Organizing community level forest surveys for REDD+:

Manual for Community Technicians

Version 5: 10 April 2014

Introduction

The purpose of this manual is to guide NGOs and other support organizations/technicians in the setting up systems by which communities can monitor carbon stocks in their forests at ground level for the purposes of participation in national programmes of REDD+. The material in this document (particularly Steps 3 and 4) is largely derived from a manual developed by J. Verplanke and E. Zahabu of the KTGAL project, see Resources section of the website www.communitycarbonforestry.org, and adapted by M. Skutsch and D. Benet. Step 6 is a software programme developed by staff of CIGA-REDD+, UNAM, Mexico particularly by A.P. Larrazábal, and M.A. Salinas Melgoza (http://redd.ciga.unam.mx).

There have been several other manuals available on internet for some years (see Appendix 1). A Toolkit for Community carbon Monitoring is reportedly being developed by the Rainforest Alliance but was not available at the time this manual was written, and there are a number of country specific ones that have recently been prepared under the UN-REDD+ programme. Most of these manuals are concerned only with the measurement methods. In this guide, we walk through the entire process of community carbon monitoring, starting with how to make informed decisions about how to measure and record the data, and continuing with tailor-made measurement and data recording protocols.
In any forest carbon survey, the idea is to measure forest biomass stock at a given point in time and to repeat the measurements at regular intervals (once per year or once per two years). This will enable the change in stock to be determined. Change in stock could occur in three ways:

a. Deforestation (loss of forest area) occurs when an area which was forest in the first period becomes permanently non-forest in the second and subsequent periods. In order to determine whether an area has been deforested it is important to have a clear definition of what is forest and what is non-forest (see glossary). It is also important to establish that the area that has been cleared has been permanently cleared. An area which is temporarily cleared e.g. as part of a shifting cultivation cycle should be considered degraded, not deforested, as regrowth of trees will be expected within a couple of years. **Deforestation, and its opposite afforestation, is best measured using remote sensing (RS) rather than on-the-ground surveys.** Many community support organizations will have sufficient GIS skills to carry out assessments of change in forest area over time from available RS, and this is not dealt with in any detail in this manual, which focuses on community monitoring inside the forest.

b. Degradation (for the purposes of REDD+, meaning reduced density of trees in the forest) occurs when there is a reduction of biomass but the area remains forest. This could occur as a result of selective logging or in shifting cultivation cycles, and it often a gradual process. As such, annual or two yearly changes in stock are usually impossible to detect from remote sensing, much less can they be measured from satellite imagery. **On the ground monitoring is essential and CBM is often a good option for this.**

c. Forest enhancement occurs (i) when an area of non-forest becomes forest, for example by afforestation or through natural regeneration (which is best measured using remotely sensed images) and (ii) when the density of trees within the forest increases as a result of natural regeneration or enrichment planting. **This can be assessed at ground level through CBM.**

It is important to understand that for REDD+ what matters most is the change in stocks over time, since it is the change, not the absolute value that is valorized in REDD+. The carbon content of the biomass is estimated by dividing the measured biomass by 2 (since carbon makes up 50% of the chemical weight of tree cellulose). To estimate CO2 equivalent the carbon stock is multiplied by 3.6 (based on the relative chemical weights of C and CO2).
Step 1: Important points to consider in designing a community monitoring strategy

The form that CBM takes will depend on:

1. Data requirements and guidelines laid down by the national REDD+ programme itself. In most countries these are not yet specified, but they could include rules concerning:
   a. What variables are to be included (for example, which carbon pools have to be measured)
   b. What methods are to be used in measuring the variables and
   c. How frequently surveys are to be repeated
2. The type of forest. Dense tropical forests may require different sampling methods and different measurement approaches from open or dry forests
3. The types of drivers that are thought to be causing deforestation and forest degradation or which are supporting forest enhancement
4. The availability of supporting materials such as locally appropriate allometric equations, data on typical forest densities and growth rates etc

Before starting to implement CBM with communities, some important choices have to be made:

1. Estimates of carbon stock in the forest can be made in three fundamentally different ways:
   a. By measuring the dimensions of trees (diameter at breast height, height) in fixed, permanent sampling plots, and later applying allometric equations to this data to obtain an estimate of biomass
   b. By using a relascope which estimates basal area, in fixed, permanent sampling plots
   c. By proxy, without direct measurements, but quantifying the difference between estimated rate of off-take and rate of natural growth (using the so-called Gain-Loss method, see Appendix 2). This can only be done if there is very clear understanding of what is causing loss of forest biomass and if there are reliable statistics both on the extraction rates and on the biological growth rates of trees (the normal mean annual increment of the forest).

The default method used in this manual is the first of these (a), as this is the standard method which is the most commonly applied.
2. The level of error that is acceptable in estimating the mean stock. This is usually 10% or 5%. The value selected will affect the number of sampling plots that are required. The default value applied in this manual is 10%.

3. The size and shape (circular or rectangular) of sampling plots to be used (circular plots are easier for communities to lay out). In open forests where the number of tree stems per hectare is low, larger sampling plots will be needed than in dense forests.

