Mahausakande Tropical Rainforest Regeneration Initiative

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BASELINE ASSESSMENT OF SEQUESTERED STANDING CARBON STOCK IN MAHAUSAKANDE REGENERATING RAINFOREST

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EXECUTIVE SUMMARY

Understanding of standing carbon stock in forest trees is an important knowledge base for management decision making for forest regeneration programmes aimed at mitigating climate change, biodiversity loss, sociological and hydrological issues. This study examined forest carbon storage in tree biomass of above 1cm DBH in a regenerating forest stand located in Mahausakande ($6^0$76'68.9"N-$80^0$25'38.4"E) with a history of rubber cultivation. Permanent plots measuring 10m x 10 m were set up in 13 locations in the study site. Woody plants in plots were enumerated for height, DBH and number of individuals. Plants were identified by species, and organic carbon in biomass was estimated by using the allometry equation. The results revealed that the regenerating forest stand in Mahausakande had a relatively lower level of forest carbon amounting to 1030.2 MT in a 15.3 ha area (67.7 MT/ha), in comparison to well developed rainforests. The dominant species having a high carbon concentration included *Hevea brasiliensis, Alstonia macrophylla* and *Alstonia scholaris*. The floristic features as well as the above ground carbon content of this area is indicative of the fact that the forest cover is currently in an intermediate stage of succession, thus demanding suitable restoration interventions in future to accelerate natural succession and storage of carbon.

Key words: Sri Lanka, carbon sequestration, standing carbon, plant biomass, forest regeneration.

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APPENDICES

1. INTRODUCTION

Tropical rain forests play a major role in the global carbon cycle; they encompass over a third of terrestrial carbon stocks,[1] and contribute to approximately 30% of terrestrial net primary productivity.[2] Not only are many tropical forests under direct threat from land-use changes and logging,[3,4,5] but it has also been suggested that pristine, apparently undisturbed rainforests may also be undergoing widespread shifts in carbon stocks and floristic composition as a result of large-scale anthropogenic environmental changes.[6]

As both carbon sources and sinks, tropical forests have the potential to form an important component in efforts to combat global climate change. In the global carbon cycle, carbon dioxide (CO2) is exchanged between the atmosphere and terrestrial ecosystems through processes of photosynthesis, respiration, decomposition and changes in the use and cover of the land. Tropical forest ecosystems play particularly an important role in global carbon budget.[1,2] The tropical forests store on average about 50% more carbon than forests outside the tropics. Hence, the tropical forestry sector plays a vital role in the global balance of green house gases (GHGs). Deforestation alone accounts for approximately 20% of anthropogenic emissions[7,8] and the forestry sector represents upwards of 50% of global greenhouse gas mitigation potential.[9] The standing biomass of forests at a given time consists of organic matter resulting from primary production through photosynthesis minus consumption through respiration and harvest. Assessment of biomass provides information on the structure and functional attributes of a forest.[10] With approximately 50% of dry forest biomass comprised of carbon,[11] biomass assessments also illustrate the amount of carbon that may be lost or sequestered under different forest management regimes.

1.1 Site Description

The Mahausakande regenerating rainforest (MRF) is located in Kiriella (6^{0}76’68.9”N-80^{0}25’38.4”E) of Ratnapura district. The site was managed as a rubber cultivation 10 years ago, and is currently being converted to a rainforest ecosystem through assisted forest regeneration activities. The main forest community is composed of rubber trees mixed with pioneers and primary forest species typical of lowland wet zone rainforest areas. The area receives an annual rainfall of 3200mm.[12] Topographically, the site is located in a low mountainous area at an elevation of 190 m-above sea level. This area is adjacent to a natural rain forest at Bambaragala Mookalana and most of the peripheral lands are used for tea plantations, rubber plantations and semi wild tree dominated home gardens. The current land use types of the MRF site is shown in Figure 1.1.

Figure 1.1: Map of the Mahausakande forest area

1.2 Rationale

Carbon pools are components of the ecosystem that can either accumulate or release carbon and have classically been split into five main categories: living above-ground biomass , living below-ground biomass, dead organic matter in wood, litter and soil organic matter (see Figure 1.2). Carbon stock accounting sums carbon pools at a single point in time. Decisions on which carbon pools should be included are largely dependent on the availability of existing data, costs of measurement and the level of conservativeness required.[13] Trees often represent the greatest fraction of total biomass of a forested area, with other carbon pools being only a small fraction of the total tree biomass.[10] Above-ground biomass in trees also responds more rapidly and significantly as a result of land use change than other carbon pools. As a consequence, the majority of carbon accounting efforts is focused on tree above-ground biomass. The present investigation on forest carbon stock in tree flora of MRF offers an opportunity to assess its significance in relation to carbon sequestration, an important process to reduce atmospheric carbon and mitigate climate change. Moreover, it would evaluate the efficacy of various forest management activities carried out in the site over the last decade, and also facilitate carbon trading ventures that may arise in the future.

