IPAC Working Paper ##

A Write UP Report ON Method AND Materials OF CARBON Pools Assessment FOR LAND-Use Carbon Project Document Development Writeshop

BY

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Land-Use Carbon Project Document Development Writeshop

PROTECTED AREAS CARBON ASSESSMENT

Abstracts:

Land use carbon project document development writeshop is aimed to develop carbon project document. An inventory is completed for carbon pools data. The carbon pools are: above ground carbon, below ground carbon, litter, dead organic matters and soil organic carbon. Data are measured under a approved protocols for measuring and reporting carbon stocks. This report is emphasized on field method and methodology for assessing current carbon stocks and analysis technique for assessing future carbon stocks.

Introduction:

Land use carbon project document development writeshop is organized to develop carbon project document (CPD) for 7 protected areas of forest. A carbon project document includes one individual protected area. Protocols for measuring field data for carbon assessment are developed. Field trainings are given to the relevant project personnel to validate protocols. The inventory works on the particular protected area are completed to estimate carbon sequestration, deforestation and degradation of forest. The inventory works are emphasized on methods and methodologies during the measuring of field data collection. Protocols are included carbon assessment, sampling design and plot layout. It is provided the procedure of analysis techniques. Data form format is developed for field data recorded, they are 10 different types. Data for project area, plot location and size, topography, etc., are recorded in land-use category. Trees, saplings, seedlings and bamboos are recorded in volume plot consisting 5 sub-plots. Each sub-plot is 10m radius circular plot and area is 0.03ha. The biomass plot shape is circular and concentric laid out with an iron ring. The leaf, litter, twigs; grasses lying on ground with in the ring are weighted. The sample of 500gm in a poly bag from selected plot has been kept 7 days in the office side for air dry biomass and selective sample has been taken for oven dry weight in laboratory.

The data of different carbon pools collected from field are computerized in data based excel file. The carbon pools are estimated as above ground biomass; a) woody and b) non-woody, below ground biomass, woody debris (dead organic matter), and litter and soil organic carbon. The one-way volume equations are used to calculate over bark volume. The over bark volume is multiplied by 1.2 to get total volume of a tree with foliage. The total biomass of a tree is estimated in kilo gram (kg) by using density of trees. The carbon estimation is done by multiplied biomass with conversion factor 0.5. Carbon assessment for all wood and non-wood above ground are totaled together in tones and then converted to hectare. Below ground carbons are 26% of above ground carbons. Litter, seedlings, bamboos and canes are non-woody biomass. The dead trees, dead sapling, dead seedlings and dead liana have been estimated as woody debris or dead organic matters (DOM). In the case of woody debris and litter are followed same way. Densiometer is used to collect data on canopy.

Carbon stocked with out project is estimated as above ground woody biomass, below ground biomass, dead organic matter, and litter and soil organic carbon.

Method and Materials of Carbon Pools Assessment:

There are 7 protected areas (PAs). Grid maps for all PAs have been supplied and sample plots have been selected for field measuremen. Plot areas of different PAs have been estimated by grid scale with ground. A plot of Meda Kachopia represents area 9.6ha, a plot of Fashiakhali represents 17.6ha, a plot of Rema-Kelanga represents 68.8ha, a plot of Dudpukuria represents area 70.0ha, a plot of Inani represents area123.0ha, a plot of Teknaf represets area 155.0ha and a plot of Sitakunda represents area189.0ha respectively.

An inventory worked has been carried out at 7 protected areas in the year 2010 by the ACF of Forest Department and technical stsff of IPAC. A training course at Savar and field training in Sundarban Natural Forests areas had completed in last year. Field training had validated the developed protocals for measuring carbon stock. The training had included method of plot establishment, trees measurement, and biomass measurement by destructive harvest and canopy covered measurement. Data form format have been developed and prepared for