<table>
<thead>
<tr>
<th>Vegetation characteristics</th>
<th>Plot radius (m)</th>
<th>Plot size (m^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very dense vegetation, stands with large numbers of small stems, or highly uniform distribution of larger stems (e.g even aged plantations)</td>
<td>5.64</td>
<td>100</td>
</tr>
<tr>
<td>Moderately dense woody vegetation</td>
<td>8.92</td>
<td>250</td>
</tr>
<tr>
<td>Moderately sparse woody vegetation</td>
<td>12.62</td>
<td>500</td>
</tr>
<tr>
<td>Sparse woody vegetation</td>
<td>14.56</td>
<td>666.6</td>
</tr>
<tr>
<td>Very sparse woody vegetation</td>
<td>17.84</td>
<td>1000</td>
</tr>
</tbody>
</table>

It is common practice to use nested plots (in which a small plot is defined within the larger one). In this case, all trees above a given diameter at breast height (e.g. DBH >10cm) are measured in the large plot but smaller trees (say 2.5 – 10 cm diameter) are measured only in the small, inner plot.

The default method used in this manual is circular plots of 12.5m (approx 12.64) diameter with an inner plot of 2m diameter. All trees above 7.5 cm DBH are measured across the larger plot and those >2.5 are measured in the small inner plot.

4. Which carbon pools will be measured. The possible pools are:
   a. Above ground tree biomass
b. Below ground tree biomass (roots)
c. Soil carbon
d. Shrub and herb layer (bushes etc)
e. Litter layer (leaves)
f. Deadwood (fallen branches etc)

In most forest ecosystems, the majority of the carbon is found in the above ground parts of the trees themselves, and more importantly for the purposes of REDD+, it is this pool that is likely to change most as a result of deforestation, degradation or forest enhancement.

However, in some forest systems, e.g. secondary dry tropical forests, the soil may be an even greater store of carbon. Whether this should be included and measured in CBM depends on whether the soil carbon is likely to change as a result of deforestation, degradation or forest enhancement. If these processes do not a priori affect the amount of carbon in the soil, it makes little sense to measure it, since measurement requires laboratory analysis of a large number of soil samples. It may be necessary to justify why the CBM includes or excludes soil carbon.

The below ground tree biomass is commonly estimated using an expansion factor (i.e. it is considered to be a direct function of the biomass of the upper parts of the tree). However, in most cases deforestation does not remove the roots of trees, and this should be taken into consideration when analyzing the data.

The litter and shrub layers generally form a very small proportion of the overall carbon within the forest ecosystem, and are frequently omitted from carbon surveys.

The importance of deadwood varies according to circumstances, and the question of whether to include it or not will have to be made based on an assessment of whether this pool is subject to change as a result of deforestation, degradation and forest enhancement.

The default method used in this manual is to measure only above ground tree biomass, and to calculate carbon in roots using an expansion factor.

5. Data recording technology
If measurements are made by community members in the field, the data has to be recorded. The simplest method is to design a paper format for each sampling plot, which the team doing the survey then fills in. However, this data would have to transcribed into a database, checked, used in calculations of biomass per hectare and similar variables, and eventually sent electronically for use in the national recording system. It is therefore much easier if the survey teams themselves use an electronic system in the field and enter data directly into an electronic database. The advantage of this is that data such as GPS coordinates of the plots can be automatically recorded alongside the data on tree dimensions and photographs can also be linked to each plot. There is also less likelihood of errors of transcription.

In terms of hardware, tablets and smartphones are the best equipment to use for this as they have built in GPS and camera facilities. These days, smartphones are not just more affordable than they were; it may be expected that even in quite remote communities, they may be available, if not to community members themselves then to the support organizations.

In terms of software, there is a large range of suitable programmes available, including Cybertracker, Google’s ODK system and Poimapper.

The default system that we present here uses Cybertracker, for which we have developed an app for immediate use (it requires an Android system). Cybertracker is freeware which can be downloaded from the internet. The app can be freely accessed at http://redd.ciga.unam.mx

For the support organization, Step 1 in setting up a monitoring system at community level is therefore to make clear and justifiable decisions on all the above issues. This should be done taking into consideration any guidelines or rules that have been developed for community monitoring by the national REDD+ programme, since the data from the communities may need to be compatible with standards being used at national level.
Step 2: Preparing the sampling grid

Since it is clearly not feasible to measure all the trees in the forest it is normal to develop a set of sampling plots which are spread out over the entire forest area.

In order to do this it is essential to have a map of the forest, preferably at a scale of around 1:10,000, or at least 1:25,000, which shows the boundaries of current forest areas. If there is no such map available, the best alternative is to download and print a map of the area from Google Earth and to work with (informed members of) the community to draw these boundaries, based on their local knowledge.

Alternatively, a map can be developed using the GPS/GIS function of the smartphone/tablet. This requires the user to walk along the boundaries of the forest and mark waypoints with the GPS. This procedure could also be used to check the boundaries as identified and sketched by the community.

