Technical specification for smallholder carbon management project, Bushenyi Uganda

System: Sole species woodlots

Species: Maesopsis emini

Summary

The system involves block planting one tree species namely Maesopsis emini on pieces of land that farmers have difficulty managing due to labour shortage, low soil productivity, distance, theft or vermin constraints. Such lands usually undergo traditional long bush fallow systems with little or no economic value. With its low management requirement, the tree woodlot system is thus an attractive economic alternative to diversify farm products and derive economic benefits such as timber, firewood and shade support to agricultural crops. Choice of Maesopsis for this system stems from its popularity in terms of fast growth, germplasm availability, ease of propagation, compatibility with most agricultural crops, and superior timber products. Consequently, Maesopsis accounts for over 50% of species so far planted in the Bushenyi project area. This technical specification explores the carbon sequestration potential of Maesopsis woodlots, as an additional economic benefit, under a given management regime.

Ecology of the species

Maesopsis is a large tree found in tropical forest ecosystems of East, Central and West Africa. It can thrive in a wide range of ecological types with an altitudinal range of 700 to 1500 masl and mean annual rainfall of 1200 to 3000 mm Katende et al., 1995). The species is a light demander and grows up to 30 m high. Prefers a wide range of soil conditions but deep moist moderately fertile soils are preferred. Maesopsis is one of the quickest growing timber trees in Uganda. The rotation is 12-20 years for timber in productive sites. Earlier harvesting at 7-10 years can yield fuel wood and pulp.

Table 1: Maesopsis growth in its optimum range

	Tree parameters			
Age	**DBH [cm]**	**Bole height [m]**	**Tree height [m]**	**Crown diameter [m]**
2	10	3	7	4.4
7	25	5	16	7.7
9	30	6	18	8.8
11	40	7	20	11.0
13	45	8	22	12.1

Source: Buchholz et al., 2004

Description of the project area

Location, topography and land cover type

The project area is located in Bushenyi District, SW Uganda lying approximately between 671003 M East and 324000 M North (UTM coordinate system). The topography is undulating with broad ridge tops and generally small valleys around central Bushenyi, but more steeply sloping in the southern and northern parts. The altitude ranges from 910 to 1950 m.a.s.l. The main land use/land cover systems are farmland (80%), woodland (12%), and grassland (5%).

Soils, farming systems, and productivity

The predominant soil types are yellowish brown sandy clay loams developed from phyllite, schists, and gneisses rocks. Black sandy loams developed from volcanic ash and rift valley sediments are a common occurrence towards the North and Northwestern part of the District (Harrop, 1960). The FAO classification characterises these soils as predominantly feralsols and acrisols. Soil productivity is largely characterised as medium, owing to good soil depth, structure and inherent soil fertility. Banana production dominates the use of the cropped land (81%), followed by bean (4%), maize (4%), sweet potato (4%), finger millet (3%) and sorghum (2%) as the main food crops. Tea, coffee (both robusta and arabica) as well as cotton and Irish potato are the dominant cash crops. Dairy livestock is also a dominant farming system.

Table 2: Crop performance [kg ha^{-1}] under various soil fertility levels

	Soil fertility levels		
Crop type	High	Medium	Low
Millet	1500	750	300
Bananas	10000	6063	2750

Climate and population

Bushenyi District has a climate characterised by mean annual rainfall of 1200 mm, which occurs in a bimodal pattern. Mean minimum and mean maximum temperatures are 14 and 26°C, respectively. This favourable climate and the potentially fertile soils coupled with historical factors led to high population densities in the area. The population density stands at 220 people per km^2 with a growth rate of 3.1%.

Management objectives

The Maesopsis woodlot system provides an opportunity to farmers to use available land, which is not optimally utilized in a profitable manner, or place it under a less intensive management system. Land may be too far from farmers' compounds because of fragmentation, or theft or vermin originating from the neighboring protected area may affect crops grown. Other farmer constraints include inadequate labor.

