Sustainable Biomass Production in Sri Lanka and Possibilities for Agro-forestry Intervention

By

Dr H A J Gunathilake, Head,
Agronomy Division
Coconut Research Institute, Sri Lanka

P G Joseph, Director,
Alternative Energy Division,
Ministry of Science & Technology

Harsha Wickremasinghe, Director (Project),
Energy Conservation Fund, Sri Lanka

and

T S G Peiris, Head
Biometry Division
Coconut Research Institute of Sri Lanka

ABSTRACT

A Research Project was carried out over a period of five years commencing in 1998 on the theme of "Sustainable supply of fuel wood to meet Sri Lanka's energy needs' having two main objectives:

a) to demonstrate the technical feasibility of short-rotation fuel wood plantation particularly on degraded lands, as sources of energy for Sri Lanka and
b) to enhance institutional capacity in Sri Lanka in the knowledge of fuel-wood as a source of energy.

The project was supported by the European Commission under its Tropical Forestry Budget Line. Initially, the project studied the growth and performance of 14 tree species. However, the

emphasis was placed on key species of Gliricidia sepium, Acacia auriculiformis and Leucena leucocephala. A split-plot design was adopted. Three species (as above), two plant spacings (1 m x 1m; 1m x 2m) and two harvesting regimes (HI - annual coppicing at a height of about 1m; H2 - continuous harvesting removing branch materials as is expected a diameter of 25 mm, cutting at a height above 1.5 m on the main stem). Initially 12 sites were established but later this was reduced to 10 due to various management reasons.

Wood yield (at 20% moisture level) was the main parameter used to assess performance of particular species withinin the various spacing and harvesting regimes. The results of these 10 sites were compared with similar trials performed at the Coconut Research Institute (CRI) for other agronomic evaluations on soil and soil water.

Both Gliricidia and Acacia performed well in wide range of sites compared to Leucena. However, Gliricidia was the best in many locations due to a high wood yield, high rate of leaf decomposition, ability to tolerate frequent harvesting with less mortality, easy establishment with vegetative propagation, easy handling due to uniform size of branching and multiple use (animal fodder, green fertiliser etc). On average, Gliricidia and Acacia yielded 24m.t and 18 m.t. per ha respectively, grown at the density of 10,000 trees/ha.

Comparing the two espacements, both Gliricidia and Acacia appeared to perform best at the closer spacing of 1 m x 1 m. On average, the yield difference was 30 %. Hence, it is advisable to plant specially Gliricidia at the closer espacement of 1 m x lm equating to a density of 10,000 trees/ha. However, in practice, due to the need for access, the density of planting will average no more than 8,000 trees/ha. In terms of harvesting regimes, annual coppicing (all branches at the same time) at a height of 1 m produced the highest yield (30 m.t./halyr).

Trials conducted at the CRI showed that Gliricidia improved soil fertility and the micro climate and it was concluded that Gliricidia is ideal for fuel wood production under a programme of sustainable agriculture.

Recently, the Government of Sri Lanka declared, Gliricidia sepium as the fourth main plantation crop in addition to three existing crops of tea, rubber and coconut. These estate crops fall under the purview of Ministry of Plantation Industries. The development of fuel wood produced mainly from Gliricidia in the agro-based energy sector (eg; tea factories, desiccated coconut mills) is providing the right encouragement for the country to meet its overall energy security.

INTRODUCTION

Sri Lanka has been successful in developing an extensive hydro-power infrastructure. However, the limit on further major expansion was reached some years ago. In 2002, 39% of the country's energy needs was met from imported oil, whilst biomass provided 53% -chiefly for domestic needs. The country has no fossil fuel and the key economic aspects such as energy security, economic viability and productivity, cost of living, investment in economic development are not being adequately addressed at present. Under this scenario, development of alternative energy sources has been accepted as a top priority area. Among them, wood based energy applications appeared as a viable alternative to fossil fuels due to both economic and social benefits.

Wood-based energy production is able to alleviate poverty, save foreign exchange and to be sufficiently supported by local technology. Further, it is a fully renewable energy source being dependent on coppicing trees. With regard to land availability, there is an extensive area of scrub land with minimal value for food crops, due to inadequate rainfall and low fertility, but suitable for the growing of forest plantations particularly for short rotation fuel wood. This would lead to an increase of the present forest cover of 1.7 million ha to a more acceptable level.

