CARBON STOCKS OF HOMEGARDEN SYSTEMS IN LAMPUNG, INDONESIA

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ABSTRACT

Homegardens are a common smallholder agroforestry system in Indonesia and through the world. They are species rich tree-based system produce non-wood and wood products for both homeuse and market sale. Due to their high biomass these systems simultaneously offer potential for carbon storage, which may help slow global warm and positively effect related environmental problems. Field study in North Lampung, Indonesia reveal that 13-year-old homegardens stored 107 t C ha^{-1}. Comparison and extrapolation of this data with carbon stocks for other tree-based systems in Lampung indicate that at age_30 years homegardens will contain 210-220 t C ha^{-1}. Even decreasing the total by 20% for the periodic removal of wood the remaining carbon stock (184 t C ha^{-1}) is significantly higher than that of *Imperata* grasslands, which are low (35 t C ha^{-1} in Lampung) due to the periodic wildfires that maintain the *Imperata* ecosystem. While individual homegardens, or other smallholder agroforestry systems, store small amounts of carbon on a per hectare basis these systems can storage as much carbon natural forests. In aggregate, smallholder agroforestry systems can contribute significantly to a region's carbon budget. Smallholder agroforestry systems have the added advantage of contributing to subsistence and income generation objectives of smallholder farm families. The paper suggests that it is timely and appropriate to explore mechanisms by which communities or consortium of smallholder farmers may access international carbon investments to convert low-biomass (low-carbon) underutilized landuse systems it to productive tree-based systems containing high carbon stocks.

INTRODUCTION

Increasing levels of atmospheric 'greenhouse gases' are believed to be a main contribution to global warming, which studies indicate is changing the earth's weather patterns and could raise ocean levels substantially in the next 100 years. These climatic changes will impact environmental norms and human populations causing serious negative disturbance to the global economy. As international concern over greenhouse gas emissions and global warming in industrial, political, and social spheres find common ground, it appears that carbon will become an internationally traded commodity.

Forest-based landuse systems – natural forests, forest plantations, and agroforestry systems – sequester carbon dioxide, an important greenhouse gases, through the carbon stored in their biomass. By changing landuse practices it is possible to increase or decrease the amount of carbon stored in a landuse system. The most significant increases in carbon storage

Proc. Seminar Toward Sustainable Agriculture in Humid Tropics Facing 21st Century: 552 - 564
Bandar Lampung, Indonesia, September 27 – 28, 1999

can be achieved, and the rate of global warming slowed, by moving from lower-biomass landuse systems – grasslands, agricultural fallows, and permanent shrublands – to tree-based systems. Forest-based carbon storage projects are a feasible option for utilities and industries interested in investing in sequestration to offset part of the carbon released by their use of fossil fuels. An essential component of these projects will be an accurate, user-friendly, and cost-effective method of monitoring carbon sequestration (MacDicken 1997).

Indonesia provides an attractive environment for carbon investment. There are over 8.5 million hectares of *Imperata* grasslands in Indonesia (Garrity et al. 1997). Originally forests these lands include pure grasslands, cyclic fallows, and shrublands and are acknowledged to be underutilized. There is clear interest, at both governmental and smallholder farmer levels, to convert some of these lands to a more productive landuse, including tree-based systems (Garrity et al 1997). Homegardens are a type of smallholder agroforestry system common to many parts of Indonesia. These species-rich tree-based systems occupy land near the house producing a diverse array of food and other products. Traditionally intended to produce goods mainly for home consumption, the advent of rural infrastructure and market-economies has made home gardens more commercial-oriented. Homegardens production now commonly serves both household and market demand, providing families with much needed income (Michon and Mary 1994; Krol 1992).

Simultaneously homegardens, and other tree-rich smallholder systems, offer potential for carbon storage because of their high woody biomass. While this hypothesis meets common sense, more data is needed to evaluate it fully. The objective of this study was twofold: to generate carbon stock inventory data for homegarden systems in North Lampung, Sumatra, and to test an accurate, simple carbon monitoring method appropriate for agroforestry systems The results, which also produced information on the tree species composition of homegarden systems, are compared to carbon stock data for other landuse systems in Sumatra.

