THIRD MILLENNIUM ALLIANCE

Biomass Inventory of Small Forest Plots in the Pacific Equatorial Forest

Prepared by:

Lana Dolgova

Jama-Coaque Ecological Reserve

Third Millennium Alliance

2011

Introduction

Developing a conservation protocol for tropical rainforest requires – amongst many elements – an accurate biomass inventory. Knowing how much carbon is stored in particular forest types allows for more effective strategies in forest management and long-term protection. The inventory would also help carbon offset policy-makers determine the urgency and value of forest conservation. The Jama-Coaque Ecological Reserve encompasses several forest types, namely moist evergreen forest, premontane cloud forest, transition zones as well as agroforestry zones. Given the history of the land, some forest plots can be further subdivided into primary and secondary growth. No previous biomass inventories exist for the reserve ecosystem.

Biomass Inventory – Methods

Experimental Set-Up

The objective for the inventory project was to extrapolate an over-all carbon stock figure for the entire Jama-Coaque Reserve. In order to obtain the required carbon numbers, four forest types have been selected: primary growth moist evergreen, secondary growth moist evergreen, cloud forest and agroforest. Three plots would be set up in every forest type, except for agroforestry where the number of plot number has been reduced to two (only a small percentage of the total land is being used up by agroforestry). A plot consisted of a circle with a diameter of 20 m. Two strings with the length of 20 m each was used to divide a plot into four quadrants, as such:

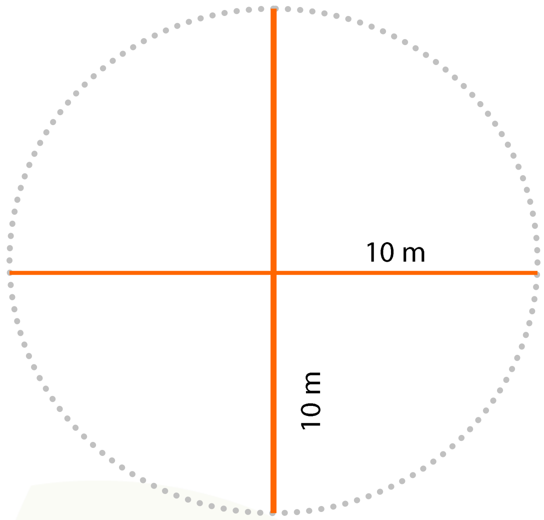

Figure 1 – Rough set up of the plot. The two strings (orange lines) divide the plot (grey circle) into four quadrants. The plot outline is imaginary.

The subdivision of the plot made the process much more manageable. Within the plot circle, the circumference of every tree was measured using a tape measure. Usually, trees just outside the plot were measured as well to account for loose string or any other factor that reduced the plot size. For our purpose, "tree" was defined as a woody plant, therefore bamboo and palms were not included in the dataset (also excluded were dead woody plants and vines). The circumference of trees was measured at breast height (approximately 1.5 m above ground) and only those bigger than 10 cm were considered. The height was estimated using the thumb method (when possible; see Discussion section) but usually without use of any precise scale or equipment. All data was recorded in a table as such:

Plot #7	Wednesday, September 14, 2011		
Coordinates: 0597770, 9986633		**Elevation**: 492 m	
Forest Type: agroforestry – primarily cacao and bananas			
Tree #	**Circumference (m)**	**Height (m)**	**Remark**
1	0.28	3.9	cacao

Figure 2 – Example of the data table for an agroforestry plot

The coordinates and the elevation of every plot were recorded using the GPS.

Analysis and Results

All the data was entered into an Excel spreadsheet, separated by forest type. The circumference and height were used to calculate volume using the below equation:

$$V = h\,c^2 / 4\pi$$

where V = volume, h = height, c = circumference

The total volume per forest type was then used to calculate total carbon per forest type.

This required calculating total area used, in hectares. The following table sums up the findings, separated by forest type:

Forest Type	# Plots	Total Area Measured (ha)	Total Volume m^3	Total m^3 of Carbon per ha
Agroforestry	2	0.063	7.66	121.91
1 º Evergreen	3	0.094	40.82	433.11
2º Evergreen	3	0.094	30.57	324.36
Cloud	3	0.094	39.43	418.36

Figure 3 – Summary of findings.

The ultimate measurement needed is metric tons of carbon per hectare (tC/ha). For all calculations, the constants and formulae were set in accordance to previous biomass studies (see Appendix section).

From the 'Total m^3 of Carbon per ha' found in Figure 3, we can now derive tC/ha. The table below summarizes the findings (for calculations, see section below).