It is important that different types of forest (coniferous, oak, dry tropical forest etc) are identified and that the areas under these different natural types are clearly marked on the map. Ideally areas which are heavily degraded will also be delimited. In this way, the total forest area will be divided into different strata, which can be sampled independently of one another.

The size of the sampling plots should be selected according to the typical density of the forest (see Step 1 above). The number of sampling plots needed in each stratum is calculated through estimating the variance around the mean of the basal area, which will reflect the variability of tree sizes present (mean basal area is the cross sectional area of all the trees in a plot, measured at breast height, divided by the plot area and averaged over all the plots within the stratum).

In each stratum, make a pilot survey to estimate the variance in tree stocking. For this purpose, tree data should be taken from at least 15 sample plots distributed all over each stratum to cover all possible variations (for how to gather this data, see Step 4). The plots used for the initial training of community members could be used also for the pilot, to save time and efforts.

With data from the 15 plots, the number of sampling units (n) is calculated using the formula:

\[ n = \frac{CV^2 t^2}{E^2} \]

Where:
N is the number of plots required

CV = is the coefficient of variation of the basal area, which is the measure of variability of the readings of the cross-sectional area of the trees that have been taken

t = is the expression of confidence that the true average is within the estimated range; values can be obtained for specific sample sizes in a statistical handbook.

E is the error that you are willing to accept (in this manual we have selected E = 10%; use of 5% instead would greatly increase the sample size needed.)

Example: If CV is 40%, T = 1.71 and E = 10% then n = 50

To obtain the CV of the mean basal area:

1. Basal area of a tree (g) is its cross-sectional area at breast height,
   \[ g = \pi d^2 / 4 \]

Plot basal area (\( G_i \), expressed in \( \text{m}^2/\text{ha} \)) is calculated by summing up individual tree basal areas in each plot, and dividing by the plot area (a) in hectares.

   \[ G_i = \Sigma (g/a) \]

Mean plot basal area (G, in \( \text{m}^2/\text{ha} \)) is then given by averaging all the plots in the pilot sample

   \[ G = \Sigma (G_i/n) \]

Standard deviation (SD) of plot basal area is:

And the coefficient of variation (CV) is the standard deviation divided by the mean

   \[ CV = SD/G \]

Once the number of sample plots per stratum has been calculated, these need to be distributed in a grid pattern as explained in the next step
For the support organization, Step 2 implies working with the community to define and map the forest areas that are to be monitored, to do some preliminary pilot measurements to establish the sample size, and to lay out the location of these sample plots on the map.

**Step 3: Locating the sample plots in the forest**

When the sample plots are ready and distributed in a grid pattern, steps must be taken to ensure the group doing the monitoring will be able to locate them on the ground. First, a sketch map of the forest area with its different strata is needed, a set of equally spaced transect lines are drawn across this and the sampling points are placed at fixed intervals along the transects such that they are evenly distributed over the entire area, as shown in the example below.
The start point of the first transect must be located. This can be done using the navigation capacities of a standalone GPS. Also, description and recording of landmarks are essential, as these will facilitate future sample plots to be found. Using a compass, the direction of the transect is determined and the distance between plots measured, either by using tape or the GPS. There are several things to be considered regarding the landscape. If the sample plots are located on hill or mountain areas with steep slopes, then distances measured must be corrected for slope factor (see table below). The advantages of using a GPS is that it measures horizontal distances automatically, so there is no need to do further corrections.

<table>
<thead>
<tr>
<th>Slope</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope less than 5%</td>
<td>1</td>
</tr>
<tr>
<td>5%</td>
<td>1.0012</td>
</tr>
<tr>
<td>10%</td>
<td>1.005</td>
</tr>
<tr>
<td>15%</td>
<td>1.0112</td>
</tr>
<tr>
<td>20%</td>
<td>1.0198</td>
</tr>
<tr>
<td>25%</td>
<td>1.0308</td>
</tr>
<tr>
<td>30%</td>
<td>1.044</td>
</tr>
<tr>
<td>35%</td>
<td>1.0595</td>
</tr>
<tr>
<td>40%</td>
<td>1.077</td>
</tr>
<tr>
<td>45%</td>
<td>1.0966</td>
</tr>
<tr>
<td>50%</td>
<td>1.118</td>
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<tr>
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<tr>
<td>70%</td>
<td>1.2207</td>
</tr>
<tr>
<td>80%</td>
<td>1.2806</td>
</tr>
<tr>
<td>90%</td>
<td>1.3454</td>
</tr>
<tr>
<td>100%</td>
<td>1.4142</td>
</tr>
</tbody>
</table>

Plots are established with the help of measuring tapes and a compass. Brightly coloured poles or any other marker can be used at the center and coloured paper or cloth at the edges of the plots.

The description of the plots and any landmarks must be detailed, as there might be some places where GPS signal might not be available. Also, the same order when measuring trees (e.g. recording them clockwise from the plot center facing the direction of the transect) is useful for future ease when locating plots and trees to be measured.
Step 4: Principles of measuring above ground tree biomass

The community team will need training in how to measure trees within the sampling plots. It is a very straightforward process, but it requires a number of tools. A variety of tools exist, the ones recommended here are generally cheap and readily available.