METHODS

Study Area

The study was conducted in North Lampung, Sumatra, Indonesia at one of the benchmark areas of the global Alternatives to Slash-and-Burn (ASB) project. Soils are well drained, deep, acidic, and of low fertility. Elevation is 100 m above sea level, mean annual temperature is 28 °C, varying between 22-33 ° C (van Noordwijk and Purnomosidhi 1995; van Noordwijk et al 1996). Annual rainfall averages 2200-2500 mm, with 5-6 months greater than 200 mm and 1-4 months than 50 mm. The study site is a government-sponsored transmigration area where homegardens allotments, inclusive the house area, are typically 0.25 ha and generally established from fallow agricultural land. Species composition of homegardens include trees which produce fruit, vegetables, spice, oil, medicine, other non-wood products and timber; perennial understory plants that produce non-wood products; and annual vegetable and food crops - such as cassava, maize and rice (Gintings et al. 1996). The other major landuses in the area are sugarcane plantations, agriculture crops, *Imperata* grasslands, and degraded secondary forests.

Site Selection

Detailed landuse maps at the smallholder level were not available for the study area. Sites were selected if the farmer gave permission and the structure and species were considered typical of local homegardens. Sites were excluded if they contained primarily (50% or more) agriculture crops (cassava, maize, rice, vegetables, etc) or one market-oriented tree crop (coffee, coconut, *Paraserianthes falcataria*, etc). Homegardens that contained large areas (25% or more) of rice paddies or fishponds were also excluded. Roughly 25-30% of the assessed were rejected for these reasons.

Carbon monitoring system

The carbon monitoring system used in this study was developed by Winrock International's Carbon Monitoring Program to quantify the amount of carbon in landuse systems using forest and agroforestry inventory principles and practices (MacDickens 1997). The system brings field research methods to bear on commercial-scale inventories, at levels of precision specified by funding agencies and investors. It quantifies carbon sequestered by measuring changes in four main carbon pools over time. These carbon pools are: aboveground biomass, litter, herbaceous material, and soils. Root biomass is estimated as a percent of aboveground biomass. The methods are similar to those used described by Palm et al. (1994).

Plot installation and measurement

At each site, the dimensions of the homegarden were measured and uncorrected GPS coordinates taken. Most homegardens were rectangular in shape and, excluding the house area, roughly 75 x 25 meters. The center point of each homegarden was located an two subplots were laid-out perpendicular to the longest borders, along a line that bisected the center point, half the distance between the center point and the short borders. For L-shaped homegardens 3 sub-plots were established. Each sub-plot was a circle with a radius of 8.9 m. The diameters of all trees in each subplot with a diameter breast height (dbh), 1.3 meters, greater than 5 cm were measured and the species name recorded. For tree species not covered by the standard diameter-biomass relationship (coconut, banana, etc.) heights were measured using a clinometer. Diameters of down but intact trees – either living or dead – were also recorded. Pieces of dead trees within the plot were recorded by mid-point diameter and length. From the subplot center, four points were established (north, east, south and west) one meter inside the subplot boundary. At these four points samples were collected of herbaceous vegetation (all living plants < 5 cm diameter), litter (organic matter above the soil surface having a diameter of < 5 cm), and soil (to 30 cm depth).

The herbaceous and litter samples were collected by cutting all living material, within a circular aluminum sample ring (0.28 m^2), at the soil surface. To minimize damage to farmers crops, neither juvenile trees or agriculture plants within the sampling ring were destructively sampled for inclusion in the herbaceous sample. All herb and litter samples were weighed using a spring scale. Herb samples were mixed and subsampled for moisture content determination at the homegarden. The same process was used for litter subsampling. Soil samples were collected within the aluminum ring after all herb and litter materials were collected by digging a 30-cm pit and slicing a sample from the pit wall from 0 to 30-cm depth. Sample size was approximately 1cm thick, 10 cm wide and 30 cm long. 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 Brawijaya University, Malang, East Java. At one of the two subplots a soil bulk density sample was taken at a depth of 15 cm by hammering an aluminum cylinder into the pit wall. Bulk density was determined by drying the sample in an oven at 100° C for 24 hours. Soil carbon per hectare in determine according the following formula: Walkley-Black value (percent carbon) x bulk density (g/cm^3) x 3000 kg/ m^2 (MacDicken 1997).

