Assessment of Net Carbon Benefit for Emiti Nibwo Bulora project in Kagera, Tanzania (Final Version)

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Summary

This study was undertaken to assess the net carbon benefit of reforestation and agroforestry activities being undertaken by participating communities as part of the Emiti Nibwo Bulora Plan Vivo project in Kagera region of Tanzania. The approach for estimating the long-term carbon benefit of reforestation and agroforestry activities (used to generate Plan Vivo certificates) is based on average net increase of carbon storage in biomass and forest products over a 25 year crediting period relative to the baseline. The results of this study for four land use systems (technical specifications) are shown in Table 1. The reforestation and agroforestry activities described in the technical specifications are only eligible for establishment on smallholders or community land which is either currently cultivated or neglected. These systems are not applicable for establishment on land that already supports natural forest cover.

Table 1: Summary of results of assessment of net carbon benefit of Emiti Nibwo Bulora land use activities in Tanzania

Technical Specification	Sink (tC/unit area)	Baseline (tC/unit area)	Net (tC/unit area)	Buffer (%)	Tradeable (tC/unit area)	Tradeable (tCO2/unit area)
Woodlot (per hectare)	50	2	48	20%	38.4	140
Dispersed interplanting (per hectare)	23	2	21		16.8	61
Boundary planting (per 100 meters)	2	0.06	1.9		1.5	5.6[a]
Homestead Fruit orchard (per hectare)	8	2	6		4.8	17

N.B A factor of ~3.67 is applied to convert carbon (C) to carbon dioxide (CO_2) by dividing carbon value by 12, then multiplying the output by 44.

1 Introduction

To generate emissions reduction credits (referred to as carbon credits, carbon offsets, emission reductions and Plan Vivo certificates) land use change and forestry projects must create real, measurable and long-term benefits related to the mitigation of climate change, and must be additional to the baseline scenario that would occur in the absence of the project activity[b] (Figure 1). It is therefore necessary to determine carbon stocks at project inception, and the predicted change in carbon stocks in the absence of the project activities. No published tree growth data was available to calculate the carbon sink potential of the project activities, nor is it possible to measure every tree in the project area to determine the carbon baseline. A sampling approach is therefore necessary to determine the net long term carbon benefit of the project activities. The choices and assumptions made during sampling must be transparent, and contribute to a conservative estimate of the sink and baseline

[a] 1 decimal place maintained for tradeable tCO_2 under the boundary planting land use system because net carbon gain is relatively low and rounding down would result in significant decrease in carbon offsets by >10%.
b Kyoto protocol, Article 12.5b,c http://unfccc.int/kyoto_protocol/items/2830.php

carbon stocks. It is also important that the cost of sampling, and required expertise, do not exceed those which can be supplied by the project. The methodology used (Berry, 2008) was designed to ensure that sampling provides a robust estimate of the carbon stocks[c], with minimal reliance on external resources and expertise.

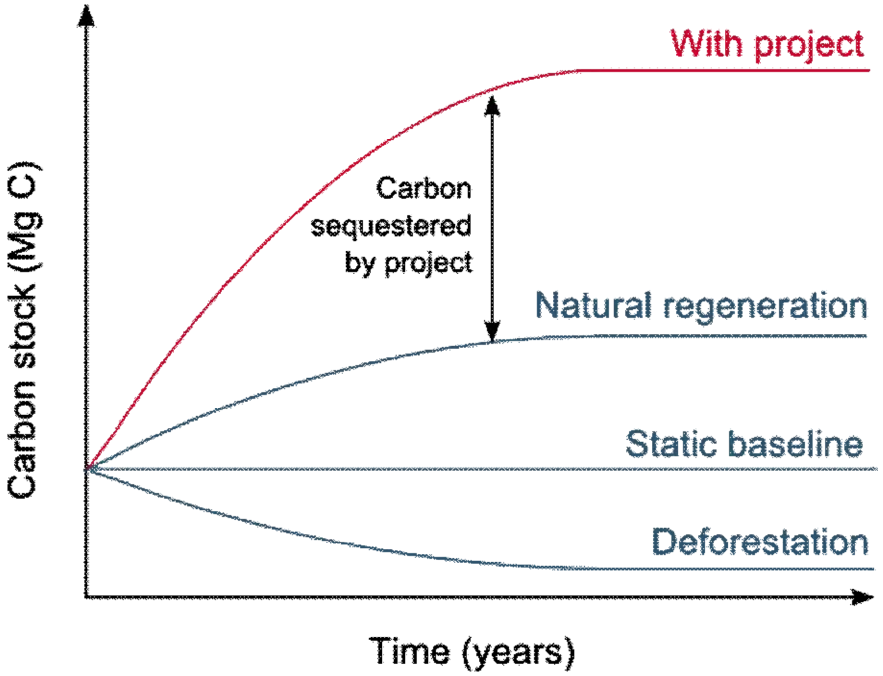


Figure 1: Projection of changes in carbon stocks over time

The carbon offset by the project is equal to the difference between the carbon sequestered by the project, and the baseline. A static baseline applies to projects where the current land use is unlikely to change in the absence of project activities (for example for planting agroforestry trees on agricultural land). If carbon would be accumulated in the absence of project activities the baseline will have to account for this natural regeneration. If deforestation is expected in the absence of intervention in the project area, a reduction in carbon stocks with time is the appropriate baseline against which to record carbon sequestration[d] .

2 Assessment of baseline carbon stocks

The carbon pools measured as part of the assessment of the baseline carbon stocks for Emiti Nibwo Bulora Plan Vivo project in Kagera Region of Tanzania were those stored by trees (>7cm dbh). This includes carbon pools in the tree stem, branches and roots. This assessment does not include baseline carbon stocks in leaf litter and dead wood, soil and non tree vegetation.

The project area was stratified according to two land use categories for baseline data collection: cultivated land and neglected land.

c Marrakesh accords http://unfccc.int/cop7/documents/accords_draft.pdf
d For information on determining baselines involving deforestation see the ECCM report "Determining baselines for avoided deforestation projects"

- Cultivated land typically is cultivated using annual crops (such as maize, groundnuts beans etc.) and perennial crops such as banana whilst isolated trees may occur (either planted or naturally).
- Neglected land is typically found on hillsides. The high forest has been removed and the remaining vegetation is highly degraded. ÒNeglectedÓ areas are typically used for pasture, firewood collection etc.

2.1 Data collection methods

For cultivated areas a complete survey of all trees > 7 cm dbh in areas where Emiti Nibwo Bulora planting has occurred (2007 Ð 2008) or planting was planned as part of the Emiti Nibwo Bulora Plan Vivo project in 2008 Ð 2009 (i.e. this sample included all 24 of the pilot project farms).

For neglected land two methods were used: where the size of land was less than 2 ha, a full survey was undertaken (i.e. all trees with dbh>7cm on the potential planting areas were measured). On large tracts of land (>2ha), nested sample plots of 0.01, 0.05 and 0.1 ha located in areas where project planting is planned were used to survey all trees > 7 cm dbh. 56 plots were surveyed on one such site covering 41.5 ha, with plots locations determined on a regular grid with spacing of at least 50 metres between sample plots as shown in Figure 2 below. The innermost plot was 0.01ha, within which all trees above 7cm dbh were surveyed. In the next plot (0.05ha), all trees with dbh≥20cm were surveyed and lastly, in the outer plot (0.1ha), all trees with dbh≥50cm were surveyed.

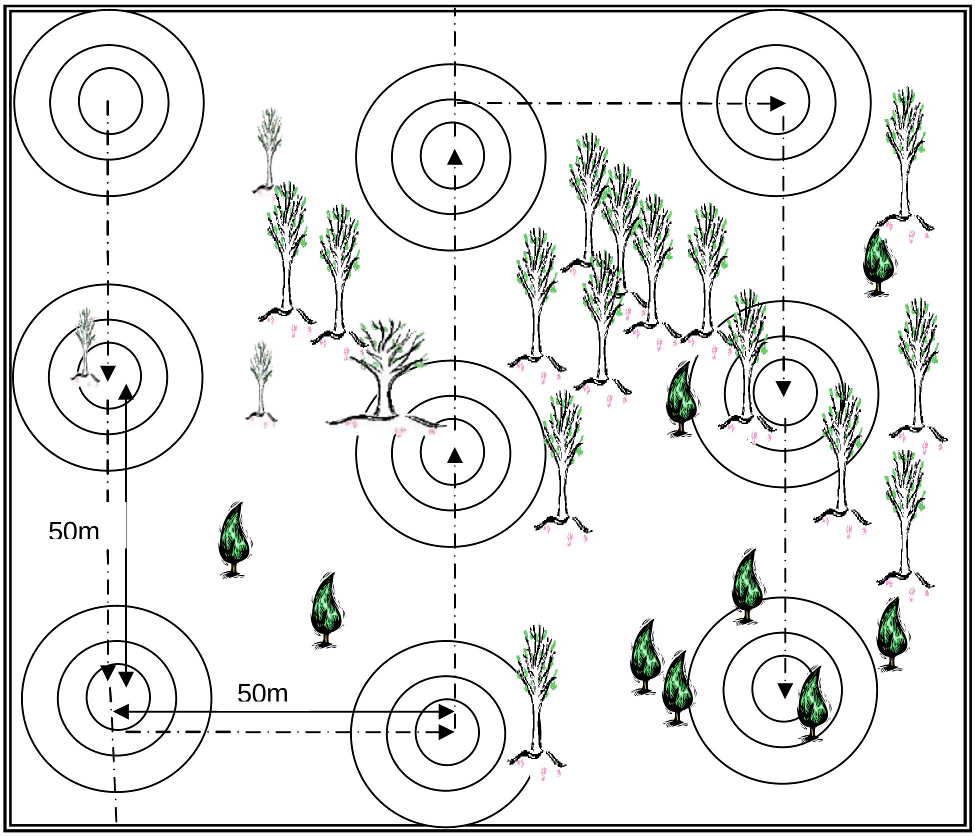


Figure 2: Layout of nested sample plots (0.01, 0.05 and 0.1ha).

The carbon stock (C; in kg) in above and below ground woody biomass was estimated for each tree with the equation:

$$C = \sigma\left(\frac{\pi\left(\frac{D}{200}\right)^{2} H}{\theta}\rho b\right) r$$

Where σ is the estimated carbon content of woody biomass (47%[e]), *D* is the diameter of the tree in cm at 1.3 m above ground level, *H* is the height of the tree in m, θ is a form factor to account for the taper of the stem when estimating stem volume (a value of 3 was used to estimate stem volume as the volume of a cone[f]), ρ is the wood density of the tree species[g] in kg m^{-3}, *b* is an expansion factor to account for the carbon content of branches (a value of 1.2 was used based on the assumption that the biomass of branches is 20% of stem biomass[h]), and *r* is an expansion factor to account for the carbon content of belowground biomass (a value of 1.25 was used based on the assumption that the root biomass is 25% of aboveground biomass[i]).