Before starting it is essential to determine what kind of allometric equations are available to transform the physical measurements into biomass equivalents. Since tree forms vary even within one species across different geographical regions, locally developed, species specific allometric equations are always to be preferred. However, in many places they not available and generalized equations will have to be used (see Appendix 3). Since the aim of the measurement is to assess changes over time, the effects of using non-local allometric equations is not likely to lead to large errors provided the same equations are used each time. It is important however to check the equations in advance to see which variables they require: all are based on diameter at breast height, but not all require a term for tree height. In the case of regenerating areas where all trees are young and small, special equations for saplings may be used.

Tools for measuring tree diameter at breast height (1.3m above the ground)

Diameter at breast height can be measured using calipers or a diameter tape. Calipers are normally made of wood, steel or aluminium. Aluminium calipers are more convenient because they are light and durable. Often a single caliper measurement is adequate. However for an elliptical cross section of a stem, two caliper readings at right angles should be made and the average recorded. To obtain reliable measurements, operators must be trained to ensure that:

- the point of measurement is located correctly (it is recommended to use a stick of 1.3m consistently whenever dbh is measured, and a good trick is to stick a piece of masking tape across the clothing of the team member doing the measurement at exactly 1.3 m, since body size will affect breast height)
- the place of the calipers is at right angles to the longitudinal axis of the tree
- the correct pressure is applied at the moment of measurement
- the bar of the caliper is pressed against the stem.
The diameter tape actually measures the circumference of the stem, but calibrates for diameter, with graduations based on the relationship between diameter and circumference. Diameter measurements with the tape are more consistent than with a caliper, provided the tape is level and pulled tightly at the time of measurement.

Calipers are convenient for measuring trees up to 50 cm diameter. Diameter tapes are preferred for larger trees because large calipers are bulky and inconvenient to handle. Measuring elliptical stems with the tape however tends to overestimate diameter in which case a caliper is preferable.

**Tools for measuring tree height**

Note that height measurements are only required if the available allometric equations include a term for height.

Instruments for measuring height are known as clinometers. These are trigonometric instruments which measure angles; a common brand is the Brunton clinometer. Poles with graduated scales can also be used to measure tree height, especially in forests with many rather short trees (for example in selvabaja/miombo woodlands), however the default tool used in this guide is the clinometer.
Brunton clinometer

Height measurement with pole: E. Zahabu

**Instructions for measuring diameter at breast height (dbh)**

In most cases, when trees are of normal shape and size, measurements can be made using either calipers or diameter tapes. It is important that the pressure is applied with the calipers and that the tape is taut at the time the measurement is read. In the case of trees of abnormal shapes, advice is provided in the figure below. As far as possible these techniques should be followed in order to maintain consistency in consecutive measurements of dbh.
From: MacDicken, K.G. (1997) A guide to monitoring carbon storage in forestry and agroforestry projects. Winrock, Washington DC (http://www.fcarbonsinks.gov.cn/thjl/Winrock%20International%20%E7%A2%B3%E7%9B%91%E6%B5%8B%E6%8C%87%E5%8D%97.pdf)
For trees with buttress roots the custom is to measure immediately above the buttress

Instructions for measuring tree heights

The observations should always be taken from a position level with, or above, the base of the tree (not from below), and at a distance which enables the observer to see the top and the bottom of the tree (see diagram).

The clinometer is held vertically as shown in the photo. The observer keeps both eyes open, looking through the instrument with one eye and aligning the horizontal line in the instrument with the top, and then the bottom, of the tree. There are two scales visible in the instrument, one measuring angles and the other measuring % slope; it is much easier to calculate using the % slope measure. In the case of the Bruntonclinometer this scale is on the right hand side. This may not be the case in all clinometers so care should be taken to ensure correct usage.
Readings should be taken and recorded for the top (A) and the bottom (B) of the tree, and the distance from the point at which the observer is standing to the bottom of the tree is measured with a tape.

The height of the tree is calculated as \((A + B) \times \text{distance}\)

This calculation is carried out automatically in the Cybertracker programme which we present in step 6.

Errors in height measurement can result from:
- Incorrect identification of top and bottom of the tree. Erroneous top identification is particularly common due to wind sway or nature of the tree crown
- Incorrect estimation of the horizontal distance
- Leaning trees: A tree leaning towards the observer will cause an overestimate and vice versa.

**Step 5: Selection and training of community monitoring team**

A forest monitoring brigade needs 4 to 5 people, hence if 10 persons are trained there should be sufficient for two teams. Criteria for selection of the community teams will include:
- education level; literacy/numeracy will be required in at least some members of the team,
- knowledge of the forest (its extent and character),
- knowledge of local trees, which will assist in their identification,
- permanence of residence, to ensure continuity as annual or bi-annual surveys will be required,
- gender: both men and women have shown themselves to be well suited to this work.