field work. Field data form for carbon assessment is Form-1, Form-2, Form-3, Form-4, Form-5, Form-6, Form-7, Form-8, Form-9, and Form-12. Plot details including name of project area, plot location, topography, etc., has been recorded in Form-1. Form-2 has been developed for land-use category of 5 sub-plots. Each sub-plot has area 0.1ha of radius 17.84m. Form-3 has been developed to carry out canopy coverage estimation from 4(four) direction (e.g. N, S, E and W) of each sub-plots. Each sub-plot has an area 0.03ha of radius 10m. Form-4 has been developed to record data of seedlings and sapling from each sub-plot. It is concentric sub-plot of volume sub-plot. Each sub-plot for seedling and sapling has an area 0.003ha of radius 3m. The sapling trees have been taken into measurement that the trees having ≤10cm diameter at breast height and height attained ≥1.3m. The seedlings have been considered height not attained 1.3m. Form-5 has been developed to record data of trees from volume plot. The volume plot has 5 sub-plots. The each volume sub-plot is 10m radius and 0.01ha area. All trees the diameter at breast height ≥10cm and heights reached ≥1.3m have recorded by DBH. From volume sub-plot two dominant and co-dominant trees have bee measured. Trees, saplings and seedlings have been recorded live and dead separately. Form-6 has been developed to record data of woody debris. Woody debris has been collected from only volume plot. Woody debris is small, medium, large and extra large branches. In each sub-plot 4 transect lines have been laid out of 10m length each. Form-7 has been developed for data of litter including leaves, bushes and grasses. The litter plot is 0.564m radius, laid out by iron ring and collection method is clipped out vegetation and destructive harvest of weeds. The collected samples of litter have been taken weighted. Form-8 has been developed for soil sample collection data. Form-9 has been used for bamboo sample and cane sample recording sheet. The bamboo plot is also concentric of volume plot. The bamboo plot includes cane. The plot area is 0.005h of radius 4m. The samples of bamboo or cane have been collected by destructive harvested. The weight of bamboo or cane sample has been recorded. Finally form-12 has been developed for seedlings data. Again the plot is concentric. The area of plot is 0.003ha of radius 3m. The sample has been collected by destructive harvest method. The weight of seedling sample has been recorded.

Volume Plots

The volume plot is tree measuring plot of 5 sub-plots. Each sub-plot is 10m radius circular plot and area is 0.03ha. Sapling, seedling, bamboo and biomass plots are concentric plots of volume plot. The shape of volume plot is circular. All trees of DBH 10cm and more with in the volume plot area have been measured. Two trees height of dominant and co-dominant trees have been recorded. Half and more portion of a tree base is on circumference of circular plot then it has been included for measurement. If a tree is on slope, it has been measured from up hill side. The forked trees have been measured, if the forking point is below DBH point then the forked trees have been considered as two trees, if the forking point is at DBH point then the forked trees have been measured 5-6cm below the forked point. The trees in volume plot less than 10cm DBH and heights attained 1.3m and up have been measured as saplings. Only DBH of all saplings have been measured. Similarly, trees/shrubs are not measured as saplings or trees, they have been considered seedlings. Destructive harvest method has been done for seedling sample collection. Trees, sapling and seedlings have been stocked of individual sub-plot made estimation of yield per hectare.

Biomass Plot

The biomass plot shape is circular and concentric. A circular iron ring has been laid out to make biomass plot. Leaf, litter, twigs; grasses lying on ground has been clipped from inside circular iron ring and weighted to estimate biomass. The weight of vegetation on ground from each plot has been recorded as green weight biomass. The sample of 500gm in a poly bag from selected plot has been kept 7 days in the office side for air dry biomass. After air dry some selective sample has been taken for oven dry weight.

Field Data Compilation

The computer entry data of protected areas were stored in database of excel. The stored data have been used for carbon pools estimation. The carbon pools at base line scenario have been estimated as above ground biomass; a) woody and b) non-woody, below ground biomass, woody debris (dead organic matter), and

litter and soil organic carbon. The collected data from different protected areas have checked and verified for making standardization and uniformities. Some data of all protected areas are found non uniformities about spelling and naming of species. To solve the problems, all collected data of trees have been pooled together and sort out with species. To make same standardization and uniformities, spelling has been corrected in all the protected areas. Name of species has been written in local, English and scientific name. Data of trees have been kept in separate spreadsheet. Dead trees have been kept separately. Same processed have been done for sapling. Seedlings, bamboo, cane, banana, liana, etc. have been kept in spreadsheets. In the tree and sapling spreadsheets, there are more than 50 species found in the PAs. The species are:

Acacia, Achar, Amm, Amoloki, Arjun, Amra, Batna, Baen, Badarhola, Bhadi, Bohera, Chalta, Champa, Chapalish, Civit, Chatian, Chikrashi, Damur, Dhaki jam, Eucalyptus, Epil-epil, Gamar, Garjan, Jam, Jarul, Kadam, Kanthal, Keora, Koroi, Lohakath, Mahogony, Mandar, Manjium, Pitraj, Rubber, Raintree, Simul, Sal, Sisoo, Telsur,Teak, etc.