Farmers within the drier areas of the country are mostly dependent on a single annual crop of rice linked to the monsoon rains. For the major proportion of the year, households are often under-employed and need to find alternative work to meet their requirements for an adequate income which would be flexible to fit into the demands of the current farming calendar. Fuel wood plantations are seen to be one possible activity.

Materials and Methods

This research project was funded by the EU and had two main objectives:

(a) To demonstrate the technical feasibility of short-rotation fuel wood plantations, particularly on degraded lands, as source of energy for Sri Lanka and

(b) To enhance institutional capacity in Sri Lanka in the knowledge of fuel wood as a source of energy.

This project set out to determine, the growth and performance for a range of well known fuelwood species using a range of different management techniques. Although 14 species were used in the trials, the emphasis was placed on the key species of *Gliricidia sepium, Acacia auriculiformis, Leucaena leucocephala, Cassia simaea* and to a lesser extent *Eucalyptus camaldulensis* and *Calliandra calothyrsus*. Eucalypts was not as well represented as had been intended, due to poor planting stock. Planting was carried out from the end 1998 to 1999. Details of locations are given in Table I.

Table 1 Details of Project Sites and Species.

Site No. Location (Site Ownership)	**Zone**	**Principal Species (spacing) (m)**	**Establishment Date**
Anamaduwa, Puttalam (Forestry Department)	Dry Zone, Low Country	Acacia (I x l & 1x2) Gliricidia (1x1 & lx2)	end 98
Lunugamwehera, Hambantota, (ForestryDepartment)	Dry Zone, Low Country	Acacia (1 x 1 & 1x2)	end 98
Korakahawewa. Anuradhapura I (Forestry Department)	Dry Zone, Low Country	Acacia (1 x 1 & l x2) Gliricidia (1 x 1 & 1x2)	end 98
Illuppankadawala Anuradhapura II (Forestry Department)	Dry Zone, Low Country	Gliricidia (1 x 1 & 1x2)	end 98
Kanichiagalla, Polonnaruwa (Forestry Department)	Dry Zone, Low Country	Acacia (1 x 1 & 1x2) Gliricidia (1 x I & 1x2)	end 98
Thalakolawewa, Kurunegala (Forestry Department)	Intermediary Zone, Low Country	Eucalyptus (1x I , 1x2) Acacia (I x 1 & 1x2)	end 98
Kundasale, Kandy (University of Peradeniya)	Intermediary Zone, Low Country	Calliandra (Ix I , I x2) Acacia (Ix l & 1x2) Gliricidia (1x1, 1x2)	end 98
Maha Illuppallama (Regional Agric. Research Centre) Eastern University, Batticaloa	Dry Zone, Low Country	Ipil Ipil (Ix 1, 1x2) Gliricidia (1 x 1 , 1 x2) Cassia (1 x 1, I x2) Gliricidia (1x1, 1x2)	end 99 end 2000

A split-plot design was adopted to test the interaction of species, espacement and harvesting regime. Final results were fully analysed for the 3 key species (*Gliricidia. Acacia and Leucaena*), 2 spacings (l x lm and l x 2m) and 2 harvesting regimes (HI- annual coppicing roughly at a height of 1 m ; H2 - continuous harvesting removing branch materials as it reaches the desired diameter of 25 mm; cutting at a height above 1.5m on the main stem). This generated 3 x 2 x 2 = 12 treatments in total.

Total extent of each site was 3.0 ha and original plots divided to sub-plot of 10 m x 20 m. Actual layouts of individual site however, had to be adjusted to local conditions and the number of treatments was restricted for different reasons at most sites.

Establishment success varied considerably. Although 12 sites were originally selected, two had to be abandoned due principally to fire damage (eg. Site- 3 Monaragala).
One of the trial sites at the Open University, Nawala was also abandoned soon after establishment in 2001 when it was discovered that the soil quality was much poorer than had been first assumed. Cattle grazing also caused varying degrees of crop damage at some sites.

At the end of the first year, pre-harvest pruning was done with a uniform cut at a height of lm or 1.5 m (depending on the treatment.) Wood yield per tree basis was measured at 20% moisture level.