The carbon stock of all trees was summed and divided by the area sampled to give an estimate of carbon density in tC ha^{-1} prior to project intervention for each cultivated area, or sample plot on neglected land.

2.2 Results of baseline survey

2.2.1 Pilot study to determine number samples necessary

The usual method used in determining the number of samples is to calculate the variation in carbon stocks from an initial survey of ten or more potential planting areas on cultivated land, and on neglected land (Pearson 2005). However, in this case, the number of pilot farmers currently engaged in the project (2008) was only 24 and therefore all of these pilot planting sites were surveyed (100% survey). An additional 5 sites belonging to farmers who might be included in future project expansion were surveyed, bringing the total number of surveyed sites to 29 (the inclusion of these additional plots was purely based on time availability).

2.2.2 Baseline survey

10 cultivated areas, 18 uncultivated areas, and 56 plots in an area of degraded forest covering were surveyed (see Table 2 for details). The baseline survey was carried out in Nyakayanja, Nyaishozi, and Nyabiondo where farmers included in the pilot project are located.

e 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use, Chapter 4 (Forest Land)
f http://www.farmforestline.com.au/pages/6.5_standing_tree.html
g http://www.worldagroforestry.org/resources/databases/agroforestree
h Pearson (2005)
i 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use, Chapter 4 (Forest Land)

Table 2: Summary of site description for baseline survey

Land use type	No. of sites surveyed	Ha	No. of trees measured	Survey method	Comments
Cultivated	10	9.1	350	Full	Consists of planted or and un-harvested naturally growing trees
Uncultivated (a)	18	19	560	Full	Land never cultivated or left fallow for >10years
Uncultivated (b)	1	41.5	180	Nested plot sampling	Significantly higher carbon baseline. Excluded from carbon modelling. 56 nested plots
TOTAL	29	69.6	1090		

Figure 3 below shows the spatial distribution of the sites surveyed with their associated carbon baseline values (in tCO_2/ha).

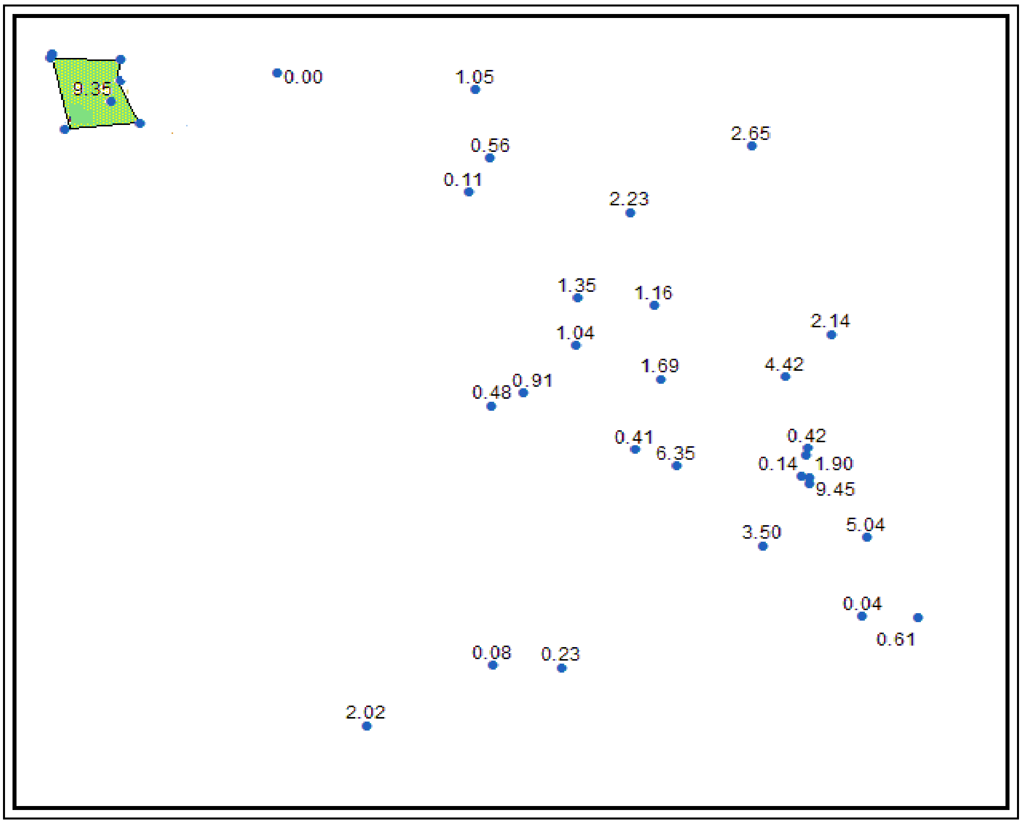
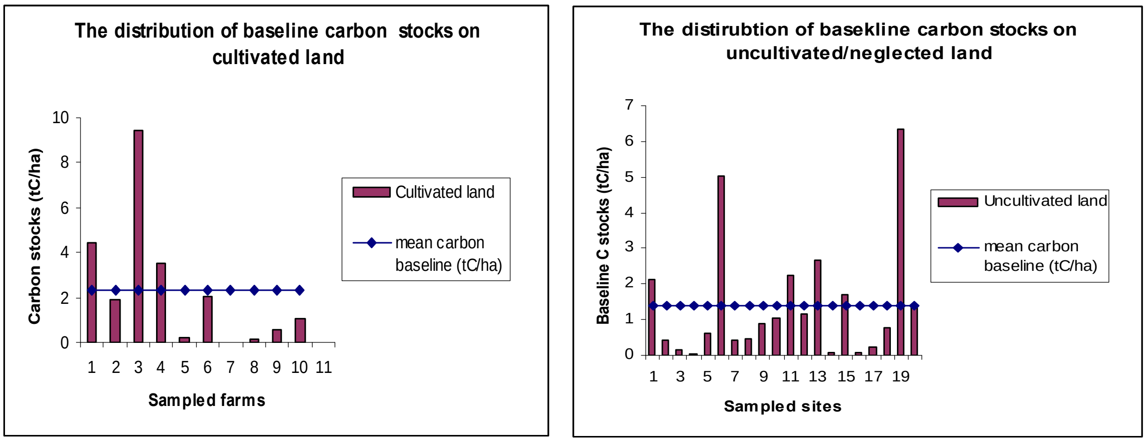


Figure 3: Spatial distribution and carbon stocks of proposed planting areas surveyed for the estimate of carbon stocks in cultivated and uncultivated areas prior to project intervention. (Baseline Carbon values in tC/ha are shown alongside each point).

The results of the baseline carbon assessment are shown in figures 4 and 5 below.



Figures 4 & 5: The distribution of baseline carbon stocks on cultivated and uncultivated/neglected lands

The carbon density on both cultivated and uncultivated lands is quite variable. In the case of cultivated lands, this depends on the level to which individual farmers have undertaken tree planting, or the number of trees left standing when virgin land is cleared for farming. On neglected lands this is a function of the extent of degradation individual sites have been subjected to.

Although the mean carbon density in cultivated land was slightly higher than that on uncultivated land, the difference was not statistically significant. Statistical analysis first involved performing an F-test assuming unequal variance. The two-sided F test was not significant (F statistic of 3.056196 against critical value of 2.510158) and therefore there was no need to assume unequal variances hence allowing a t-test to be performed for the purpose of mean comparisons.

A t-test conducted assuming equal variance, gave a t - statistic of 1.120135 against critical (two-tailed) t - value of 2.048407 and hence the null hypothesis was accepted (i.e., that there was no difference in the mean carbon values between cultivated and uncultivated land). Therefore, a pooled mean baseline value of 1.74 tC/ha (rounded to 2 tC/ha) was recommended.

Two values for carbon stocks in both cultivated and uncultivated areas prior to project intervention are therefore recommended:

- 2 tC ha^{-1} for woodlots, fruit orchards, and dispersed interplanting; and
- 0.06 tC m^{-1} for boundary planting (100m of boundary planting is assumed to be 2.97% of a hectare and therefore the baseline value of 2 tC^{-1} was multiplied by 0.0297 to get the baseline per 100 metre).

However, the baseline on the 41.5 - ha site in Nyabiondo (shaded green in Figure 3 above) where plot sampling was used is higher, at 9.35 tC/ha. The site is considered a valuable ecosystem (see picture below) which is already supporting forest cover[j] of indigenous tree species that should ideally be maintained and/or improved using other methods, such as

[j] Forest cover is defined as area exceeding 0.25 hectares, canopy cover of more than 30% and tree heights of at least 4 – 7 meters

enrichment planting with indigenous species. Under the Plan Vivo system, no indigenous species on the site are allowed to be cut, and it is appreciated that this might not be commercially viable to the farmer as he can only then plant a few commercial trees in the gaps without trees. The site is therefore considered unsuitable for reforestation using the agroforestry systems designed for the project to date, i.e. Fruit Orchard, Boundary Planting, Dispersed Interplanting and Woodlot and is not included in the subsequent carbon baseline or carbon sink calculations which are only intended for use only on non-forest land.

The intensity of resource use in cultivated areas and neglected land is high, so increases in carbon stocks from natural regeneration are not expected. Human populations in the project area are expected to expand putting greater pressure on resources in the future, so the maintenance of the above carbon stocks over the entire project period represents conservative estimates for baseline carbon stocks in the absence of project activities.

Figure 5: A 41.5 - hectare tract of land in Nyabiondo proposed for woodlot establishment under Plan Vivo System.

3 Assessment of carbon sequestration potential

The methods used to assess the potential carbon sequestration by the four land use systems to be used as Plan Vivo activities by VI Skogen Kagera are described by Nick Berry (2008)[k]

3.1 Data collection

No published tree growth data was available for any of the tree species identified for use by Emiti Nibwo Bulora Plan Vivo tree planting activities in Kagera, Tanzania. Therefore, to determine how these trees are likely to grow under the conditions found within the project

k Estimating growth characteristics of agroforestry trees, ECCM (2008) and Carbon modelling protocol, ECCM (2008).

area field measurements of trees of a known age were made to help determine annual (stem) volume increments (m^3/yr). The number and age classes of trees measured are shown in Table 3.

