Field Test of Carbon Monitoring Methods in Home Garden Systems in Indonesia[1]

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1. Introduction

Carbon sequestration is thought to be a promising means for reducing atmospheric carbon dioxide, an important greenhouse gas. If carbon becomes an internationally-traded commodity, as it appears likely, then monitoring the amount of carbon fixed by projects will become a critical component of any trading system. Winrock International has developed a cost-effective system for monitoring carbon storage in forestry and agroforestry projects. The purpose of this study was to field test those carbon monitoring methods for agroforestry systems in Indonesia. The specific objectives of the study were:

1. Measure the carbon in above-ground biomass, soils, litter, and herbaceous vegetation of home garden systems in Indonesia.
2. Evaluate the carbon monitoring methods and make recommendations for their improvement.

1.1 Study Area

The field test was conducted in North Lampung Province (4° 26.453' S, 104° 54.768' E), Sumatra, Indonesia. The study site is called the North Lampung benchmark area (NLBA) and covers a 42,500 ha area along the lower reaches of the Tulang Bawang river (van Noordwijk et al. 1996). Soils are well drained, deep, acidic, and of low fertility. Aluminum toxicity is common, especially below a depth of 15 cm. Root development is possible down to a plinthic layer at 1-1.5 m. The major soil groups are Oxisols/Ultisols, Inceptisols, and Entisols covering 64, 29, and 7% of the area, respectively. Annual rainfall is about 2200 mm on average, with 1-4 months having less than 50 mm of rainfall (van Noordwijk 1995).

The population in the NLBA has increased dramatically since the early 1980's, when a Indonesia government program encouraged transmigration from populated areas in Java into North Lampung. The population of the NLBA can be divided into three main groups. The first group is the original inhabitants who own fertile lands close to the main rivers that run through the area. The second group are transmigrants who inhabit upland infertile lands. The third group are the spontaneous migrants who have arrived in the area over the last several years, and inhabit any other lands that are available (van Noordwijk 1995).

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1.2 Land-use in the North Lampung Benchmark Area

The major land-use types found in the NLBA range from wet rice cultivation to secondary forest. Home garden systems (HGS) were chosen for sampling in the NLBA because it is a common land-use practice in this part of Indonesia. Little information exists about this land use system, yet it is believed to offer significantly more carbon benefits versus other types of land uses (agriculture, grasslands). HGS are small household owned plots of land (0.25 ha.) which were converted from secondary forest and planted with food crops such as cassava, maize, and rice. Spices, medicinal plants, coconuts, and lemon trees are also cultivated (Gintings et. al 1995). A wide range of tree and plant species are found in HGS (Table 1). The difference between a HGS and traditional agroforest systems is not well defined but HGS tend to be close to a farmers home, small, and the crops produced are usually for family consumption.

Table 1. A list of species found in 19 home gardens in Lampung, Indonesia

Botanical name	Local name
Acacia ariculiformis	akasia
Acacia mangium	mangium
Aleurites moluccana	candlenut / kemiri
Alstonia spp.	pulai
Anacardium accidentale	cashew / jambu mete
Annona muricata	soursop / sirsak
Anona reticulate	sweet sop / buah nona / jambu nona
Archidendron pauciflorum	jengkol
Arenga pinnata	kolang kaling
Artocarpus heterophyllus	nangka
Artocarpus integer	cempedak
Averrhoa bilimbi	belimbing
Ceiba pentandra	kapok
Cinnamonum parthenoxylon	kayu lada
Cocos nucifera	coconut
Coffea canephora var robusta	kopi / coffee
Erythrina spp.	dadap
Flacourtia rukam	rukam
Gliricidia sepium	gamal
Gnetum gnemon	melinjo
Hevea brasiliensis	karet
Hibiscus tiliaceus	waru
Leucaena leucocephala	lamtoro
Mangifera foetida	pakel

Mangifera indica	mango
Mangifera odorata	kurai / kuweni
Melia azedarach	mindi
Musa spp.	banana / pisang
Nephelium lappaceum	rambutan
Paraserianthes falcataria	sengon
Parkia speciosa	petai
Peltophorum plerocarpum	petean
Peronema canescens	sungkai, sekai
Persea americana	alpokat
Psidium guajava	guava / jambu biji
Schima wallichii	puspa
Spondias spp	kedongdong
Syzygium aceum	jambu air
Tamarindus indica	asam
Tectona grandis	teak / jati
Terminalia citrina	jaling
Theobroma cacao	cacao

1.3 Project site description

Local name of site: Villages of Negara Jaya, Tegal Mukti, and Tiuh Baru
Elevation (m): 100
Ecological zone or general site type: Tropical humid zone (Holdrige)
Most common slope class: Gentle (0-5^o)
Mean annual rainfall (mm): 2,500
Rainfall regime: Bimodal (5-6 months >200mm, 2-4 dry months <100mm)
Maximum length of dry season: 4 months (<50 mm)
Mean annual temperature ^{o} C: 28
Surface (0-5cm) soil texture (sand, silt, clay): 61.7, 24.9, 13.4%
Sub-soil (5-15cm) texture (sand, silt, clay): 71.1, 6.19, 22.7%
Soil depth to impermeable layer: >100 cm
Surface soil pH (0-5 cm): 3.74 (KCL), 4.25 (H_2O)
Sub-soil pH (5-15 cm): 3.50 (KCL), 4.25 (H_2O)