Results of this project were compared and incorporated with similar trials performed at the Coconut Research Institute of Sri Lanka (CRI). Wood yield along with foliage yield and other agronomic parameters were extensively studied at the CRI.

<u>Results</u>

1. Wood Yield :

This is presented for 7 sites. Except for site 11 Angunakollapellessa, in all other sites *Gliricidia* produced the highest wood yield over *Acacia*, *Leucaena* or *Eucalyptus*. *Cassia siamea* yielded 31 m.t/ha at lm x 1m at Angunakolapellessa. In terms of wood production *Acacia* overall was next best. Wood yield of *Eucalyptus* was not as promising as for *Gliricidia* and *Acacia*.

In many instances wood yield/tree of the above species was in fact higher for the lm x 2m espacement, however the lm x lm spacing tended to produce <u>the highest wood yield per ha</u>.

Table 2a. : Wood yield of different species performed in different locations.

Site	Spp	Spacing	Wood Yield	
		(m)	Kg/tree	Mt/ha
1. Anamaduwa, Puttalam	Gliricidia	1 x 1	I.2	14.0
		1 x 2	1.2	6.0
	Acacia	1x1	0.9	9.0
		1 x 2	1.1	5.5
4. Korakahawewa,Anuradhapura	Gliricidia	1 x 1	2.8	28.0
		1 x 2	2.6	13.0
	Acacia	1 x 1	0.4	4.0
		lx 2	0.5	2.5
5. Illuppankadawala-Anuradhapura	Gliricidia	1 x I	3.2	32.0
		1 x2	4.5	22.5
6. Kanichiagalla-Pollonaruwa	Gliricidia	1x1	3.9	39.0
		1 x 2	4.0	20.0
	Acacia	1 x1	3.2	32.0
		1 x2	3.1	15.5
7. Thalakolawewa.Kurunegala	Gliricidia	1x1	1.9	19.0
		1 x2	1.6	8.0
	Acacia	1 x 1	1.2	12.0
			1.0	5.0
	Eucalyptus	1x1	0.3	3.0
		1x2	0.4	2.0
8. Mahiyangana-Badulla	Gliricidia	1 x 1	1.7	17.0
		1 x2	1.8	9.0
	Acacia	1 x 1	1.5	15.0
		1 x 2	1.6	8.0
	Eucalyptus	1 x 1	1.1	11.0
		1 x 2	1.1	5.5
11. Angunakola	Gliricidia	1 x 1	1.6	16.0
		1 x 2	1.16	8.0
	Ipil	l x l	1.6	16.0
		1 x 2	2.2	11.0
	Cassia	1 x 1	3.1	31.0
		1 x 2	1.8	9.0

Table 2 (b)Wood Yield at two harvesting regimes in 6 selected sites.

	Harvesting regimes	Wood Yield Kg/tree
Site -1	HI	1.2
	H2	1.0
Site – 4	HI	1.7
	H2	1 .0
Site - 5	HI	5.0
	H2	2.3
Site ?	HI	1.6
	H2	0.9
Site 8	HI	1.7
	H2	1.2
Site 11	HI	2.1
	H2	1.6

H1 - Annual coppicing at height of 1 m.
H2 - Continous harvesting removing branch material as it exceeds a diameter of 25 mm, cutting at a height above 1.5 m on the main stem.

2. Establishment of Gliricidia

All *Gliricidia* sticks were planted by cuttings (length of about 1m and diameter of 2.5-3.0 cm) during the October-November rainy season. At the initial planting, sprouting percentage was 58% and consequently replanting was required to obtain an average of 94% establishment rate at the end.

3. Effect of Gliricidia on micro-climate

3(a) Sunlight penetration to the ground

Underneath the coconut, 94 percent of sunlight reached to the ground (Table - 3). On average, after two months of pruning, 75% of sunlight was used by coconut plus *Gliricidia* tree system as indicated by measurements taken in the middle and ground level of *Gliricidia* rows. The same measurement at 6 months after pruning was 94 percent.