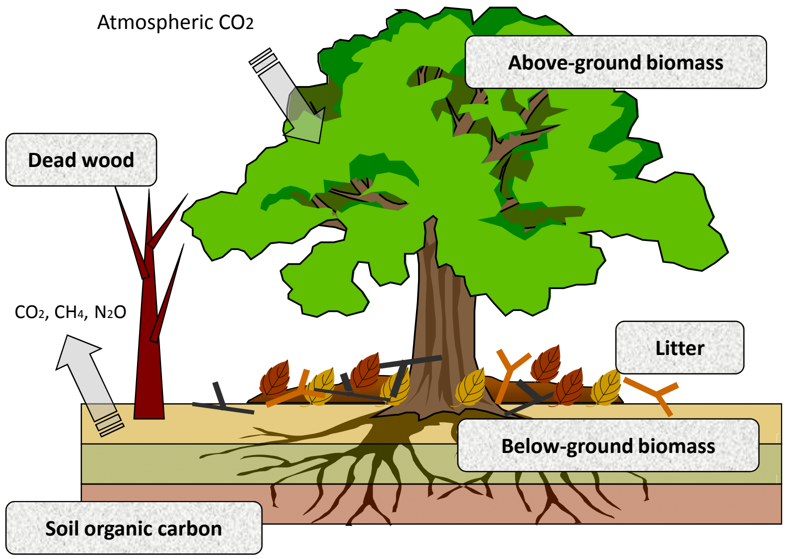

Figure 1.2: Carbon pools

1.3 Research Hypothesis

It is hypothesized that, over the past decade, the forest regeneration activities at MRF has resulted in a progressive increase of carbon sequestered in tree biomass.

1.4 Objectives

The specific objectives of this research included the following:

1. To provide a preliminary estimate of sequestered carbon stock at a point of time (2011) in a regenerating forest with permanent sampling plots.

2. To gain an idea of sequestered carbon quantity in different vegetation types, and establish a baseline for forest carbon status.

3. To make recommendations for ongoing forest restoration activities that attempts to diversify the ecosystem services related to MRF.

It should be noted that this study was not intended to provide a statistically robust estimate of forest carbon, but rather to provide a rapid initial estimate of its variability in different vegetation types, under limited resources and time constraints.

2. MATERIALS AND METHODS

2.1 Field Methods

Considering the available time, resources and extent of forest, woody flora were enumerated in 10mx10m sampling plots (13 in total) laid in randomly selected locations in MRF representing different vegetation types (see Table 2.1 and Photos 1-12).

Table 2.1: Habitat characteristics of the plots

PLOT CODE	HABITAT CHARACTERISTICS
AR1A; AR1B; AR2A; AR2B	Abandoned rubber plantation site where natural and planted tree species are growing among unmanaged rubber plants.
RE1A; RE1B	Forest adjacent to a stream – a patch with riverine forest characteristics.
RF1A; RF1B; RF2A	Regenerating forest with many small plants, dominated by *Symplocos cochinchinensis* (Bombu) of small diameter class; 10cm or less.
SF1A; SF1B	Regenerating forest at early stage of succession, lower strata dominated by pioneer species *Clerodendrum infortunatum* (Pinna), and *Trema orientalis* (Gedumba); mainly 5cm or less in diameter.
TR2A; TR2B	A patch of rubber plantation where latex is harvested on a regular basis. Some wild tree species also occur within this plantation.

These were permanent sampling plots earmarked not only for forest carbon studies but also for other ecological parameters, especially for long term observation of changing structure and composition of regenerating flora. In each plot, all trees ≥ 1 cm in dbh (diameter at breast height) were tagged, identified botanically, and diameters measured to the nearest millimeter. The default point of measurement was at 130 cm above ground following standard forestry techniques.[14] Measurements were made at a different height in case of an irregularity of the bole; 50 cm above any buttresses or deformities. Height of trees above 10m were measured using a laser range finder (Nikon Forestry Pro), and smaller plants below 10m were directly measured using a graduated pole.

2.2 Estimation of Tree Biomass from Field Inventories

The biomass and total organic carbon of standing trees was estimated by non destructive methods. Above-ground biomass was calculated using a regression model that converts stem diameter, wood density and tree height into an estimate of total oven-dry above-ground biomass.[15] The evaluation looked for the contribution of above-ground carbon of woody plants ≥1 cm in dbh, excluding lianas, rattans and non-woody monocots. The following allometric regression model was applied for individual plants to convert the inventory data into above ground biomass.[15]

$AGB = 0.0509 \times q D^2 H$

where,

AGB = above-ground tree biomass [kg];

q = wood specific gravity [g cm^3];

D = tree diameter at breast height [cm]; and

H = tree height [m].

