Technical specification AF-ACME-TROP1

System: Improved Fallow
Variation: *Cedrela odorata* (Spanish cedar or cedro)
plus *Swietenia macrophylla* (mahogany or caoba)

Summary[1]
The improved fallow system involves the management of secondary vegetation for the production of timber, fuelwood and other products through enrichment planting.

Ecology[2,3,4]
Cedrela odorata and *Swietenia macrophylla* are fast-growing, high-value timber trees native to large areas of Central and South America from 28ºS–26ºN and 18ºS-23ºN respectively. *C.odorata* is found naturally at altitudes between 0 and 1500 masl, where mean annual rainfall is between 1200-3000 mm per year and where the mean annual temperature is 20-32ºC. *S.macrophylla* is also found at altitudes between 0 and 1500 masl, and exhibits best performance with mean annual rainfall of between 1000-2000 mm per year and a mean annual temperature of around 24ºC. Both species will grow on light, medium or heavy soils but thrive on free draining, fertile soils. These are light demanding species that thrive in open spaces or large clearings in highly diverse tropical broadleaved forests but in much of their native range the gene pool has been severely depleted due to the high demand for their valuable timber. *C.odorata* and *S.macrophylla* are grown as plantation trees throughout the tropics (see additional information).

Classification of climate/ site productivity
Climate is classed as optimal and sub-optimal based on available ecological information and experiences within the project as shown below. (The use of this system in areas classified as sub-optimal for climatic conditions is not recommended.)

Optimal	Tropical, humid 300-1200 masl 1200 - 2250 mm/yr
Sub-optimal	Subtropical/temperate, subhumid <300 or >1200 masl <1200 mm/yr

Site productivity is inferred from locally reported yield of maize and soil conditions for the site as shown below[5]. (Exceptions occur in waterlogged soils where *C.odorata* will not grow well despite high maize yield on these soils, *S. macrophylla* is more suited to moist soils.)

	High	**Medium**	**Low**
Maize yield (in a 'good' year without fertilizer)	> 2000 kg/ha	1000-2000 kg/ha	< 1000 kg/ha
Soil type	Deep (>30cm) well drained, brown-black, few stones	20-30cm depth, heavy clays or sandy	Thin (<20cm) stoney, compacted or oxidised clays soils

Management objectives

The primary objective is timber production, other products include fuelwood and posts from thinnings and non-timber products. Soil conservation is improved on steep slopes.

Potential income[6] - The value of cedro and caoba timber at the saw mill is US$78/$m^3$, costs of harvesting and transportation are approximately US$ 33.09 /m^3. If the net value of standing timber is assumed to be US$35/ m^3, 400 m3 timber /ha would give a total net income of US$14,000 US$ /ha at then end of the 25 year rotation. (Volume estimated from average reported yield).

Costs of implementation[7] - Estimated costs per ha over the rotation are: establishment US$385, maintenance US$260 and opportunity cost (lost production from land) US$0-1350 depending site quality

Management operations

Establishment

1. Planting lines of 2m width should be cleared through the existing secondary vegetation to reduce competition for light. The planting lines should be cleared of all herbaceous and shrubby vegetation and all overhanging branches cut back; planting lines may be diverted round larger trees to save labour. It is recommended to cut these lines on an east-west axis to maximise the available sunlight.
2. Holes for seedlings should be 30cm depth and 30cm diameter – large holes produce better conditions for root development. The topsoil is more fertile and should be placed in the bottom of the hole for better rooting. Very compact soils holes may be dug after the start of the rains.
3. It is important to obtain good quality planting stock, which should be ready for planting at the beginning of the rainy season. The roots of seedlings should be pruned just prior to planting to help root development.
4. Planting density should be between 700 and 500 stems per ha (7x2 to 7x3m).

Maintenance

1. Weeding should be carried twice per year along the planting lines until canopy closure.
2. Pruning is vital to maintain tree form where is there is evidence of *Hypsipyla* attack (see additional information below) to prevent forking and reduce lateral branching
3. Planting lines should be maintained clear of overhanging branches until the pine trees reach the height of surrounding secondary vegetation.

