Growth and fuelwood production of *Cassia siamea* and *Eucalyptus camaldulensis* under short rotation in the eastern Terai of Nepal

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Two plots of *Cassia siamea* and *Eucalyptus camaldulensis* were established in July 1990 at Tarahara, eastern terai of Nepal. *C. siamea* and *E. camaldulensis* had a good survival up to 2.5 years after which it dropped down due to the damage caused by wild elephants and deer. The height growth of the thickest shoot of *E. camaldulensis* was better than *C. siamea* before clearfelling at 3.5 years and during the period of 4.5 - 6.5 years. Diameter at Breast Height (DBH) of the thickest coppice shoot of *C. siamea* and *E. camaldulensis* did not differ significantly except at 9.5 years when *E. camaldulensis* had lower dbh than *C. siamea*. The mean number of sprouted shoots of *C. siamea* was higher than that of sprouted shoots of *E. camaldulensis*. The increased number of coppice shoots at 10.5 years indicates the good coppicing capacity from the stool. Wood production of *C. siamea* was higher than *E. camaldulensis* in the clearfelling at second and third rotations. In *C. siamea*, mean wood biomass accumulation per stool increased with the age of stool and successive rotation. The biomass accumulation of *E. camaldulensis* decreased with the increased age of stool. The study gives estimates of land needed for family of four in the Terai needs about 731 m^2 land to meet their fuelwood demand.

Keywords: Fuelwood Production, Terai – Nepal, *Cassia siamea, Eucalyptus camaldulensis*

From the primitive days, the fuelwood is being used to generate energy for cooking and heating. The per capita energy consumption in Nepal is 14.06 GJ (WECS 1994), which is considered as very low and only four other countries in the world have lower per capita energy consumption than Nepal (WECS 1995). The contributions of fuelwood , animal waste and agriculture residues to the national total energy consumption are 68 %, 15 % and 8 % respectively (WECS 1995), and remaining 9% is met from coal, petroleum and electricity. According to the estimates of Master Plan for the Forestry Sector (1988), there will be a fuel deficit except for the Far Western Region and High Himal by 2000/01. The annual fuel deficit at the national level is estimated to be 3 million tons in 2000/01 (HMG/ADB/FINNIDA 1988).

Though the fuelwood/firewood demand is not increasing in the urban areas, its demand in the rural areas is very high mainly due to population growth. The heavy exploitation of the forest has occurred due to lack of sufficient alternate sources. Besides that, Kathmandu has an annual demand of 1460 metric tons of fuelwood for the cremation of the dead body (Personal Communication).

The ever-increasing demand of the fuelwood for cooking and heating purpose mainly in the rural areas has raised the scope of the fuelwood plantation. Furthermore, the higher prices of the petroleum products and electricity have raised its importance for the rural communities. Energy plantations at present are not in a position to meet the firewood demand of the people. There is a tremendous scope of the firewood or energy plantation in the community and private forestry. The suitable species, their management for optimal yield are emerging as current research needs. To address this need, the Forest Research Division (FRD) of the Department of Forest Research and Survey (DFRS) has been working since 1990. Considering the characters like fast growing, high coppicing power, ease of establishment, two species *C. siamea* and *E. camaldulensis* were selected to compare the growth, yield and their suitability.

Species Description

C. siamea Lam. is a native species of Southeast Asia from Burma to Indonesia. It is a fast growing tree with smooth gray bark. Streets (1962) describes it as an evergreen tree of medium size with handsome yellow flowers, a small hardwood and wide sapwood used mainly for fuel. It is extensively planted in tropical to warm temperate climates where it has proved very resistant to termites, drought and even light frost. It prefers moist well-drained fertile soils. The roots are shallow. It does not tolerate swampy or water logging conditions and the areas with a heavy growth of grasses, particularly *Imperata* spp. It makes excellent fuelwood, though it burns with smoke. In Ceylon, the wood is used as a locomotive fuel. The Calorific value of wood is 5825 Kcals/kg (Chaturvedi 1985).

E. camaldulensis Dehn. is widely distributed in Australia, occurring in every state, except Tasmania. It can grow in a wide range of climates, from tropical to cool temperate (Boomsa, 1950) and it is absent only in the major deserts and the south of the continent. Its best growth is on deep and lighter soils such as sandy loam, but it is not adapted to calcareous soils (Midgley *et al.* 1989). Its coppicing ability is up to six or more rotations (NAS 1980). At least three coppice crops can be harvested from coppicing stumps, but more than five coppice crops from well-managed stands (FAO 1979). It is one of the most widely introduced species into the plantations of tropics. It is a good firewood species with a calorific value of 4800 Kcal/kg (Kapur and Dogra 1989).