Volume Estimations: The developed volume equations of Bangladesh Forest Research Institute (BFRI) for the important species have been used for volume estimation (Annexure 1). The live trees have been calculated by using available volume equations (Annexure 2). The one-way volume equations have been used as diameter at breast height (DBH) for all trees and saplings have been measured. The sapling volume has been calculated using same volume equations (Annexure 2). Mixed volume equation has been used to calculate volume of some naturally grown trees. The volume equations can calculate volume over bark of a tree but no foliages. The total volume of a tree with foliage has been calculated volume over bark multiplied by biomass expansion factor i. e. 1.2. The volume equations of different species have been used for saplings also. Same method has been used to calculate total volume of a sapling with foliage. The total biomass for a tree or sapling including foliage has been estimated in kilo gram (kg) by using density of specific tree species (Annexure3). Trees have no specific density, 0.67 has been used to estimate the biomass. Biomass of trees or saplings in kg has been estimated in tones. The

carbon estimation in tones has been done with conversion factor 0.5. The total volume of all trees in a sub-plot has been summed up. The sub-plot volume has been divided by sub-plot area to get volume per hectare. Average volume per hectare of 5 sub-plots has been totaled in a plot volume per hectare. Saplings volume per hectare has been estimated in same method. Thus the total biomass in tones and carbon in tones have been estimated.

Data of banana and liana have been collected from PAs of Rema- kalenga in Sylhet. The proposed methodoly have been suggested for them to calculate volume as same as live trees using volume equation of mixed species. Then the total volume and biomass have been estimated. The carbon stocked estimation of banana has been done using conversion factor 0.1 instead of 0.5 due to quick decomposing of banana. The carbon stocked estimation of liana has been done same as trees. The dead banana will not be considered in carbon stocked. The height of live liana is proposed to consider equivalent of attached tree. Dead lianas have been estimated in dead wood matters.

Dead Organic Matters (DOM): The dead trees, dead sapling, dead seedlings and dead liana have been estimated as woody debris. Woody debris is found on standing and lying condition. The standing includes dead trees, dead sapling, dead seedlings and dead liana. The standing DOM includes also dying trees (more than 50% decayed), broken and stumps. Lying DOM includes extra large branches including downed and fallen trees, large, medium and small branches. The standing dead, decayed and broken trees have been estimated same as tree volume and converted to total volume by using biomass conversion factor (1.2). If stumps height is known, they have been calculated using cylindrical formula. Standing dead trees are looked like live or sound but no foliage has been calculated using tree volume equation. Decayed trees top diameters are not known has been calculated using cone formula. Decayed trees top diameters are known has been calculated using cylindrical formula. Biomass of above said woody debris has been calculated by using tree density 0.67. Lying dead wood of soundness or rotten has been calculated using supplied formula that covert to volume per hectare and used wood density to convert biomass. Lying woody debris of extra large branches sound and rotten has been calculated volume per hectare using formulae from protocols of trees measurement (annesure 3) and

then Biomass has been calculated (Biomass = Vol.*density class). Diameter size classes and wood density classes have been given to use for calculating the woody debris of large, medium and small branches. Woody debris of large, medium and small branches have been calculated volume per hectare using formulae from protocols of trees measurement (annesure 3) and then Biomass has been calculated (Biomass = Vol.*density class).

Non-woody Biomass:

1) Litter – Samples of litter from biomass plots have been collected. Weight of green has been measured and recorded. Some selected samples have been collected for air dry and oven dry processed. No results are available, so dummy value (0.47) has been used to estimate biomass of litter in oven dry condition.

2) The seedlings, bamboos and canes have been counted individual from volume plot and recorded in total numbers. Destructive harvesting data of some seedlings, bamboos and canes samples have been collected to estimate biomass of them. But this is not done, so dummy value of seedlings, bamboos and canes (0.7, 1.5 and 1.0 respectively) have been used to estimate biomass of them

Canopy Cover: Densiometer has been used in the field to collect data on canopy. Canopy covered estimation has been calculated as per manuals (Annexure 7).

Carbon Assessment: Woody carbons of all sub-plots in the PAs have been totaled together in tones and counted number of sub-plots. The total carbon has been divided by number sub-plots in the PAs to get carbon tones per sub-plot. The carbon per sub-plot has been divided by sub-plot area (=0.03) then carbon estimation to be carbon tones per hectare. Similarly, non-woody carbons have been estimated and converted into non-wood carbon per hectare. Sum of wood and non-wood carbons have been made above ground carbon per hectare. Same procedures have been followed to estimate carbons of woody debris and litter. Below ground carbons have been converted from above ground carbons multiplied by 0.26.

Baseline: Carbon base line with out project scenario has been included; 1) above ground biomass included wood and non-wood, 2) below ground biomass, 3) woody debris or dead organic matter, 4) litter and 5) soil organic mater.