Table 3: Summary table of tree growth data collection

Tree species	Age class (yrs)	No. of trees measured (per age class)	Total no. of trees measured
1. *Maesopsis eminii*	1 - 10	20	98
	11 - 20	41	
	21 - 30	24	
	31 - 40	7	
	41 - 50	0	
	>50	6	
2. *Casuarina equisetifolia*	1 - 10	19	39
	11 - 20	20	
	21 - 30	0	
	31 - 40	0	
	41 - 50	0	
	>50	0	
3. *Podocarpus spp.*	1 - 10	100	168
	11 - 20	0	
	21 - 30	15	
	31 - 40	0	
	41 - 50	31	
	>50	22	
4. *Markhamia lutea*	1 - 10	0	31

	11 - 20	23	
	21 - 30	5	
	31 - 40	3	
	41 - 50	0	
	>50	0	
5. *Mangifera indica*	1 - 10	3	59
	11 - 20	2	
	21 - 30	47	
	31 - 40	0	
	41 - 50	0	
	>50	7	

6. *Citrus spp.*	1 - 10	95	160
	11 - 20	20	
	21 - 30	40	
	31 - 40	5	
	41 - 50	0	
	>50	0	
7. *Persea americana*	1 - 10	25	38
	11 - 20	10	
	21 - 30	3	
	31 - 40	0	
	41 - 50	0	

	>50	0	
8. *Artocarpus heterophyllus*	1 - 10	5	31
	11 - 20	20	
	21 - 30	2	
	31 - 40	2	
	41 - 50	0	
	>50	3	
9. *Acrocarpus fraxinifolius*	1 - 10	10	48
	11 - 20	38	
	21 - 30	0	
	31 - 40	0	
	41 - 50	0	
	>50	0	
10. *Cedrela odorata*	1 - 10	0	26
	11 - 20	8	
	21 - 30	14	
	31 - 40	4	
	41 - 50	0	
	>50	0	
11. *Grevillea robusta*	1 - 10	20	85
	11 - 20	42	
	21 - 30	0	
	31 - 40	0	

	41 - 50	23	
	>50	0	
12. Albizia lebbek	1 - 10	0	2
	11 - 20	2	
	21 - 30	0	
	31 - 40	0	
	41 - 50	0	
	>50	0	
13. Albizia coriara	1 - 10	0	3
	11 - 20	2	
	21 - 30	0	
	31 - 40	0	
	41 - 50	1	
	>50	0	
14. Acacia nilotica	1 - 10	0	0
	11 - 20	0	
	21 - 30	0	
	31 - 40	0	
	41 - 50	0	
	>50	0	
15. Acacia polyacantha	1 - 10	0	4
	11 - 20	4	
	21 - 30	0	

	31 - 40	0	
	41 - 50	0	
	>50	0	
16. *Acacia xanthophloea* (Fever tree/Yellow Acacia)	1 - 10	0	0
	11 - 20	0	
	21 - 30	0	
	31 - 40	0	
	41 - 50	0	
	>50	0	
TOTAL TREES MEASURED			**792**

The criteria used to select trees are described by Berry (2008) in *Estimating Tree Growth Protocol.* Tree height and diameter at breast height (dbh) data were recorded for all of the trees listed in Table 1.

3.2 Estimating tree growth rates

The tree measurement data (height and dbh) was used in the following way in order to derive annual increment for different tree species (m^3/ha/yr):

1. Estimate dbh:height relationship (plotted dbh vs height and calculated best fit line)
2. Estimate dbh:age relationship (plotted age vs dbh and calculated best fit line)
3. Estimate height:age relationship (plotted height vs age and calculated best fit line)
4. Calculate individual tree stem volume in (m^3). This is done by using the predicted dbh and heights from trees of age 1, 2, 3, ...5é 20, etc. Calculate the predicted stem volume of the tree at ages 1, 2, 3, ...5é 20, etc. based on the volume of a cone using the following formula:

$$v_i = \frac{\pi\left(\frac{d_i}{200}\right)^2 h_i}{\rho}$$

Where ρ = form factor (a form factor of 3 has been used for all tree species)[i].

[i] http://www.farmforestline.com.au/pages/6.5_standing_tree.html

5. Calculate annual increment per tree at age in successive years from planting to harvesting. as the increase in volume between the two ages (e.g. volume at age 15 minus volume at age 10) divided by 5 (years)
6. Multiply the CAI per tree by the number of trees in the technical specification (refer to the establishment and maintenance plan) to annual volume increment per hectare (m^3/ha).

The results for CAI (m^3/ha) for the different tree species used to model potential carbon sequestration are shown in Table . Refer to Appendix I for graphic representation of dbh:age and height:age relationships and CAI.

Table 4: Current annual increment (ages 5 to 25 years) for tree species used by Emiti Nibwo Bulora Plan Vivo project in Kagera, Tanzania

Tree species	CAI (m3/ha)				
	5 years	10 years	15 years	20 years	25 years
Maesopsis eminii	14.27	15.29	11.49	15.15	18.68
Acrocarpus fraxinifolius	6.74	5.82	5.02	4.45	4.03
Markhamia lutea	0.53	8.7	5.96	6.88	7.46
Grevilllea robusta	2.46	5.49	7.88	9.45	10.14
Podocarpus spp.	11.83	27.25	24.58	17.08	22.04
Cedrela odorata	2.15	3.64	3.82	3.74	3.59
Mangifera indica	0.74	1.08	1.41	1.74	2.04
Persea americana	1.78	2.32	2.25	2.11	1.98
Citrus spp.	0.34	0.26	0.22	0.19	0.17
Artocarpus heterophyllus	0.67	1.29	1.81	2.20	2.44

Some of the species, e.g. *Maesopsis eminii* appear in more than one technical specification (i.e. woodlot, dispersed interplanting and boundary system). In such a case, the CAI shown in Table 3 is that for the highest stocking density, which is either woodlot or dispersed interplanting. It can also be seen that some of the species above (e.g. *Podocarpus*) show an increase in CAI, followed by a drop in subsequent years, and then it picks up again. This is a result of thinning, which reduces tree numbers, but because of decreased competition, there is faster growth showing a faster increase in CAI in later years.

3.3 Modelling carbon sequestration

Carbon storage is calculated using the CO2FIX-V3 model (Mohren et al 2004). Carbon sequestration potential is based on average net carbon storage in biomass (i.e. the living parts of the tree including the main stem, canopy and roots) and forest products (i.e. poles, timber used for furniture and construction etc.) Details of the parameters used (basic wood carbon content; timber production; total tree increment relative to timber production; product allocation for thinnings, expected lifetime of products etc.) for each tree planting system (technical specification) are listed in Appendix II. Refer to Appendix III for graphical representation of long term average carbon sink for each planting system.

3.4 Carbon sequestration results

The potential long term average carbon storage was calculated separately for each of the land use systems (technical specifications). Refer to Table 5 to see the results.

Table 5: Results (tC and tCO_2) of modelling long term (25 years) average carbon storage potential of VI Skogen Plan Vivo activities in Kagera, Tanzania.

Technical Specification	Sink (tC/unit area)	Sink (tCO_2/unit area)
Woodlot (per hectare)	50	183
Dispersed interplanting (per hectare)	23	84
Boundary planting (per 100 meters)	2	7
Homestead fruit orchard (per hectare)	8	29

3.5 Calculating carbon offset

For the purposes of quantifying Plan Vivo certificates (carbon offset), the net carbon benefit of each tree planting system in addition to the baseline has been calculated. In accordance with Plan Vivo standards (http://www.planvivo.org/) 20% of all the carbon offset (i.e. net carbon benefit) is set aside to be kept as a risk buffer (i.e. non tradable carbon asset). Records of all buffer stock should be maintained in the database. The net carbon benefit, buffer stock and tradable carbon offsets (Plan Vivo certificates) generated by each of the land use systems (technical specifications) is presented in Table 5.

Table 6: Quantification of the net carbon benefit and tradable carbon offsets generated by Emiti Nibwo Bulora Plan Vivo project activities in Kagera, Tanzania.

Technical Specification	Sink (tC/unit area)	Baseline (tC/unit area)	Net benefit (tC/unit area)	Buffer (%)	Tradeable (tC/unit area)	Tradeable (tCO2/unit area)
Woodlot (per hectare)	50	2	48	20%	38.4	140
Dispersed interplanting (per hectare)	23	2	21		16.8	61
Boundary planning (per 100 meters)	2	0.06	1.9		1.5	5.6
Homestead fruit orchard (per hectare)	8	2	6		4.8	17

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http://www.planvivo.org/

Kyoto protocol, Article 12.5b,c http://unfccc.int/kyoto_protocol/items/2830.php

Marrakesh accords http://unfccc.int/cop7/documents/accords_draft.pdf

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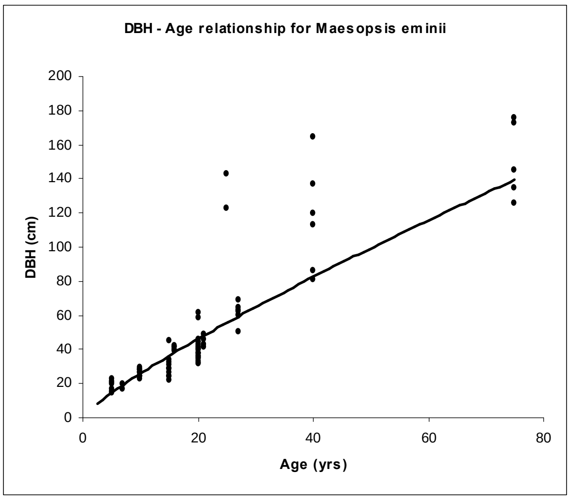
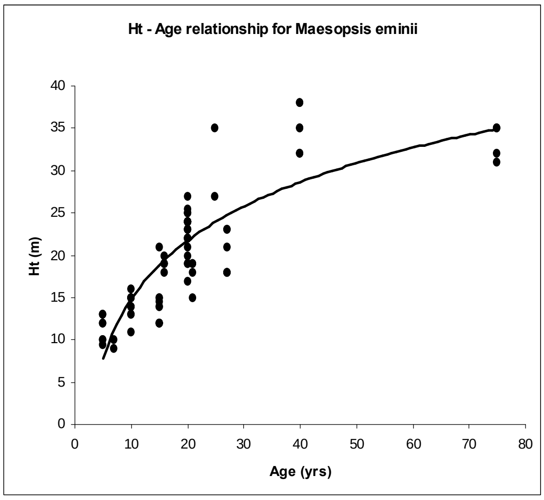
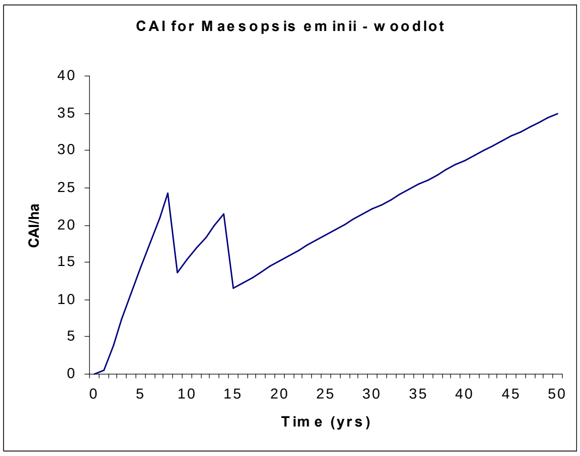
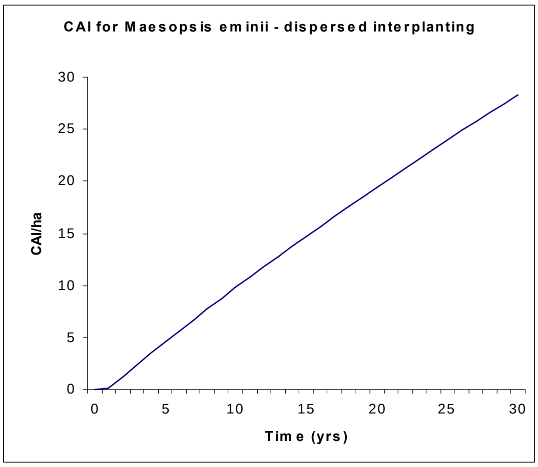
APPENDIX I: DBH ï AGE, HEIGHT - AGE RELATIONSHIPS AND CAI FOR SPECIES RECOMMENDED IN EACH SPECIFICATION

