Growth performance of *Tectona grandis* in the western Terai of Nepal

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Assessment of growth, biomass and volume of *Tectona grandi*s (teak) was done at a 13-year old plantation established at Shankarnagar, Rupandehi district. Operations such as prunning, prunning and singling, and thinning were carried out at 4, 7.5 and 8.5 years respectively. Diameter increment was 2.3 cm within one year of thinning. Estimated average fresh wood production was 58.8 kg (87.6 tons ha^{-1}) and 29.6 kg (16.1 tons ha^{-1}) in thinned trees and 75.5 kg (71.4 tons ha^{-1}) for trees after thinning. Likewise green leaf production was 5.1 kg $tree^{-1}$ (7.5 tons ha^{-1}). Above ground green biomass was 32.6 kg $tree^{-1}$ (17.7 tons ha^{-1}) for thinned trees, 63.9 kg $tree^{-1}$ (95.1 tons ha^{-1}) for trees before thinning and 81.9 kg $tree^{-1}$ (77.2 tons ha^{-1}) for trees after thinning. The mean over bark stem volume was 0.0707 m^3. In thinning, 21 m^3 per ha^{-1} volume was removed. The volume of standing trees before thinning at 7.5 years was 105.2 m^3 ha^{-1}. After thinning, per unit and mean basal area, biomass and over bark stem volume has increased considerably during 4-years from 7.5 years to 11.5 years. This rotation period could be applied for future plantations and already established teak plantations on good sites in the Terai / Inner Terai of Nepal to supply the wood for veneer and small timbers.

Keywords: *Tectona grandis*, growth, biomass, volume, rotation, thinning, Nepal

Teak is a multipurpose tree for agroforestry in many parts of Asia, Africa and tropical America (Bhat and Ma 2004). Importance and value of *teak timber* was considered some 150 years ago by renowned German forester Dietrich Brandis.

Teak is distributed in South-East Asia, the Indian Sub-continent, Myanmar, Thailand and the Western part of Laos. It touches the Western part of Cambodia. It is naturalized in the Eastern part of Java, Indonesia. Its northern limit is 25^0 N in Myanmar and southern limit is 9^0 N in India. Its longitudinal limits are 70^0 – 100^0 E. It is widely planted in South-East Asia, West Africa and to some extent in Central America, East Africa and Oceania (Keiding 1993). Teak covers seventy five percent of the world's high-quality tropical hardwood plantations (Keogh 1999). In Nepal, governmental teak plantation began in 1960 in Chiliya, Rupandehi District (Kayastha 1974) followed by some block plantations in Sagarnath, Sarlahi and Ratuwamai, Jhapa districts by Forests Products Development Board, few research plots at Sagarnath and other places were established by the Department of Forest Research and Survey.

This paper attempts to provide information on early growth, thinning yield and wood and foliage biomass, and aboveground biomass of *Tectona grandis* at 7.5 years and subsequent years which will be useful to community and private plantations.

Materials and methods

Tectona grandis plot was established on 7th July 1992 in 0.50 hectare at a spacing of 2.5m x 2.5m by the Plantation Section of Department of Forest Research and Survey at Shankarnagar, Rupandehi District, in the western Terai of Nepal. The site consists of sub-tropical monsoon climate. Its altitude is about 205 m above msl; latitude and longitude are 27^0 42' N and 83^0 28' E respectively. More than 90% of the rainfall occurs between June to October. Mean maximum and minimum temperature were 30.21^0C and 20.21^0C respectively, absolute maximum temperature being 44.9^oC in April and May and absolute minimum temperature 4.3^oC in January (based on 15 years record, cited in Jackson 1994). Mean annual rainfall of this site was 2452 mm (20 years record cited in Jackson 1994). This site, generally, remains dry from November to May, except for occasional light shower during winter.

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The stumps were raised in District Forest Office nursery in Bhairahawa, Rupandehi District. Spot cultivation was carried out at 0.5m radius around each plant twice a year for the first three years. There was no application of irrigation or fertilizers.