2.0 Methods

2.1 Selection criteria for HGS

Field work took place between 2/23-2/28 1998. Pre-planning consisted of talking with local officials, and researchers at the International Center for Research in Agroforestry (ICRAF). No maps on soil type or land use existed for HGS in the area, so no stratification could be done. Instead, farms were selected for measurement if the farmer gave permission, and if the HGS had a predominant tree cover of species intended for primarily home use. Thus, HGS that contained primarily agriculture crops (corn, cassava, vegetables, etc) or one market-oriented tree crop (coffee, cacao, coconut, *Paraserianthes*, etc), were excluded. HGS that contained areas with rice paddies or fish ponds, were also excluded. Even with these criteria the species composition and tree density of the HGS varied greatly from farm to farm. Understory vegetation also varied greatly, from forest like conditions (containing a lot of natural regeneration and saplings), to areas where the understory was barren.

2.2 Plot installation and measurement

At each site, the perimeter of the home garden was first measured with a 100 m measuring tape. A sketch was made of the plot, and uncorrected GPS coordinates were taken in the home garden with a Garmin 12XL GPS receiver. According to the methodology in *A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects*, four subplots should have been placed in each farm. However, since the average HGS was 0.18 ha in area, and they were usually 25 m in width and 75 m in length, locating the plots as suggested in the protocol was impossible. We determined it was best to establish two sub-plots per farm instead of four. Sub-plots were laid-out perpendicular to the longest borders, along a line that bisects the reference point (center point) of the HGS. If the farm was irregularly shaped a third plot was established.

From the subplot center, the crew supervisor established four points (N, E, S, and W) 7.9 m away, or one meter inside the subplot boundary. At these four points herbaceous material (< 5 cm diameter), litter (< 5 cm diameter), and soil (to 30 cm) were sampled. The herb and litter samples were collected by clipping all material within a circular aluminum sample ring (0.28 m^2). However, in cases when a juvenile tree or agriculture plant fell within the sampling ring it was not clipped because this is a preliminary study, and we wanted to minimize the impacts on the farmers crop. Soils were sampled within the aluminum ring after all herb and litter material were collected. Within one of the four subplots a soil bulk density sample was taken at a depth of 15 cm with a aluminum cylinder. The diameters of all trees in each subplot with a diameter at breast height (dbh) > 5 cm were measured and when possible the species name recorded. In cases when there were trees without a diameter-biomass relationship (coconut, banana etc.) heights were measured using a clinometer.

In each farm, at least 2 subplots were established for a total of at least 8 herb, litter, and soil samples. Each of the herb and litter samples were weighed using a spring scale. All the herb samples were mixed and a subsample taken for moisture content determination. The same was done for litter. Soils were sieved through a 5 mm mesh screen, mixed to a uniform color and consistency and a subsample taken for carbon analysis. Walkley-Black analysis for soil organic carbon was done at a local university. A total of 10 bulk density samples at 15 cm depth were taken. Each sample was dried in an oven at 100^o C.

2.1 Estimating aboveground biomass

In order to estimate biomass of aboveground vegetation, a general biomass equation was used. There were cases when the general equation was not suitable for the types of vegetation encountered in the plots, and an alternative equation was used. The second equation is from a study done in Puerto Rico for the palm *Prestoea montana* (Frangi and Lugo 1985).

Table 1. Equations used for the calculation of aboveground biomass in agroforestry systems in Indonesia

Species	Equation	Source	R^2
General	$y=\exp\{-2.134 + 2.530 * \ln(D)$	Brown 1997	.97
Palms	$y=4.5 + 7.7 * H$	Frangi and Lugo 1985	.90

where exp {…}means "raised to the power of {…}"
ln means "natural log of (…)"
y = above-ground biomass in kg
H = height in m
D = diameter at breast height (1.3 m)

Below-ground biomass was estimated by taking 15 % of above-ground biomass.

3.0 Results

3.1 Carbon Inventory

A total of 19 plots were measured, and the amount of carbon in the aboveground, soils, litter, and herbaceous material ranged from 10 to 126 t C ha^{-1} (Table 3).

Table 3. Carbon stocks by component for home garden systems in the North Lampung benchmark area, Indonesia.