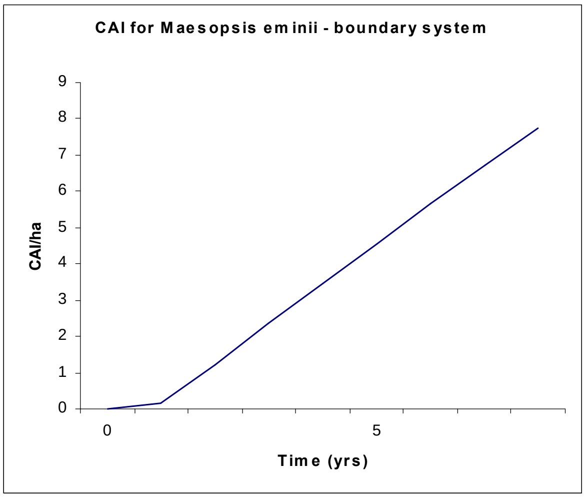
Maesopsis eminii



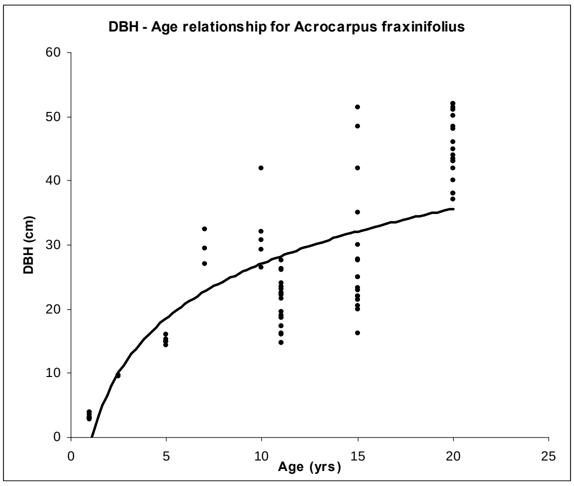


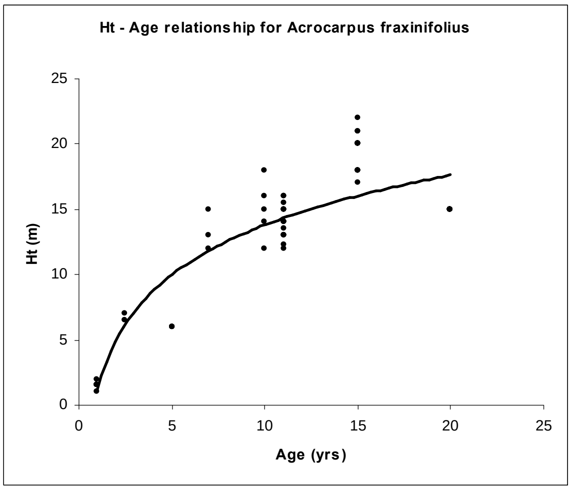


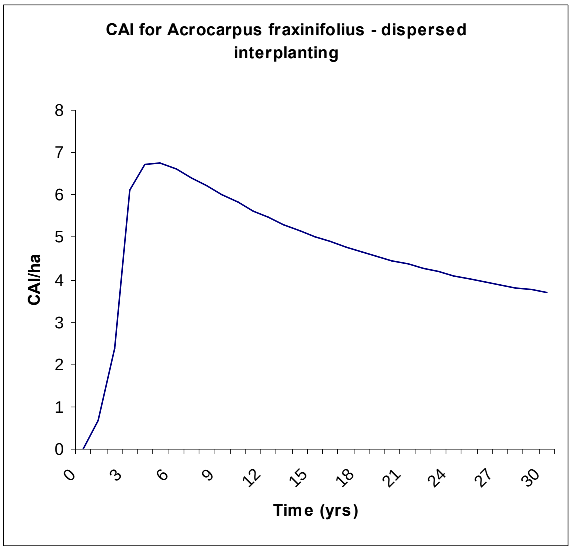




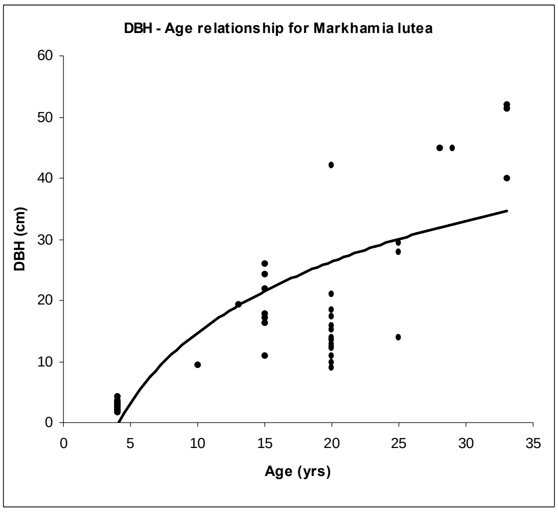
Acrocarpus fraxinifolius

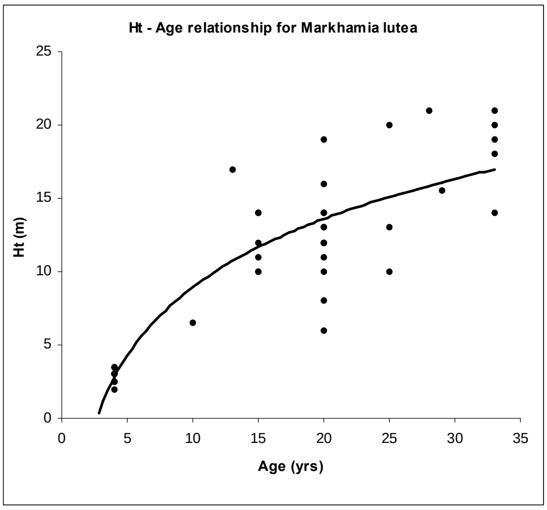


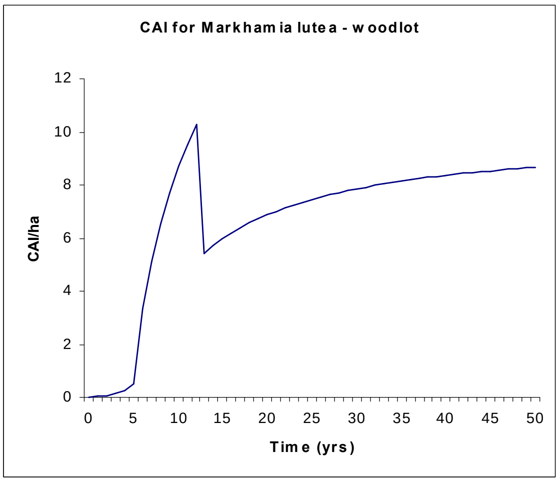


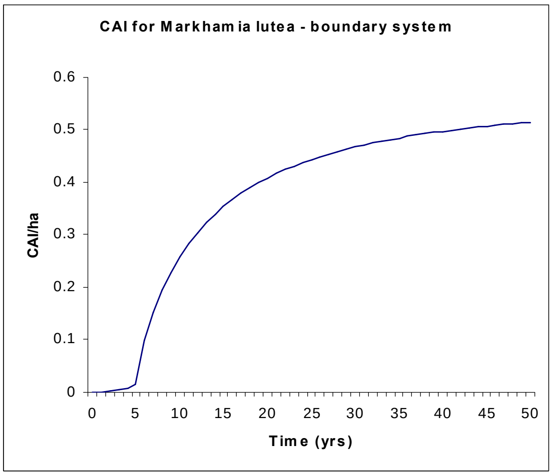


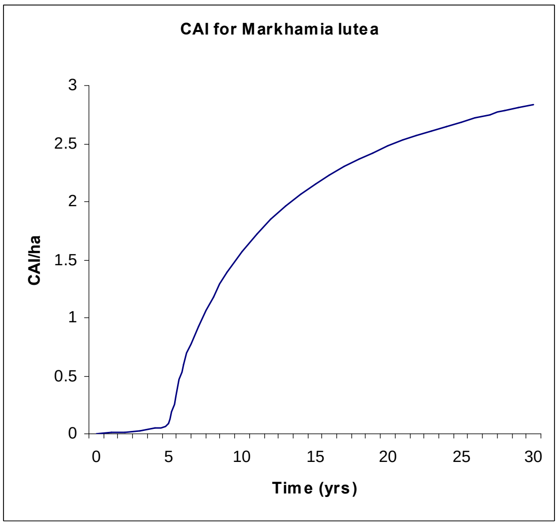
Markhamia lutea



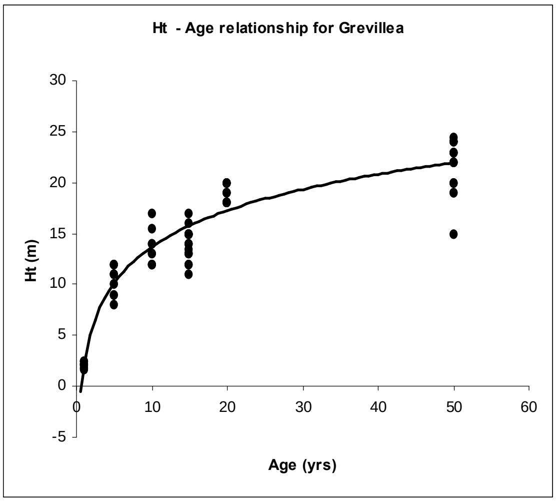


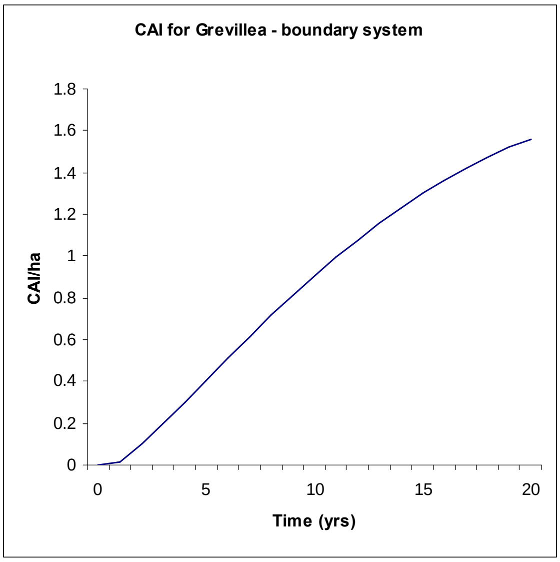


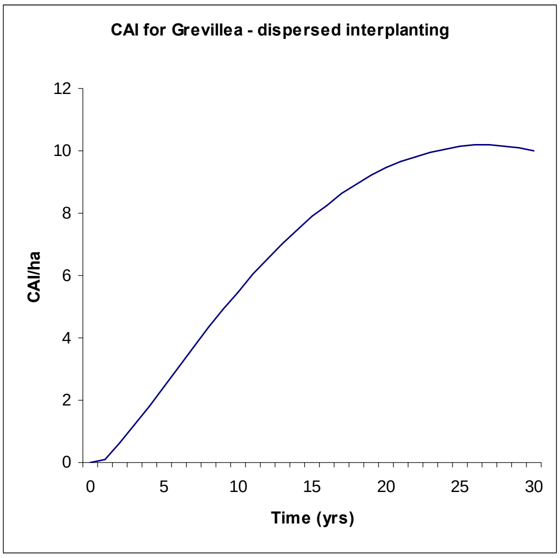




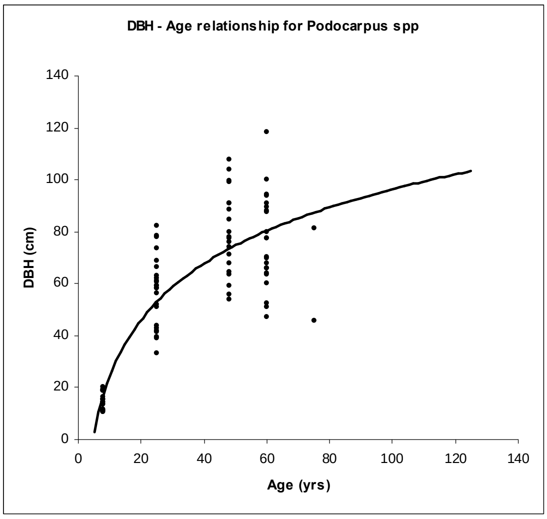
Grevillea robusta

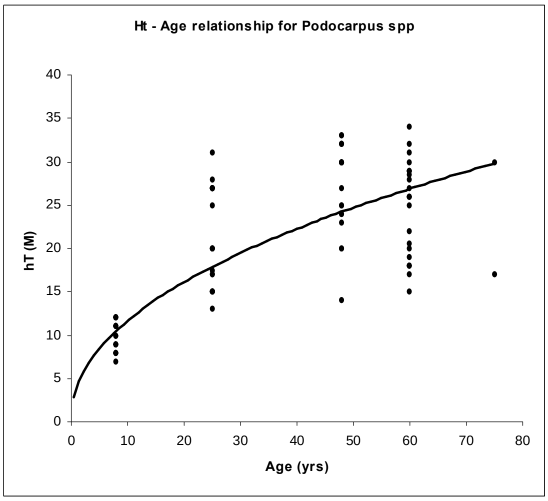


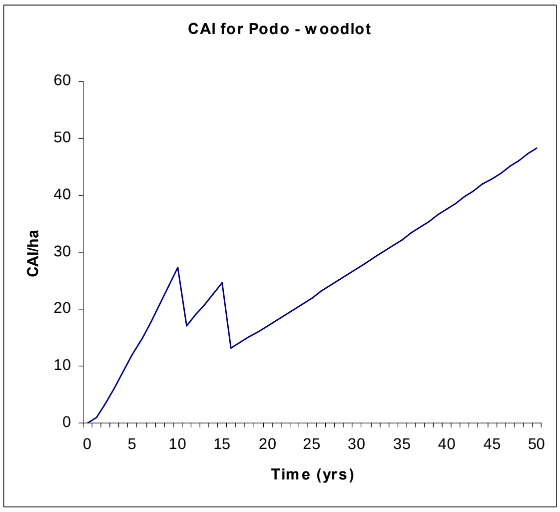




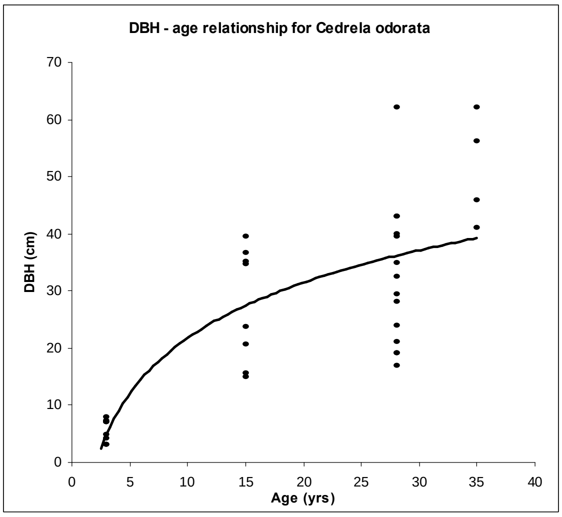
Podocarpus spp.