The allometric regression model was selected on account of published literature which revealed that it is most suitable for use with tropical forests and biogeographic zone of the present investigation. Wood densities were taken from Zanne et al.[16] and Forest Department.[17] Wherever the wood density of tree species was unavailable, the mean value of the relevant plant genera was taken from Zanne et al.[16] which is the best option as per Chave et al.[18] In case the wood density is not available for at least the generic level, the standard average value of 0.6 g/cm^3 was taken.[19] The below-ground biomass was calculated considering 15% of the above-ground biomass.[13] The sum of the above-ground biomass and the below-ground biomass was the total tree biomass. The total biomass was divided by 2 in order to calculate the amount of carbon in biomass.[20,21] In the case of multiple-stemmed trees, the allometric model was applied to each stem and summed, to provide a tree-level above-ground biomass estimate.

2.3 Constraints and Limitations

The estimation of carbon content during the present study may be influenced by the following constraints and limitations:

a. Limitations associated with the use of allometric equation that was not developed for exactly the same forest species and forest sub type. Minor variations may arise when used in different locations.

b. Element of subjectivity related to approximation of wood densities.

c. Possible errors of laser finder instrument.

d. Limitations related to small size of the samples adopted considering time and resource constraints.

Photo 1: Small diameter trees in regenerating forest

Photo 2: Plots demarcated for long term monitoring

Photo 3: Measurement of tree stem DBH

Photo 4: Measurement of tree height

Photo 5: Trees labeled with metal tags

Photo 6: Regenerating forest

Photo 7: Abandoned rubber plantation

Photo 8: Mist and high rainfall facilitates regeneration

Photo 9: Secondary forest

Photo 10: Forest adjacent to stream

3. RESULTS

3.1 Estimate of Carbon Stock in Forest Trees

A total of 1145 individual stems belonging to 74 tree species were enumerated for estimation of carbon stock in the forest stand. The list of species and number of stems enumerated is presented in Appendix 1. The tree species that accounted for the largest number of stems was *Symplocos cochinchinensis* (Bombu – 251 stems), followed by *Clerodendrum infortunatum* (Pinna - 219 stems). The trees were of varying diameter and heights, as summarized by grouping of those parameters in Tables 3.1 and 3.2.

Table 3.1: Distribution of diameter classes of trees in survey plots

Diameter Class	Survey Plots													Diameter Class Totals
	AR 2A	AR 2B	AR1A	AR1B	RE1A	RE1B	RF1A	RF1B	RF2A	SF1A	SF1B	TR2A	TR2B	
A = 5cm & below	56	79	77	100	38	93	56	61	66	154	123	35	15	953
B = 5cm plus - 10cm	6	9	4		1	1	14	32	27	16	6	2	3	121
C = 10cm plus - 15cm			2			5	6	3	6	2			1	25
D = 15cm plus - 20cm		2				1	2		3	1		1	2	12
E = 20cm plus - 25cm	1				2	2				1	2	2	3	13
F = 25cm plus - 30cm	1		2	1	2	1	1					1		9
G = 30 cm plus - 35cm		2			1	2							1	6
H = 35 cm plus - 40cm			1	1		1								3
I = 40cm plus - 45cm			1	1										2
J = 45cm plus - 50cm					1									1
Plot Totals	**64**	**92**	**87**	**103**	**45**	**106**	**79**	**96**	**102**	**174**	**131**	**41**	**25**	**1145**

Table 3.2: Distribution of height classes of trees in survey plots

Height Class	Survey Plots													Height Class Totals
	AR 2A	AR 2B	AR1A	AR1B	RE1A	RE1B	RF1A	RF1B	RF2A	SF1A	SF1B	TR2A	TR2B	
A = 3m & below	24	21	42	69	20	49	21	12	17	35	20	16	9	355
B = 3m plus - 6m	34	55	35	32	18	46	40	52	51	123	106	20	9	621
C = 6m plus - 9m	4	11	4		1	1	5	30	28	13	3	1	1	102
D = 9m plus - 12m		1				5	10	1	5	2				24
E = 12m plus - 15m		1	4	1	2	2	2	1	1	1	2		1	18
F = 15m plus - 18m	1	3	2	1	3	3	1					4	5	23
G = 18m plus - 21m	1													1
H = Above 21m					1									1
Plot Total	**64**	**92**	**87**	**103**	**45**	**106**	**79**	**96**	**102**	**174**	**131**	**41**	**25**	**1145**

Based on the contribution of different tree species in MRF to the carbon pool of forest biomass (see Appendix 2), the total estimate is about 1030.2 metric tons in 15.3 ha of present forest area (67.1 metric tons per ha). The 10 leading tree species contributing to forest carbon pool at MRF are presented in Table 3.3 below.

Table 3.3: The 10 leading tree species contributing to forest carbon pool in Mahausakande forest

No.	Botanical Name	Total C Kg in plots (1300 m^2)	Total C MT in the forest area*
1	*Hevea brasiliensis*	3873.38	457.4161398
2	*Alstonia macrophylla*	796.71	94.08567403
3	*Alsotonia scholaris*	764.05	90.22901526
4	*Caryota urens*	573.62	67.74043873
5	*Symplococs cochinchinensis*	512.99	60.58036527
6	*Artocarpus nobilis*	384.79	45.44118719
7	*Artocarpus heterophyllus*	233.53	27.57861754
8	*Pometia pinnata*	224.35	26.49374595
9	*Albizia falcataria*	184.58	21.79749525
10	*Clerodendrum infortunatum*	183.65	21.68742497

* 1 MT=1000Kg; Area of 13 plots=1300 m^2; Total C MT of each species in the forest area (153520 m^2 or 38 acres)=[Sum of C kg in each species in 13 plots/1000] x [153520 m^2 / 1300m^2]

The above 10 leading species alone contribute 913.05 metric tons of carbon out of 1030.24 metric tons of total carbon in the forest stand.