Carbons of live trees and sapling have made woody biomass. Carbons estimation of seedlings, bamboos, canes and litter has been summed together to non-woody biomass. Total of woody and non-woody carbons has been become above ground biomass. The below ground biomass has been estimated as above. All dead wood materials of trees, sapling, seedling, decayed, broken, stumps etc. have been made biomass of woody debris. Litter and soil biomass have been estimated with the same procedures. Carbon pools have been estimated of total biomass of 5 lined up biomass pools and deducted the removal carbons, this is called preliminary baseline or initial carbon stock.

Land Use Category: A table has been made with plots and land use category wise to estimate the total of individual pools (Annexure 5). Woody and non-woody biomass has been calculated in above ground biomass. All carbon pools have been tabulated pot wise. All pools have been summed up individually. The total carbon in tones has been divided by total hectare areas to get average carbon tones per hectare across the project areas. The average carbon pools have been pulled over the project areas that would be the total carbon in tones that is the initial carbon stock of the project.

Additionality: Carbon stocked has been pooled over time series with out project, the scenario of trend declined. Project activities and planned have been taken as per management plan resulted changed carbon stocked. In project period the projected carbon stocked has increased over time, scenario has been changed due to additionality (Annexure 4). Suppose additionality would be increased 40% in 4yr. Every year it is increased 10%.

Tests of pool significance: The pooled items have been ranked from highest to lowest in tones carbon (tc). Individual carbon pools have been made percent as part of total. The pooled items have been added % of pools from top rank down up to 95% then stopped. If one or two pooled items have been laid out side the 95% level, the out layer pooled items may excluded. The carbon inventory in future would not include the excluded pool items for assessment.

Carbon stocked with out project is above ground woody biomass, below ground biomass, dead organic matter, litter and soil organic carbon. Conversion ratio with above ground biomass and other carbon pools biomass with out project can be calculated like BGB: AGB. Similarly other pools ratios are DOM: AGB, LR : AGB and SOC: AGB. Carbon stocked with project has above ground biomass. The conversion ratios can use to estimate below ground biomass with project. The other carbon pools with project can also be estimated.

Annexure 1

Table: Volume Equations of Important species

1.	Kanak		Schima Wallichii	ln(V) = exp(2.337*ln(D)-8.5703)	
2.	Chapalish			ln(V)=exp(2.24074*ln(D)-8.179774)	
3.	Bohera			ln(V)=exp(2.1338*ln(D)-8.0446)	
4.	Teak			ln(V)=exp(2.12337*ln(D)-7.566916)	
5.	Akashmoni			ln(V)=-8.208+2.2389*ln(D)	
6.	Mangium			ln(V)=-8.209+2.2178*ln(D)	
7.	Jam			V=0.00506138D^2+0.00217385-0.00111102*D	
8.	Gamari			ln(V)=exp(2.1472*ln(D)-7.9022697)	
9.	Garjan			ln(V)=exp(2.35556*ln(D)-8.5116354)	
10	Chapalish			ln(V)=exp(2.24074*ln(D)-8.179774)	
11.	Bhadi			ln(V)=exp(2.08627*ln(D)-7.574983) (mixed of Chickrassi, Lohakath, Champaful)	
12.	Koroi			ln(V)=exp(2.463398*ln(G)-12.093533)	
13.	Mehagoni			ln(V)=exp(2.460647*ln(G)-12.045383)	
14.	Kadam			ln(V)=exp(2.32592*ln(G)-11.6329)	
15.	Jackfruit			ln(V)=exp(2.18203*ln(G)-11.06320)	
16.	Sal			ln(V)=exp(2.51789*ln(D)-9.1727759)	
17.	Civit			ln(V)=exp(2.14002*ln(D)-7.631146787)	
18.	Bohera			lnV)=exp(2.1338*ln(D)-8.0446)	
19.	Chundul			ln(V)=exp(2.0291*ln(D)-7.077637)	
20.	Mango			ln(V)=exp(2.24506*ln(G)-11.27269)	
21.	Neem			ln(V)=exp(2.25814*ln(G)-11.33340)	
22.	Eucalyptus			ln(V)=exp(2.297689*ln(G)-11.177929)	
23.	Shimul			ln(V)=exp(2.3088*ln(D)-8.4630)	
24.	Banderhola			ln(V)=exp(2.4987*ln(D)-9.2929)	
25.	Urium			ln(V)=exp(2.337*ln(D)-8.5703)	
26.	Kanak/Banak			ln(V)=exp(1.6912*ln(D)-6.3428)	
27.	Pine			ln(V)=exp(2.410755*ln(D)-8.7854)	
28.	Pitraj			ln(V)=exp(2.4781*ln(D)-9.2157)	
29.	Sissoo			ln(V)=exp(2.49978991*ln(G)-12.14678171)	
30.	Rain Tree			ln(V)=exp(2.5086408*ln(G)-12.287524)	
31.	Mixed SPP			ln(V)=exp(2.08627*ln(D)-7.574983) (mixed	