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Site Description

Tarahara is situated in the Terai of Sunsari District in Eastern Development Region. Its latitude and longitudes are 26^0 42' N and 87^0 16' E respectively. Its altitude is about 200 m above mean sea level (masl). It has a flat terrain. It consists of well-drained loamy to sandy clay loam soil with a pH range of 5 to 6.5 in A and B horizons respectively. The organic matter ranges from 0.2 - 5%, and nitrogen content low to medium, potassium and phosphorus medium to high (Thapa 1998). Annual mean daily temperature is 24.3^0 C. The mean maximum and minimum temperatures are 30.2^0 C and 18.3^0 C respectively. The annual average absolute maximum and minimum temperatures are 38.8^0 C and 5.5^0 C respectively, the mean maximum being 38.6^0 C in May and the mean minimum being 5.2 ^{0} C in January. The site has a humid sub-tropical climate with a summer monsoon and about seven months dry from November until May. The total annual precipitation varies from 1502 mm to 2104 mm, with mean annual precipitation being 1925 mm. More than 90% of annual rainfall occurs from June to October. The mean number of days with temperature more than 30^0 C is 231 in a year (Department of Hydrology and Meteorology 1997 and 1999).

Materials and Methods

Two plots of *C. siamea* and *E. camaldulensis* were established in 0.24 ha in July 1990 at Tarahara. The seedlings of both species were raised at Tarahara nursery. The seed sources for *C. siamea* and *E. camaldulensis* are Dehra Dun, India and North West of Chillagoe, Queensland, Australia respectively. About three months old seedlings were planted in each pit (size: 30 cm x 30 cm x 30 cm) at a spacing of 2.5 x 2.5 m. Beating up was carried out within a month of plantation establishment. No irrigation or fertilizers were used.

Generally, spot cultivation (0.5 m radius of each plant) was carried out once between August and October immediately after planting, two times thereafter in March - May and September-October up to about three years. The complete cultivation was carried out in September-October 1990. *Eupatorium* weeds were uprooted during this operation. The clearance of *Eupatorium* weeds was carried out when required. A fireline of about four meters was maintained every year along the fencing line. Heights were measured using height rod or sunto clinometer from 6 months and diameter after 2.5 years. For both species, trees within the plot (10 x 10 trees) were cut down with a bow saw at about 10cm above ground level. The harvesting was carried out at the plantation ages of 3.5, 6.5 and 9.5 years in the winter of 1994, 1997, and 2000. After felling, leaves with small twigs that did not have firewood value were separated from wood. Branch and stemwood were cut into manageable length and weighed. Wood samples were taken from 12 and 7 trees of *C. siamea and E. camaldulensis* respectively. Representative sub-samples of wood were collected for the determination of moisture content and dry matter percent. Discs of 5 to 10 cm widths from lower, middle and upper portion of the tree were taken from trees of various representative size. These sub-samples were weighed immediately and fresh weights recorded. These sub-samples were brought into the laboratory in Kathmandu and oven dried at 105^0C for 48 hours, until a constant weight was attained. For air-dry weight determination, three bundles of fresh firewood of both species were kept for four months from February to May and weighed again.

Results and Discussion

General Observation

In September 1990, the *C. siamea* seedlings were heavily attacked by caterpillars and most of the plants were without leaves. Forty to fifty caterpillars were found even in a single plant. *C. siamea* had multiple shoots after 2 years. Two trees were found damage by elephant in September 1994. The damage of *E. camaludlensis* by wild elephants and deer was observed in different visits.

Survival

Survival of *C. siamea* was found better than *E. camalduelnsis.* Survival percentage of *C. siamea* dropped from 99% at 2 months to 77% at 3.5 years and then remained constant over subsequent years (Table 1). For *C. siamea,* mortality continued up to 3.5 years. In *E. camaldulensis,* survival percent ranged from 100% at 0.17, year (2 months) to 57% at 10.5 years. Frequent damage to *Eucalyptus* trees by wild elephants and bark striping by deer resulted into a large reduction in survival even after 2.5 years (Table 1) and is still continued.