Growth assessment was carried out annually. Pruning was carried out in the winter of 1996, pruning and singling in the winter of 1999. Pruning was done up to one-third height of each tree. Selection thinning operation was carried out in the winter of January/ February 2000. Diameter at breast height (dbh) of all trees was measured before thinning. For thinning, 233 dead, dying, diseased, suppressed, poorly grown, few dominant and co-dominant trees were selected in the population and marked. Out of these selected trees, 29 were used for biomass measurements. The samples covered the entire range of dbh in the population. The marked trees were cut down with a bow saw at about 10 cm from the ground level. After felling, the total length of the tree was measured. Leaves along with small twigs were separated from branches and the stem was cut into 1.5 to 2 m sections. Stem sections, branches, and foliage were weighed separately and recorded. Representative six trees were selected for sub-samples of wood, and leaf. Three to four pieces of the discs of about 5 to 10 cm width were taken from lower, middle and upper portions of the stem section and weighed. Similarly, leaf sub-samples were weighed and recorded. These sub-samples were brought to the laboratory in Kathmandu and stem and branch discs were oven dried at 105^0C for 48 hours and leaf for 24 hours. During that period a constant weight of stem, branch and leaf was attained.

Percent oven-dry matter of the samples were used for the general data to convert fresh weight of tree components to dry weight The model (Ln W or V = a+b* Ln DBH where W stands for weight of wood and foliage, V for over bark stem volume, dbh for diameter at breast height, a and b regression constants), was selected to estimate the biomass of tree components (wood and leaf) and for estimation of over bark stem volume (see Annex 1). The mean annual production was obtained by dividing the total biomass of tree components, total aboveground biomass and total over bark stem volume by the age of the plantation.

Results and discussion

Height and diameter Growth

Mean height of *T. grandis* was 9.2m at 6.5 years at Shankarnagar (see Table 1) whereas that of *Dalbergia latifolia* at Belbari was 5.9 m at the same age. Similarly mean diameter of teak was 10.3 cm at 7.5 years while it was 8.2 cm in *D. latifolia* at Belbari (Thapa 2004). It indicated that *T. grandis* grew faster than *D. latifolia* in the early age.

The height and dbh of teak plantation, were 9.99m and 4.4cm respectively at the age of six years in Solakhpur; slightly lower in height growth, but significantly higher diameter than at Shankarnagar. At Chilia, 14 years teak had 15.2m of height, periodic annual increment (pai) was 1.09m, significantly higher height growth in Shankarnagar (Kayastha 1974).

The annual diameter increment was 2.3 cm within 1-year of thinning (see Table 1), which is mainly due to removal of inferior small-sized trees during thinning. Despite that, the periodic diameter growth was found almost the same (1.3-1.5 cm) in different

Table 1 : Growth performance of teak at Shankarnagar

Age (year)	Mean height (m)	Std. error (m)	CV (%)	PAI of height (m)	CAI of height (cm)	Mean dbh (cm)	Std. error (m)	CV (%)	PAI of dbh (cm)	CAI of dbh (cm)
0.5	0.2	0.04	50	0.4	-	-	-	-	-	-
1.5	1.0	0.03	56	0.7	0.8	-	-	-	-	-
2.5	2.3	0.06	48	0.9	1.3	-	-	-	-	-
3.5	4.1	0.06	37	1.2	1.8	-	-	-	-	-
4.5	-	-	-	-	-	6.7	0.1	31	1.5	-
5.5	-	-	-	-	-	8.4	0.1	29	1.5	1.7
6.5	9.2	0.12	23	1.4	-	9.9	0.2	28	1.5	1.5
7.5	-	-	-	-	-	10.3	0.1	27	1.4	0.4
8.5	-	-	-	-	-	12.6	0.11	18	2.1	2.3
9.5	18.8*	0.18	6	2.0	-	13.9	0.13	19	1.5	1.3
10.5	19.2*	0.24	8	1.8	0.4	14.5	0.14	20	1.4	0.6
11.5	20.2*	0.31	10	1.0	1.0	15.0	0.16	21	1.3	0.5

* Top height (100 largest trees ha^{-1})

years. There decreasing trend in annual diameter increment with the increase in tree age. It is obvious that the trees grow slowly when they get older.