Estimating aboveground biomass

In order to estimate biomass of aboveground vegetation, a general allometric biomass equation was used (Brown 1997). In cases when the general equation was not suitable for the types of vegetation encountered alternative equations was used. The biomass of palms were estimated using an equation from a study of *Prestona montana* palms conducted in Puerto Rico (Frangi and Lugo 1985). Banana biomass was estimated using an equation developed by Marquéz (1999). All three equations are listed in Table 1. Root biomass was estimated by taking 25% of aboveground biomass (Cairns et al. 1997). Above ground biomass is converted into carbon by multiplying by 0.5 (MacDicken 1997).

Table 1. Equations used to calculate aboveground biomass of home garden systems.

Species	Equation	R^2	Source
General	$Y=0.118\ D^{2.53}$	.97	Brown 1997
Palms	$Y=4.5 + 7.7 * H$	.90	Frangi & Lugo 1985
Bananas	$Y=0.185+0.882\ ((\ln D)/D^2)$	--	Marquéz 1999

Note: Y = above-ground biomass in kg
D = diameter at breast height (1.3 m)
H = height in m

RESULTS

Carbon stock

A total of 19 plots were measured. Plot age varied from 11 to 17 years, with an average age of 13 years. Total carbon per plot ranged from 56 to 174 t C ha^{-1} with an average of 107 t C ha^{-1} (Table 2). The tree biomass (aboveground plus roots biomass) and soil components accounted for the majority of these carbon stocks, 41% and 57% respectively, and the variation between plots. Only in four plots did the carbon in the tree biomass exceed that in the soil.

Tree component

The home gardens were diverse containing 45 tree species, including banana (*Musa* spp.), as part of the aboveground biomass. Total number of trees sampled was 597, an average of 34 per homegarden. TtThe species, their predominance in the home gardens, and their primary uses are given in Table 3. Eighty percent of the species in the homegardens provide primarily non-wood products or services - fruits, vegetables, spice, oils, medicines, resins, soil improvement, etc. Coincidentally, these species also account for 80% of the trees sampled in the homegardens. Some of these species may be used for timber or other wood products, but generally the wood is not utilized until the tree is old and its productivity for its primary non-wood products has declined. Twenty percent of the species in the homegardens, representing 20% of the trees sampled, are primarily wood-producing – from here on referred to as timber trees. These species may also produce non-wood products or services, but these products and services are generally of secondary importance. It is important to note that 55 dead trees were surveyed during the study. Of these, 18 were rambutan (*Nephelium lappaceum*) of various ages that had died during the drought of 1996. This number equals one-third of the living rambutan trees surveyed, indicating that rambutan is a risky species for the study area.

Table 2. Carbon stocks by main pools for homegarden systems in Indonesia.

Plot	Age (yrs)	Aboveground (t C ha^{-1})	Litter (t C ha^{-1})	Herbaceous (t C ha^{-1})	Soil (t C ha^{-1})	Roots (t C ha^{-1})	Total (t C ha^{-1})
HGS 1	15	61.9	2.4	0.4	65.7	15.5	145.9
HGS 2	15	6.3	0.3	0.2	55.3	1.6	63.7
HGS 3	15	34.1	2.7	0.1	10.4	8.5	55.8
HGS 4	15	17.6	3.2	0.2	52.1	4.4	77.5
HGS 5	12	14.4	2.5	0.1	44.9	2.6	64.5
HGS 6	12	21.6	1.9	0.3	69.3	5.4	98.5
HGS 7	12	23.0	0.2	0.2	41.2	5.8	70.4
HGS 8	13	34.8	2.3	0.1	72.5	8.2	117.9
HGS 9	12	24.9	1.6	0.3	40.3	6.2	73.3
HGS 10	12	22.6	1.2	0.5	72.5	5.6	102.4
HGS 11	14	65.3	1.7	0.3	55.3	16.3	138.9
HGS 12	17	17.1	2.7	0.4	65.7	4.3	90.2
HGS 13	13	21.6	2.8	0.5	51.6	5.4	81.9
HGS 14	13	45.4	3.6	0.2	77.5	11.4	138.1
HGS 15	13	84.0	0.0	0.0	69.3	21.0	174.3
HGS 16	12	56.2	1.4	0.8	76.1	14.0	148.5
HGS 17	13	46.3	0.8	0.3	103.7	11.6	162.7
HGS 18	13	53.8	4.0	0.1	69.3	13.4	140.6
HGS 19	13	19.3	2.9	1.4	62.1	4.8	90.5
Total	254	670.2	38.2	6.4	1154.8	166.5	2035.6
Mean (SD)	13.4	35.3 (21.0)	2.0 (1.2)	0.3 (0.07)	60.8 (4.4)	8.8 (5.3)	107.1(8.1)
CV	---	60%	57%	95%	32%	60%	34%
% of Total	---	32.9 %	1.9%	0.3%	56.7%	8.2%	100%