				of Chickrassi, Lohakath, Champaful)	
	Achargula			do	
	Amloki			do	
	Amra			do	
	Arsol			do	
	Ata			do	
	Barta			do	
	Boilan			do	
	Boroi			do	
	Bot			do	
	Chamafal			do	
	Chatian			do	
	Chikrassi			do	
	Gab			do	
	Guava			do	
	Gutgatia			do	
	Haritaki			do	
	Hijol			do	
	Holdu			do	
	Kajubadam			do	
	Kakra, Arsol			do	
	Kamdeb			do	
	Kamranga			do	
	Katbadam			do	
	Kawgula			do	
	Koros			do	
	Krishnochura			do	
	Lebu			do	
	Litchi			do	
	Lohakat			do	
	Mander			do	
	Narikel			do	
	Pitali			do	
	Ronge			do	
	Telsur			do	
	Toon			do	
	Ujalpata			do	
32.	Keora			V=-0.0360+0.000558967*D^2	
33.	Arjun			ln(V)=exp(2.222144*ln(G)-11.1885)	

Annexure 2

Sample calculation of volume:

Ln V = b*Ln(DBH) – a

Where, V= Volume of individual tree (cum), Ln = log base e and DBH = Diameter taken in the field at 1.3m/ breast height, a is regression constant and b is regression co-efficient.

How to calculate volume of individual tree:

Vtob = EXP(2.08627*LN(12) -7.574983

Where, Vtob= Volume of individual tree, Exp = exponential function, DBH = Diameter taken in the field at 1.3m/ breast height, -7.574983 a is regression constant, 2.08627 is regression co-efficient and cum = cubic meter.

Table: Volume of trees

Plot	Sub-plot	Species	DBH (cm)	Vtob (cum)
1	3	Agar	12.9	0.002075379
2	2	Agar	12.0	0.002075379
3	4	Agar	22.7	0.004075379
4	4	Agar	13.9	0.002777019
5	3	Agar	15.2	0.01599569

How to calculate volume of individual sapling:

Vtob(s)= EXP(2.08627*LN(2.7)-7.574983

Where, Vtob(s)= Volume of individual sapling.

Table: Volume of sapling

Plot	Sub-plot	Species	DBH (cm)	Vtob (cum)
1	3	0	0	
2	2	0	0	
3	4	Agar	2.7	0.00075379
4	4	Agar	3.9	0.000777019
5	3	Agar	5.2	0.00099569
58	3	Agar	2.2	0.002058354

Annexure 2

How to calculate total volume for a tree with foliage:

Vtf = (Vtob) * 1.2

Where, Vtf= Volume of individual tree with foliage, Vtob= Volume of individual tree or sapling.

Table: Total Volume

Plot	Sub-plot	Species	DBH (cm)	Vtob (cum)	Vtf (cum)
58	3	Dumur	4.5	0.011830534	0.01419664
58	1	Dumur	1.7	0.001552406	0.00186289
57	1	Fennikata	2.4	0.003187499	0.00382500
60	2	Garjan	3.5	0.765538784	0.91864654
60	2	Garjan	1	0.002120559	0.00254467

How to calculate total biomass for a tree/sapling in tones:

Bio(t) = (Vtf) * Density of tree species/1000

Where, Bio(t) = Biomass of individual tree or sapling in tones.

Table: Total Biomass

Plot	Sub-plot	Species	DBH (cm)	Vtob (cum)	Vtf (cum)	Biomass(ton)
58	3	Dumur	4.5	0.011830534	0.01419664	0.000961295
58	1	Dumur	1.7	0.001552406	0.00186289	0.000832425
57	1	Fennikata	2.4	0.003187499	0.00382500	0.00000769
60	2	Garjan	3.5	0.765538784	0.91864654	0.00000987
60	2	Garjan	1	0.002120559	0.00254467	0.001939631

How to calculate total carbon for a tree/sapling in tones:

Carbon(t) = Bio(t) * 0.5

Where, Carbon (t) = Carbon of individual tree or sapling in tones.

