected land);
- the proposed planting system and area to be used for Plan Vivo project (if known).

Within each planting area assign each plot a unique number (e.g. P1)

Within each plot assign each tree a unique number (e.g. T1) and record:

- the species;
- 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 5). Record the value in cm to one decimal place (i.e. 10.2 cm);
- the height of the tree, measured directly for smaller trees, or with the technique described in Figure 6 for larger trees. Record the value in m to one decimal place (i.e. 3.4 m);
- age of trees that are known to have been planted (do not include any trees planted through Plan Vivo project activities);
- any signs of management (e.g. coppicing or pruning).

An example of a data collection form is provided in Appendix A.

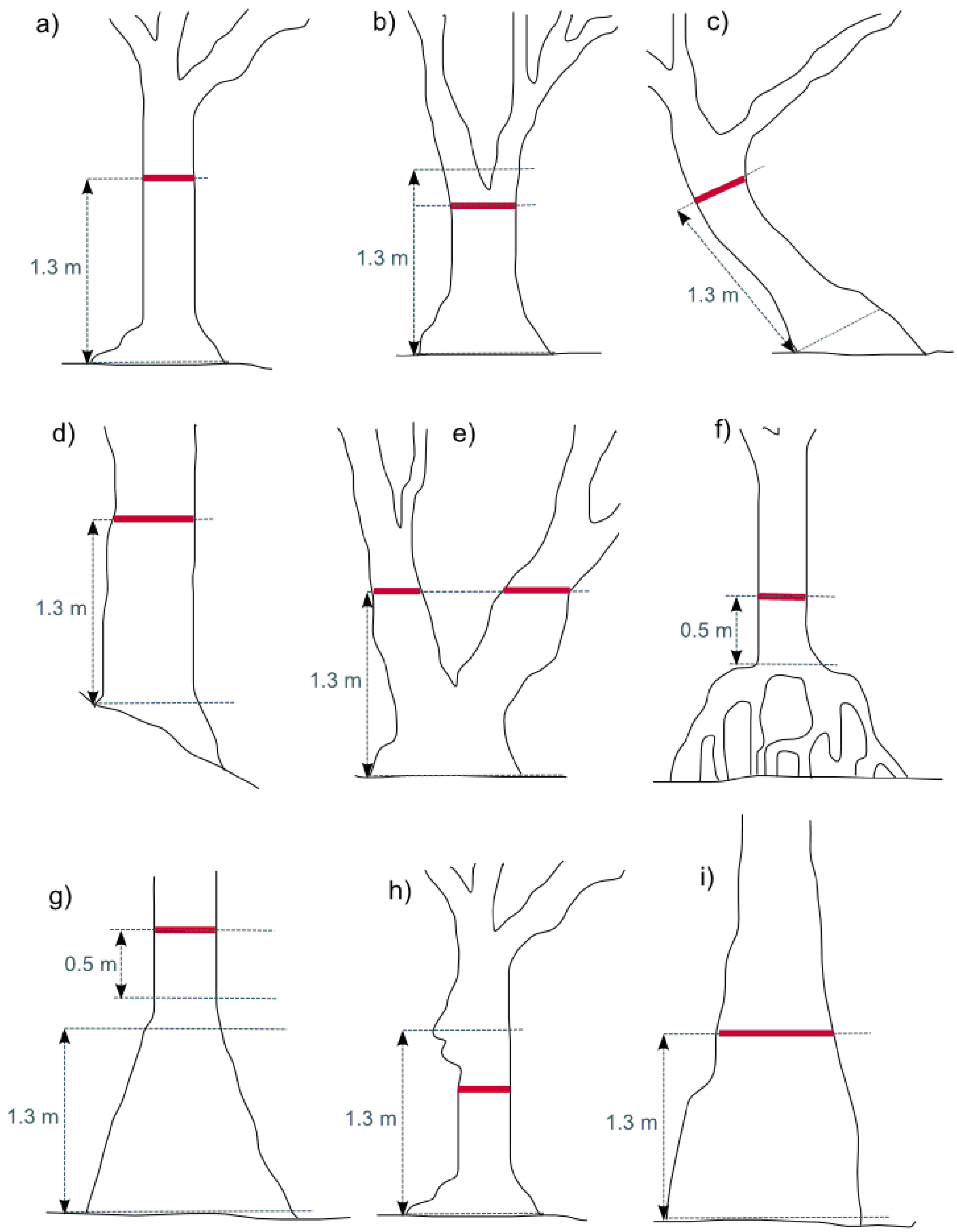

Figure 5. To determine the point of measurement for trees: a) Whenever possible record dbh at 1.3 m height b) if the tree is forked at or below 1.3 m, measure just below the fork point; c) if the tree is leaning, make sure the tape measure is wrapped around the tree according the tree's natural angle (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.