The primary objective of this system is to produce high-quality timber at the end of established rotations, as well as fuel wood obtained through woodlot management operations (thinning and pruning). Some farmers are using Maesopsis for provision of shade under coffee and banana land use systems. It has long been established that shade coffee yields better and is of superior quality than the conventional un-shaded coffee. Other products and services from Maesopsis woodlots include fodder (fruits), support to honey production, and restoration of positive environmental and ecological functioning in heavily degraded areas. Such functions include: runoff and soil erosion control, micro-climatic modifications, and increased terrestrial biodiversity (e.g. birds).

Ex-ante cost benefit analysis of Maesopsis woodlots for timber production

Under proper management regimes, Maesopsis woodlots have the potential to generate good financial returns from timber and firewood products, as well as additional revenue accrued from the option of integration with crops. The major labour and input costs associated with establishing, managing and harvesting a 20-year Maesopsis woodlot are given in table 3 below. Major inputs include planting seedlings and crop seeds if crops are to be integrated in the first 3 years of tree establishment before tree canopy closure. Crop integration is recommended not only as a way of shortening the payback period and maximizing returns but also serves to provide nursing for young trees. Seedlings of indigenous trees have a slower growth rate than crops and therefore require shade protection and good weed control measures. Crops provide shade and the more intensive weeding provided to crops simultaneously benefits the trees. Use of herbicides for weed control may start after end of cropping (at canopy closure) and continue for 2-3 years until when tree canopies can completely suppress under-storey weed growth.

Major labour costs include land clearing and tillage operations, tree and crop planting, weeding, harvesting of crops, tree thinning and pruning, crop harvesting, timber harvesting etc. Labour data for some of these field operations are adapted from Siriri and Raussen (2003) while some are estimated. Labour data is presented in man-days per hectare where a man-day is regarded as 6 hours of work. The prevailing on-farm labor wage rate of USD 0.6 per man-day is used. The input costs (e.g. Maesopsis seedlings and maize seeds) and the value of crops, firewood and timber are derived from the prevailing market prices. The maize yield level used in this analysis is deliberately very conservative (1500-2000 kg ha^{-1}) to take care of the competitive influence of trees on crops and the fact that land chosen for tree planting is likely to be less fertile.

Table 3: Values used for the cost-benefit analysis

Parameter	Value
Inputs	
Tree density at planting [no. ha^{-1}]	400
Tree density at harvesting [no. ha^{-1}]	200
Maesopsis potted seedling cost [USD $seedling^{-1}$]	0.3
Maize seed rate, kg ha^{-1}	25
Maize seed cost (H622), USD kg^{-1}	0.7
Maesopsis Outputs and price	
Maesopsis timber [USD $tree^{-1}$]	25
Maesopsis firewood value [USD $tree^{-1}$]	3
Harvest losses [%]	10
Crop Outputs	
Yield of integrated maize (Total over 6 seasons) [kg ha^{-1}]	10500
Maize grain farm gate price [USD kg^{-1}]	0.15
Labor	
Wage rate for common field operations [USD man-d^{-1}]	0.6
Land opening (slashing and initial hoeing)	100
Crop land preparation (twice per year for 3 years), [man-d ha^{-1}]	180
Tree planting and gapping [man-d ha^{-1}]	30
Crop planting [man-d ha^{-1}]	60
Weeding (four times per year for 3 years), [man-d ha^{-1}]	240
Crop harvest and handling [man-d ha^{-1}]	60
Thinning, [man-d ha^{-1}]	30
Spot weeding and slashing (from year 4 to 7 [man-d ha^{-1}]	120
Tree harvesting (clear cut logging) [USD m^{-3}]	9

Table 4 gives an economic analysis of the Maesopsis woodlot system with crop integration for the first 3 years. The net financial benefits accrued from the system is determined as the difference between the total benefits (crop and tree returns) and the total costs (input and labor costs). The net benefits over a twenty-year rotation are converted to annual returns per hectare. The returns to labor are calculated as total discounted benefits less none labor costs divided by the total man-days for a particular land use system.