HGS – Home Garden System

DISCUSSION

There is great variation in the home garden systems studied. Tree density varied from 260 to 1180 per hectare (13 to 59 trees sampled per homegarden) and the understory varied from crop production (mainly cassava) to forest-like natural regeneration, pasture and even bare soil. Tree biomass accounted for only 33% of the total carbon in the homegarden systems. Studies under the ASB project in Jambi, Sumatra show that the portion of a tree-based landuse system's total carbon in its woody biomass increases with age up to 80% for a

120-year-old natural forest containing 500 t C ha^{-1} (Tomich et al 1998). ASB studies in Lampung indicate woody carbon accounts for 60-65% of total carbon in 30-year-old secondary forests and mature agroforests (Hairiah 1997). Aggregate data from the ASB project show that all tree-based land-use systems included in the studies accumulate similar carbon stocks over similar time periods. This indicates that in terms of carbon sequestration the homegardens, average age 13 years, are still very young and will continue to steadily accumulate carbon for a long time depending on management. Eighty percent of the species in the homegardens are primarily utilized for non-wood products. These trees are maintained until their productivity for non-wood products declines at which time they may be harvested for wood. Experience indicates that the economic life span of these species is mostly greater than 30 years, a likely length of a carbon investment project. Only 20% of the homegarden species are timber trees, with rotation ages of 7-30 years.

Although the homegardens are highly variable their average carbon content compares favorably with other landuse systems in Lampung. Hairiah (1997) reported carbon stock data for five landuse systems in Lampung: mature agroforests, secondary forests, young rubber agroforests, *Imperata* land and cassava fields. Although methods used by Hairiah (1997) and those reported here differ, each accurately measures the carbon content of landuse systems. Table 5 provides a comparison between the two methods. The main difference occurs in measuring soil carbon, Hairiah (1997) uses samples collected from a depth of 0-15 cm and our method uses samples collected from 0-30 cm.

Table 5. Comparison of carbon inventory methods.

Carbon pools	Hairiah (1997) Method	MacDicken (1997) Method
Basic study unit	Transect size 0.02 ha	Homegarden (HGS) size 0.18 ha
Aboveground biomass	• $200 m^2$ transect (2 / ha) • all plants with diameter > 5 cm • formula $Y=0.118D^{2.53}$ (Hairiah et al. 1999)	• $248 m^2$ circular plot (2 / HGS) • all plants with diameter > 5 cm • formulas as specified in Table 1
Herbaceous	• Tree based systems - $.25 m^2$ square sample • Imperata lands – $1.00 m^2$ square sample • all material < 5cm in diameter (8 / transect)	• $.28 m^2$ circular sample (8 / HGS) • all material < 5cm in diameter
Liter	• $.25 m^2$ square sample (5 / ha) • all organic material above the soil surface	• $.28 m^2$ circular sample (8 / HGS) • all material above the soil surface
Soil	• sampled at 0-5 cm and 5-15cm with bulk density measured at 0-5 cm	• sampled 0-30 cm with bulk density measured at 15 cm
Roots	• Not estimated separately	• 25% of aboveground biomass