Table 3 : Effect of Gliricidia inter-cultivation on sunlight usage

Situation	% of sunlight received at the ground level	Usage by crops
Open field	100	0
Coconut alone	94	6
Coconut + Gliricidia (immature - 4 month after pruning)	25	75
Coconut + Gliricidia (6 month after pruning)	6	94
Coconut + Gliricidia (at maturity 8 month after pruning)	15	85

3(b) Soil temperature:

During the dry months (July-September), soil temperature at 14.00 hrs averaged 41.4 C° under the coconut; for the coconut plus *Gliricidia* system, the comparative temperature was 31.5 C° Thus the incorporation of *Gliricidia* in to the farming system had the positive effect of reducing soil temperature by up to 10 ^{o}C compared to coconut monoculture.

3 (c) Soil moisture

After a prevailing 30 days dry spell, up to the depth of 15 cm, soil moisture was slightly higher in the coconut stand than in the coconut + *Gliricidia* system (Table 4). However, the difference was not observed at the depth of 30 cm. After 45 days without rain, the soil moisture levels were always higher in the coconut + *Gliricidia* system compared to the soil moisture levels in coconut alone up to a soil depth of 60 cm.

Table 4 :Effect of Gliricidia/Coconut cultivation on soil moisture

A) After 30 day dry spell

Situation		Soil depth (cm)	
	0-15 cm	16-30 cm	31-60 cm
Coconut only	4.7	4.8	5.2
Coconut + Gliricidia	4.0	4.9	5.6
B) 45 days dry spell			
Coconut only	2.2	3.4	3.6
Coconut + Gliricidia	4.1	4.6	5.2

4. Effect of Gliricidia on soil fertility and coconut nutrition

4(a) Nutrient levels of 14^Th leaf of coconut

Nitrogen level of 14th leaf of coconut was considerably increased where coconut was grown in combination with *Gliricidia*. Coconut palms with *Gliricidia* showed high N level over the leaf sufficiency range too (Table 5). Levels of Ca also followed the same trend. P and Mg levels were not different in the coconut with or without *Gliricidia*. However, coconut palms with *Gliricidia* inter-cultivation showed reduced K levels in comparison to coconut without *Gliricidia*.

Table 5 : Effect of Gliricidia inter-cultivation on coconut nutrition (14th leaf)

	N%	P%	K%	Mg%	Ca%
Coconut alone	1.68	0.11	0.91	0.35	0.39
Coconut + Gliricidia	2.18	0.12	0.84	0.33	0.54
Sufficiency range/level	1.9-2.1	0.11-0.13	1.2-1.5	0.25-0.35	0.35-0.5

4(b) Soil organic carbon and nutrients

Soil organic carbon:
Soil from the mixed cropping area had a greater proportion of soil carbon. This was particularly prominent in the upper soil layer.

Table 6 : Effect of Gliricidia inter-cultivation on soil organic matter level

Situation	Soil depth (cm)	
	0-15	16-30
Coconut only	0.46	0.5
Coconut + Gliricidia	0.76	0.55

Nitrogen : The level of soil nitrogen was elevated nearly 1.5 fold in the Gliricidia plots compared to the non-*Gliricidia* cultivation. This increase was also noted at the depth of 16-30 cm (Table 7)

Phosphorus (ppm) : P level was more than doubled where coconut with *Gliricidia* at the soil depth of 0-15cm and continued to be high at 16-30 cm depth (Table 7).

Potassium: Soil K level were also increased by the presence of Gliricidia in the cropping pattern at both soil depths of 0-15cm and 16-30 (Table 7).

Magnesium: Soil Mg levels gave comparable results to that for K levels

Table 7 :Effect of Gliricidia inter-cultivation on soil N,P,K, Ca and Mg

Situation	N (ppm)		*P* (ppm)		K %	Mg %
	0-15	**16-30**	**0-15**	**16-30**	**0-15 16-30**	**0-15 16-30**
Coconut only	490	327	3.4	Trace	0.15 - 0.17	0.8-0.7
Coconut+ Gliricidia	644	471	8.1	5.6	0.23-0.26	1.1-1.1

5. Cost-Benefits

During the first year, establishment of 1 ha of Gliricidia cost Rs. 20,700. Of the total establishment costs, 50% was for labour. From the second year onward, maintenance cost did not exceed Rs 4,000 per ha/year. At the fifth year, the cost of harvesting increased to Rs. 18,000 per ha in addition to the transport cost of cut material which amounted to a further Rs 12,000 (Table 8).