Plot	Aboveground biomass (t C ha^{-1})	Litter (t C ha^{-1})	Herbaceous material (t C ha^{-1})	Soil (t C ha^{-1})	Roots (t C ha^{-1})	Total (t C ha^{-1})
HGS 1	61.9	2.4	0.4	65.7	9.3	140
HGS 2	6.3	0.3	0.2	55.3	0.9	63
HGS 3	34.1	2.7	0.1	10.4	5.1	53
HGS 4	17.6	3.2	0.2	52.1	2.6	76
HGS 5	14.4	2.5	0.1	44.9	2.2	64

HGS 6	21.6	1.9	0.3	69.3	3.2	96
HGS 7	23.0	0.2	0.2	41.2	3.5	68
HGS 8	34.8	2.3	0.1	72.5	5.2	115
HGS 9	24.9	1.6	0.3	40.3	3.7	71
HGS 10	22.6	1.2	0.5	72.5	3.4	100
HGS 11	65.3	1.7	0.3	55.3	9.8	132
HGS 12	17.1	2.7	0.4	65.7	2.6	89
HGS 13	21.6	2.8	0.5	51.6	3.2	80
HGS 14	45.4	3.6	0.2	77.5	6.8	134
HGS 15	84.0	0.0	0.0	69.3	12.6	166
HGS 16	56.2	1.4	0.8	76.1	8.4	143
HGS 17	46.3	0.8	0.3	103.7	6.9	158
HGS 18	53.8	4.0	0.1	69.3	8.1	135
HGS 19	19.3	2.9	1.4	62.1	2.9	89
Mean (SD)	**35.3(21.0)**	**2.0(1.2)**	**0.3(0.07)**	**60.8(4.4)**	**5.3(0.7)**	**104(8.1)**
CV	**60%**	**57%**	**95%**	**32%**	**60%**	**34%**

Data from the 19 HGS were compared with other data available from ICRAF (Table 4), and are included here (Rosalina et al. 1997).

Table 4. Carbon stocks of different land-use systems in the Northern Lampung benchmark area, Indonesia. Results for home garden systems are based on 19 plots sampled during field work for this study.

Land-use type	t C ha^{-1}
Primary forest	325
Secondary forest	177
Imperata grassland	3*
Home garden systems	104

*does not include soil carbon

3.2 Time required for inventory

The crew took two days to learn the inventory methods. During that period the crew inventoried two HGS per day. Field time averaged 2 hours 30 minutes on the first day and 1 hour 40 minutes on the second day. After day three, inventory time per HGS was approximately 1 hour 15 minutes. ANOVA analysis was done on the data, comparing the amount of aboveground biomass with the amount of time required for sampling. No significant relationship between the two ($p > 0.05$) was found. The same was true for herb, litter, roots and soil.

There were usually seven people in the crew actively participating in the inventory. This could likely be reduced to six - three collecting tree data and three collecting soil/herb/litter data. We usually had a person accompanying the crew who knew the community and thus where to look for home gardens that fit our selection criterion. This person would engage the local residents in conversation and answer their questions. He also reassured residents that we were not going to damage their crops.

4.0 Discussion

4.1 Recommendations for adjusting methodology

If the agroforestry farms are not a standard size and shape, it is advisable to adjust the monitoring protocol. This should be done before the field work begins or at the first farm site. In the HGS measured there were two basic shapes, rectangular and square, and one standard size, 0.25 ha. Actual size of HGS systems varied because most farmers had built a house on the quarter hectare site and home gardens where excluded from the house area.

Observations indicated that bamboo was a component of approximately one-third of the HGS inventoried. However, bamboo was not sampled in the sub-plots because it was most often planted in the corners or back borders of the HGS. A shortcoming of the methods is that the sub-plots do not include species that are planted along the borders of agroforestry systems.

4.3 Pre-Planning carbon inventory work

Beside actual field time there are a number of related activities that need to be considered when planning inventory work of agroforestry systems.

These include:

1. Meeting with local village leaders, who are government representatives and responsible for foreigners in their jurisdiction. It is important to make a short social call to explain the intended work. Visits usually last about 15 minutes, but under some circumstances may require an hour (travel time, finding the leader, waiting for the leader to be available).
2. Talking with farmers. This is important to let the farmers feel at ease about the inventory work.
3. Evaluation and selection of sites. This often required only a few minutes (5-10). However, on a few occasions finding HGS that fit our selection criterion took up to an hour. This process can be greatly assisted by having a crew member who is familiar with the area and requesting assistance from village leaders and local farmers, who are generally glad to help.
4. Include training time in schedule of field work. As mentioned previously, it will take the crew approximately two days to learn the inventory methods and develop a comfortable pace.
5. If permanent plots are to be established on small-holder farms, it will be necessary to increase the inventory time to include the establishment of markers and schedule time to complete Farmer Interview Forms.

5.0 Conclusions

The information compiled on the HGS in Lampung is important because carbon inventory data was not previously known for these systems. Additionally, a good understanding of the species composition of the HGS was gained. This information can be used to expand baseline knowledge of the carbon storage capacity of agroforestry systems.

The carbon monitoring methods were well suited for sampling HGS in Indonesia. The most common modification to the methods was to install two subplots per farm instead of four, due to the small size of the HGS. The carbon content of HGS were higher than Imperata grasslands, demonstrating their importance to the overall carbon budget of the region. Field test results also showed the importance of pre-planning, most importantly meeting with local officials and keeping the community informed about field work activities.

6.0 References

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