**Training**

The entry point is to introduce the trainees to the idea of forest assessment and monitoring for the generation of accurate data on changing tree stocks of their village forests. This introductory part could also be attended by other members of the community, particularly the community leaders and other community forest or
environmental committees. The communities should also be told about the prospects of getting financial income from the carbon benefits of their forests through REDD policy or other mechanisms, but without raising false hopes, since at present there is no mechanism in place for this in most countries.

Practical training will involve two separate techniques; training on basic forest measurement techniques for assessing stock, and training in how to record the data using electronic media including its GPS function, of which the Cybertracker programme presented below is an example. If there is no opportunity at all for the use of such electronic equipment in the field, the tree measurements can be recorded on paper, provided a stand alone GPS is used to identify the locations of the sample plots. However, smartphones are becoming very common and the advantages of this in terms of data processing are enormous.

Training in forest measurement can be carried out within half a day. The team(s) should pace or measure out a pre-determined distance into the forest and set up a circular plot using measure tapes, with a smaller plot at its centre, under the guidance of the trainers. Data characterizing the plot (GPS position, aspect etc) is then entered into the smartphone by one of the team. The trainers should demonstrate how to use the calipers or diameter tape and explain that trees with less than 7.5 cm diameter will not be measured in the larger circle (trainees learn quickly to recognize when trees are below this level, but should be encouraged to measure trees which are on the borderline in this respect; however they will only be recorded if the measurement indicates they have a diameter of more than 7.5cm.) Trainers should ensure that the trainees hold the tape (or calipers) tightly when taking the reading and that the height at which the reading is taken is indeed 1.3m above ground level. On sloping ground and for the case of non vertical trees, trees with buttress roots or sites where all trees are saplings, attention should be drawn to the special ways of making measurements. One or two persons should be on measurement duty (one for dbh and one for height), while one identifies and calls out the species or tree name, and a fourth records all this information using the smartphone. It may be useful to have a fifth person to mark the trees to ensure that all within the circle are counted. Dividing the circle into four quarters with tapes makes it easier to identify which trees have been counted and which have not. When all the >7.5 trees have been measured throughout the plot, the smaller inner plot will be measured for trees of 2.5-7.5 cm.

Two or three plots can be measured in a single afternoon and ideally these training plots should be in forests of different types: if not of different species, then in areas with different levels of degradation or use. The data from these plots can be used by the
supporting organization to calculate the variance around the mean dbh, which is needed to calculate the total number of sample plots that will be required.

**Training in use of the smartphone**

Initial training should take place indoors, but for practical reasons not more than 2 people can use one smartphone at any one time, since the screen is small (although a powerpoint demonstration could be made to walk the trainees through the different screens and familiarize them with the system). The application has been designed to be as user friendly as possible and more or less self-explanatory (see Step 6).

A problem with Smartphones is that they need to be recharged regularly. One solution is to use solar chargers, or to have back up batteries available. The default assumption is that electric power will be available at night at the home base for recharging, but in some remote locations this may not hold. More power will be used if the option of taking photos in each plot is used. Organizers should experiment with the equipment available to see how many hours each smartphone can be expected to last, and plan the survey on this basis.

To get started with the smartphones the first step is to download the programmeCybertracker onto the PC that will house all the data. Then find the Cybertracker application that we have developed, on [http://redd.ciga.unam.mx](http://redd.ciga.unam.mx). This is freeware and can be downloaded without cost.

Open the programme and then the application. You will see that the application has different versions for different devices: there is one for a Motorola-Moto G phone, and one for a Samsung.... This is because different smartphones have different resolution characteristics and you need to pick the one that fits your phone best.

To start using the app on your phone
1. On your phone, go to settings and ensure that the checkbox titled ‘Unknown sources’ is checked.

2. Connect your phone to the PC and select the “Install to Mobile Device” option, this will first download Cybertracker into your phone as an “apk” file directly in the root directory.

3. Search the file and start, allowing the installation when requested.

Now proceed to install the specific application to measure biomass repeating the step 2. This time the phone will display the follow screen.

![Install screen](image)

Unplug the phone and be ready to use the app.
Step 6: Recording data on the smartphone using Cybertracker

This module describes how to use a software programme which has been developed for use by communities in the field for recording measurements of biomass. From this data, carbon stocks can be calculated. It follows the procedures for biomass measurement outlined above, using sampling plots with two concentric circles. Recording of the data requires a Smartphone in which the Cybertracker programme has been installed, and which has GPS facilities and a camera, but no other equipment is needed. However, data stored in the Smartphone should be downloaded into a database on a PC or laptop on a daily basis, and which will be used for further analysis.

Each day, the first step is for the monitoring team to enter their names. Then, when they reach the first sampling plot, they enter general information relating to it. Within this they first count and register the small trees within the 2m inner plot (those trees that are 2.5-7.5 cm diameter), and then they take measurements of each tree (> 7.5 cm diameter) in the 12.5m circle, entering the data on each tree individually into the Cybertracker programme.

The application has 21 screens, grouped by theme, and each contains instructions on how to register the data. When the data has been entered on a given screen, the user uses the arrow on the right hand side to move on to the following screen.
These three screens and the sub-screen (text editor) correspond to the data that needs to be entered only once per day.