3.2 Estimate of Carbon Stock in Different Plots and Habitats

The estimation of tree carbon pool in different 10mx10m plots representing diverse habitat variations revealed that riverine plots (RE1A and RE1B) has the highest stock of carbon; 1133.21kg and 1374.56kg in each plot (see Table 3.4). Sampling plots in early succession stage forests where most of the rubber trees have been removed for forest regeneration had a lower stock of carbon; 204.8kg in SF1B and 260.19 kg in RF1B.

Table 3.4: Standing forest carbon in survey plots

Plot	Total C Kg/plot	Total C MT/ha
SF1B	204.80	20.47966
RF1B	260.19	26.01943
SF1A	292.50	29.24953
RF2A	413.79	41.37879
AR 2A	424.41	42.44125
TR2A	507.09	50.70862

RF1A	538.94	53.89424
AR 2B	623.14	62.31393
AR1B	625.70	62.56961
TR2B	764.56	76.45645
AR1A	1133.21	113.3205
RE1B	1374.56	137.4557
RE1A	1561.23	156.1228
Total = 8724.11 per 13 plots		67.1 (Average MT/ha)

Often, the tree carbon pool is highly concentrated in a single species in a given plot, and the leading plant species in each plot having the highest accumulation of carbon is shown in Table 3.5. The full list of trees in each plot and their standing carbon levels are given in Appendix 3.

Table 3.5: Highest carbon accumulating species in different plots

Plot	**Botanical Name**	**Total C kg**	**% C contribution in plot**
TR2A	*Hevea brasiliensis*	491.6484136	96.95558754
AR1B	*Hevea brasiliensis*	604.9958581	96.69164518
AR1A	*Hevea brasiliensis*	1016.522973	89.70334041
AR 2A	*Hevea brasiliensis*	362.4947309	85.41094642
AR 2B	*Hevea brasiliensis*	488.7504567	78.43358407
TR2B	*Hevea brasiliensis*	481.0420055	62.91712161
SF1A	*Clerodendrum infortunatum*	141.983699	48.54221112
RF1B	*Symplocos cochinchinensis*	109.0625421	41.91580758
RF2A	*Symplocos cochinchinensis*	161.3285252	38.98821324
RF1A	*Alstonia macrophylla*	203.0328723	37.67246188
SF1B	*Albizia falcataria*	76.54747178	37.37731416
RE 1A	*Alsotonia scholaris*	478.7684905	30.666151
RE 1B	*Artocarpus nobilis*	382.0602828	27.79515389

4. DISCUSSION

Green plants consume carbon dioxide gas in the atmosphere in the process of photosynthesis and use it to produce sugars and other organic compounds for growth and metabolism. Long-lived woody plants store carbon in their wood and other tissues until they die and decompose, at which time the carbon in their wood may be released to the atmosphere as carbon dioxide, carbon monoxide or methane, or it may be incorporated into the soil as organic matter. [25] Plant tissues vary in their carbon content, and many studies have shown that it is related to aspects such as climate, geographic region, physiographic features, soil fertility, plant species, age, stand density, and stand vigour.[26-35] Similarly, the content of carbon in soil also varies depending on climate, associated land use practices, plant species, physico-chemical properties, parent material and microbial activities.[36,37] Therefore, the stock of soil carbon in a given forest is highly specific to the location. Lal[22] has stated that the magnitude and quality of soil carbon stock is depended on the complex interaction between climate, soil, tree species and management, and the composition of litter, as determined by the dominant species. A study done in tropical lowland forests in Guyana shows that the forest hold a total of 271 MT per ha in its carbon pool; and in that 66% is in above ground biomass, 14% in roots, 7% in dead biomass and 12% in soil.[38]

The overall assessment in MRF revealed that the current generalized carbon content in the woody flora of forest stand is 1030.2 MT in 15.3 ha, which converts to 67.7 MT/ha. A similar study done in Sinharaja tropical rainforest, has shown that tropical rain forests can hold a carbon content of 357.9 MT/ha.[22] Therefore, MRF being in the same biogeographic zone as Sinharaja has the potential to be gradually restored into a forest that can hold five times the current content of carbon. Contrary to the research hypothesis, the results indicate that the regenerating activities carried out in MRF has not been able to increase the forest carbon content so far, when comparing the values obtained for plots with regenerating forests and those under existing rubber plantation. The regenerating forest sites (i.e., plots SF1B, RF1B, SF1A & RF2A) have lowest amount of stored carbon, and this can be attributed to the fact that these plots are still dominated by pioneer tree species of small diameter and height class plants. In future such species would be replaced by large size rain forest trees through the progression of the regeneration process, thereby increasing the standing carbon content. A positive trend is that in such regenerating forest patches, the carbon content is not highly concentrated in one or two species as in the case with plots associated with rubber.