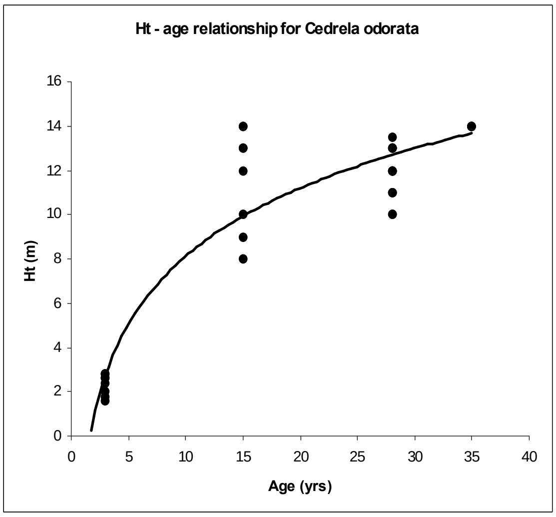


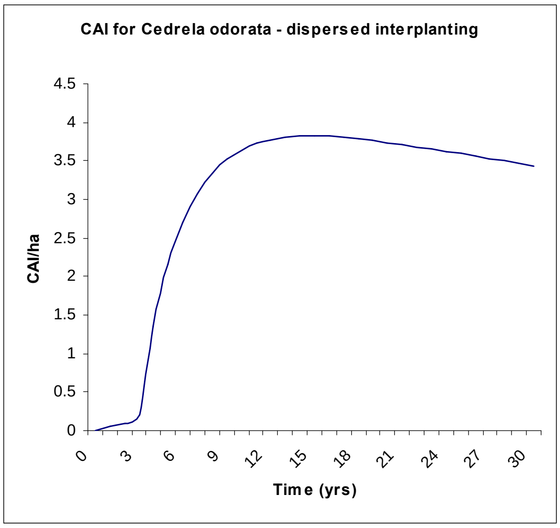




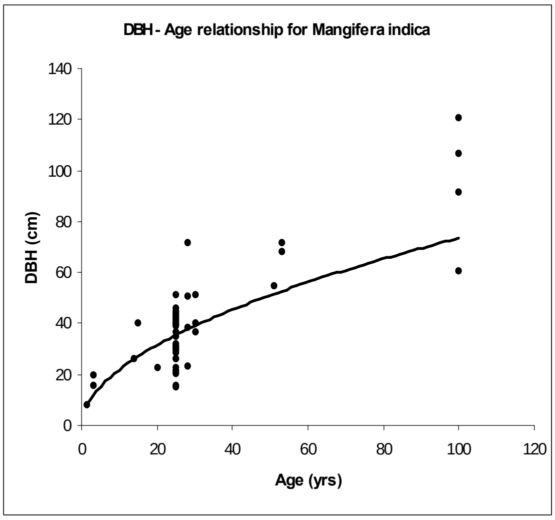
Cedrela odorata

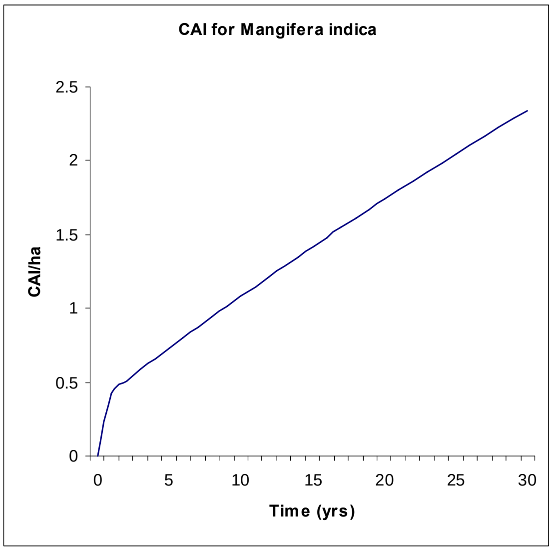




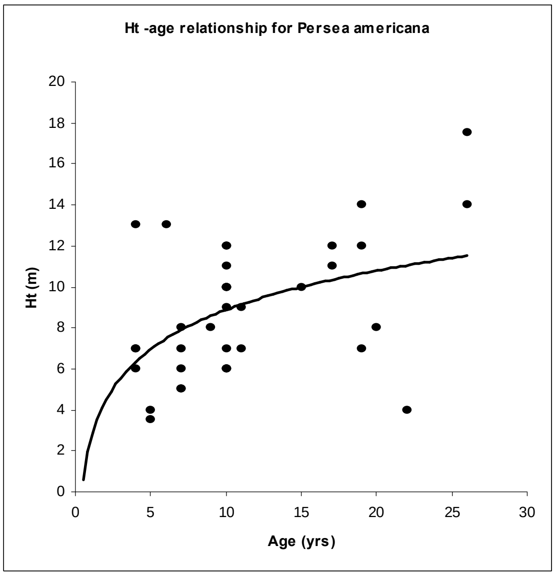


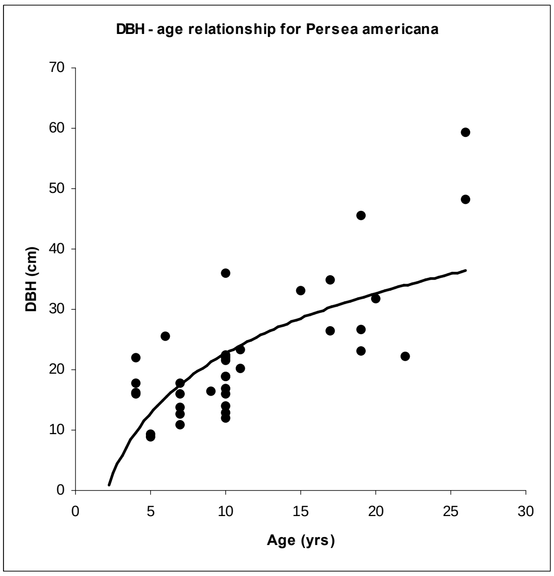
Mangifera indica

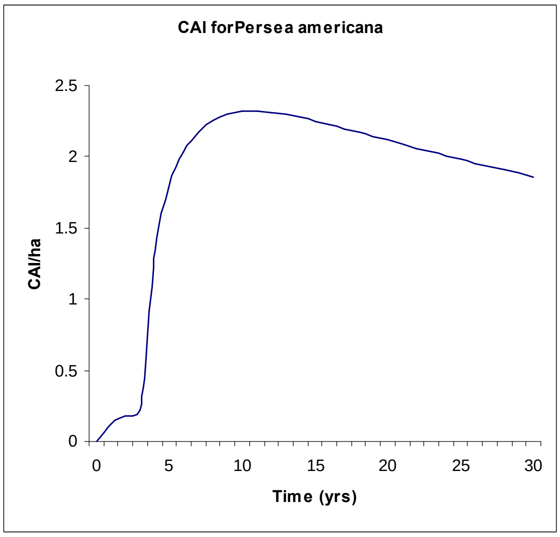




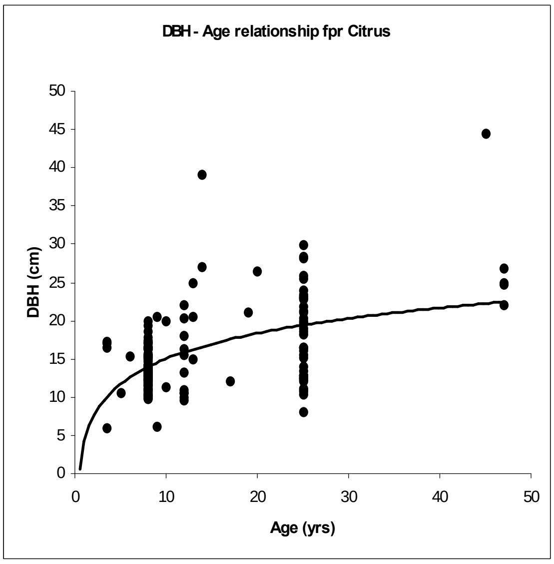
Persea americana

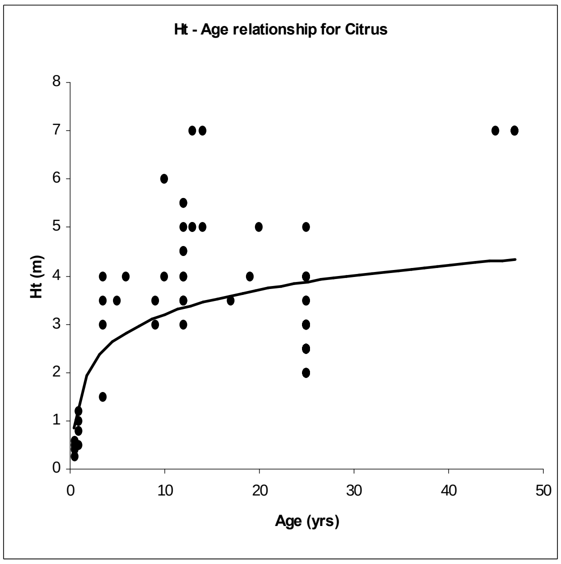


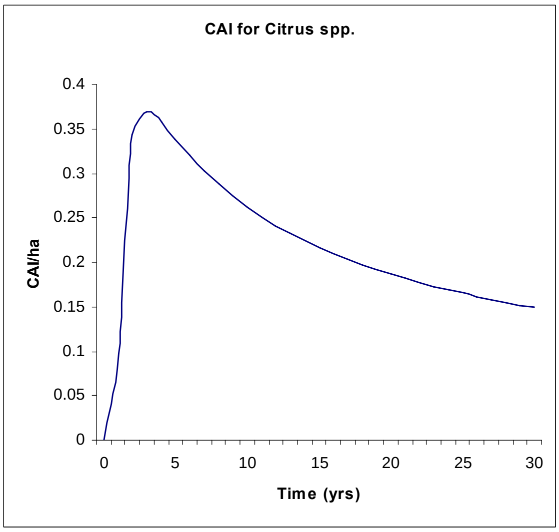




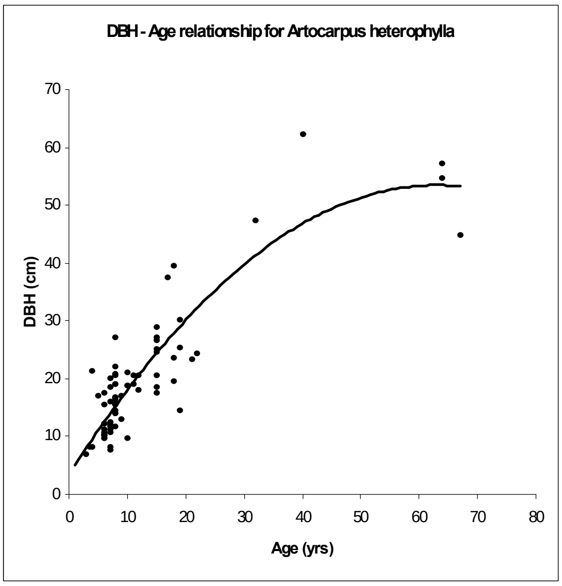
Citrus spp.

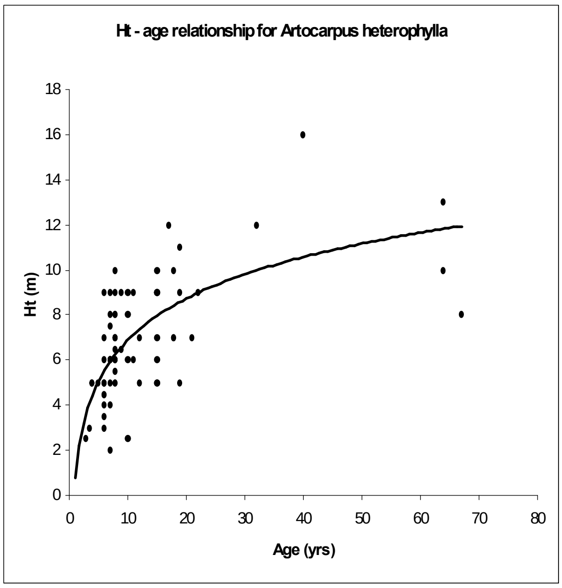

DBH - Age relationship fpr Citrus
DBH (cm)
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
Age (yrs)

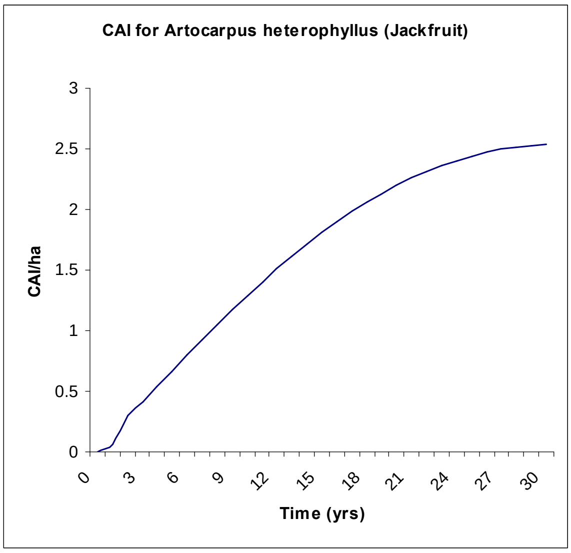

Ht - Age relationship for Citrus
Ht (m)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
Age (yrs)


CAI for Citrus spp.
CAI/ha
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
5
10
15
20
25
30
Time (yrs)

Artocarpus heterophyllus (Jackfruit)







APPENDIX II: PARAMETERS USED FOR MODELLING

VI Skogen Kagera woodlot technical specification - parameters used for modelling carbon sequestration potential.

			CAI at 746 stems per ha (m^3/ha)				
Species	**Wood density ($MgDM/m^3$)** [m]	**Stems per ha**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
MAEMIN	0.43	375	6.42	6.88	5.12	6.82	8.41
ACROC	0.61	156	6.33	5.47	4.72	4.18	3.79
PODO	0.60	111	2.37	5.45	4.92	3.42	4.41
MARLUT	0.79	56	0.03	0.43	0.30	0.34	0.37
total		**698**					