Thinning and harvest

1. The first thinning may take place in year 8, trees of good form should be retained, those of poorer form being removed to leave 3-400 stems per ha (approx 25%).
2. The second thinning should take place in year 16 again retaining trees of good form to leave 250 stems per ha as the final density (approx 15%).
3. The harvest should take place in year 25 when dbh>40cm

Re-establishment

1. Shelterwood: 25 to 30 trees per ha (approx. 20x20m) may be retained as seed trees when the main crop is felled to provide seed for the new crop. Regeneration should be maintained by regular weeding.
2. Re-establishment through the taungya system. An increase in soil fertility may make the plot suitable for replanting with seedlings combined with cultivation of maize for the first 3-4 years.

Carbon sequestration potential[8,9,10,11,12]

Carbon sequestration potential over 100 years with a crop rotation of 25 years on an average quality site with optimal climatic conditions is 96 tC/ha above an initial soil and vegetation carbon baseline of 93 tC/ha. (For details of carbon storage see appendix 1).

Carbon sequestration potential is based on average net carbon storage in tree biomass and forest products. Carbon storage is calculated using the CO2FIX model (Mohren and Klein Goldewijk 1990, Mohren *et al* 1999). Details of the parameters used (basic wood carbon content; initial soil carbon content; timber production; total tree increment relative to timber production; turnover rate; humification factor; litter and humus residence time; product allocation for thinnings and expected lifetime of products) are given in de Jong *et al* (1996). The model uses an assumed annual timber production of 14.9m3/ha for planted trees; details of the productivity data are given in de Jong *et al* 1995. (For details of model inputs see appendix 2).

The soil baseline (75 tC/ha) is based on de Jong et al 1996. The vegetation baseline (18 tC/ha) is based on Ambio 2002. The baseline assumes that current land use would continue unchanged and that the long term average carbon storage would be the same as current carbon stock.

Monitoring[11]

Monitoring targets for the first 3 years are based on establishment; the farmer must have completed planting by the third year with at least 85% survival of seedlings. Thereafter monitoring targets are based on DBH, the expected DBH at the time of monitoring is based on a predicted mean annual diameter increment on which carbon sequestration estimates are based.

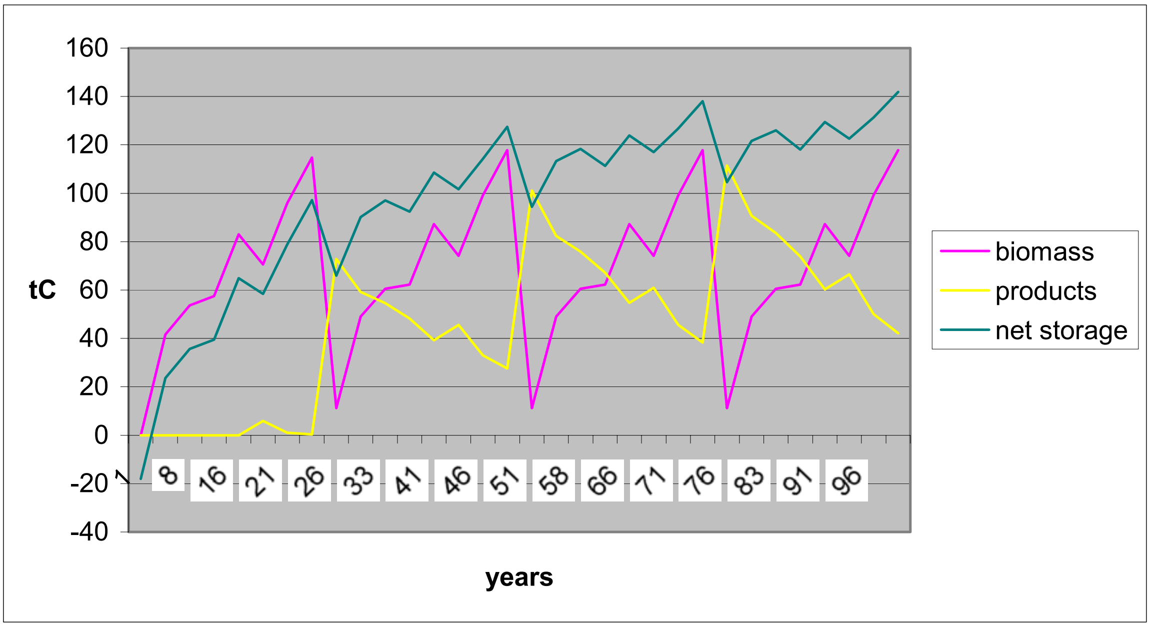
Year	Indicator
1	At least 33% plot established
2	At least 66% plot established
3	Whole plot established, 85% survival At least 333 stems /ha planted
5	Average DBH not less than 9cm
10	Average DBH not less than 18cm At least 300 stems /ha remaining
15	Average DBH not less than 26.5cm At least 250 stems /ha remaining