Table: Total carbon

Plot	Sub-plot	Species	DBH (cm)	Vtob (cum)	Vtf (cum)	Biomass(ton)	Carbon (ton)
58	3	Dumur	4.5	0.011830534	0.01419664	0.000961295	0.00048
58	1	Dumur	1.7	0.001552406	0.00186289	0.000832425	0.00043
57	1	Fennikata	2.4	0.003187499	0.00382500	0.00000769	0.00000
60	2	Garjan	3.5	0.765538784	0.91864654	0.00000987	0.00000
60	2	Garjan	1	0.002120559	0.00254467	0.001939631	0.00096

Annexure 2
Table: Trees

PA	Pl0t	Species	DBH(cm)	Vtob (cum)	Vtf (cum)	Carbon (tones)	Carbon (tones)/ha
RKWS	39	Kakra	11.0	0.076357423	0.091628908	0.030695684	
RKWS	39	Bohera	14.0	0.089512279	0.107414735	0.041891746	
RKWS	39	Dumur	10.5	0.069295221	0.083154265	0.049892559	
RKWS	39	Bohera	39.2	0.805431148	0.966517377	0.376941777	
RKWS	39	Bohera	10.4	0.047470122	0.056964147	0.022216017	
RKWS	39	Kakra	18.2	0.218310226	0.261972272	0.087760711	
RKWS	39	Dunra	10.2	0.065228736	0.078274483	0.026221952	
RKWS	39	Bonak	16.2	0.19538389	0.234460668	0.140676401	
RKWS	39	Bonak	11.3	0.106248602	0.127498322	0.076498993	
RKWS	39	Bonak	31.9	0.614564915	0.737477898	0.442486739	
RKWS	39	Kainula	12.8	0.104752797	0.125703356	0.042110624	
RKWS	39	Kakra	11.2	0.079282444	0.095138933	0.031871542	
RKWS	39	Kawa	21.5	0.309067307	0.370880769	0.124245058	
RKWS	39	Bonak	13.2	0.138188401	0.165826082	0.099495649	
RKWS	39	Jam	14.4	1.035702919	1.242843503	0.416352573	
RKWS	39	Mehagoni	14.2	0.067211088	0.080653306	0.027018858	
RKWS	**39**	**Bohera**	**16.3**	**0.123834177**	**0.148601012**	**0.057954395**	**163.1418283**
RKWS	58	Dumur	15.0	0.145837964	0.175005557	0.105003334	
RKWS	58	Belpai	61.0	2.72211681	3.266540172	1.094290958	
RKWS	58	Kakra	12.0	0.091556336	0.109867603	0.036805647	
RKWS	58	Jam		0.00217385	0.00260862	0.000873888	
RKWS	58	Jarul	13.0	0.303288	0.3639456	11.1003408	
RKWS	58	Pistli	23.0	0.355761228	0.426913473	0.143016013	
RKWS	**58**	**Pistli**	**12.0**	**0.091556702**	**0.109868042**	**0.036805794**	**546.6787568**

Annexure 2
Table: Sapling

Plot	Species	DBH (cm)	Vtf cum	Biomass (tones)	Carbo (tones)	Carbon (tones)/ha
58		9.0	0.00061575	0.000412556	0.000206278	
57		6.5	0.00382500	0.002562749	0.001281374	
58		4.2	0.00289497	0.001939631	0.000969816	
63		1.5	0.00489045	0.003276604	0.001638302	
63		5.4	0.00143477	0.000961295	0.000480647	
39		1.5	0.00004995	3.3467E-05	1.67335E-05	
39		3.4	0.00289497	0.001939631	0.000969816	
58		4	0.00061575	0.000412556	0.000206278	
58		1.6	0.00106445	0.00071318	0.000356590	
58		0.7	0.00014500	9.71523E-05	0.00004858	
60		1.8	0.00840390	0.005630612	0.002815306	
60		3.5	0.04964441	0.033261755	0.016630877	
60		3.5	0.00061575	0.000412556	0.000206278	
60		4.5	0.00029258	0.000196027	0.00009801	

60		1	0.00014500	9.71523E-05	0.00004858	
60		1	0.00143477	0.000961295	0.000480647	0.031716944
57		0.9	0.02076725	0.01391406	0.00695703	
63		0.5	0.00143477	0.000961295	0.000480647	
58		1.5	0.00791073	0.005300188	0.002650094	
58		0.7	0.01110370	0.007439477	0.003719739	
58		1.8	0.00164156	0.001099847	0.000549923	
63		3.5	0.00029258	0.000196027	9.80134E-05	
57		3.5	0.00209882	0.00140621	0.000703105	0.049745035
39		4.5	0.00840390	0.005630612	0.002815306	0.117015008
63		1	0.00840390	0.005630612	0.002815306	
63		1	0.01419664	0.009511749	0.004755875	
58		0.9	0.00061575	0.000412556	0.000206278	
58		0.5	0.00061575	0.000412556	0.000206278	0.127540506
63		1.5	0.00049425	0.000331147	0.000165573	
63		0.7	0.00014500	9.71523E-05	4.85761E-05	0.026700967