Table 1: Survival of *C. siamea* and *E. camaldulensis*

Age (years)	Survival percentage	
	Cassia siamea	*Eucalyptus camaldulenssis*
0.17	99	100
0.6	94	99
1.5	80	91
2.5	80	84
3.5	77	84
4.5	77	80
5.5	77	77
6.5	77	67
9.5	77	64
10.5	77	57

Height growth

Height of *E. camaldulensis* was better than *C. siamea* before clearfelling operation carried out at 3.5 years (Table 2). Height growth of coppice shoots of *C. siamea* and *E. camaldulensis* was significantly higher than uncoppiced shoots.

Height growth of *E. camaldulensis* decreased in 3-year period coppice growth at 9.5 years (third rotation) whereas it slightly increased in *C. siamea*. Mean height of the coppice of thickest stem of *C. siamea* increased from 8.2 m to 8.9 m between second clear felling (6.5 years) and third clear felling (9.5 years). Height growth of *E. camaldulensis* shoots was found better in the second rotation (Table 2).

The mean height of *C.siamea* was 4 m at 18 months at Adabhar, Bara district (Hawkins 1986) whereas it was 3.6m and 3.8m at Tarahara and Belbari repectively, slightly lower figure than Adhabar where intercropping was done for about 3-years which sufficiently reduced the weed growth. At Sagarnath, the mean height of *C. simea* was 6.3 m at 2 years and 7.5 m at Butwal at the age of 2.5 years (Jackson 1994), slightly higher than both sites (Table 2) The good sites and intercropping at Sagarnath and Butwal resulted into a higher growth than Tahara.

Table 2: Height of uncoppice and coppice stems of *C. siamea* and *E. camaldulensis*

Plantation age (years)	Coppice age (years)	Species					
		C. siamea			*Eucalyptus camaldulensis*		
		Mean height of all stems (m)	Mean height (m)*	Height increment (m)	Mean height of all stems (m)	Mean height (m)**	Height increment (m)
(A) Before clearfelling							
0.6		-	0.8	-	-	2.2	-
1.5			3.6	2.4	-	7.1	4.7
2.5		4.8	5.0	2.0	-	8.9	3.7
3.5		.	6.3	1.8	-	12.0	3.4
(B) Coppice shoot							
4.5	1	4.1	4.3	-	-	5.3	-
5.5	2	5.9	6.1	3.1	-	7.0	3.5
6.5	3	-	8.2	2.7	9.0	9.5	3.2
9.5	3	8.6	8.9	2.9	-	7.7	2.6
10.5	1	3.9	4.2	-	3.5	4.4	-

* height at 2.5 years and thereafter refer to the mean height of the thickest shoot.
** mean height of the thickest shoot.

The trend in height increment is not the same for both species during second rotation. The height growth of *E. camaldulensis* was found higher than *C. siamea* during this period (Table 2). Both species had similar height gains at the age of 10.5 years. At 9.5 years the height gains of *C. siamea* was better than *E. camaldulensis*.

Mean height of *E. camaldulensis* was 12.5 m, with a mean annual increment of 2.3 m, in earlier species trial conducted at Tarahara (Thapa 1998), the mean height in the present study was 12 m at 3.5 years (Table 2). At the age of 5 years, mean height of *E. camaldulensis* was 5.8 m in Jabalpur, M.P., India (Prasad *et al.* 1984) which is lower than that of Tarahara. Mean height of *E. camaldulensis* at Puttalum in dry zones of Sri Lanka at the age of six years was 8.4 m (Ranasinghe and Mayhead 1991), which was better than in Tarahara.

Coppice shooot

Two and half years *old C. siamea* had multiple stems. The sprouting capacity of both *C. siamea* and *E. camaldulensis* increases with the age of stool (Table 3). The maximum number of shoots in a single tree of *C. siamea* recorded up to 15 at 10.5 years, whereas it was 10 for *E. camaldulensis*. In general, *C. siamea* sprouted more vigorously than *E.camaldulensis* with the age (Table 3). The stronger power of *C. siamea* is a very positive aspect for firewood production over a longer period.

Table 3: Mean number of shoots of *C. siamea* and *E. camaldulensis*.

Plantation age (years)	Coppice age (years)	Species			
		Cassia siamea		*Eucalyptus camaldulensis*	
		Mean number of shoots	Range of shoots	Mean number of shoots	Range of shoots
3.5	-	3.5	-	-	-
4.5	1	5.5	1-10	4.0	1-8
9.5	3	4.2	1-8	2.4	1-6
10.5	1	8.1	3-15	4.8	1-10

Diameter growth

Before clearfelling, Mean dbh of *E. camaldulensis* was higher than *C. siamea* (Table 4).