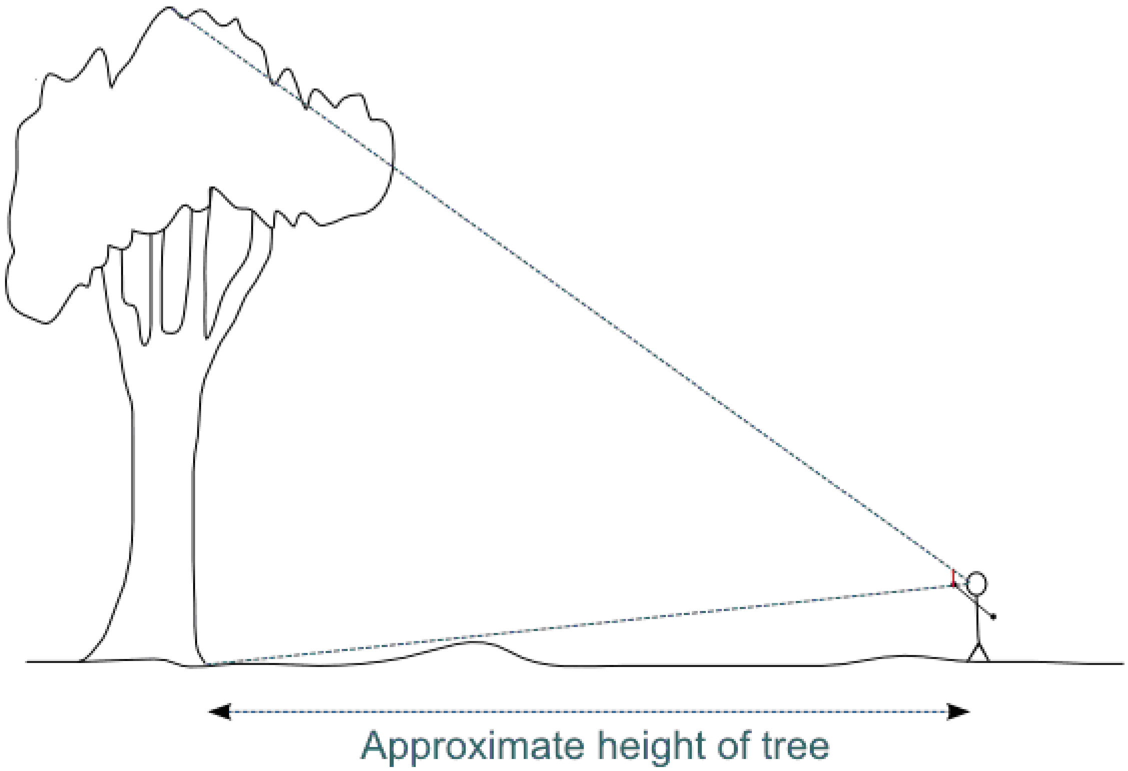

Figure 6. For a rough estimate of tree height, cut a straight stick to exactly the same length as your arm. Walk away from the tree to a point where, when holding the stick vertically at arm's length, the entire tree's vertical centre-line is hidden behind the stick. The distance to the base of the tree is approximately the same at the tree's height (as long as the ground is not sloping).

2.4 Calculating the baseline for each stratum

For each strata it is necessary to determine which type of baseline will be used:

- If the carbon stock is expected to remain relatively constant over time (for example on agricultural land). The baseline for the period of the project is therefore estimated to remain at the level recorded in the baseline survey. A static baseline at the mean value for from the baseline survey will therefore be applied across the planting areas.
- If carbon stocks are expected to change over time (for example on neglected land, if vegetation would recover over time). The carbon stocks from neglected land of known age, determined during the baseline survey, can be used to determine the relationship between age and carbon stock. This relationship can then be applied to predict baselines for individual planting areas.

For both approaches it is necessary to convert measurements of individual trees to estimates of carbon stock per hectare. This is achieved through the use of allometric equations which convert measured dbh and/or height to an estimate of above ground biomass. It is best to use allometric equations developed for the species and areas included in the project, 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[8]).