Forest Type	Total m^3 of Carbon per ha	Stem Biomass (t/ha)	Total Biomass (t/ha)	Total Carbon (tC/ha)
Agroforestry	121.91	73.15	117.04	58.52
1 º Evergreen	433.11	259.87	415.79	207.90
2º Evergreen	324.36	194.62	311.39	155.70
Cloud	418.36	251.02	401.63	200.82

Figure 4 – Summary of biomass findings.

Sample Calculation

The area of one plot:

$A = \pi r^2 \rightarrow A = \pi (10\ m)^2 \rightarrow A = 314.16\ m^2$

Since we had two agroforestry plots, we multiply it by 2 for a total area of agroforestry surveyed of $314.16\ m^2 * 2 = 628.32\ m^2$ or 0.063 hectares (1 ha = 10 000 m^2).

Using the volume equation above, the total volume for all agroforestry plots was found to be 7.66 m^3. To find the volume per hectare, we divide 7.66 m^3 by 0.063 ha which results in 121.91 m^3/ha of carbon.

To find total carbon (tC/ha), we first need to convert volume to mass, using the formula:

$$M = V * D$$

where M = Mass, V = Volume, D = Density (constant, set at 0.6[i])

To continue with the agroforestry example, we take our last finding, 121.91 m^3/ha and convert this volume to mass: 121.91 m^3/ha * 0.6 t/m^3 = 73.15 t/ha. This is Stem Biomass, and in order to get Total Biomass, we multiply by a constant ratio, 1.6[ii]: 73.15 t/ha * 1.6 = 117.04 t/ha.

To convert from biomass into carbon, we simply divide by 2[iii], and thus total tons of carbon per hectare of agroforestry is 58.52 tC/ha.

Discussion

The findings above suggest that primary growth moist evergreen forest contains the greatest amount of aboveground carbon, whereas agroforestry contained the least. The same is said for tons of carbon per hectare of forest type. Any discrepancies between expected and observed data can be attributed to human error. Height measurement was done by human estimation while standing at the base of the tree looking up. However, the top of the tree was frequently obstructed from view by canopies of neighboring trees or low cloud coverage (especially true for taller specimens). It was also sometimes unclear as to what consisted of the 'top' of a tree, depending on how much it branches out. Usually, it was assumed that the top branches put together would equate to the circumference of the trunk, and therefore height was estimated to the very end of the topmost branches.

Another difficulty with carbon estimation occurred in the presence of trees containing buttress roots. Because of their nature, these types of roots tend to spread horizontally above the ground, thus containing a significant amount of carbon but making it hard to measure. Also, if the roots were protrusive enough, it made trunk circumference measurements difficult to estimate at breast height.

The thumb method may be used to estimate height when the density of the trees in a plot is low, such as agroforestry plots. It consists of tying the measuring tape around a tree one meter from the ground. The surveyor would then back up, holding her thumb in a thumb's up position. At the point where their thumb is the same height as the meter mark, one would estimate how many "thumbs" would fit into a tree, and multiply that by one meter. For future surveys, it would be best to have a laser rangefinder, or similar. It is also important to have the same person do all the height estimation; that way any error in estimation is assumed to be consistent.

It has been suggested that for future plots, the diameter should be reduced to six meters. This will make the plots much more manageable and will allow the surveyor to do more repetitions, leading to a greater sample size.

Appendix and Citations

[i] – "The arithmetic mean and most common wood density values (t/m^3 or g/cm^3) for tropical tree species by region. America: 0.6 t/m^3"

FAO Forestry. *Estimating Biomass and Biomass Change in Tropical Forests*. Rep. 1997. Web. Oct. 2011. <http://www.fao.org/docrep/W4095E/W4095E00.htm>.

ISBN: 103955. ISNN: 0259-2800.

Wood density class for Tropical America: mean = 0.6 g/cm^3

Reyes, Gisel, Sandra Brown, Jonathan Chapman, and Ariel E. Lugo. *Wood Densities of Tropical Tree Species*. Rep. no. SO-88. New Orleans: United States Department of Agriculture, 1992.

[ii] – "The ratio of total biomass to usable stem biomass was assumed by the German Bundestag to be 1.6 for closed forests and 3 for open forests […]"

Brown, Katrina *Carbon Sequestration and Storage in Tropical Forests*. Global

Environmental Change Working Paper 92-24, Centre for Social and Economic Research on the Global Environment, University of East Anglia, University College London. 1992.

[iii] - Brown, Katrina *Carbon Sequestration and Storage in Tropical Forests*. Global

Environmental Change Working Paper 92-24, Centre for Social and Economic Research on the Global Environment, University of East Anglia, University College London. 1992.