Literature, show that growth rates of teak differ from place to place. At Sagarnath, the mean height of 10 years old tree site was 15.3m, periodic height increment being 1.5m (Joshi 1982). These growth rates are equivalent to quality II in Laurie and Ram's yield tables but the highest quality in these tables is mostly from Burma. They fall within quality I of the tables for Nilambur teak in Kerala, India (Troup 1921). Hence the growth rates in this plantation are very satisfactory. It indicates that high quality teak plantations can be grown in certain sites of Terai and Bhabar regions of Nepal. The growth of teak in Shankarnagar, Rupandehi and Sagarnath, Sarlahi is similar to the growth of site quality II in India.

An indigenous popular tree *Dalbergia sissoo* (sissoo) attained 8.4 cm diameter at 5.5 years at Tarahara. The periodic annual increment during that period was 1.5. cm (Thapa 1998) which is the same as teak at 5.5 years (see Table 1). It can be inferred that teak grows as fast as sissoo in its early stage of growth. The fastest growth recorded of teak plantations in the world is from Kapati, Bangladesh. Trees of 21 years age had average height of 29.3m, pai being 1.4m and average diameter of 30 cm, pai being 1.4cm (Gogate 1995)

The highest growth under plantation conditions in India was seen in Haldwani Division. At age of 20, the height growth was 23.1m, PAI equivalent to 1.2m and diameter was 23.1cm, PAI equivalent to 1.4cm. It is said that plantation teak grows slowly after an age of 15 years (Parameswarappa 1995).

Basal area

The basal area of trees per unit area is mainly governed by the size and density of trees. At 10.5 years, *T. grandis* had a basal area of 22.1 m^2 ha^{-1} at Sagarnath, Sarlahi, and periodic basal area increment was 2.1 m^2 ha^{-1} $year^{-1}$ (Joshi 1982) whereas the basal area of teak in that age at Shankarnagar was found to be 16 m^2 ha^{-1}, slightly lower than Sagarnath. It may be due to lower stocking at Shankarnagar. At 7.5 years, the mean basal area of thinned trees of *D. latifolia* was 0.0045 m^2 at Belbari (Thapa 2004) whereas it was 0.0052 m^2 for teak at the same age at Shankarnagar. The results indicated that slightly larger-sized trees were thinned at Shankarnagar.

As the periodic annual increments of basal areas of *D. sissoo* at Tarahara and *T. grandis* at Shankarnagar were 0.0011 m^2 (Thapa 1998) and 0.0012 m^2 (see Table 2) respectively, which are almost similar. But the mean basal area of *D. latifolia* at 7.5 years was 0.0071 m^2 $tree^{-1}$ (0.0009 m^2 $tree^{-1}$ $year^{-1}$) higher in *T. grandis* (0.0012 $m^2 tree^{-1} year^{-1}$) (Thapa 2004). It indicated that both sissoo and teak grow at similar rate in early age and teak is faster than *D. latifolia* later.

Biomass

The dry matter contents of wood and foliage of 7.5 years old *T. grandis* at Shankarnagar were 40% and 33% respectively. Previous study showed that the dry matter contents of wood of 5.5 years old *D. sissoo* at Tarahara and 7.5 years old *D. latifolia* at Belbari were 43.9% (Thapa 2000) and 48.3% (Thapa 2004) respectively whereas the dry matter content of wood of 3.5 years old *C. siamea* and *Euealyptus camaldulensis* at Tarahara, Sunsari District were 45/1 and 45.4% respectively (Thapa and Subedi 2000). It indicated

Table 2: Dbh, basal area and periodic annual increment of basal area of 7.5 years *Tectona grandis* at Sankarnagar

Parameter	Thinned trees	Standing trees	
		Before thinning	After thinning
Mean dbh (cm)	7.8	10.3	11.7
Mean basal area (m^2)	0.0052	0.0089	0.0111
Periodic annual increment of basal area ($m^2 ha^{-1} year^{-1}$)	0.0007	0.0012	0.0015
Basal area (m^2 ha^{-1})	2.8	13.2	10.4
Over bark stem volume (m^3 $tree^{-1}$)	0.0386	0.0707	0.0893
Over bark stem volume (m^3 ha^{-1})	21	105.2	84.2
Stocking (stems ha^{-1})	545	1488	943
Percentage of the original stocking	34.0	93.0	59.0

Basal area removal (%): 21.2 Removal of trees in first thinning (%): 36.6

that moisture content of wood is more in teak than *Acacia catechu*, *D. sissoo, C. siamea*, *E. camaldulensis* and *D. latifolia.* As a result, oven dried wood biomass of *T. grandis* would be lower than the above five species. At Sagarnath, Sarlahi, air-dried wood was found to be about 67% of green wood (Joshi 1982). The conversion factor 0.67 of Sagarnath can be used to convert green wood to air-dried wood at Shankarnagar also.