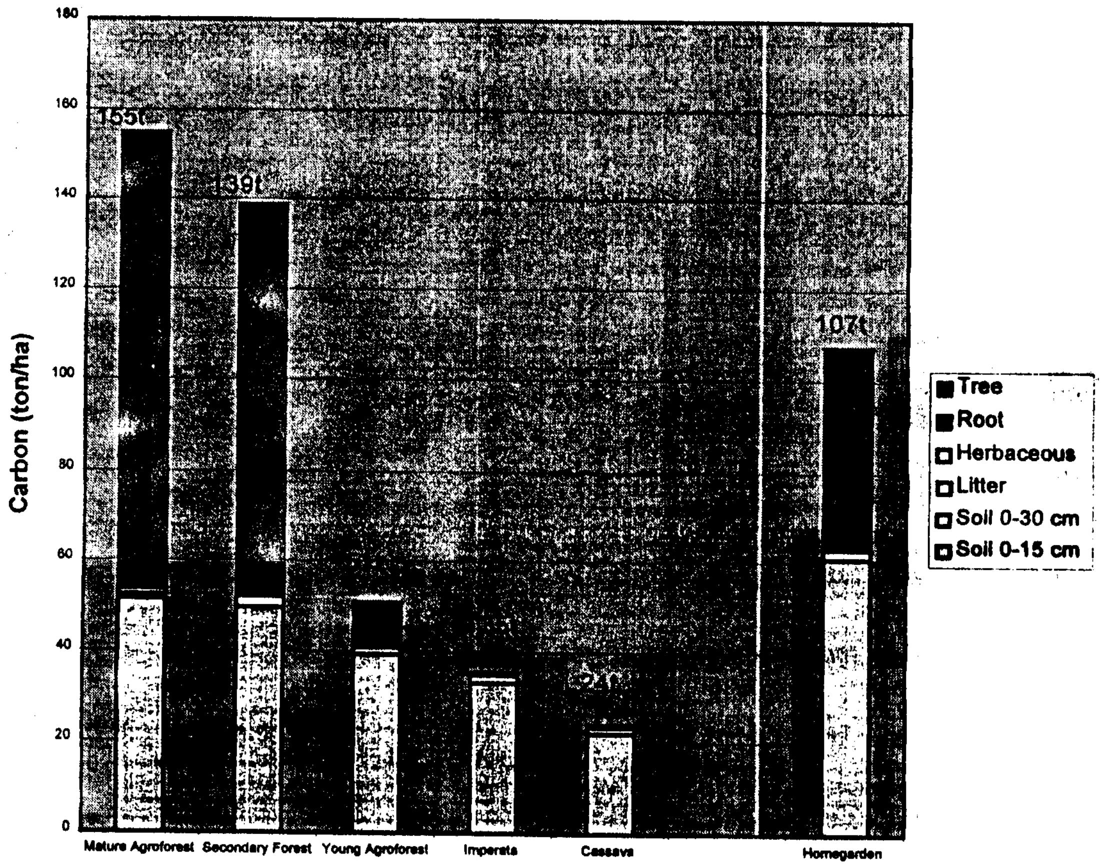
Figure 1 compares carbon stocks and age for the six landuse systems North Lampung. In terms of carbon stocks, homegardens are clearly superior to those of cassava fields, *Imperata* grasslands, and young rubber agroforests, containing 446%, 306% and 210% as much carbon respectively. Mature agroforests and secondary forest contain higher stocks of carbon than homegarden systems, but not remarkably. At a much younger age, homegardens already contain 69% and 77% of the carbon in these other tree-based systems. Younger trees with lower biomass accounts for the differences in total carbon stocks between homegardens and those of mature agroforests and secondary forests. The other three major carbon pools –

herbaceous, litter and soil – are relatively constant between the land use systems. The carbon stocks of the mature agroforests and secondary forests measured in Lampung are lower than might be expected because these systems suffer degradation from wildfires, which intrude from surrounding *Imperata* land. These systems are generally located 2-3 kilometers outside of the main village and cultivation area. Additionally the secondary forests suffer from unregulated extraction do to their remote location and the paucity of other accessible forests in the province. Homegardens are not vulnerable to these degradations because the proactively managed/protected and land ownership/tenure is recognized. Assuming linear growth without harvesting at 30-years, a likely length of time for a carbon investment project, the homegardens in this study will contain about 215 t C ha^{-1}. This estimate is support by extrapolation of ASB data for Jambi, which reports carbon stocks of 40-year-old and 25-year-old tree-based systems as 250 t C and 200 t C ha^{-1} respectively (Tomich et al 1998).

To adjust this estimate for the periodic removal of timber crops we decrease the total by 31 t C ha^{-1} (20% of future woody biomass) for a total of 184 t C ha^{-1}. Because of periodic fires that maintain the grass ecosystem, the carbon stocks in *Imperata* lands are generally constant. Thus, over a 30 year period, the establishment of a homegarden systems on *Imperata* lands in Lampung represents a potential carbon investment of 149 t C ha^{-1} (184 – 35 = 149). This crude yet conservative analysis supports the idea that homegarden systems might be targeted to increase carbon stocks in location like Lampung.