Income from *Gliricidia* is calculated from the sale of the wood and the use of leaf biomass for fertilization of coconut. Value of wood at 20% moisture level was Rs. 2.60 per kg and this market price generated Rs. 63,000 per ha per year in addition to the value of leaf biomass. At the fifth year, leaves of *Gliricidia* utilised as a supplementary green manure was calculated as have a value equivalent to Rs. 6,200/ha/year looking at the savings made in the use of urea. The total value of leaves and wood was calculated to be Rs. 69,388 /ha in year 5. By year 5 (reaching maturity) *Gliricidia* inter-cultivation with coconut was able to generate approximately Rs. 35,000 as net profit, excluding the value of the coconut crop.

Table 8 :Expenditure and Income from inter-planting Gliricidia in 1.0 ha of coconut during the initial 5 year period (Rs.)

Activity°	Year 1	Year 2	Year 3	Year 4	Year 5
A) Materials					
Planting Materials	4500	-	-	-	-
Weedicides	6000	-	-	-	-
B) Labour					
Land clearing	2500	-	-	-	-
Planting	2800	-	-	-	-
Vacancy filling	900	-	-	-	-
Maintenance (weeding	4000	4000	4000	4000	4000
Harvesting	-	9000	13500	15000	18000
Transport	-	6000	9000	10000	12000
Total Cost	20700	19000	265000	29000	34000
C) Income					
wood	-	31720	47320	52520	63180
Leaf *	2064	2576	3278	5200	6208
Total	2064	34296	50598	57720	69388
D) Net Profit (Rs/ha.)	(-18636)	15296	24098	28720	35388

* Value of leaf was calculated on the basis of urea equivalent with 1.0 kg of urea = Rs.16.00

Wood price - Rs. 2.50 per kg (at 20% moisture level)

Discussion

The present energy crisis has meant that the Government of Sri Lanka has begun to recognise that biomass is a major resource for large scale power development and that its use would provide a lever to shift power generation away from full reliance on expensive fossil fuels. Encouragement is therefore now being given for dendro plantations for the supply of fuel wood for power generation from both semi-utilised lands being used for the estate crops of tea and coconut as well as in the largely unutilized lands. Support for the development of this activity is now available for rural farmers and also for large-scale plantation enterprises to engage in dendro cultivation. This is a vehicle for rural development and thereby poverty alleviation programmes with special emphasis on "Samurdhi recipients" and other low income families. No doubt sustainable development of fuel wood farming would be the ideal alternative energy supply to address local issues of energy security, increase access to energy or electricity and to increase of purchasing power by a segment of rural people.

Accordingly to Energy Sector Master Plan, 2004, 50% of the energy needs in Sri Lanka are still being met by *the use of bio- mass*. (Anon, 2005) Excessive use of fuel wood is a threat to the country's forest cover, Hence, any such expansion in the use of wood for energy has to go hand in hand with an expansion in the cultivation of trees with a proven coppicing ability.

Nitrogen fixing trees such as *Leucaena* and *Cassia* are known to Sri Lanka over three decades on both an experimental basis and to a lesser extent in practical agriculture. *Gliricidia* is well known over 300 years of cultivation in Sri Lanka and is found extensively in tea and coconut plantations as a shade and fence tree. In most locations *Gliricidia* has tended to out-perform *Acacia* and *Eucalyptus*. However, it is suggested that soil and climatic conditions should be properly assessed when selection of a fuel wood tree for a given area and in the drier areas, *Gliricidia* may not necessarily be the best choice.

Overall, *Gliricidia* produced the highest wood yield in the range of 15-30 m.t. per ha. (stocking10,000 trees/ha). From trials conducted at the CRI (Anon,2004) *Gliricidia* was identified as the best tree species with the capacity to fix biological nitrogen into the soil, to provide enhancement of soil fertility; other desirable characteristics include the prevention of soil erosion, encouragement of soil rehabilitation capacity in poor quality coconut plantations; able to demonstrate easy propagation; quick regrowth following regular pruning and almost free from pest and disease. In addition, prunings of *Gliricidia* branches have proved to be highly suitable for the operation of gasifiers.