Some preliminary studies carried out in Sri Lanka on biomass accumulation and carbon sequestration in rubber plantations indicates that total biomass accumulated in a tree at the age of 33 years is 1.8 MT which amounts to 963 MT per hectare.[39] This value is made up of biomass accumulated in fruits, leaves and fallen branches and trees uprooted at the end of the trees' economic life span of 33 years. The amount of carbon sequestered in one hectare of a 33 year-old stand is 596 MT, the major portion coming from the trunks and branches. The total amount of carbon sequestered in one hectare of rubber plantation made up of tree biomass, latex produced and contribution from leguminous cover crops amount to 680 MT.[39]

The plots in the riverine zone have the highest amount of stored carbon amounting to 1374.56 kg (137 MT/ha) and 1561.23 kg (156 MT/ha) in each plot. These riverine areas can be considered as old growth forest stands with a higher status of maturity, hence more carbon content. The carbon content in the riverine forest patches is not highly concentrated in one or two species, but spread across diverse naturally occurring tree species.

The allometric equation applied in the present study is not free of errors in calculating carbon levels in different trees. Such errors are caused by approximation of wood densities of trees, slight deviations of biological make up of species in different sites that are not equal to where the allometric equation was developed, and site specific environmental conditions. As a solution, the allometric equations formulated for other countries should be calibrated to suit local situations through field research, and then use them to determine the carbon levels in indigenous flora.

5. CONCLUSIONS AND RECOMMENDATIONS

This baseline assessment has shown that MRF is harboring more than 1000 MT of carbon in its forest biomass and also has the potential to significantly increase its carbon stock through gradual progression into a mature rainforest. The floristic composition as well as the above ground carbon content of this area is indicative of the fact that the forest cover is currently in an intermediate stage of succession, thus demanding active restoration interventions in future in order to accelerate natural succession and storage of carbon. Based on the results of this baseline assessment, the following recommendations are proposed for future regeneration work at MRF:

- The most important forest regeneration strategy will be to enrich the forest with native rainforest tree species capable of enhancing the forest carbon stocks as in the Sinharaja tropical rainforest; particularly plants of Family Dipterocarpaceae which are generally massive trees.

- The patches of lands dominated by pioneer species such as *Symplocos cochinchinensis* (Bombu), *Clerodendrum infortunatum* (Pinna) and *Trema orientalis* (Gedumba) where limited forest planting has been carried can be used to introduce high carbon rainforest tree species as a priority. Selection of species can be done considering biodiversity, socio-economy and hydrology as well. The existing cover of pioneer plants is ideal for accelerating the forest regeneration using primary forest species. Some studies have shown that certain primary species, as well as a few climax species, could regenerate naturally in the understory layer.[23]

- A programme for periodic monitoring of forest carbon in MRF needs to be established. This has to be upgraded as a project that looks into total carbon pool of the forest ecosystem that determine time series carbon levels in live biomass, dead biomass and soil.

- A strategic development plan should be prepared to promote the MRF centre as a national reference point in forest carbon studies that provide services such as capacity building, building of national and international partnerships, replication of forest carbon studies in different ecosystems elsewhere, develop nationally applicable tools for carbon trading while the institution itself reaps benefits from carbon trading, and promotion of the corporate sector for climate change mitigation through evidence based lobbying.

- The MRF management should initiate discussions with the national focal point for the United Nations Reducing Emissions from Deforestation and Forest Degradation (REDD) programme, to use MRF as a pilot location for a REDD project.

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Appendix 1:

List of plants and number of stems enumerated in sampling plots

No.	BOTANICAL NAME	No. of Stems Enumerated
1	*Symplocos cochinchinensis*	251
2	*Clerodendrum infortunatum*	219
3	*Alstonia macrophylla*	65
4	*Syzygium caryophyllatum*	59
5	*Ochlandra sridula*	51
6	*Dillenia suffruticosa*	47
7	*Hevea brasiliensis*	45
8	*Syzygium operculatum*	36
9	*Alsotonia scholaris*	35
10	*Carallia brachiata*	32
11	*Dipterocarpus zeylanicus*	28
12	*Cinnamomum verum*	20
13	*Gyrinops walla*	20
14	*Acronychia pedunculata*	18
15	*Melastoma malabathricum*	16
16	*Antidesma bunious*	15
17	*Caryota urens*	12
18	*Turpinia malabarica*	11
19	*Elaeocarpus serratus*	9
20	*Thottea siliquosa*	9
21	*Ficus hispida*	8
22	*Artocarpus nobilis*	7
23	*Pometia pinnata*	7
24	*Albizia falcataria*	6
25	*Artocarpus heterophyllus*	6
26	*Hedyotis fruticosa*	6
27	*Pagiantha dichotoma*	6
28	*Trema orientalis*	6
29	*Antidesma pyrifolium*	5
30	*Pericopsis mooniana*	5
31	*Bhesa ceylanica*	4
32	*Breynia vitis-idaea*	4
33	*Dillenia retusa*	4
34	*Gaertnera vaginans*	4
35	*Litsea longifolia*	4
36	*Macaranga peltata*	4
37	*Coffea arabica*	3
38	*Garcinia quaesita*	3
39	*Horsfieldia irya*	3
40	*Stereospermum coalis*	3
41	*Vitex altissima*	3
42	*Albizia odoratissima*	2