Currently there is over 220,000 hectares of *Imperata* land in Lampung, 8.5 million across Indonesia, and 35 million throughout Asia (Garrity et al. 1997). These exotic ecosystems are prone to burn and generally underutilized both biologically and economically. They represent a vast land resource, part of which could be use to establish tree systems to meet smallholder's household and income needs, while making a significant contribution to the regional carbon budget. Based on our conservative projection, converting 2% of the *Imperata* area in Lampung to smallholder agroforestry systems would provide a carbon investment of 655,600 t C over a 30 period (220,000 hectares x .02 x 149 t C). This is a large enough quantity to attract the attention of international carbon investors.

In discussion with ICRAF and Winrock staff, smallholders in Lampung show a clear interest in expanding their tree farming activities, particularly on fallow agricultural land invaded by *Imperata*. The reasons indicated by farmers can be summarized as: 1) a desire to have their own trees resources for the production of both home-use and commercial non-wood and wood resources, due to declining access to dwindling local forests; 2) a desire to diversify and intensify their farming systems and income streams; and 3) a shortage of the labor or financial resources required to cultivate annual crops on all of the family's agricultural land. The farmers add that *Imperata* quickly invades their uncultivated agricultural land. Despite their knowledge of homegardens and interest in tree farming, most smallholder in the study area have limited experience with intensive tree planting and management systems. Past attempts by individual farmers, unassisted by technical agencies, to establish tree farming systems have suffered from the use of inferior germplasm and poor species selection. This is evident in the species composition recorded during the study. Half of the wood producing



Landuse Systems	Ages
Mature Agroforest	> 30 years
Secondary Forest	> 30 years
Young Rubber Agroforest	9 years
Imperata	> 5 years since forest clearing
Cassava	< 5 years since forest clearing
Homegarden	13 years

Figure 1.. Comparison on carbon stocks for various landuse systems in Lampung.

trees recorded in the homegardens are *Paraserianthes*, an exotic trees which is planted by farmers even though its biological and economic performance in Lampung is inconstant. Including both living and dead specimens, *Nephelium lappaceum* is the most common tree surveyed, with a total of 83. This species has been planted in great numbers even though mature trees commonly die during Lampung's cyclical droughts. Combined *Paraserianthes* and *N. lappaceum*, both poorly adapted to Lampung, account for 21% trees sampled in the homegardens. A team of socioeconomic, forestry, horticultural and livestock specialists which visited the study area previously determined that smallholders' keen interest in tree farming, and the productivity of resultant tree systems, would benefit greatly from technical assistance in the form of information and resources (Gintings et al. 1996). Observations indicates these farmers are quick to adapt new technology that serves their needs. Evidence shows that *Imperata* lands can be converted to tree-based systems (Utama et al. 1999, Bagnall-Oakley et al. 1997, de Foresta and Michon 1997, de Jong 1994). These efforts must be anthropogenic due to the fire-climax nature of the ecosystem. Top-down approaches frequently fail. Conversion efforts based on the subsistence and income generation objectives of local land-users have proven to be more successful (Potter 1997).

At the present time, smallholder agroforestry systems are not considered a viable option for international carbon investment. Working with a large number of independent smallholder farmers is seen as too risky for large international investors. However, there are large numbers of smallholder farmers in the tropics and vast areas of degraded land that could be rehabilitated. Agroforestation of these areas would provide global environmental benefits - carbon sequestration and the prevention of further deforestation (Schroder 1994, Sanchez 1994), as well as improving the livelihood of smallholder farm families. Project-based support to provide farmers the information and inputs they need to effectively convert *Imperata* or other underutilized lands to tree farming systems, avoiding the trial-and-error learning process which may led to failure, could be a wise investment in social, political, economic and environmental terms. It may be timely to explore mechanisms by which communities or consortiums of smallholder farmers can access carbon investment funds. Questions of 'leakage[1]'should be moot. *Imperata* lands contain low carbon stocks that are cyclically lost to the atmosphere due to fire – contributing to globally warming. They are utilized for grazing or shifting cultivation, but in general produce few commercial or homeuse products compared to the extensive area they cover. The conversion of some *Imperata* lands is not likely to greatly alter local land-use practices, particularly when abundant *Imperata* lands remain. From a carbon investment point of reference agroforestation of *Imperata*, or other low-biomass lands, is highly desirable and not likely to supplant a more effective carbon sequestration strategy.