Table 4: Diameter growth of *C. siamea* and *E. camaldulensis* before clearfelling.

Age (years)	Species				
	C. siamea			*Eucalyptus camaldulensis*	
	Mean dbh of all stems (cm)	Mean dbh (m)*	DBH increment (cm)	Mean dbh (cm)	DBH increment (m)
2.5	4.9	5.5	2.2	8.7	3.5
3.5	-	5.9	1.7	9.5	3.7

* mean dbh of the thickest stem.

DBH of the thickest shoot of *C. siamea* and *E. camaldulensis* did not differ significantly. During second rotation, dbh of *E. camaldulensis* was slightly higher than *C. siamea*, although the reverse trend was found after it (Table 5). Due to higher number of stems in *C. siamea*, combined diameter was recorded higher than *E. camaldulensis* in all ages (Table 5).

Despite the plantation age of 4.5 and 6.5 years, dbh of the thickest shoot of *C. siamea* was found slightly higher than *E. camaldulensis* (Table 4). The dbh growth of three years coppice shoots of *C. siamea* was the same at the plantation ages of 6.5 and 9.5 years whereas the dbh growth of *E. camaldulensis* reduced in the third rotation. The dbh growth of one-year coppice at 10.5 years was higher for both species than one-year coppice growth at 4.5 years. It reveals that the increase in wood biomass accumulation is due to increase in diameter and volume of rootstock.

Under full cultivation for the first two and half years, among the five *Eucalyptus* species, the dbh of *E. camalduelnsis* (Petford provenance) at the 2X2 m spacing was recorded as 8 cm at the age of 3.5 years at Adabhar, Bara District (altitude 250m, annual rainfall 1800 mm, pH 5.6, and water table 10 to 20 m). At Adhabar, full cultivation was carried out for the first 2.5 years (Hawkins 1986). The result in the present study was found higher than it (Table 5). At Tarahara, it was 9.5 cm. The full cultivation was done only once at Tarahara. In an earlier study of five fast growing tree species at Tarahara, Thapa (1998) recorded a dbh of 10.1 cm in *E. camaldulensis* (Emu Creek, Petford, Australia), the dbh increment 1.8 cm, the mean dbh 9.5 cm at 3.5 years, and mean annual production being 2.7 cm. The present study has shown slightly better growth than the previous one. In *Eucalyptus* species provenance trial for fuelwood production at Adabhar in the Bhabar region of Nepal, the highest dbh was 9 cm in *E. camaldulensis* (Petford provenance) among the six provenances at the age of 4.5 years (Hawkins 1986), the average diametre was 2 cm whereas the the average diametre in the present study was 9.5 cm, higher than the former one.

At the age of 5 years, mean dbh height of *E. camaldulensis* was 6.1cm in Jabalpur, M. P., India (Prasad *et al.* 1984), lower than Tarahara (Table 5). The diameter growth of *C. siamea* was slightly higher in Tarahara than diameter (4.9 cm) growth of Butwal at the age of 1.5 years.

Table 5: Diameter growth of coppiced shoots of *C. siamea* and *E. camaldulensis*.

Plantation age (years)	Coppice age (years)	Species							
		Cassia siamea				*Eucalyptus camaldulensis*			
		Mean dbh (m)*	Mean dbh (m)**	Comb. dbh (cm)	Com. dbh increment (cm)	Mean dbh (m)*	Mean dbh (m)**	Combined dbh (cm)	Com. dbh increment (cm)
4.5	1	3.0	3.1	4.6	-	-	3.3	3.7	-
5.5	2	4.6	5.0	7.8	3.9	4.7	4.8	5.7	2.9
6.5	3	-	6.8	-	-	6.8	7.2	8.3	2.8
9.5	3	5.4	6.8	11.1	3.7	-	5.1	6.8	2.3
10.5	1	2.8	3.8	8.1	-	2.3	3.6	5.4	-

* mean dbh of all stems
** mean dbh of the thickest shoot

Wood Production

The wood production of *C. siamea* was higher than *E. camaldulensis* (Table 6) at second and third rotations. Fresh wood of *C. siamea* increased from 30.5 kg per tree in the first rotation to 63.8 kg per stool in the third rotation, more than 100% increase in wood production. On the contrary, fresh wood production of *E. camaldulensis* decreased from 45.4 kg per tree in the first rotation to 27.6 kg per stool in the third rotation (Table 6), about 40% decrease in wood production. An increase in number of shoots in each stool of *C. siamea* has contributed significantly in the accumulation of wood biomass.