Whatever allometric equations are used, it is important to verify their accuracy for the project site. This can be achieved by comparing the value estimated from the allometric equation to a more basic estimate derived from the estimated volume of the tree with the equation[9]:

$$AGB = 1.2 \times \rho \times \left(\frac{\left(\frac{\pi}{200}\right) \times d^2 \times h}{3} \right)$$

Where *AGB* is aboveground biomass in kg, *ρ* is wood density in kg/m^3, *d* is dbh in cm, and *h* is height in m.

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 (×100 for 0.01 ha subplot, ×20 for 0.05 ha subplot, and ×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.

Values for belowground biomass are determined from aboveground biomass estimates with the equation[10]:

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

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 on agricultural land is then applied as the baseline for that strata.

For neglected land a graph is produced from the carbon pool in each plot against the length of time it has been neglected for. The best-fit line for this graph can then be used to determine the

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

9 Assuming a form factor to convert the volume of a cylinder to stem volume of 2/3, and an expansion factor from stem volume to tree volume of 1.2

10 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.

trajectory of the baseline over the length of the project, with the age of neglected land determining the starting point for each area (see Figure 7).

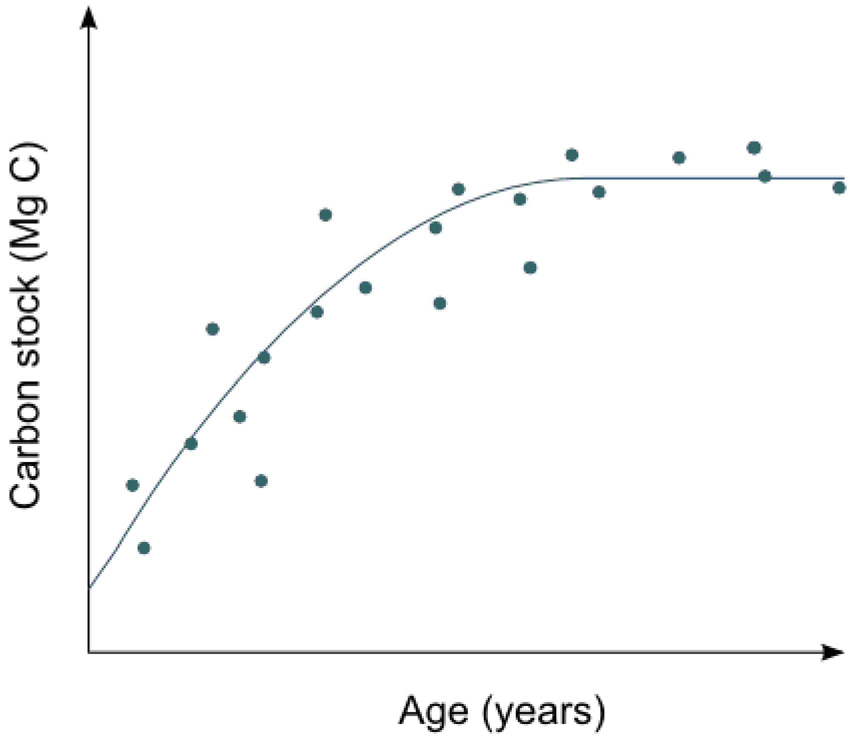

Figure 7. Using a regeneration trajectory to determine a non-static baseline.

3 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, 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

4 Equipment

Equipment required by each survey team includes:

- a compass
- 20 m long cord for locating plots
- 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
- a stick for determining tree height
- hand trowel for checking soil characteristics
- maps of local area
- pencils
- record sheets

Survey teams would also benefit from the use of:

- GPS
- a clinometer
- an altimeter
- a digital camera

5 Appendix A – example data sheet

AGROFORESTRY BASELINE DATA SHEET - *START A NEW SHEET FOR EACH FIELD OR NON-CULTIVATED AREA SURVEYED*

Name:		Date:	
District:	Sector:	Farm:	
Field:		Area of field (ha):	
Survey method: plot / full survey	Plot size (if used): 0.01ha plot for all trees >7cm OR nested plots of 0.01, 0.05, and 0.1ha		
Planting system:	Elevation (m.a.s.l.):	Rainfall (mm/yr):	Soil type:
Would the area be planted without the CHDI project: yes / no	Longitude:	Latitude:	Management:
Landuse: cultivated / non-cultivated		Length of time since last cultivated (for non-cultivated areas):	

Plot number (if used)	Species	DBH (cm)	Height (m)	Planted or natural	Age of tree (if known)	Management (e.g. pruning/coppicing)	Notes