Additional information[4,13]

The most important pest on plantation of Cedrela odorata and one of the most important factors in establishment is the shoot borer *Hypsipyla grandela*. The larvae of the moth develop in the apical bud of young mahogany trees causing the shoot to die. This does not kill the tree but this leads to the growth of several subsidiary shoots. If not pruned this will lead to forking of the main stem and drastically reduce the value of the timber. However if damaged shoots are removed the tree will continue to grow with good form and the length of saleable timber much increased. Pruning of subsidiary shoots must take place within one or two years of *Hypsipyla* attack as the removal of older branches will put the tree at risk of disease. One means of reducing the occurrence of the shoot borer is to use a mixture of species. Although not conclusively proven, planting fast growing species with the *Cedrela* may help prevent infestation through reducing the chances host location. Chemical and biological means of control do exist but at high the cost. The advantage in small scale plantations of mahogany is that the farmer can quickly spot damaged trees and prune the shoots where necessary during routine maintenance. After approximately 5 years the trees become less susceptible to the shoot borer. It is extremely important that farmers are given training in pruning trees if they are to realise the full value of this species.

Appendix 1 – carbon storage

year	biomass	products	total storage	Net storage	accumulated tCyr
1	0	0	0	-18	-18.00
6	41.65	0	41.65	23.65	-3.88
8	53.61	0	53.61	35.61	55.39
11	57.49	0	57.48	39.48	168.02
16	82.96	0	82.96	64.96	429.12
16	70.52	5.92	76.44	58.44	429.12
21	95.93	0.97	96.9	78.9	772.47
25	114.72	0.4	115.11	97.11	1124.49
26	11.17	72.78	83.95	65.95	1206.02
31	49	59.19	108.19	90.19	1596.37
33	60.49	54.52	115	97	1783.56
36	62.23	48.21	110.44	92.44	2067.72
41	87.19	39.29	126.48	108.48	2570.02
41	74.11	45.55	119.66	101.66	2570.02
46	99.2	33.06	132.26	114.26	3109.82
50	117.8	27.62	145.42	127.42	3593.18
51	11.17	101.19	112.37	94.37	3704.08
56	49	82.34	131.35	113.35	4223.38
58	60.49	75.86	136.34	118.34	4455.07
61	62.23	67.09	129.32	111.32	4799.56
66	87.19	54.68	141.87	123.87	5387.53
66	74.11	60.94	135.05	117.05	5387.53
71	99.2	45.61	144.81	126.81	5997.18
75	117.8	38.28	156.09	138.09	6526.98
76	11.17	111.42	122.6	104.6	6648.33
81	49	90.69	139.68	121.68	7214.03
83	60.49	83.55	144.03	126.03	7461.74
86	62.23	73.89	136.12	118.12	7827.96
91	87.19	60.23	147.42	129.42	8446.81
91	74.11	66.49	140.6	122.6	8446.81
96	99.2	50.13	149.33	131.33	9081.64
100	117.8	42.12	159.93	141.93	9628.16



Appendix 2 - CO2Fix Inputs

Stand parameters		
Rotation length (yr)		25
Number of rotations		4
Adjustment of assimilate to account for non-optimal site conditions	Foliage	1
	Branches	1
	roots	1
Initial biomass (Mg/ha)	Foliage	0
	Roots	0
	Litter	0
	Soil humus	150
	Branches	0
	Stems	0
	Deadwood	0