Although the crop component has additional input and labour demand beyond what is needed for the tree component, integration of crops provides attractive additional revenue, which farmers can use to finance tree management operations than come later. Indeed the total 3-year net returns from the crop component can finance almost all tree management and harvesting operations over a 20-year period. The only challenge to crop integration is the higher labour requirement, which results in a lower return to labour. Returns to labour under the tree component are very impressive, posting a value 10 times higher than the average wage rate. In conclusion this analysis shows that whereas crop integration has vital added benefits, its practice depends on whether labour and input acquisition are not serious constraints.

Table 4: Financial analysis of Maesopsis woodlots integrated with crops for the 1st three years

Financial parameters	Tree component [USD]	Crop component [USD]
Gross returns, Ha^{-1} $year^{-1}$	373	525[c]
Input costs, Ha^{-1} $year^{-1}$	15	35[c]
Labour costs, Ha^{-1} $year^{-1}$	80[d]	105[c]
Net benefits, Ha^{-1} $year^{-1}$	220	382[c]
Benefit-cost ratio	2.3	2.7
Returns to labor, day^{-1}	5.8	4.5

[C] Average of 3 years

[d] 95% of total labour costs come during tree harvesting

Management operations

a) Land clearing

This involves cutting down and uprooting where possible all shrubs, herbs and climbers growing on the designated plot. Initial tillage to break ground is recommended especially if plot has been under pasture or long-term fallow. Additional smooth land preparation may be required if crops are to be integrated. Work out the area and estimate the number of planting material required.

b) Establishment

Planting stock should come from seeds or wildlings of high quality mother trees selected for form, vigor, and bole height in the protected areas or the agricultural landscape. Plant seedlings should be healthy, non-deformed, and of the right height (15-30cm). Overgrown seedlings have restricted root development. Planting holes of 30 cm diameter and depth should be made and topsoil or manure used in the rooting zone if possible. The planting design consists of block planting Maesopsis seedlings at a spacing of 5 m between rows and 5 m within rows (5m x 5m) resulting in an initial population density of 400 trees per hectare. Planting rows should be straight except on a slope where they should be contour-planted to minimise erosion. Crop integration can be done between Maesopsis rows for 2 to 3 years until tree canopies close.

c) Maintenance

“Beating-up” to replace dead or poor performing seedlings is crucial. This should be done between 4 to 8 weeks after initial planting. Controlling weeds is crucial for good performance of trees, especially in the early stage of growth. Three options for weed management can be adopted: spot weeding, herbicide use, and complete weeding. Spot weeding and use of herbicides are recommended where crops are not integrated. Spot weeding is recommended at a rate of twice a year. Herbicide use can be a low cost way of controlling weeds, especially notorious perennial weeds. Herbicides like Roundup kills treated weeds and translocates throughout the treated weed, moving from the foliage down into the stems and roots, to prevent re-growth from underground reproductive parts. Herbicides can be applied at a rate of twice a year. Where crops are integrated, complete weeding is necessary. Initially marking trees with a stick will help to prevent tree losses when weeding.

As trees get bigger, their requirement for growth resources increases, hence a need for progressive increase of tree spacing. To attain this, thinning (removal of some trees especially those with poor health and bad form) has to be done at 5 years to a population density of 300 trees ha^{-1} and later repeated at 10 years to attain a final population density of 200 trees ha^{-1}. Tree pruning should be practiced to encourage best tree from. When harvested before timber size, Maesopsis does not make good construction poles but provides high quality fuel wood. In year 8+, Maesopsis crowns are expected to start closing.

Table 5: Management model for Maesopsis woodlots

Activity	Age (Years)	Stand density (N/ha)
Establishment	0	400
Thinning	5	300
Thinning	10	200
Harvest	20	200

d) Harvest

Maesopsis will be harvested at 20 years for timber. It is expected that harvesting will be done through local pit sawing.