At Adabhar, 50% of *C. siamea* trees were cut every winter from the second year onwards and the subsequent coppice growth singled out in a mixture plantation of this species with *E. camaldulensis* planted at a spacing of 3 x 3m. The air dry mass of wood per tree was 11.1 kg (MAP 4.4 kg per tree) at the second thinning at 30 months (Shakya 1990). This figure is significantly lower than Tarahara (Table 6).

Bara District (Hawkins 1986), the mean annual production being 12.5 tons per ha, higher than the mean annual production (7.5 tons per ha) of Tarahara at the same age. The higher production at Adabhar may be due to full cultivation applied up to 2.5 years. The results of Adabhar and Sagarnath (Hawkins 1986; White 1986) indicate that full cultivation or intercropping is essential for the early growth of *E. camaldulensis.*

At the age of 5 years, mean dry wood production of *E. camaldulensis* was 12.4 tons per ha (MAP 2.5 tons per ha), in Jabalpur, M. P., India (Prasad *et al.* 1984), significantly lower wood production (Table 7) than Tarahara. Although, Prasad (1987) recorded green above ground wood biomass of *E. camaldulensis* as 110.6 tons per ha (Mean annual production 22.1 tons per ha) at the age of 5 years in another site in M. P., India. This figure is slightly

Table 6: Mean wood production (fresh, air dry and oven dry) of shoot and stool of *C. siamea* and *E. camaldulensis*

Rotation	Age of plantation (year)	Total number of shoots		Fresh wood per shoot (kg)		Fresh woof per tree or stool (kg)		Air dry wood per stool (kg)		Oven dry wood per stool (kg)	
		CS	EC	CS	EC	CS	EC	CS	EC	CS	EC
1	3.5	270	-	8.7		30.5	45.4	21.4	30.9	13.7	17.1
2	6.5	193	119	19.9	21.9	48.5	39.1	33.9	26.6	21.8	17.8
3	8.5	323	158	21.6	11.5	63.8	27.6	44.7	18.8	28.7	10.4

CS - *Cassia siamea*; EC- *Eucalyptus camaldulensis*
Conversion factor from fresh wood to air dry wood of *C. siamea* = 0.702
Conversion factor from fresh wood to air dry wood of *E. camaldulensis* = 0.68
Conversion factor from fresh wood to oven dry wood of *C. siamea* = 0.45
Conversion factor from fresh wood to air dry wood of *E. camalduelnsis* = 0.454

Air dry wood of *C. siamea* ranged from 27.3 tons per ha in the first rotation to 57.4 tons per ha in the third rotation In *E. camaldulensis*, it was 39.5 tons per ha in the first rotation to 24 tons per ha in third rotation. The total estimated air dry wood production of *C. siamea* and *E. camaldulensis* were 128.2 tons and 97.5 tons per ha respectively. So *C. siamea* had about 31.5% higher wood production (Table 7 and figure 1). Oven dry wood production of *C. siamea* per unit area was lower than *E. camaldulensis* in the first rotation, although it was higher in second and third rotation. The wood production of *C. siamea* is increasing with the increased age of the stool, but it is decreasing in *E. camaldulensis.* Among the five *Eucalyptus* species, the dry above ground wood of *E. camalduelnsis* (Petford provenance) was found to be 43.9 tons per ha at the age of three and half years at a spacing of 2 x 2 m at Adabhar,

higher than the figure of Tarahara (Table 7). Such variation in figures of production are influenced by the site type, degree of management, climatic, edaphic, and biotic factors.