43	*Bombax ceiba*	2
44	*Bridelia moonii*	2
45	*Canthium coromandelicum*	2
46	*Dillenia triquetra*	2
47	*Glochidion coriaceum*	2
48	*Lantana camara*	2
49	*Leea indica*	2
50	*Mallotus tetracoccus*	2
51	*Myristica dactyloides*	2
52	*Neolitsea lancifolia*	2
53	*Nothopegia beddomei*	2
54	*Shorea sp2*	2
55	*Artocarpus gomezianus*	1
56	*Barleria restita*	1
57	*Breynia retusa*	1
58	*Cleistanthus sp.*	1
59	*Cryptocarya membranacea*	1
60	*Cryptocarya wightiana*	1
61	*Enicosanthum acuminata*	1
62	*Erythroxylum indicum*	1
63	*Ficus sp.1*	1
64	*Gliricidia sepium*	1
65	*Mussaenda frondosa*	1
66	*Ochna jabotapeta*	1
67	*Persea macrantha*	1
68	*Quassia indica*	1
69	*Sandoricum indicum*	1
70	*Shorea affinis*	1
71	*Shorea ovalifolia*	1
72	Unknown sp.2	1
73	Unknown sp.3	1
74	Urandra sp.	1
	Total	**1145**

Appendix 2:

Contribution of plant species to forest carbon pool in Mahausakande

BOTANICAL NAME	Total C Kg in plots ($1300\ m^2$)	Total C Tons in forest area ($153520\ m^2$ or 38 acres)
Hevea brasiliensis	3873.38	457.4161398
Alstonia macrophylla	796.71	94.08567403
Alsotonia scholaris	764.05	90.22901526
Caryota urens	573.62	67.74043873
Symplocos cochinchinensis	512.99	60.58036527
Artocarpus nobilis	384.79	45.44118719
Artocarpus heterophyllus	233.53	27.57861754
Pometia pinnata	224.35	26.49374595
Albizia falcataria	184.58	21.79749525
Clerodendrum infortunatum	183.65	21.68742497
Elaeocarpus serratus	162.84	19.22991883
Carallia brachiata	141.33	16.68978753
Trema orientalis	114.47	13.51753686
Turpinia malabarica	104.28	12.31505572
Syzygium operculatum	93.36	11.02534859
Mallotus tetracoccus	59.08	6.977313551
Acronychia pedunculata	43.71	5.161639663
Bhesa ceylanica	38.46	4.54171313
Syzygium caryophyllatum	32.64	3.854665497
Dipterocarpus zeylanicus	31.50	3.719519662
Gyrinops walla	26.37	3.113565016
Antidesma bunious	24.71	2.917621845
Pagiantha dichotoma	22.51	2.658487219
Dillenia suffruticosa	12.98	1.532974044
Quassia indica	11.51	1.359541125
Enicosanthum acuminata	8.01	0.945361156
Nothopegia beddomei	7.16	0.845567329
Ochlandra sridula	7.12	0.840300032
Albizia odoratissima	4.15	0.490340036
Pericopsis mooniana	3.73	0.440393905
Bombax ceiba	3.67	0.43285567
Hedyotis fruticosa	3.55	0.418938063
Neolitsea lancifolia	3.00	0.354162463
Cinnamomum verum	2.96	0.349547507
Antidesma pyrifolium	2.80	0.330628357
Macaranga peltata	2.73	0.322880109
Horsfieldia irya	2.36	0.278576457
Melastoma malabathricum	2.28	0.269629796
Myristica dactyloides	1.89	0.223148345
Breynia vitis-idaea	1.58	0.186454738
Gaertnera vaginans	1.37	0.161573163