Note : In the technical specification, *Maesopsis* and *Acrocarpus* are to be planted at a stocking density of 625 stems/ha while *Podo* and *Markhamia lutea* will each be planted at 1111 stems/ha in a pure woodlot. In a mixed woodlot (which is recommended here), Maesopsis will constitute 60% or approximately 375 stems/ha, Acrocarpus will constitute 25% (approximately 156 stems/ha), Podo will constitute 10% (approximately 111 stems/ha) and Markhamia will constitute 5% or approximately 56 stems/ha, bringing the total stocking density to 698 stems/ha. Maesopsis, podo and acrocarpus will all be felled at age 25yrs and since they constitute 95% of the woodlot in total, this implies that at 25yrs 95% of the biomass (i.e., >100tC) will be transformed into carbon stocks in the products (including short term, medium term and long-term products). Markhamia requires thinning at year 12 but because of its low CAI and relative proportion in the species mix, the resultant biomass drop is not significant to show in the graph.

These proportions are only indicative and are based on farmer preferences for species. In practice, some farmers will prefer to plant more or less of each, or even some species not included in the analysis (up to a maximum of 10% of other indigenous or naturalised tree species). Since the specifications for such species are likely to fall within the ranges of those given here, there will not be much difference in CAI. The carbon sink values will also not be seriously affected because again, the dry wood densities of those other species fall within the ranges of the species above. The sink created is a function of both CAI and dry wood density.