Tree Growth Table				
Age (yr)	Stem increment (m3/yr)	Dry weight increment relative to stem		
		needles	Branch	roots
0	14.9	0.7	0.6	0.7
10	14.9	0.4	0.4	0.4
15	14.9			
20	14.9	0.4	0.4	0.4
25	14.9			

Tree species Parameters		
Basic density of stemwood (kg/m3)		500
Carbon content of dry matter (kg/kg)		0.5
Turnover of various biomass components (1/yr)	Needles	0.5
	Branches	0.05
	Roots	0.07
Mortality as a fraction of trees per year (1/yr)		0.02
Average residence time of carbon in wood products (1/yr)	Dead wood	10
	Energy	1
	Packing	5
	Construction	25
Humification and decomposition coefficients (yr)	Humification	0.1
	Litter decomposition	1
	Humus decomposition	100
Carbon content of stable soil humus (kg/kg)		0.5

Thinning and harvest table					
Thinning age	Fraction stem removed	Dead wood	Energy	Packing	Construction
8	0.25	0.4	0.6	0.4	0
16	0.25	0.2	0.4	0.4	0
Final harvest		0	0	0	1

References

[1] This specification is based on a system used in Chiapas, Mexico
[2] Webb D.B., Wood P.J., Smith J.P. and Henman G.S. (1984) *A Guide to Species Selection for Tropical and Subtropical Plantations*. Tropical Forestry Paper 15, Oxford, UK
[3] CABI Forestry Compendium
[4] Mayhew J.E. and Newton A.C. 1998 The Silviculture of Mahogany. CABI Publishing, UK
[5] Site class characteristics are based on surveys conducted with farmers in the region
[6] Méndez Gamboa, J.A. s/f. *Manejo Integrado de Bosque Natural. Costos de las Actividades de aprovechamiento forestal en el bosque natural de la zona norte de Costa Rica*. Comisión de Desarrollo Forestal de San Carlos (CODEFORSA), Ministerio del Ambiente y Energia (MINAE) e Instituto Tecnológico de Costa Rica (ITCR). Colección Técnica Manejo de Bosque Natural No. 1. Ciudad Quesada, Costa Rica. 17 pág
[7] Data adapted from Tipper R., de Jong B., Ochoa-Gaona S., Soto-Pinto M., Castillo-Santiago M., Montoya-Gomez G. and March-Mifsut I. (1999) Assessment of the cost of large scale forestry for CO2 sequestration: evidence from Chiapas, Mexico. IEA Greenhouse Gas R&D Programme
[8] Mohren G. and Klein Goldewijk C. 1990. CO2FIX: A dynamic model of the CO2-fixation in forest stands. De Dorschkamp Resrach Institute for Forestry and Urban Ecology. Report 624. 35p + app. Wageningen, The Netherlands
[9] Mohren G., Garza Caligaris J, Masera O., Kanninen M., Karjalainen T. and Nabuurs G. 1999. CO2FIX for Windows: a dynamic model of the CO2 fixation in forest stands. Institute for Forestry and Nature Research, Instituto de Ecologia, UNAM, Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), European Forest Institute. Wageningen The Netherlands, Morelia Mexico, Turrialba Costa Rica, Joensuu Finland. 27p.
[10] de Jong B., Soto-Pinto L., Montoya-Gomez G., Nelson K., Taylor J. and Tipper R. 1996. Forestry and agroforestry alternatives for carbon sequestration: a study from Chiapas, Mexico. In: W. Adger, D. Pettenella and W. Whitby (eds) *Climate Change Mitigation and European Land Use Polices*. CAB International pp.269-284
[11] de Jong B., Montoya-Gomez G., Nelson K., Soto-Pinto L., Taylor J. and Tipper R. (1995) Community forest management and carbon sequestration: a feasibility study from Chiapas, Mexico. *Interciencia* 20(6):409-416
[12] Ambio 2002
[13] Newton A., Baker P., Ramnarine S., Mesen J. and Leakey R. 1993. The mahogany shoot borer: prospects for control. *Forest Ecology and Management* 57: 301-328