On average, *Gliricidia* was able to produce 23 m.t./ha of usable foliage which can be applied as a soil mulch for improving soil fertility. (Anon, 2004) This foliage could be used for feeding cattle along with straw. The total profit to the grower could be as much as Rs. 250,000 per ha and in addition the dung from the cattle could be used for generation of bio-gas. This energy chain based on a tree coppice crop, the production of leguminous soil enhancement, provision of animal fodder and biogas production can provide a family with a fully integrated farming system.

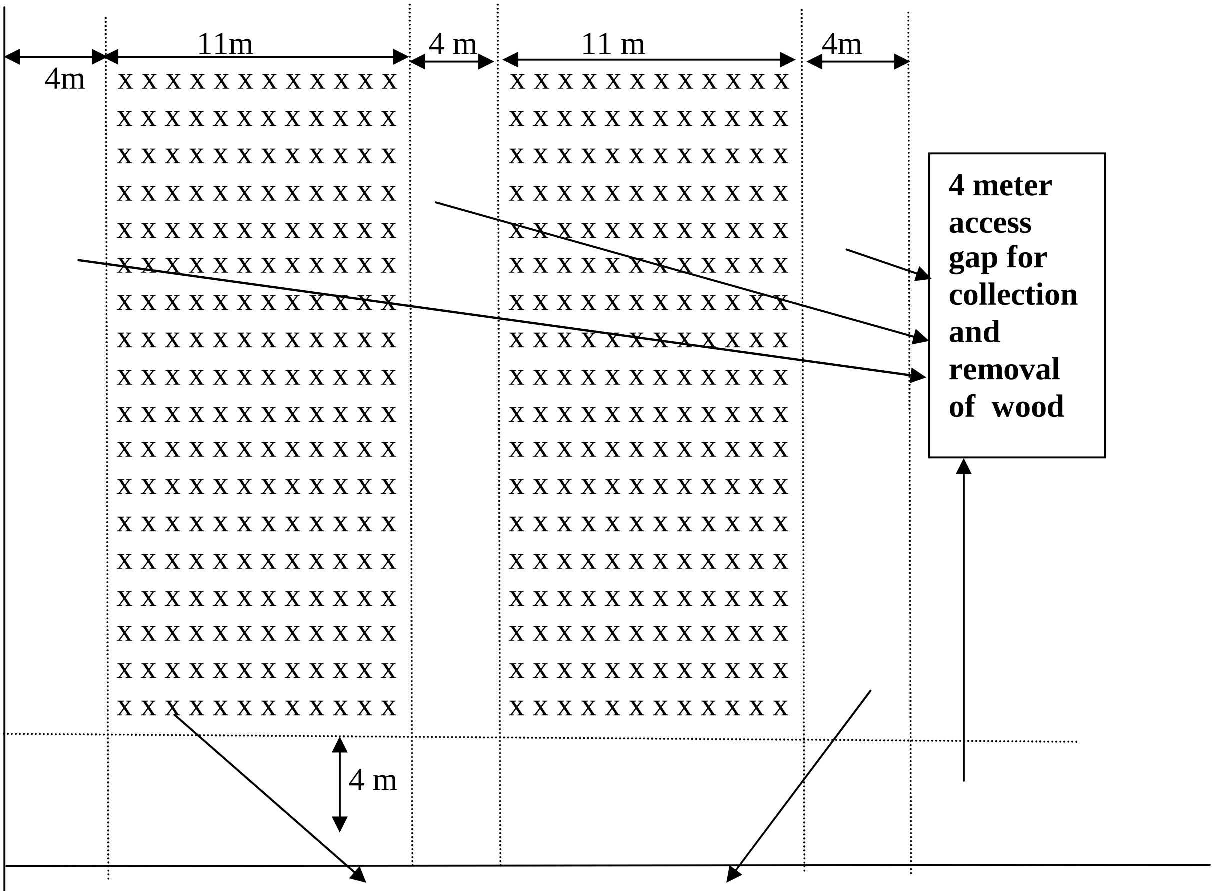
The trials conducted by the CRI showed that new cultivars brought from Guatemala and Mexico are able to produce much improved wood and foliage yield over the existing local cultivars. Hence, the further introduction and rapid multiplication of such new cultivators may substantially improve the future yield to power generation systems.