At 6.5 years, 3 tons ha^{-1} green wood was obtained from pruning/singling operation. Before thinning, estimated average fresh wood production of 7.5 years old *T. grandis* was 58.8 kg (87.6 tons ha^{-1}) and 29.6 kg (16.1 tons ha^{-1}) in thinned trees and 75.5 kg (71.4 tons ha^{-1}) for trees after thinning (see Table 3). Wood production of *T. grandis* was higher than *D. latifolia*, (37.6 kg tree^{-1}) at 7.5 years (Thapa 2004). Similarly, another study showed that at Sagarnath, 10.5 years old teak attained 137.2 tons green wood in a hectare (Joshi 1982).

The estimated average green leaf production of *T. grandis* at 7.5 years was 5.1 kg tree^{-1} and 7.5 tons ha^{-1}, while it was 5.4 kg/tree and 2.8 tons ha^{-1} in *Dalbergia latifolia* (Thapa 2004) of the same age. It shows that *T. grandis* had significantly higher foliage production per unit area than in *D. latifolia* at an early stage of its growth. It is mainly due to density of trees, as *D. latifolia* had a spacing of 4 x 2m whereas *T. grandis* had a spacing of 2.5 x 2.5 m. However, in both the species, average leaf content varied very little (see Table 3). On an average, the contribution of green leaf in total aboveground biomass was 8% in *T. grandis* and 12% in *D. latifolia* (Thapa 2004) (see Table 3), slightly less than *D. latifolia*. Less production of foliage in *T. grandis* may be due to smaller sized and less number of branches than *D. latifolia*.

Above ground green biomass was estimated 32.6 kg tree^{-1} (17.7 tons ha^{-1}) for thinned trees, 63.9 kg tree^{-1} (95.1 tons ha^{-1}) for trees before thinning and 81.9 kg tree^{-1} (77.2 tons ha^{-1}) for trees after thinning in *T. grandis* as compared to 26.7 kg tree^{-1} (4.4 tons ha^{-1}) for thinned trees, 43.0 kg tree^{-1} (22.5 tons ha^{-1}) for trees before thinning and 51.8 kg (18.7 tons ha^{-1}) after thinning in *D. latifolia* (Thapa 2004).

Productivity

Productivity of green wood (stem and branch) of *T. grandis* was 11.7 tons ha^{-1} year^{-1} and rate of accumulation was found to be 7.8 kg tree^{-1} year^{-1} (see Table 4); similar to the rate of accumulation of *D. sissoo* and *Acacia auriculiformis* but less than *A. catechu* and *E. camaldulensis* but higher than *D. latifolia*. At Tarahara, productivity of green wood of 5.5 years old *D. sissoo*, *Acacia auriculiformis*, *Acacia catechu*, and *E. camaldulensis* were 10.5, 13.0, 16.2, and 19.7 tons ha^{-1} year^{-1} and rate of accumulation of these species were 7.79, 7.35, 13.74, and 15.21 kg tree^{-1} year^{-1} (Thapa 2000). Similarly Joshi (1982) found that productivity of green and air-dried-wood of 10.5 years old teak at Sagarnath were 13.07 and 8.72 tons ha^{-1} year^{-1} respectively.