Annexure 3

Specific gravity of timber species of Bangladesh

Species	Density	Species	Density	Species	
Chapalish	0.49	Bohera	0.78	Mixed	0.67
Bohera	0.78	Chundul	0.36		
Teak	0.61	Mango	0.54		
Akashmoni	0.70	Neem	0.76		
Mangium	0.56	Eucalyptus	0.68		
Jam	0.67	Shimul	0.67		
Gamari	0.44	Banderhola	0.46		
Garjan	0.78	Urium	0.54		
Chapalish	0.49	Kanak/Banak	0.72		
Bhadi	0.65	Pine			
Koroi	0.73	Pitraj	0.54		
Mehagoni	0.67	Sissoo	0.74		
Kadam	0.47	Rain Tree	0.59		
Jackfruit	0.49	Bohera	0.78		
Sal	0.82	Chundul	0.36		
Civit	0.61	Mango	0.54		
Bohera	0.78	Neem	0.76		
Chundul	0.36	Eucalyptus	0.68		
Mango	0.54	Shimul	0.67		
Neem	0.76	Banderhola	0.46		
Eucalyptus	0.68	Urium	0.54		
Shimul	0.67	Kanak/Banak	0.72		
Banderhola	0.46	Rain Tree	0.59		
Urium	0.54	Pitraj	0.54		

Kanak/Banak	0.72	Sissoo	0.74		
Pitraj	0.54	Keora	0.56		
Sissoo	0.74	Arjun			
Rain Tree	0.59	Jarul	0.61		

Annexure 3.

Procedure of Carbon Pools.

Carbon Pools

1. Above : ground biomass
   a) woody biomass — trees + saplings
   b) non-woody biomass — seedlings, bamboo, cane

2. Below ground biomass (tc/ha)
3. Dead organic biomass (tc/ha)
4. Litter (tc/ha)
5. Soil organic biomass (tc/ha)

Total biomass (tonnes)
Removals
Baseline

Dead organic matter (DOM)

1. Standing DOM
2. Lying DOM

1. Standing DOM includes
   - dead trees/seedlings
   - dying tree (more than 50% decayed)
   - snags/broken trees
   - stumps

2. Lying DOM includes
   - extra large branches
   - downed trees/fallen trees
   - large branches
   - medium branches
   - small branches

1.1. Standing dead, decayed broken
- measure same as trees volume * BCEF=m^3 (biomass conversion & expansion factor 1.2)
- also for stumps where ht. known
- decomposition classes:

1. looks like live trees except no live foliage
2. decaying
    - estimate volume using formula for cone if top dia. unknown
    - estimate volume using formula for cylinder if top dia. known

B (biomass) =1/3π* $\left(\frac{B.d}{200}\right)^2$ *ht*density class (0.67)

Complete for each tree of sum by plot

2. <u>lying dead wood:</u>

Step 1: sort by density (or soundness) state

a. sound
b. rotten

$$V = \pi^2 * \left(\frac{\sum_{n=1}^{N} dia^2}{8 * L} \right)$$

(Where N= # pieces, L= transect length)

Convert to volume per ha. for each plot (not spp.)
Biomass = Vol.*density class

Extra large branches:

$$V = \pi^2 * \left(\frac{diam1^2 + d2^2 + d3^2 + ...dn^2}{8 * L} \right)$$

Small, medium & large branches:

$$V = \pi^2 * \left(\frac{Ni * QDMDi^2}{8 * L} \right)$$

m^3/plot

Ni= # pieces of size class:
QDMDi = quadratic mean diameter of size class i

Small: 0.45 length = 2m

Medium: 1.20 length = 5m

Large: 3.17 length = 10m

t/ha
Biomass = vol.*density class

extra large: sound 0.39 small = 0.59g/cm^3
rotten 0.24 med. = 0.54
large = 0.48

Canopy Cover

Densiometer readings

Dots counted
*
1.04
Divide by 100 = %
1-not occupied
=% cover
Add % cover per N, E, S, and W
In each subplot

Divide by 4 = avg. %/subplot

Avg. all 5 subplots to give % cover per plot

Carbon Assessment

- total carbon (ton)/plot
- c (tones)/plot
- plot area (=0.03 ha) trees $\left(A = \pi r^2 = \pi 10^2\right)$ for 10 m radius subplot