The results comparing stocking have indicated that either *Gliricidia* or *I,eucaena* grown at 1 m x 1m (10,000 nos. trees/ha.) maximized wood yield. Field observations also revealed that planting of these trees into 1m x l m system quickly suppressed weed growth and led to the production of small diameter sticks which could be easily harvested. In terns of plantation design, access tracks are required and the favoured design seems to be blocks of 12 rows of trees at 1x 1 m with 4 m gaps to provide harvesting access. (Refer Fig 1).

Harvesting regimes also affect the yield of wood and foliage. Results shows that annual coppicing at a height of 1.0 m from ground level produced the highest wood yield. This result is also supported by the experiments carried out at the CRI. Complete removal (pruning) of all branches showed that re-growth is fast and uniform branches also could be obtained, compared to the harvesting regime of continuous harvesting where the removal of branches is limited to those that are over 25 mm. only. Removal of all branches at the same time would help to maintain apical dominance of the tree. In this project, the harvesting interval was set at 12 months, however, it is required to adjust the harvesting interval to optimize both wood and foliage yields. The harvesting interval may vary with climate, soil, etc. The trials at the CRI have shown that an 8-month harvesting interval is the best for *Gliricidia* in the intermediate Low Country (IL), region of Sri Lanka.

Gliricidia in coconut plantations led to a significant improvement in the soil and micro climate. There was noted to be a reduction in soil temperature underneath the *Gliricidia* canopy, which may have several benefits. Among them being an increase in root activity, a reduction of soil moisture losses, and a reduction in soil carbon oxidation. Leaf litter collected from shredded *Gliricidia* leaves will also cover soil and thereby reduce soil temperature.

Soil fertility improvement by *Gliricidia* is the key for development of degraded soils and agriculture. One hectare of *Gliricidia* with coconut produced approximately 24 m.t (fresh weight) of leaf biomass annually. Organic materials are considered as important resources for building soil fertility. Soil under *Gliricidia* has shown elevated levels of organic carbon. N, P over non-Gliricidia plots. These changes in soil nutrient profile are general, because *Gliricidia* could mine plant nutrients such as P, K. Ca, Mg. from deeper layers of soil. With the continuous lopping of *Gliricidia* as a renewable forestry, such plant nutrients are expected to be high in the surface layers of soil.



Strips of 12 trees, 1-meter apart, separated by 4-meter gaps. Width of strip = 11 meters.

→ Outer Fence

Figure 1 - Optimum Design of Short Rotation Coppice Crop

Based on overall results of this study, *Gliricidia* could be identified as promising tree for fuel wood production. It is appeared that the general maintenance cost of a *Gliricidia* is low. The major part of the cost of management being harvesting and transportation costs. An economic analysis done at the CRI showed that the transport of *Gliricidia* fuel wood within the radius of 15 km. from power generating plant is still economical.

Income from wood is considerable and the ratio between wood and leaf is 10:1. Considering the low cost of maintenance, net profit of *Gliricidia* plantation seems to be attractive for coconut growers. Demand of *Gliricidia* fuel wood is growing and the price is also now in an increasing trend due in part to the continuous hike in the cost of oil-based fuel.

Conclusion

Due to the high cost of fossil fuel and the associated environmental hazards, the development of alternative energy sources which are cost effective and environmental friendly has become essential. The use of biomass and wood is now being given a higher priority in Sri Lanka. To save natural forest plantations, sustainable fuelwood farming with nitrogen fixing trees that have demonstrated good coppicing ability could be developed as a renewable forest source. Among the many tested species, *Gliricidia sepium* seems to be a leader. It has been shown to have the capacity to produce wood in excess of 20 mt./ha/year.

The Sri Lanka Government has given recognition to upgrade fuel wood farming to a similar level to that for other major plantation crops such as tea, rubber and coconut by declaring *Gliricidia* as the 4^{th} Plantation Crop. Following on from this decision, it is hoped that this will lead to a mini- revolution through a change from standard food farming to one of agro-energy farming. This would create a highly favourable impact both economically and agronomically on our traditional farming systems.

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