The first, ‘Measurement of biomass’ presents the programme and gives the user an idea of what is expected of the people doing the monitoring. It gives a brief welcome, and explains the point of the application. Being the very first screen, it explains how to move on to subsequent screens using the black arrow, at the bottom right of the screen.

The second screen, ‘How to navigate’ explains the symbols used in the application, so that they will be recognized easily.

In the third screen, ‘Monitoring team’ the team that is doing the measurements that day fills in their names (this is done only once per day). To access the text editor you just have to click on the white space which has the words ‘tap to edit’ , and the software will open a new window in which you can write the names using the touch keyboard, and save them by pressing the ‘OK’ button in the top right corner. If when the key board appears it pushes the the window too high up, so that you can’t reach the OK button, then you should save the keyboard first, using the telephone controls. It is quite important to enter the names of the members of the team so that there is a record later of who was involved in the work, also so that if there are some doubts about particular measurements, it is easier to track who was involved.

**Sampling plot**

This screen presents two images; the first is a diagram which shows the form of the sampling plot, with the two concentric circles. The text in the middle explains this. The photo below shows a monitoring team fixing the central point of the sampling plot.
General data

This group of screens is for characterizing the site. There is one screen of introduction and 8 for capturing the data.

The first two screens do not need direct user input as one is just the welcome screen and the second has a ready-programed counter which will record the number of the plot. Each new plot will automatically be assigned a new number in sequence.

The screen ‘Geo-reference’ is for registering the GPS coordinates of the centre of the plot (be sure to be standing in the centre of the plot when you do this). The application will register the date and time automatically. It is possible at this point to take photos and record them although this is not obligatory.

In the screen ‘Description of the site’ you need to fill some text into each of the three spaces (this is to give more detail about where the site is and what its condition is). If there is no information on this, write ‘no data’, and continue.
The next four screens allow users to select one or multiple options thus no tapping is needed.

The screen ‘**Municipality**’ needs to be adjusted internally in the programme to show the names of municipalities or counties in which the sample site falls. The names given in the example are illustrative only. The screen ‘**Accessibility**’ gives an idea of how easy it is to reach the site. The screen ‘**Type of vegetation**’ will also need to be adjusted internally to represent types of vegetation relevant in the area under study; the example is illustrative only.

‘**Current environmental impacts**’ screen and ‘**Observation**’ screen are to register the kinds of human uses the sample plot is being used for (if any). Observations can be made here (multiple responses are possible). Give the answer ‘none’ if there are no human uses visible. There is also a screen with space to write additional comments if the monitoring team feels this to be necessary.
Recording data in the 2 meter circle

Recording of the trees should start with those in the inner, 2m, circle. Within this small circle, all trees which have a diameter at breast height of between 2.5 and 7.5 cm are counted, by tree type. These are the saplings or young, up-coming trees. For example, the first type of tree sapling may be ‘oaks’. ‘Oak’ is entered into the top line of the screen, and in the second line a second name for the type of tree, for example the species, may be included, while in the third there is space for comments. All oak saplings of between 2.5 and 7.5 cm diameter within the 2m circle are counted and the number is entered into the green line. Then the right arrow can be tapped, so that the ‘Continuing’ screen appears to give the user the option to record a second tree type, for example, pines, or to continue to the large circle.

Recording data in the 12.5 meter circle

For this circle there are 5 screens for entering data. The first three explain the data that need to be entered and how to enter this information. The screen called ‘12.5m radius’ illustrates trees.

The screen ‘How to measure the DBH’ reminds the monitors that they need to take the diameter measurements at exactly 1.3m (i.e. breast height) from the ground, and record those that have diameters of more than 7.5 cm. Note that for the
purposes of these measurements, the large trees in the inner circle should also be measured and recorded. The next screen shows how to make sure the diameter measurements are taken at 1.3m.

In addition to measuring the diameter, we often have to measure the height of each tree, using a hypsometer or clinometer. The screen ‘How to measure angles’ reminds the monitoring team about the correct use of this equipment. A position should be taken which is below or level with the bottom of the tree. Readings are then taken of the top of the tree and the bottom of the tree and this data is entered into the screen. Be sure to record the measurement that is in terms of percentages, not the angles (readings are usually on the right hand side in the clinometer viewer).

The following screen is for entering data on the measurements of individual trees, remembering that we are only measuring those that have a diameter at breast height of more than 7.5 cm. The counter at the top right should register ‘1’ (i.e. first tree to be measured in this plot) when you start. The type of tree (tree name) is entered in this screen, together with observations such as ‘has two trunks’ or ‘dead’. The right arrow leads to a screen in which the four pieces of information about this particular tree can be entered.
To activate the recording of the value the corresponding box needs to be checked. The first line requests the distance between the person with the clinometer and the base of the tree, measured with a tape, followed by the DBH recording. The reason that there are two spaces for DBHs is because sometimes a tree has two trunks. If it has only one, just ignore the second space. In the fourth line enter the clinometer reading to the base of the tree (use the %), in the fifth line the reading to the top of the tree. Note that the programme should not allow you to proceed to the next screen until you have entered at least one DBH, the two slope measurements and the distance, since these data are essential for the calculation of biomass.