Mean dry above ground wood biomass of *E. camaldulensis* was 37.2 tons per ha (MAP 6.2 tons per ha) at Puttalum and 24.9 tons per ha (MAP 4.2 tons per ha) at Monergala in dry zones of Sri Lanka at the age of 6 years (Ranasinghe and Mayhead 1991), slightly higher production was found in Tarahara (Table 7 and 8). According to Zohar and Karchen (1989), green above ground wood of *E. camaldulensis* was 173.9 tons per ha (MAP 43.5 tons per ha), 176 tons per ha (MAP 44 tons per ha) and 101 tons per ha (MAP 25.3 tons per ha) planted at spacing of 1 × 3m (3300 stems per ha), 2 × 3m (1670 stems per ha)

Table 7: Mean wood production (fresh, air dry and oven dry in tons per ha) of *C. siamea* and *E. camaldulensis*

Rotation	Plantation age (years)	Coppice age (years)	Fresh wood (tons/ha)		Air dry wood (tons/ha)		Oven dry wood (tons/ha)	
			CS	EC	CS	EC	CS	EC
1	3.5	-	39.0	58.1	27.3	39.5	17.6	26.4
2	6.5	3	62.1	50.0	43.5	34	27.9	22.7
3	9.5	3	81.7	35.3	57.4	24	36.8	13.3
Total wood production at 9.5 year			182.8	143.4	128.2	97.5	82.3	62.4

CS - *Cassia siamea*; EC- *Eucalyptus camaldulensis*
The calculation of wood biomass per unit area is based on the following stockings:
Stocking for *C. siamea* at Tarahara = 1280 trees per ha
Stocking for *E. camaldulensis* = 1280 trees per ha

and 3 x 3m (1100 stems per ha) respectively at the age of 4 years in Hula valley, Israel. In this site, the wood production was the highest in a spacing of 2 x 3m. Significantly higher production was found in Israel than Tarahara, particularly in two spacing of 1 x 3m and 2 x 3m. It may be due to better sites and better management in Israel than Tarahara.

Annual biomass production

The highest productivity of *C. siamea* was found in the third rotation from 6.5 to 9.5 years, MAP ranged from 11.1 fresh wood tons per ha in the first rotation to 27.2 tons per ha in the third rotation. MAP of *C. siamea* is still increasing. In *E. camaldulensis*, mean annual wood production (MAP) decreased considerably in the third rotation (Table 8).

E. camaldulensis (Petford provenance) was found as the most productive species in Sagarnath, Nepal. Dry wood production of this species was 63.4 tons per ha, the mean annual production being 15.9 tons per ha (Hawkins 1987), at the age of 4 years, whereas its mean annual production of dry wood was in a range of 4.4 to 7.6 tons per ha at Tarahara (Table 8). The dry mean annual production was 7.6 tons per ha in a study done by Thapa (2000) at Tarahara. In both studies, MAP of wood was almost similar at Tarahara. The higher yield at Sagarnath may be due to site preparation and adoption of intercropping which was not done in Tarahara.

In a study of five fast growing species at Tarahara, mean annual oven dry wood production of *E. camaldulensis* was 8.2 tons (Thapa 2000), slightly higher mean annual oven dry wood production than this study (Table 7 and 8). At Adabhar 1.5 years old *E. camaldulensis* with 10000 trees per ha, had a mean annual increment of 9.7 tons per ha. Oven dry weight of fuelwood was considered to be too close (Hawkins 1986).

Fuelwood yields of *C. siamea* have been reported to vary from 11 to 30 m^3 per ha per year (Annon 1983). Based on the density of airdry fuelwood 470 kg /m^3 at 2.5 years (Hawkins 1987), 11 to 30 m^3 comes to be 5.2 to 14.1 tons per ha per year. The airdry MAP of *C. siamea* over 3 years was 7.8, 14.5 and 18.3 tons per ha in three different rotations. So, fuelwood production of Tarahara represents an average site for *C. siamea.*

Productivity of oven dry wood of *E. camaldulensis* is in decreasing trend resulting into less accumulation of wood biomass in shoots whereas productivity of oven dry wood of *C. siamea* is increasing, indicates the higher wood biomass accumulation in the shoots.

Table 8: Productivity (fresh, air dry and oven dry tone per ha per year) of *C. siamea* and *E. camaldulensis* at Tarahara

Rotation	Plantation age (years)	Fresh wood (tons/ha/years)		Air dry wood (tons/ha/years)		Oven dry wood (tons/ha/years)	
		CS	EC	CS	EC	CS	EC
1	3.5	11.1	16.6	7.8	11.3	5.0	7.5
2	6.5	20.7	16.7	14.5	11.3	9.3	7.6
3	9.5	27.2	11.8	19.1	8.0	12.3	4.4