Methodology used for calculating carbon accumulation

The carbon sequestration potential of trees can either be derived from tree biomass or stand volume. The tree biomass approach uses tree biomass curves that relate biomass production to age of trees. On the other hand the volume approach uses correlations between stand volume and age of trees by assuming that trees in a stand have the same allometric structure hence uniform volume. The stand volume approach can only be used for single species woodlots that are growing in fairly uniform manner. In mixed tree species planting systems where each species has a different growth pattern, the biomass approach will be preferred in order to develop growth curves for each species. Since this technical specification is focusing on Maesopis single species woodlot, the stand volume approach was therefore used.

Table 6: Single-tree management model for *Maesopsis eminii* (Buchauchholz et al, 2004)

Activity	Age	Height	DBH	Bole length	Stand density	Square spacing	Mean annual increament (MAI) in timber volume
	(years)	(m)	(cm)	(m)	(N/ha)	(m)	m³/ha/a
Establishment	0	-	-	-	200	10	-
Thinning	5	17.1	34	8.5	100	10	13.4
-	10	25	46	12.5	50	14	13.6
-	15	31.1	54	15.5	50	14	14.1
Harvest	20	34.6	59	17.3	50	14	13.9

To derive the correlation between Maesopis stem volume and age, data from Buchauchholz et al (2004) was used (Table 6). Changes in stem volume was calculated from the mean annual increment (MAI) in volume and adjusted for thinning removals. This resulted in a polynomial correlation shown in Fig. 1 below. The regression equation in Fig. 1 was then used to calculate yearly stem volume over a 20-year period. Stem volume was then used to obtain the volume of branches and roots using proportion constants in table 7. Total tree volume was obtained by summing the volumes of stems, branches and roots. Total tree volume was converted to biomass using density of Maesopsis, which has been given as 449 kg m^{-3} (Cannel and Dewar, 1995). The amount of carbon in the tree biomass was obtained by assuming that carbon constitutes 58% of the weight of dry wood.

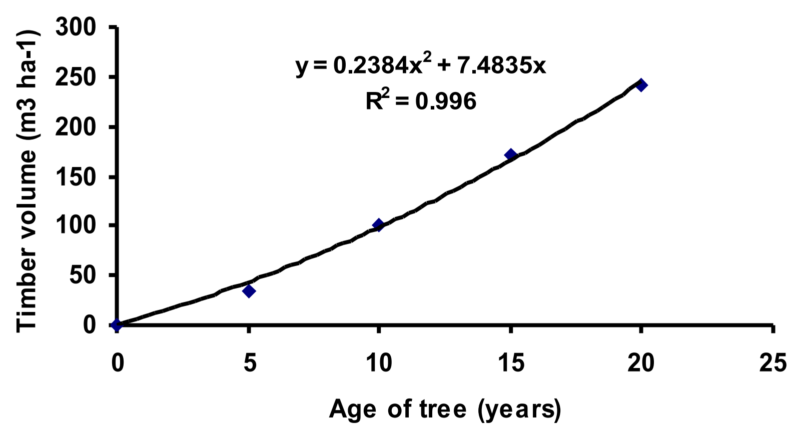

Figure 1: Change in Maesopsis stand volume with age

Table 7: Assumptions used in the carbon calculations

Parameter	**Value**
Dry wood density	449 kg m^{-3}
Proportion of branch to stem volume	47%
Proportion of woody roots to stem volume	30%

Carbon sequestration potential of sole Maesopsis woodlots

Following the above methodology of determining carbon sequestration under sole Maesopsis woodlots, total carbon accumulation over a 20-year period will be **125 tones per hectare** while the annual carbon offset will be **61 tones per hectare** (Fig. 2). Although these figures are impressive and can greatly contribute to farmer's income under carbon credit payment schemes, they are lower than estimates from other parts of the world. The critical factor in determining carbon sequestration potential in Maesopsis woodlots appears to the management regime, particularly tree spacing and thinning regimes. In this case, the data used in deriving parameters for carbon estimation (Table 6) assumes a widely spaced Maesopsis planting regime, which after thinning gives a final plant population of 50 trees per hectare at harvest. This may not be entirely representative of the farmer's management regimes, which may have a higher tree population at harvest. However, higher tree populations don't neccesaririly result in higher tree volumes. Given these complexities and the limitations in secondary data, these technical specifications are recommended as a starting point that provides a fair understanding of carbon accumulation under Maesopsis. However, they will have to be refined as tree growth data from the project areas start to be available.