After this data has been entered, the machine will present three possibilities:

1. Go to the next tree in the plot (the number on the screen should automatically record that you are now going to measure the second tree)
2. Finish this plot (i.e. when you have measured all the trees of DBH greater than 7.5cm within the 12.5m circle). The machine will then open again for you to enter the data for the new plot.
3. Finish for the day. The machine will open next time at the screen for entering the team’s names.

There are some important practical issues you need to consider:

- You should enable the “Use SD card for backup” option if your device supports it. This will protect the data from being lost if the battery runs out.
- Remember that removing the battery will reset the system, so you will lose the recorded data. To avoid this an external charger is advised.
- If you are using a smartphone you should put it in airplane mode to save battery while you are working, but be sure to re-activate the GPS when you move to a new plot.
- If you are not using an Android device you should synchronize it with the PC before transferring the app into it.
Step 7: Processing the data

At the end of the day, the data from the smartphone needs to be uploaded onto the PC which holds the database. Open the Cybertracker programme on the PC, attach the smartphone to the PC using the cable, and hit ‘File’, ‘Get data from connected device’ (F7)- and the data will pass from the phone to the computer. Note that it will no longer be stored on the phone. In the computer, the data appears as shown in the example below:

To add or remove columns just double click on the name.

From here, it can be transferred to an Excel sheet and used to make calculations of total carbon at the plot level.

To make the calculations of total carbon, the following mathematical steps need to be followed.

1. Calculate height of each tree.

\[ H = \left( \frac{R_1 + R_2}{100} \right) \times \text{dist} \]

Where \( R_1 \) is the reading for the top of the tree (in % slope)
2. Calculate carbon stock in each tree
Identify allometric equations for as many of the trees in the sample as possible, these may be at the level of the genus of the species, and ideally will have been developed in the area being measured or in a very similar ecosystem. Some allometric equations include a term for wood density (usually expressed as q); these cannot be used unless this factor is known. Most allometric equations use height (H) and DBH (D) as their variables, but a few use only DBH. Calculation must be made on a tree by tree basis as species vary a lot in their shape characteristics.

Typical examples of allometric equations (these are relevant to the Mexican Pacific Coast area) are:

- Oak (generic): \[ C = \left( \frac{D^2H}{2} \right)^{0.807} \]
- Pinuscooperi: \[ C = 11.5090 + (-3.1229) \times D + 0.3100 \times D^2 + 0.0004 \times (D^2H) \]
- Pinusduranguensis: \[ C = \left( \frac{11.5117 + 1.0744 H^{0.6544} x D^{2.1898}}{2} \right) \]

Where \( C = \) carbon in kg, \( D = \) DBH in cm and \( H = \) height in m, and where it is assumed that carbon makes up 50% of the biomass (in reality it can vary from around 48.5% to 51%).

However there will always be trees for which no allometric equation can be found. For these a default equation is need, such as the following, which is applicable to tropical forests in the rainfall belt 1000-4000mm per year:

- For dry forest (<1500 mm/annum): \[ C = \left[ 34.4703 - 8.0671 D + 0.6589D^2 \right]/2 \]
- For moist forest (1500-4000mm/annum): \[ C = \left[ 38.4908 - 11.7883D + 1.1926 D^2 \right]/2 \]
- For wet forest (> 4000mm/annum): \[ C = 13.2579 - 4.8945 D \]


Note however that all these equations, which are derived from linear regression of field measurements of tree biomass (using destructive sampling), have differing \( R^2 \) values; some are more precise than others.
Appendices

1. Other manuals on community monitoring

Other manuals for training communities in carbon monitoring have been produced by the following institutes:


The KTGAL project ([http://www.communitycarbonforestry.org/](http://www.communitycarbonforestry.org/), the link is under Resources, Community Monitoring)


Winrock International ([http://202.99.63.183/tanhui/thjl/Winrock%20International%20%E7%A2%B3%E7%A1%8C%20%E7%9B%91%E6%8B%B9%E6%8C%87%E5%8D%97.pdf](http://202.99.63.183/tanhui/thjl/Winrock%20International%20%E7%A2%B3%E7%A1%8C%20%E7%9B%91%E6%8B%B9%E6%8C%87%E5%8D%97.pdf))
2. Gain-loss methodology as an alternative to biomass measurements at community level

Introduction

Gain-loss methodology is approved in the IPCC Good Practice Guide as an alternative method for estimating change in forest stocks at national level, but could in principle be applied at local level also, particularly in cases where physical measurement of forest stocks is impractical, and where the main losses are due to degradation rather than deforestation (which can be more accurately assessed using remote sensing). However, the use of this method presupposes that there is considerable data available both of the gain side of the equation (natural rates of growth of the forest, MAI) and on the loss side (types of extraction at rates known and quantified).