CS - *Cassia siamea*; EC- *Eucalyptus camaldulensis*

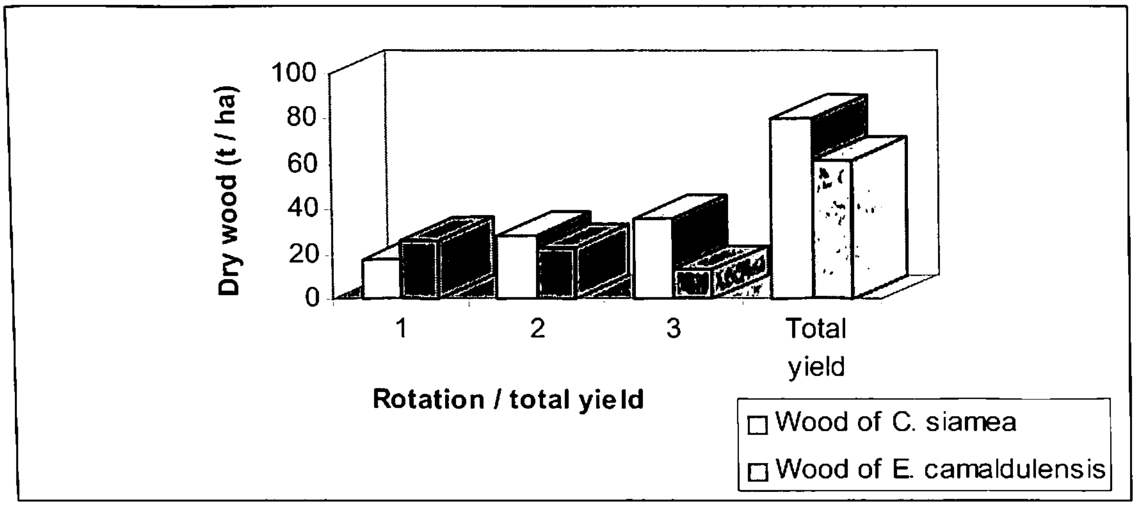

Figure 1: Oven-dry wood (tons per ha) production of *C. siamea* and *E. camaldulensis* in different three rotations and their cumulative total wood production at Tarahara

Requirement of planting area for a family

The per capita fuelwood consumption in the terai is 479 kg per annum (HMG/ADB/ FINNIDA 1988). So an average family size of five, the annual fuelwood requirement may be 2, 395 kg. As the rotation of *C. siamea* is three years, the firewood could be supplied for three years. 7, 185 Kg firewood will be required for three years. Based on this study, a tree of a *C. siamea* can provide an average of 33.3 kg of airdry fuelwood in a rotation of three years. Planting 238 trees (assuming 10 % mortality) of *C. siamea* will be sufficient to meet the requirement for three years. This estimation is based on the supply of the domestic fuelwood energy requirement solely from the fuelwood. But in rural areas, heating and cooking are done using agricultural residues and animal dung in addition to firewood. The fuelwood contribution to the domestic energy supply is about 75 % (WECS 1995). Using this type of domestic energy consumption pattern, the estimated fuelwood requirement will be 5,928 kg per rotation for a family. Following the same method as mentioned above, 180 *C. siamea* trees are required for a family in the Terai. The land required is about 731 m^2 (2.16 katha) for 180 seedlings at a spacing of 2 m x 2m. This area is needed to divide into three blocks of 244 m^2 (0.72 katha) for planting operation to be carried out in three consecutive years. such plantation blocks would provide firewood continuously even after 3 years. The plantation area required for a family could also be used for community plantation.

Other aspects

For the first three and half years and in different rotations, the land could be used for shade loving crops like turmeric, ginger, pineapple as intercrops that provide additional income for the farmers and communities. The coppice regeneration methods also reduce the cost of plantation establishment, management and removal of stumps. The increase in wood yield with the increase in the age of stool suggest that *C. siamea* is a suitable species for fuelwood plantations in the Terai. The above estimated area for a family would be applicable to those sites similar to Tarahara and under similar management. Furthermore, the selected sites must be suitable for planting *C. siamea* as mentioned earlier.

Conclusion

The results of growth and wood production of *C. siamea* in three years rotation at Tarahara, proves that it is a good species for fuelwood plantation in the Terai region of Nepal. Due to its strong coppicing ability, it seems better than *E. camaldulensis* in wood production. The community and private forestry components of the Department of Forests, other NGOs, and Projects can extend this message in the field level and can help reduce the gap between the demand and supply of the fuelwood in the Terai regions of Nepal. This study suggests that small patch of land is sufficient for establishing its plantation for continuous attainment of firewood for a family.