[m] *Note: Average Dry Wood Density values are derived from http://www.worldagroforestry.org/sea/Products/AFDbases/WD/Index.htm*

General

	Value	Description
Simulation length	25 yr	
Cohort start age	0 yr	All new plantings

Biomass

	Value	Description
Stems carbon content	0.47 MgC/MgDM	For all species
Stems initial carbon	2 MgC/ha	For all species
Foliage carbon content	0.47	
Foliage initial carbon	0	
Foliage growth correction factor	1	
Foliage turnover rate	1	
Cohort foliage relative growth	0.05	
Branch carbon content	0.47 MgC/MgDM	For all species
Branch initial carbon	0 MgC/ha	For all species
Branch growth correction factor	1	No adjustment for non-optimal site conditions for any species
Branch turnover rate	0.05 /yr	5% per year for all species
Cohort branch relative growth	0.2	Branches maintained at 20% of stem volume throughout the life of the tree for all species
Root carbon content	0.47 MgC/MgDM	For all species
Roots initial carbon	0 MgC/ha	
Root growth correction factor	1	No adjustment to account for non-optimal site conditions for any species
Root turnover rate	0.05 /yr	5% per year for all species
Cohort root relative growth	0.25	Roots maintained at 25% of stem volume throughout the life of the tree for all species

Mortality

	value	Description
Mortality rate	0.01 /yr	1% mortality per year throughout the life of the tree for all species

Management

	value	Description
Rotation length	25 years for Maesopsis and Acrocarpus, 30 for Podo and 40 for Markhamia	Full harvest at rotation age followed by complete replanting
Age	8, 12, 14, 16, years	Thinning at years 8 and 14 for Maesopsis. Thinning at 8 years for Acrocarpus Thinning at years 8 and 15 for Podo Thinning at year 12 for Markhamia Full harvest at rotation age.
Fraction removed	0.5, 0.5, 1	50% of initial plantings removed in successive thinnings, all remaining trees harvested at rotation age.
Stems logwood	0.75, 0.75, 0.25	75% of thinnings and 25% of harvested trees converted to logwood for all species. Thinnings will mostly be used as poles hence higher recovery while only 25% of final harvesting will be converted to sawn timber.
Stems pulpwood	0	No conversion to pulpwood for any species
Branches logwood	0	No branches used for logwood for any species
Branches pulpwood	0	No branches used for pulpwood for any species
Slash firewood	1	All stems and branches not used for logwood are used as firewood for all species

Products

	value	Description
Fraction of logwood converted to sawnwood	0.25	25% of logwood converted to sawnwood for all species
Fraction of logwood	0.15	Off-cuts of conversion process can be used for

converted to boards		rough construction.
Fraction of logwood converted to paper	0	No logwood converted to paper for any species
Fraction of logwood converted to firewood	0.6	60% of logwood used as firewood for all species
Fraction of sawnwood converted to long term products	0.2	20% of sawnwood used in long term products for all species
Fraction of sawnwood converted to medium term products	0.4	40% of sawnwood used in medium term products for all species
Fraction of sawnwood converted to short term products	0.4	50% of sawnwood used in short term products for all species
Production losses	No losses during production	
Recycling classification	No recycling	All products used as firewood at the end of their life for all species
Half life of long term products	20 years	For all species
Half life of medium term products	10 years	For all species
Half life of short term products	1 year	For all species

VI Skogen Kagera dispersed interplanting technical specification - parameters used for modelling carbon sequestration potential.

				CAI at 200 stems per ha (m^3/ha)				
Species	**Wood density ($MgDM/m^3$)**	**Rotation length (years)**	**Stems per ha**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
CEDODO	0.49	30	20	0.22	0.36	0.38	0.37	0.36
GREROB	0.60	30	50	0.61	1.37	1.97	2.36	2.54
MARLUT	0.79	30	20	0.009	0.16	0.21	0.25	0.27
MAEMIN	0.43	30	60	1.37	2.94	4.42	5.83	7.19
ACROC	0.61	30	50	1.69	1.45	1.25	1.11	1.00
Total			**200**					

General

	value	**Description**
Simulation length	25 yr	
Cohort start age	0 yr	All new plantings

Biomass

	value	**Description**
Stems carbon content	0.47 MgC/MgDM	For all species
Stems initial carbon	2 MgC/ha	For all species
Foliage carbon content	0.47	
Foliage initial carbon	0	
Foliage growth correction factor	1	
Foliage turnover rate	1	
Cohort foliage relative growth	0.05	

Branch carbon content	0.47 MgC/MgDM	For all species
Branch initial carbon	0 MgC/ha	For all species
Branch growth correction factor	1	No adjustment for non-optimal site conditions for any species
Branch turnover rate	0.05 /yr	5% per year for all species
Cohort branch relative growth	0.2	Branches maintained at 20% of stem volume throughout the life of the tree for all species
Root carbon content	0.47 MgC/MgDM	For all species
Roots initial carbon	0 MgC/ha	For all species
Root growth correction factor	1	No adjustment to account for non-optimal site conditions for any species
Root turnover rate	0.05 /yr	5% per year for all species
Cohort root relative growth	0.25	Roots maintained at 25% of stem volume throughout the life of the tree for all species

Mortality

	value	Description
Mortality rate	0.01 /yr	1% mortality per year throughout the life of the tree for all species

Management

	value	Description
Stems logwood	0.25	25% of harvested trees converted to logwood for all species (recovery)
Stems pulpwood	0	No conversion to pulpwood for any species
Branches logwood	0	No branches used for logwood for any species
Branches pulpwood	0	No branches used for pulpwood for any species
Slash firewood	1	All stems and branches not used for logwood are used as firewood for all species

Products

	value	Description
Fraction of logwood converted to sawnwood	0.25	25% of logwood converted to sawnwood for all species
Fraction of logwood converted to boards	0.15	15% of stemwood is left as off-cuts during conversion to timber and can be used for rough construction
Fraction of logwood converted to paper	0	No logwood converted to paper for any species
Fraction of logwood converted to firewood	0.6	60% of logwood used as firewood for all species
Fraction of sawnwood converted to long term products	0.2	20% of sawnwood used in long term products for all species
Fraction of sawnwood converted to medium term products	0.4	40% of sawnwood used in medium term products for all species
Fraction of sawnwood converted to short term products	0.4	50% of sawnwood used in short term products for all species
Production losses	No losses during production	
Recycling classification	No recycling	All products used as firewood at the end of their life for all species
Half life of long term products	20 years	For all species
Half life of medium term products	10 years	For all species
Half life of short term products	1 year	For all species

VI Skogen Kagera boundary planting technical specification - parameters used for modelling carbon sequestration potential.

Parameters

			CAI at 100 stems per 100m (m^3/100m)				
Species	**Wood density (MgDM/m^3)**	**Stems per 100m**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
GREROB	0.60	11	0.13	0.30	0.43	0.41	0.55
MAEMIN	0.43	11	0.78	1.67	2.50	3.30	4.07
MARLUT	0.79	11	0.02	0.26	0.35	0.41	0.44
total		**33**					

General

	value	**Description**
Simulation length	25 yr	
Cohort start age	0 yr	All new plantings

Biomass

	value	**Description**
Stems carbon content	0.47 MgC/MgDM	For all species
Stems initial carbon	0.087 MgC/ha	For all species
Foliage carbon content	0.47	
Foliage initial carbon	0	
Foliage growth correction factor	1	
Foliage turnover rate	1	
Cohort foliage relative growth	0.05	
Branch carbon content	0.47 MgC/MgDM	For all species
Branch initial carbon	0 MgC/ha	For all species

Branch growth correction factor	1	No adjustment for non-optimal site conditions for any species
Branch turnover rate	0.05 /yr	5% per year for all species
Cohort branch relative growth	0.2	Branches maintained at 20% of stem volume throughout the life of the tree for all species
Root carbon content	0.47 MgC/MgDM	For all species
Roots initial carbon	0 MgC/ha	
Root growth correction factor	1	No adjustment to account for non-optimal site conditions for any species
Root turnover rate	0.05 /yr	5% per year for all species
Cohort root relative growth	0.25	Roots maintained at 25% of stem volume throughout the life of the tree for all species

Mortality

	value	**Description**
Mortality rate	0.01 /yr	1% mortality per year throughout the life of the tree for all species

Management

	value	**Description**
Rotation length	8, 20, 50 years	Full harvest at year 8 for Maesopsis, 20 for Grevillea and 50 for Markhamia followed by complete replanting.
Fraction removed	1	100% of initial plantings harvested at rotation age for all species
Stems logwood	0.75, 0.25	75% of Maesopsis used as poles at year 8 and 25% of harvested Grevillea and Markhamia converted to logwood at rotation age.
Stems pulpwood	0	No conversion to pulpwood for any species
Branches logwood	0	No branches used for logwood for any species
Branches pulpwood	0	No branches used for pulpwood for any species
Slash firewood	1	All stems and branches not used for logwood are used as firewood for all species

Products

	value	description
Fraction of logwood converted to sawnwood	0.25	25% of logwood converted to sawnwood for all species
Fraction of logwood converted to boards	0.15	15% of stemwood is left as off-cuts after conversion to timber and can be used for rough construction
Fraction of logwood converted to paper	0	No logwood converted to paper for any species
Fraction of logwood converted to firewood	0.25	25% of logwood used as firewood for all species
Fraction of sawnwood converted to long term products	0.2	20% of sawnwood used in long term products for all species
Fraction of sawnwood converted to medium term products	0.4	40% of sawnwood used in medium term products for all species
Fraction of sawnwood converted to short term products	0.4	50% of sawnwood used in short term products for all species
Production losses	No losses during production	
Recycling classification	No recycling	All products used as firewood at the end of their life for all species
Half life of long term products	20 years	For all species
Half life of medium term products	10 years	For all species
Half life of short term products	1 year	For all species

VI Skogen Kagera homestead fruit orchard technical specification - parameters used for modelling carbon sequestration potential.

Parameters

			CAI at 150 stems per ha (m^3/ha)				
Species	**Wood density ($MgDM/m^3$)**	**Stems per ha**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
MAIND	0.695	62	0.29	0.43	0.56	0.69	0.81
CITR	0.84	13	0.03	0.02	0.18	0.02	0.01
PERAME	0.60	62	0.89	1.17	1.13	1.07	1.00
ARTHET	0.65	13	0.07	0.14	0.19	0.23	0.26
total		**150**					

General

	value	**Description**
Simulation length	25 yr	
Cohort start age	0 yr	All new plantings

Biomass

	value	**Description**
Stems carbon content	0.47 MgC/MgDM	For all species
Stems initial carbon	2 MgC/ha	For all species
Foliage carbon content	0.47	
Foliage initial carbon	0	
Foliage growth correction factor	1	
Foliage turnover rate	1	
Cohort foliage relative growth	0.05	
Branch carbon content	0.47 MgC/MgDM	For all species

Branch initial carbon	0 MgC/ha	For all species
Branch growth correction factor	1	No adjustment for non-optimal site conditions for any species
Branch turnover rate	0.05 /yr	5% per year for all species
Cohort branch relative growth	0.2	Branches maintained at 20% of stem volume throughout the life of the tree for all species
Root carbon content	0.47 MgC/MgDM	For all species
Roots initial carbon	0 MgC/ha	
Root growth correction factor	1	No adjustment to account for non-optimal site conditions for any species
Root turnover rate	0.05 /yr	5% per year for all species
Cohort root relative growth	0.25	Roots maintained at 25% of stem volume throughout the life of the tree for all species

Mortality

	value	**Description**
Mortality rate	0.01 /yr	1% mortality per year throughout the life of the tree for all species

Management

	value	**Description**
Rotation length	>25 years for all species	Not within crediting period.