For example, the method might be very suitable in large areas rain forest with low population densities, where the main losses are known to be caused by selective logging, and where an estimate can be made of the extraction rate (whether the logging is legal or illegal, and whether driven by local uses or external). It is more difficult to apply in areas of mixed, highly populated forest where growth rates can vary greatly over space, and where the losses of stock are due to a variety of causes such as shifting cultivation, grazing in the forest, charcoal production etc.

It may also be appropriate in situations in which the REDD+ activities envisaged will take place outside the forest, for example, a programme of improved household stoves in which the quantity of firewood saved can be estimated with a reasonable degree of accuracy, or a plan for intensification of agriculture in which shifting cultivation in the forest will be halted, in which case the areas cleared annually in the forest can be estimated and used as an indicator of carbon emissions avoided.

A procedure for making these kinds of assessments at project level known as ‘Deemed Degradation’ is currently being designed in the context of the VCS, but is not yet available.

Applying gain-loss methodology

In using gain-loss methodology, an estimate is made of state of gains and losses before REDD+ project activities are started and again at the end of a given reporting period (most likely, 2 years). Both assessments involve quantifying the net annual change in carbon stocks. In the most likely case, the first assessment will show a net loss of stock, and the second a lower net loss or a gain (i.e. indicating success of the REDD+ interventions). If the preliminary calculation shows a net annual gain, then the second calculation will have to show a great annual gain as a result of certain activities (e.g. enrichment planting).
The steps in carrying out the gain-loss method are as follows:

1. **Stratify the forest into strata which a priori may be considered to have different natural growth rates.** This means not just the forest types, but also differences in elevation or aspect, if these physical factors are known to influence growth. Estimate and map the areas under each stratum.

2. **Obtain from secondary data or from comparable forests in other parts of the country estimates of the annual growth rates of these types of forest under natural conditions, i.e. without human interference (Mean Annual Increment, MAI), and the typical size of the carbon pools that are most likely to be affected by the planned REDD+ interventions (above ground tree biomass, deadwood, in tons/ha).**

3. **List all the immediate causes of degradation in each of the strata and estimate the volumes extracted, justifying these with reference to credible indicators.** Fuelwood use might be known in terms of average per household, but its extraction will only occur in those strata which are accessible, and often involves deadwood only. Timber extraction may be estimated based on management plans or on records of past off-take, although in many cases a margin should be allowed for unrecorded and unplanned extraction. Losses due to shifting cultivation could be estimated from household surveys which indicate the typical area cleared for cultivation per year and the length of the fallow part of the cycle, times the number of farmers engaging in this form of agriculture: recuperation rates in the first years of fallow are usually faster than in later years, and could be factored in. Some forms of extraction, e.g. the impacts of cattle grazing, are however very difficult to estimate, and where these drivers are thought to have a major impact on stocks, the gain-loss method is probably not a suitable methodology. Different drivers may impact different carbon pools, for example, the use of efficient household stoves may reduce use of deadwood, but charcoal production (and thus improved kilns) affects living trees.

4. **Annual losses due to the different drivers are summed and averaged over the different strata as appropriate, to give loss per hectare per year per stratum and per pool.**

5. **The difference between the MAI and the losses will give the net annual losses per hectare per year per pool.**

6. **It is good practice to make a prediction of the expected improvements (reduction of losses) that will occur as a result of REDD+ interventions, before the project is implemented.** For example, if the target for an improved stove programme is 50% adoption rate and a drop from 1.7 tons/year to 1.2 tons per year per household, the expected savings of 0.5 tons/adopting household per year can be spread over the fuelwood catchment area and expressed in per hectare terms.

7. **Following the interventions (at the end of the reporting period, usually 2 years from the start) the calculations are repeated, using the actual achievements of the REDD+ interventions.**
Acknowledgements and credits

This manual can be used free of charge and will shortly be available in English and in Spanish on the website http://redd.ciga.unam.mx

The software application for step 6 can also be downloaded from this site.

The production of the manual was coordinated and edited by Margaret Skutsch of the Centro de Investigaciones en GeografíaAmbiental (CIGA), Universidad Nacional Autónoma de Mexico, campus Morelia.

Sections of the manual, particularly steps 3 and 4, borrow heavily from a manual developed in an earlier research (KTGAL project, www.communitycarbonforestry.org), and special credit is given here to E. Zahabu and J. Verplanke; the text was updated by M. Skutsch and M. Salinas (CIGA). Steps 2 and 3 were prepared by D. Benet of CIGA and the application for step 6 was developed by A. Larrazabal (CIGA) based on a model developed by M. Salinas. The Cybertracker software used was developed by L. Liebenberg and is freeware available on internet. Initial work on using Cybertracker for community carbon monitoring was carried by G. Peters-Guarin of the University of Twente and M. McCall (CIGA). A report on this development can be downloaded from the KTGAL site.

The production of this manual was financially supported by two projects:

1. Construcción de un modelo integral para la implementación de REDD+ en las Cuencas Orientales del Sistema Cutzamala, under the Alianza México REDD+, with funds from USAID

2. Development of GOFC-GOLD training materials for REDD+ monitoring and reporting, under GOFC-GOLD/University of Wageningen, with funds from the World Bank FCPF programme.