Garcinia quaesita	0.98	0.115879089
Leea indica	0.96	0.113340172
Ficus hispida	0.95	0.111892988
Cleistanthus sp.	0.91	0.107463487
Shorea sp2	0.90	0.106096078
Canthium coromandelicum	0.86	0.101150968
Litsea longifolia	0.75	0.088250656
Artocarpus gomezianus	0.67	0.079651598
Vitex altissima	0.66	0.078515976
Shorea ovalifolia	0.62	0.072976403
Dillenia retusa	0.57	0.067598624
Thottea siliquosa	0.50	0.059079147
Sandoricum indicum	0.49	0.058307611
Cryptocarya membranacea	0.48	0.057220021
Stereospermum coalis	0.47	0.055955663
Gliricidia sepium	0.46	0.054784588
Persea macrantha	0.38	0.04457573
Bridelia moonii	0.36	0.042927909
Cryptocarya wightiana	0.31	0.036344854
Coffea arabica	0.28	0.032890162
Dillenia triquetra	0.28	0.032493604
Urandra sp.	0.23	0.026659203
Lantana camara	0.21	0.024356743
Ochna jabotapeta	0.18	0.020925788
Shorea affinis	0.15	0.018169022
Breynia retusa	0.14	0.016015431
Glochidion coriaceum	0.14	0.016000098
Erythroxylum indicum	0.11	0.012825277
Unknown sp.2	0.09	0.010482396
Mussaenda frondosa	0.08	0.009111001
Barleria restita	0.07	0.008610344
Unknown sp.3	0.06	0.00711797
Ficus sp.1	0.06	0.006932444
Total	**8724.11**	**1030.24975**

Appendix 3:

List of Plants and Estimated Carbon Content in Survey Plots

PLOT	BOTANICAL NAME	Total C kg
AR 2A	*Hevea brasiliensis*	362.49
	Dipterocarpus zeylanicus	31.19
	Symplocos cochinchinensis	10.67
	Nothopegia beddomei	7.06
	Syzygium caryophyllatum	5.19
	Artocarpus heterophyllus	4.79
	Carallia brachiata	0.97
	Dillenia suffruticosa	0.43
	Cinnamomum verum	0.41
	Syzygium operculatum	0.37
	Clerodendrum infortunatum	0.29
	Dillenia triquetra	0.28
	Bridelia moonii	0.09
	Gaertnera vaginans	0.08
	Mussaenda frondosa	0.08
	Macaranga peltata	0.02
AR 2A Total		**424.41**
AR 2B	*Hevea brasiliensis*	488.75
	Carallia brachiata	60.08
	Symplocos cochinchinensis	23.74
	Alstonia macrophylla	13.75
	Dillenia suffruticosa	9.01
	Bhesa ceylanica	7.30
	Gyrinops walla	5.15
	Hedyotis fruticosa	3.55
	Syzygium operculatum	3.46
	Syzygium caryophyllatum	3.06
	Artocarpus nobilis	2.59
	Melastoma malabathricum	0.72
	Artocarpus gomezianus	0.67
	Dillenia retusa	0.57
	Bridelia moonii	0.27
	Antidesma pyrifolium	0.23
	Glochidion coriaceum	0.10
	Cinnamomum verum	0.08
	Breynia vitis-idaea	0.06
AR 2B Total		623.14
AR1A	*Hevea brasiliensis*	1016.52
	Alstonia macrophylla	57.39
	Carallia brachiata	36.37
	Acronychia pedunculata	8.21
	Symplocos cochinchinensis	6.81
	Neolitsea lancifolia	3.00
	Syzygium caryophyllatum	2.28

	Dillenia suffruticosa	1.27
	Melastoma malabathricum	0.50
	Syzygium operculatum	0.37
	Clerodendrum infortunatum	0.21
	Erythroxylum indicum	0.11
	Cinnamomum verum	0.08
	Horsfieldia irya	0.04
	Gaertnera vaginans	0.03
AR1A Total		1133.21
AR1B	*Hevea brasiliensis*	605.00
	Symplocos cochinchinensis	7.83
	Pericopsis mooniana	3.73
	Syzygium operculatum	3.56
	Antidesma bunious	1.22
	Carallia brachiata	1.04
	Alstonia macrophylla	0.94
	Dillenia suffruticosa	0.81
	Melastoma malabathricum	0.67
	Dipterocarpus zeylanicus	0.31
	Urandra sp.	0.23
	Gyrinops walla	0.10
	Unknown sp.2	0.09
	Artocarpus nobilis	0.08
	Unknown sp.3	0.06
	Glochidion coriaceum	0.04
AR1B Total		625.70
RE1A	*Alsotonia scholaris*	478.77
	Alstonia macrophylla	455.10
	Hevea brasiliensis	365.79
	Caryota urens	152.73
	Turpinia malabarica	104.08
	Macaranga peltata	1.28
	Clerodendrum infortunatum	0.93
	Artocarpus heterophyllus	0.59
	Litsea longifolia	0.51
	Gliricidia sepium	0.46
	Persea macrantha	0.38
	Ochlandra sridula	0.19
	Thottea siliquosa	0.13
	Nothopegia beddomei	0.10
	Garcinia quaesita	0.09
	Barleria restita	0.07
	Cinnamomum verum	0.04
RE1A Total		1561.23
RE1B	*Artocarpus nobilis*	382.06