Future research priorities

- A comparative study on wood production of *C. siamea* alone and with crops like turmeric, pineapple, ginger is needed.
- Study on various management options aimed at achievement of optimum production of *C. siamea* is crucial.
- A comparative study of other coppicing firewood species along with *C. siamea* for firewood production is needed.
- Expansion of fuelwood plantations of *C. siamea* in the Terai region of Nepal through reliable extension agents is essential.

References

Annon, 1983. A note on *Cassia siamea, Lam :Leguminosae (C). Nepal Forestry Information Bulletion* **9**: 19-20p.

Boomsa, C. D. 1950. The red gum (*Eucalyptus camaldulensis* Dehn.) association of Australia. *Australian Forestry* **14**: 99-110p.

Chaturvedi, A. N. 1985. Firewood farming on degraded lands in the Gangetic plain, U. P. Forest Bulletin No. 50, 1985.

Department of Hydrology and Meteorology, 1997. Climatological Records of Nepal: 1991-1994, Kathmandu, May 1997.

Department of Hydrology and Meteorology, 1999. Climatological Records of Nepal: 1995-1996, Kathmandu, June 1999.

FAO, 1979. *Eucalyptus* for planting. FAO Forestry Papers, Sr. No. 11, Rome, 381, 532.

Hawkins, T. 1986. Adabhar Trail Site Research Results 1980 to 1986, Forest Survey and Research Office, Kathmandu, Nepal.

Hawkins, T. 1987. Volume and weight tables for *Eucalyptus camaldulensis, Dalbergia sissoo, Acacia auriculiformis,* and *Cassia simea. Banko Jankari* **1**(2): 29-30p.

HMG/ADB/FINNIDA 1988. Master Plan for the Forestry Sector: Main Report. Ministry of Forests and Soil Conversation, Kathmandu, Nepal.

Jackson, J. K. 1994 Manual of Afforestation in Nepal, Forestry Research and Survey Center, Kathmandu, Nepal.

Kapur, S. K. and Dogra, A. S. 1987. Provenance trial of Eucalyptus camalduelnsis in Punjab. *Indian Forester* **113**(7): 471-475p.

Midgley, S. T., Eldridge, K. G. and Doran, J. C. 1989. Genetic resources of *Eucalyptus camaldulensis. Commonwealth Forestry Review* **68** (4): 295-308p.

NAS, 1980. Firewood Crops, Shrubs and tree species for energy production. National Academy of Sciences. Washington, D. C. 1, 126-127p.

Prasad, Ram, 1987. Performance of *Eucalyptus* on the wastelands of Madhaya Pradesh. *Journal of Tropical Forestry* **3** (4): 311-317p.

Prasad, Ram; Sah, A. K. Bhandari, A. S. and Choubey, O. P. 1984. Dry matter production by *Eucalyptus camaldulensis* Dehn. plantation in Jabalpur. *Indian Forester* **110** (9): 868-878p.

Ranasinghe, D. M. S. H. K., and Mayhead, G. J. 1991. Dry matter content and its distribution in age series of *Eucalyptus camaldulensis* (Dehn.) plantation in Sri Lanka. *Forest Ecology and Management* **41**: 137-142p.

Shakya, R. 1990. Plantation establishment pattern for community forestry plantation in the Bhabar Terai. *Banko Janakari* 2(4): 407-409.

Streets, R. J. 1962. Exotic forest trees in the British. Commonwealth Clarendon Press, Oxford.

Thapa, H. B. 1998. Growth of five fast growing tree species in the terai of eastern Nepal. *Banko Janakari* **8** (2): 14-22p.

Thapa, H. B. 2000. Biomass estimation of some fast growing trees in the eastern terai, Nepal. *Banko Janakari* **10** (2): 15-20p.

WECS, 1994. Alternative Energy Technology: An Overview and Assessment, Perspective Energy Plan, Supporting Document No.3, Water and Energy Commission Secretariat, Kathmandu, Nepal

WECS, 1995. Energy Sector Synopsis Report, Perspective Energy Plan, Supporting Document No.1, Water and Energy Commission Secretariat, Kathmandu, Nepal.

White, K., 1986. The Farming Practices in the Bhabar-Terai of Nepal. Manual No. 2.

Zohar, Y. and Karchen, R., 1989. Above-ground biomass of *Eucalyptus camaldulensis* Dehn. in Israel. *South African Forestry Journal* No. 120, 26-29p.