CONCLUSION

Individual smallholder agroforestry systems are of limited size and by themselves store small amounts of carbon. However, on a per area basis homegardens and other smallholder agroforestry systems accumulate significant amounts of carbon, equaling the amount of carbon stored in other tree-based systems – including primary or secondary forests – over similar time periods. Smallholder systems greatly exceed the amount of carbon stored by *Imperata* grasslands or agricultural fallow land. Thus in aggregate smallholder systems can contributing significantly to a region's overall carbon budget. Homegardens systems are established by farmers in small areas near their homes to meet household production and income generation needs. They simultaneously contribute to the global environmental objectives – carbon sequestration – and smallholder livelihood concerns.

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[1] Leakage is the loss of carbon, primarily as woody biomass, in outside areas due to changes in landuse practices resulting from carbon investment activities at the project site.

Across Asia there are millions of hectares of *Imperata* grasslands and other under-utilized low-biomass landuse systems. There is interest by both governments and smallholder farmers to convert some of these under-utilized lands in to more productive tree-based landuse systems. Government-led attempts have often faulted by failing to consider objectives and priorities of local people. The success of smallholder-led agroforestation efforts are also mixed. While farmers in some areas have developed technologies to establish and manage extensive agroforestry systems, farmers in other areas have not yet developed the experience, knowledge nor technology to become successful tree farmers on wide-scale. Observations by the authors and others indicate that in Lampung the tree farming capacity of smallholders would benefit from technical assistance in the form of information and resources to help them develop effective methodologies and avoid a trial-and-error learning process which could lead to failure and disenchantment. There are other areas in Indonesia and Asia similar to the study site where a combination of factors provide a promising environment for smallholder tree farming systems and carbon commodity investment. Providing farmers with the information and resources required to establish viable smallholder agroforestry systems may be a feasible carbon sequestration strategy that will simultaneously make a positive contribution to the livelihood of smallholder farm families. With proper species composition and management the amount of carbon stored by an agroforestry system can equal or surpass that of a secondary forest. Governments are generally support of such tree planting efforts, as a means of achieving conservation, reforestation and watershed protection objectives as well as livelihood improvement for smallholder farm families. It is likely, they would welcome such support to smallholder farmers. We suggest that it is timely and appropriate to explore mechanisms by which communities or consortium of smallholder farmers can access international carbon investment funds.

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Table 3. Tree species identified in the 19 home garden systems.

		Trees		Occurrence	
Botanical (local) name	Primary uses	Total #	% of total	#HGS	%HGS
Non-wood products – food, spice, oil, medicine, resin, soil improvement; etc.					
Cocos nucifera (kelapa)	ol; fr; vg; md; su; wd	66	11.1	17	89.5
Mangifera indica (mangga)	fr; vg; md; wd; tn	59	9.9	15	78.9
Musa spp. (pisang)	Fr	57	9.5	9	47.4
Nephelium lappaceum (rambutan)	fr; ol; st; md; wd; tn	55	9.2	9	47.4
Parkia speciosa (petai)	sp; vg; md; wd	39	6.5	14	73.7
Archidendron pauciflorum (jengkol) (syn. Pithocellobium jiringa)	vg; md; wd; tn	28	4.7	11	57.9
Artocarpus heterophyllus (nangka)	fr; vg; md; dy; tn	26	4.4	12	63.2
Ceiba pentandra (kapok)	ct; dy; ol; fr; vg; md	18	3.0	7	36.8
Gliricidia sepium (gamal)	si; or; wd	13	2.2	3	15.8
Coffea robusta (kopi)	st;	12	2.0	4	21.1
Erythrina spp. (dadap)	si; md; wd; or	12	2.0	3	15.8
Gnetum gnemon (melinjo)	fr; vg; wd; dy	11	1.8	5	26.3
Hevea brasiliensis (karet)	rs; ol; fr; vg	10	1.7	3	15.8
Spondias spp (kedongdong)	fr; vg; wd	10	1.7	3	15.8
Theobroma cacao (coklat)	ol; st; md	8	1.3	3	15.8
Syzygium aqueum (jambu air)	fr; md; wd	7	1.2	4	21.1
Anacardium occidentale (jambu mete)	fr; ol; vg; sp; md; tn	5	0.8	3	15.8
Averrhoa bilimbi (belimbing)	fr; sp; md; su; wd	5	0.8	1	5.3
Garcinia parvifolia (kardis)	fr; rs; wd	5	0.8	1	5.3
Leucaena leucocephala (lamtoro)	vg; si; st; wd; tn; or	5	0.8	2	10.5
Aleurites moluccana (kemiri)	sp; ol; fr; md; wd; dy	4	0.7	2	10.5
Psidium guajava (jambu biji)	fr; ol; sp; st; md; su	4	0.7	4	21.1
Annona muricata (sirsak)	fr; st; md; dy	3	0.5	2	10.5
Melia azedarach (mindi)	md; ol; su; wd; rs; or	3	0.5	1	5.3
Artocarpus integer (cempedak)	fr; vg; md; wd; dy	2	0.3	2	10.5