APPENDIX III: CARBON SEQUESTRATION POTENTIAL OVER 25 YEARS

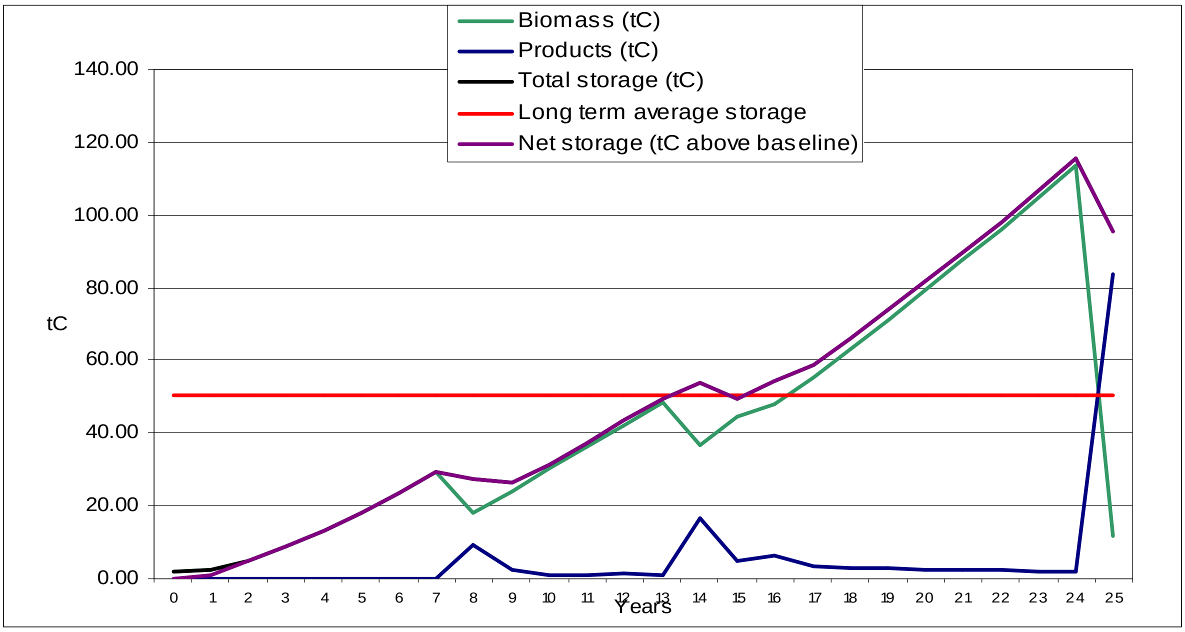


Figure 6: Woodlot technical specification carbon sequestration potential over 25 years

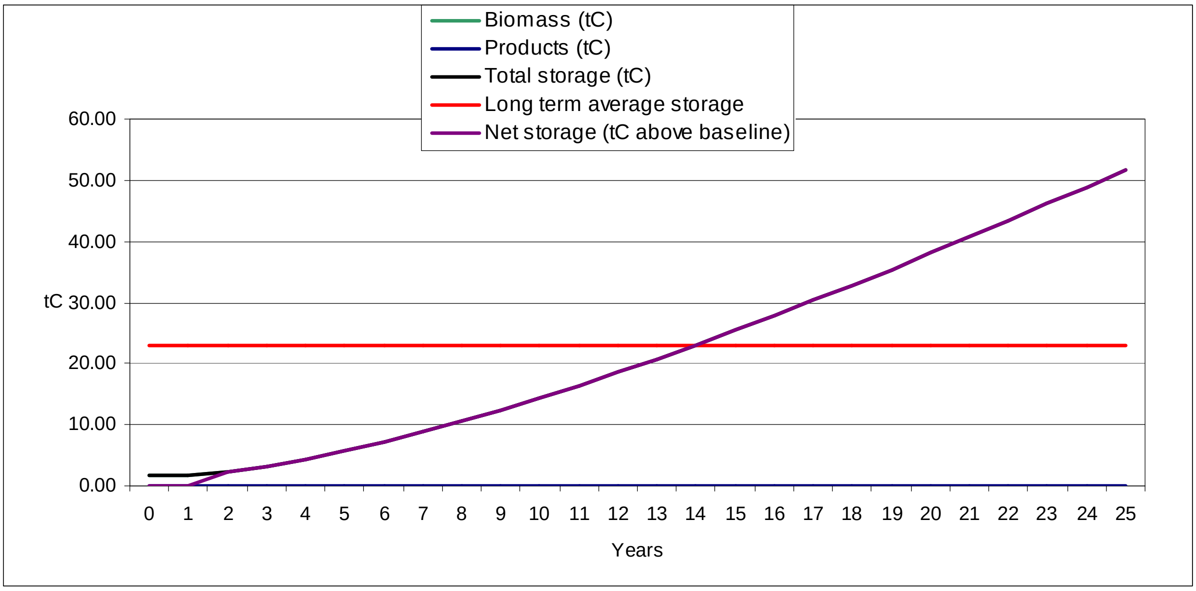


Figure 7: Dispersed interplanting technical specification carbon sequestration potential over 25 years

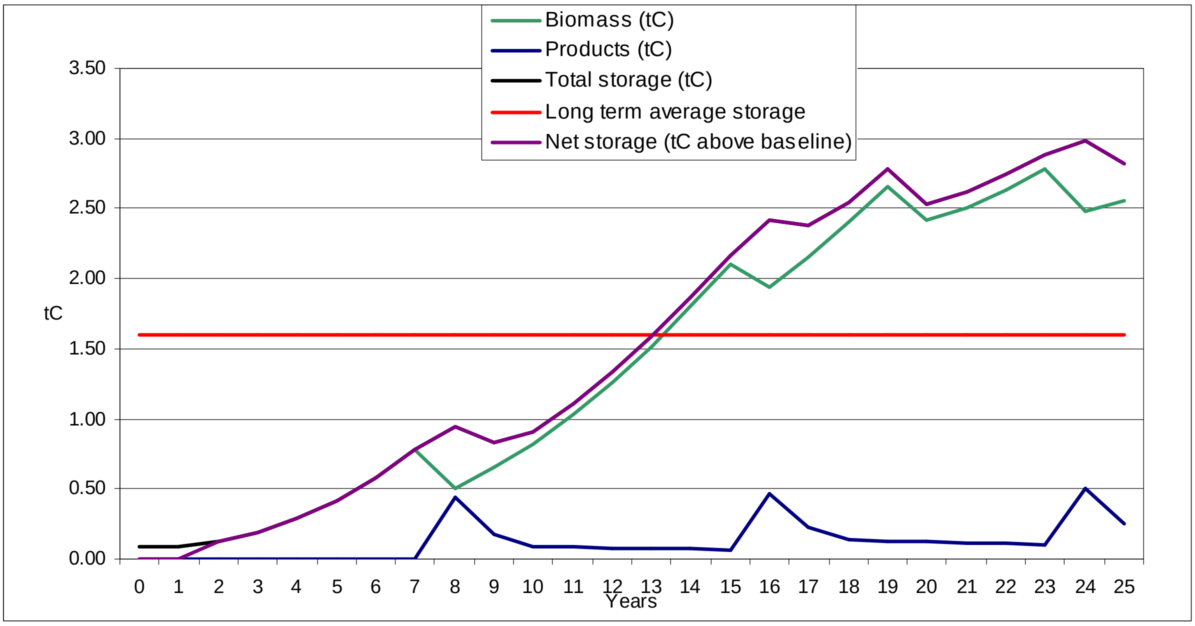


Figure 8: Boundary planting technical specification carbon sequestration potential over 25 years

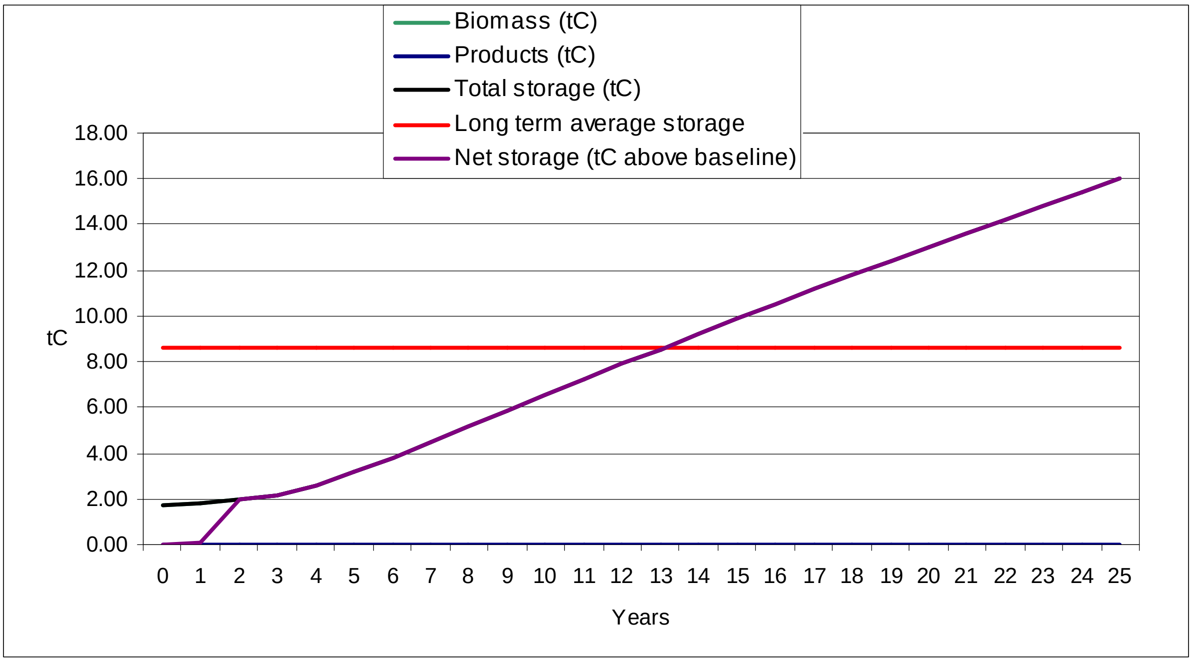


Figure 9: Homestead fruit orchard technical specification carbon sequestration potential over 25 years

Creating a sustainable low carbon society

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