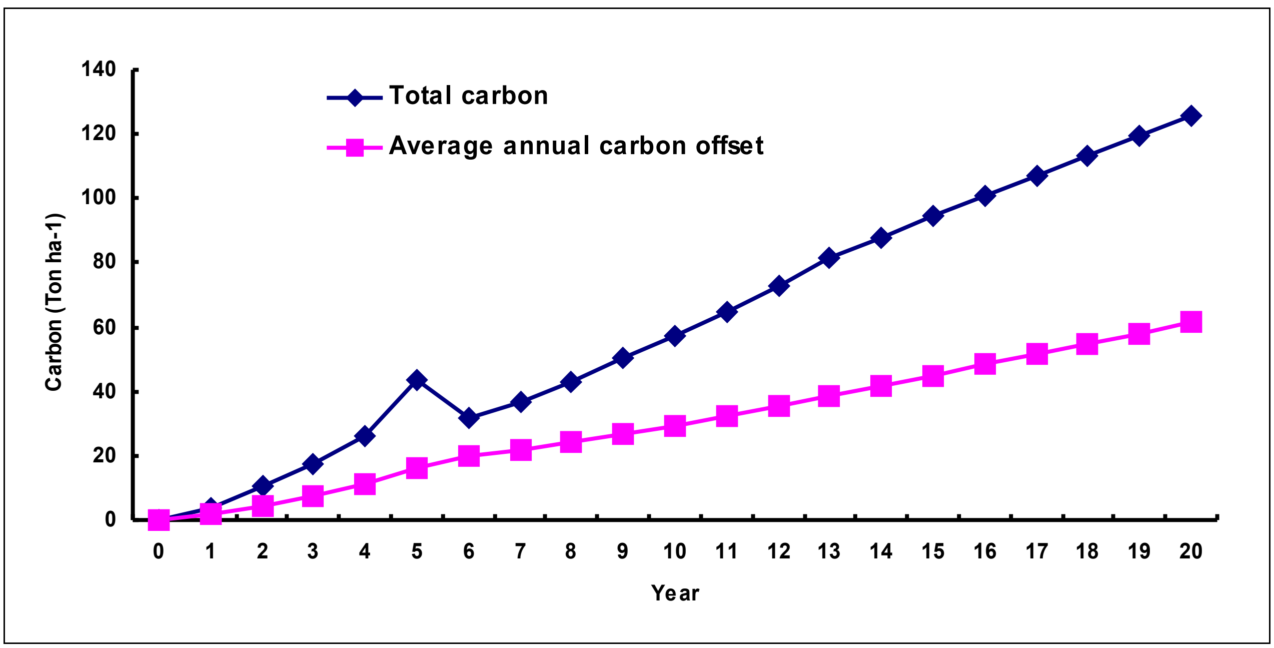

Figure 2: **Carbon accumulation under sole Maesopsis woodlots**

References

Buchauchholz T., Tennigkeit T. and Weinreigh A. 2004. *Maesopsis eminii* - a challenging timber tree species in Uganda - a production model for commercial forestry and smallholders**.** Paper presented at a IUFRO conference.

Katende A.B., Birnie A. and Tengnas B. 1995. Useful trees and shrubs for Uganda. Regional Soil Management Unit (RSCU), Nairobi, Kenya 710 pp.

Siriri D. and Raussen T., 2003. The agronomic and economic potential of improved fallows on scoured terrace benches in the humid highlands of Southwestern Uganda. Agriculture, Ecosystem and Environment 95: 359-369.

Wortmann C. S. and C.A. Eledu 1999. Uganda's Agroecological Zones: A guide for planners and policy makers. Centro International de Agricultura Tropical (CIAT), Kampala, Uganda.