Estimated volume

The mean over bark stem volume of *T. grandis* was 0.0707 m^3. The volume of thinned trees was 21 m^3 ha^{-1} whereas that of standing trees before thinning at 7.5 years was 105.2 m^3 ha^{-1}. About 20% of the total

Table 3: Average green and oven dry biomass of thinned and standing trees before and after thinning at 7.5 years

Parameter	Thinned trees (kg tree^{-1})		Standing trees (kg tree^{-1})				Thinned trees (tons ha^{-1})		Standing trees (tons ha^{-1})			
			Before thinning		After thinning				Before thinning		After thinning	
	Green	Oven dry	Green	Oven dry	Green	Oven dry	Green	Oven dry	Green	oven dry	Green	Oven dry
Wood	29.6	11.85	58.8	23.55	75.7	30.32	16.1	6.44	87.6 (98)	35.09	71.4	28.60
Foliage	3.0	1.00	5.1	1.71	6.2	2.08	1.6	0.53	7.5 (8)	2.53	5.8	1.95
Above-ground biomass	32.6	12.80	63.9	26.26	81.9	32.40	17.7	6.97	95.1 (100)	37.62	77.2	30.55

Figures in parenthesis indicate the percentage of stem wood and foliage in total aboveground biomass.

Table 4: Productivity and rate of accumulation of green and oven-dry biomass of teak at 7.5 years

	Green biomass (kg tree^{-1} year^{-1})						Green biomass (tons ha^{-1} year^{-1})					
	Wood		Leaf		Total		Wood		Leaf		Total	
	Green	Oven-dry	Green	Oven-dry	Green	Oven-dry	Green	Oven-dry	Green	Oven-dry	Green	Oven-dry
Before thinning	7.8	3.1	0.7	0.2	8.5	3.3	11.7	4.7	1.0	0.3	12.7	5.0
After thinning	10.1	4.0	0.8	0.3	10.9	4.3	9.5	3.8	0.8	0.3	10.3	4.1

volume was removed in thinning operation. The over bark stem volume of standing trees of 7.5 years old *D. latifolia* at Belbari was 0.0167 m^3 $tree^{-1}$ (8.8 m3 ha^{-1}) (Thapa 2004). Mean over bark stem volume of *T. grandis* was found less than *D. latifolia*, but per unit area volume was significantly higher in *T. grandis* than *D. latifolia*. It is mainly due to the difference in stocking of these two species. As *D. latifolia* had only 493 stems ha^{-1} whereas *T. grandis* had a stocking of 1488 $stemsha^{-1}$. Likewise freshly felled solid volume yields were estimated at 14.5 m^3 ha^{-1} $year^{-1}$ for 10.5 years old teak at Sagarnath, Sarlahi, the total over bark volume was 152.5 m^3 ha^{-1} whereas under bark volume was 119.3 m^3 ha^{-1} (78% of over bark volume). So the bark content was found to be about 22% (Joshi 1982). At Haldwani Division, India 20 years old *T. grandis* had 28.04 m^3 stem volume (Parameswarappa 1995).

Per unit area and mean basal area, biomass and over bark stem volume after thinning

Mean basal area of trees after thinning ranged from 0.0111 m^2 at 7.5 years to 0.0185 m^2 at 11.5 years, an increase of about 67% in 4-years, similarly 75.7 kg of green wood at 7.5 years to 146.2 kg per tree at 11.5 years, an increase of 93% in that period (see table 5). Mean volume of over bark stem volume ranged from 0.0893 m^3 at 7.5 years to 0.1588 m^3 at 11.5 years, an increase of about 78% in 4-years. Basal area increased from 10.4 m^2 ha^{-1} at 7.5 years after thinning to 17.1 m^2 ha^{-1}, a significant increase of 64% in that period. All of these figures state that the growth of trees has been increased in a significant manner after thinning. Similar trend is found in biomass and volume production. The remaining trees after thinning have got more space so that nutrient availability increased causing increased biomass and volume production during that period.

During 4-years, an increase in wood production was higher than foliage production (see table 5) as former was 87% whereas the latter was 62% . It is also interesting to note that 3 tons and 21 tons and of green wood was removed in pruning/singling and first thinning respectively, which if sold as firewood, can fetch Rs. 24,000 (Re 1 per kilo). If preservative treatment is applied for the poles and posts obtained from thinning, the monetary value would be even higher.