Table 3. *(continue)*

Botanical (local) name	Primary uses	Trees Total #	% of total	Occurrence #HGS	%HGS
Non-wood products – food, spice, oil, medicine, resin, soil improvement; etc.					
Persea americana (alpokat)	fr; ol; wd	2	0.3	2	10.5
Annona reticulate (buah nona)	fr; md; wd; tn	1	0.2	1	5.3
Arenga pinnata (kolang kaling)	su; fr; vg; st; md; wd	1	0.2	1	5.3
Cinnamomum parthenoxylon (kayu lada)	sp; md; wd	1	0.2	1	5.3
Flacourtia rukam (rukam)	fr; vg; md; wd	1	0.2	1	5.3
Hibiscus tiliaceus (waru)	dy; md; wd; cf; or	1	0.2	1	5.3
Mangifera foetida (pakel)	fr; vg; md; wd	1	0.2	1	5.3
Mangifera odorata (kurai)	fr; md; wd	1	0.2	1	5.3
Tamarindus indica (kayu asam)	sp; ol; fr; st; md; wd	1	0.2	1	5.3
Unknown (sanu)	--------	1	0.2	1	5.3
	Subtotal	478	80.1 %		
Wood products					
Paraserianthes falcataria (sengon putih)	wd; si; dy	59	9.9	7	36.8
Acacia ariculiformis (akasia)	wd; si; or	18	3.0	3	15.8
Tectona grandis (jati)	wd; md; tn; cf	12	2.0	4	21.1
Acacia mangium (mangium)	wd; si; or	6	1.0	1	5.3
Alstonia spp. (pulai)	wd; st; md; rs	6	1.0	4	21.1
Peronema canescens (sungkai)	wd; med; or	6	1.0	1	5.3
Unknown (ladahan)	wd;	5	0.8	2	10.5
Peltophorum dasyrachis (sengon merah)	wd; si; tn;	3	0.5	2	10.5
Terminalia citrina (jaling)	wd; md; tn	3	0.5	1	5.3
Schima wallichii (puspa)	wd; md; tn	1	0.2	1	5.3
	Subtotal	119	19.9 %		
Total non-wood product species		36	80.0%		
Total wood product species		9	20.0%		
Total species		45	100%		

Key: cotton – co; craftwood – cf; dye – dy; fruit – fr; medicine – md; oil – ol; ornamental – or; resin – rs; soil improvement – si; spice – sp; stimulant – st; sugar – su; tannin – tn; vegetables – vg; wood – wd.

Source: Mackey 1996 (Acacia mangium), Pinyopusarerk 1996 (Acacia auriculiformis), Leaving and de Foresta 1991 (all others).

Table 4. Typical harvest age of timber species in the study area.

Botanical name	Rotation	Source
Acacia mangium	7-10 years	Inhutani staff
Alstonia scolaris.	15 years; 15-20 years	Farmers; Inhutani staff
Eucalyptus sp	7-10 years	Inhutani staff
Gmelina arborea	7-10 years	Inhutani staff
Paraserianthes falcataria	7-8 years; 7-10 years	Farmers; Inhutani staff
Peronama canescens	20 years; 30 years	Farmers; Inhutani staff
Swietenia mahagoni	30 years	Inhutani staff
Tectona grandis	+ 20 years; 30 years	Farmers; Inhutani staff