$=\left(\frac{ctonnes}{ha}\right)$

3m radius (0.003 seedlings, saplings)
4m radius (0.005 bamboo & cane)

Baseline

- below ground (temporary) 0.26 *woody + non-woody above ground biomass
- temporary values for litter pool 0.47*green weight of litter in plot
- temporary values for soil organic c pool 12.16 t/ha
- preliminary baseline (initial carbon stock)
- tests of pool significance
- initial (interim) C stock pending lab result for DOM, Litter, SOC

tc/ha

Trees	Sap	AGB Woody	Seed	Bamboo	AGB n-w	BGB	DOM	Litter	Soc
Plot 1									
.									
.									
.									
Plot (n)									

total tc/ha $\frac{\text{sub total}}{\text{n}}$

Avg. tc/ha ∑all c pools

Avg. c/ha¯1 across project area

$\frac{\text{*\#ha in project area}}{}$

Total c =initial c stock

$\frac{c}{ha} x \frac{ha}{1} = c$

Annexure 4

Table: Mean Annual Increment

Species	**Ref.**	**MAI (m³/ha/yr)**
Teak	FD	4.8
Garjan	FD	11.0
D. Jam	FD	5.4
Eucalyptus	BFRI	8.64
Akashmoni	BFRI	8.67
Gamar	BFRI	11.5
Bokain	BFRI	0.71
Pine	BFRI	0.144
Kadam	BFRI	0.114

Additionality: Strata – 1, Long Rotation Plantation

Species	Particulars	Year0	Year1	Year2	Year3	Year4	Total
Teak	Area	0	17.5	35	52.5	70	70
	Vol (m3/yr)	0	28	56	84	112	140
	Biomass (ton/yr)	0	17	34	51	68	85
	Carbon (ton/yr)	0	8.5	17	25	34	42
Chapalish	Area	0	17.5	35	52.5	70	70
	Vol (m3/yr)	0	36	72	108	144	181
	Biomass (ton/yr)	0	17	35	53	70	88
	Carbon (ton/yr)	0	8	17	26	35	44

Reforestation:

Species	Area to be planted	Ha/year	# Years	MAI m3/ha/yr	Biom. Con. Fac.	Biom. Accum m3/ha/yr	C t/ha/yr
Teak	Core	20	20	0.27	0.61	0.18	0.09

Annexure 5

LUC

	a b w Trees Sab AGB tc/ha tc/ha	c d n-w seed Bam AGB tc/ha tc/ha
plot 1 plot 2 plot 3 . . .plot n	a+b trees+saplings	c+d+..... seed+bamboo+.....

Simplified test for significance:

1. Rank all pools from highest to lowest (tc)
2. Calculate % of each pool as part of total
3. Begin adding % of pools from top rank down
4. Stop when total is large than 95%

Example:

- 37% woody biomass
- 26% below ground biomass
- 15% non-woody biomass
- 12% DOM
- 7% SOC
- 3% Litter
- 100% excluded

$$\frac{AGWB}{Total} = \%$$

Annexure 6

Activity Plan:

Reforestation	ha/yr	# yrs	MAI m^3/ha/yr	Biomass conversion factor	Biomass accumulate kg/ha/yr	C t/ha/yr
Activity 1						
spp 1						
spp 2						
spp 3						
Activity 2						
spp 1						
spp 2						
spp 3						
Activity n						
spp n						

Additionality:

Activity 1	yr0	yr1	yr2	----------	yr20	sum(∑)
spp a		ha1	ha2	----------	ha20	
m^3/ha/yr	Vol.0	"	"	"	"	
Biomass accumulation kg/ha/yr	B.0	"	"	"	"	
tc/ha/yr	C.0	"	"	"	"	
spp b	same block of formulas change to correct values					
Activity 2	do					
spp a	do					
spp b	do					

Initial
C stock

Woody
Non woody
Below ground biomass
Dead organic matter
Litter
Soil organic matter
Woody-7325
BGB-2.712
BGB=2.712/7325 (ratio)
= .3702
= .37
=.37*5119=1895.25

With Project
C stock

Avg.
Woody 5119

sum of 20 years + initial
20
=Avg/year

Leakage:

GHG emissions occurring out side project area that are 1) measurable 2) attributable to project activity.

Measurements:

- Offence reports
- Social survey
- Targeted extractor surveys
- Extrapolate research results
- market volume analysis
- Remote sensing
- Threat reduction assessment
- Permitted harvest records

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