	Artocarpus heterophyllus	228.11
	Alsotonia scholaris	227.51
	Pometia pinnata	221.02
	Caryota urens	142.65
	Hevea brasiliensis	60.72
	Symplocos cochinchinensis	42.40
	Bhesa ceylanica	31.16
	Quassia indica	11.51
	Syzygium operculatum	10.67
	Ochlandra sridula	6.92
	Antidesma bunious	1.89
	Myristica dactyloides	1.89
	Antidesma pyrifolium	1.56
	Gaertnera vaginans	1.26
	Cinnamomum verum	1.09
	Cleistanthus sp.	0.91
	Thottea siliquosa	0.37
	Cryptocarya wightiana	0.31
	Coffea arabica	0.23
	Alstonia macrophylla	0.23
	Ficus sp.1	0.06
	Bombax ceiba	0.03
RE1B Total		1374.56
RF1A	*Alstonia macrophylla*	203.03
	Symplocos cochinchinensis	149.05
	Albizia falcataria	103.23
	Syzygium operculatum	53.20
	Alsotonia scholaris	11.48
	Gyrinops walla	8.31
	Syzygium caryophyllatum	4.36
	Clerodendrum infortunatum	2.95
	Acronychia pedunculata	1.57
	Antidesma pyrifolium	0.56
	Cinnamomum verum	0.49
	Carallia brachiata	0.45
	Canthium coromandelicum	0.26
RF1A Total		538.94
RF1B	*Symplocos cochinchinensis*	109.06
	Alstonia macrophylla	51.26
	Alsotonia scholaris	26.90
	Acronychia pedunculata	21.10
	Carallia brachiata	20.74
	Antidesma bunious	14.39
	Elaeocarpus serratus	5.03
	Syzygium operculatum	4.09

	Albizia odoratissima	3.15
	Syzygium caryophyllatum	1.39
	Dillenia suffruticosa	1.16
	Hevea brasiliensis	0.92
	Sandoricum indicum	0.49
	Antidesma pyrifolium	0.45
	Melastoma malabathricum	0.07
RF1B Total		260.19
RF2A	*Symplocos cochinchinensis*	161.33
	Elaeocarpus serratus	157.81
	Mallotus tetracoccus	53.43
	Syzygium operculatum	16.21
	Acronychia pedunculata	12.83
	Syzygium caryophyllatum	6.93
	Horsfieldia irya	2.32
	Alsotonia scholaris	1.40
	Hevea brasiliensis	0.50
	Cryptocarya membranacea	0.48
	Carallia brachiata	0.38
	Alstonia macrophylla	0.17
RF2A Total		413.79
SF1A	*Clerodendrum infortunatum*	141.98
	Trema orientalis	47.64
	Pagiantha dichotoma	22.51
	Carallia brachiata	18.43
	Gyrinops walla	12.81
	Alsotonia scholaris	12.55
	Enicosanthum acuminata	8.01
	Alstonia macrophylla	6.23
	Mallotus tetracoccus	5.66
	Syzygium caryophyllatum	4.90
	Albizia falcataria	4.81
	Syzygium operculatum	1.43
	Macaranga peltata	1.38
	Breynia vitis-idaea	1.26
	Symplocos cochinchinensis	1.19
	Canthium coromandelicum	0.60
	Stereospermum coalis	0.44
	Lantana camara	0.21
	Ochna jabotapeta	0.18
	Litsea longifolia	0.17
	Breynia retusa	0.14
SF1A Total		292.50
SF1B	*Albizia falcataria*	76.55
	Trema orientalis	66.83

	Clerodendrum infortunatum	37.28
	Alstonia macrophylla	8.23
	Caryota urens	7.74
	Alsotonia scholaris	4.89
	Albizia odoratissima	1.01
	Symplocos cochinchinensis	0.71
	Vitex altissima	0.57
	Dillenia suffruticosa	0.30
	Breynia vitis-idaea	0.26
	Carallia brachiata	0.21
	Litsea longifolia	0.06
	Macaranga peltata	0.06
	Artocarpus nobilis	0.06
	Stereospermum coalis	0.04
SF1B Total		204.80
TR2A	*Hevea brasiliensis*	491.65
	Pometia pinnata	3.33
	Syzygium caryophyllatum	3.05
	Carallia brachiata	2.52
	Leea indica	0.96
	Ficus hispida	0.95
	Shorea sp2	0.90
	Garcinia quaesita	0.89
	Cinnamomum verum	0.63
	Shorea ovalifolia	0.62
	Alsotonia scholaris	0.55
	Alstonia macrophylla	0.34
	Melastoma malabathricum	0.33
	Shorea affinis	0.15
	Vitex altissima	0.09
	Symplocos cochinchinensis	0.08
	Coffea arabica	0.05
TR2A Total		507.09
TR2B	*Hevea brasiliensis*	481.04
	Caryota urens	270.50
	Antidesma bunious	7.20
	Bombax ceiba	3.63
	Syzygium caryophyllatum	1.48
	Turpinia malabarica	0.21
	Cinnamomum verum	0.15
	Symplocos cochinchinensis	0.14
	Carallia brachiata	0.13
	Alstonia macrophylla	0.04
	Artocarpus heterophyllus	0.04
TR2B Total		764.56

Grand Total	**8724.11**