Increase in basal area, biomass and over bark stem volume after thinning

After thinning at 7.5 years, there was an increase of 62.1 tons of green wood and 3.6 tons of foliage in a hectare. Periodic increments from 7.5 to 11.5 years were 15.5 and 0.9 tons $ha^{-}1$ $year^{-1}$ for wood and foliage respectively. In case of over bark stem volume, there was an increase of 60.8 m^3 ha^{-1} in which periodic increment of stem volume was 15.2 m^3 ha^{-1} $year^{-1}$ (see table 6). These increased figures support the need of thinning in an appropriate time to promote the growth and production to shorten the rotation.

Soil and crop rotation

As said earlier, teak grows faster in the early stage, although the subsequent growth very much depends on the nature of the soil. The growth is affected adversely, if the sub-soil has a heavy texture and suffers from water logging. So, texture, particularly of the sub-soil, must be identified in selecting the site for planting *T. grandis* in the Terai.

Table 5 : Per unit area basal area, green and oven-dry biomass (wood and foliage), over bark stem volume of standing trees in different years

Age (years)	Basal area (m^2 ha^{-1})	Green biomass (tons ha^{-1})			Oven dry biomass (tons ha^{-1})			Over bark stem volume (m^3 ha^{-1})
		Wood	Foliage	Total	Wood	Foliage	Total	
7.5	10.4	71.4	5.8	77.2	30.32	2.08	33.0	84.2
8.5	12.2	86.7	6.8	93.5	36.81	2.41	39.23	99.9
9.5	14.9	111.8	8.3	120.2	47.60	2.94	50.55	125.0
10.5	16.0	123.5	8.9	132.4	52.75	3.17	55.92	136.1
11.5	17.1	133.5	9.4	142.9	58.55	3.43	61.98	145

Table 6 : Per unit area increment in basal area, green biomass (wood and foliage), over bark stem volume of standing trees after thinning

Age of plantation (year)	Number of years after thinning	Basal area increase (m^2 ha^{-1}) after thinning*	Green biomass (tons ha^{-1})*			Over bark stem volume (m^3 ha^{-1})*
			Wood	Foliage	Above-ground biomass	
8.5	1	1.8	15.3	1.0	16.2	15.7
9.5	2	4.5 (2.3)	40.4 (20.2)	2.5 (1.3)	42.9 (21.5)	40.8 (20.4)
10.5	3	5.6 (1.9)	52.1 (17.4)	3.1 (1.0)	55.1 (18.4)	51.9 (17.3)
11.5	4	6.7 (1.7)	62.1 (15.5)	3.6 (0.9)	65.6 (16.4	60.8 (15.2)

* Basal area, biomass and ob volume of 7.5 years is deducted from the basal area, biomass, and ob volume of 8.5, 9.5, 10.5 and 11.5 years *T. grandis*. Figures in parenthesis indicate the periodic increment after thinning operation carried out in the winter of 2000.

In the dry zones of India, teak plantations, where growth is slow, are managed on longer coppice rotations of about 40 to 50 years. The mean annual increment of *T. grandis* grown for 60-80 years in India is mostly between 4 and 8 m^3 ha^{-1} (Evans 1982). The production of high-quality wood has been in long rotations of 50-70 years, when the world's first teak plantation was established at Nilambur in India's Kerala state in 1842. However, many farmers and other small landholders in many countries like Malaysia, Thailand, India, Brazil and Costa Rica have adopted shorter rotations of 20-30 years for both veneer and saw log production for relatively quick returns (Ball *et al.* 1999, quoted in Bhat and Ma 2004). This rotation period could be applied for future plantations and already established in teak plantations on good sites in the Terai/Inner Terai of Nepal to supply the wood for veneer and small timbers. Preservative treatment should be applied in small timbers to lengthen their durability. Further, recent research findings show that teakwood obtained in short-rotation is not significantly inferior in density and strength compared to natural-grown teak (Bhat and Ma 2004). The findings of the studies (summarised in Bhat 2000 quoted in Bhat and Ma 2004) provide the following hope to plantation-growers, including smallholders:

- without altering timber strength, plantation managers can aim to produce timber with higher yields of naturally durable heartwood in each tree by enhancing growth in short rotations with judicious fertilizer application and genetic improvements on suitable sites;
- the MAI for teak plantations is generally relatively high in short rotations of 20–25 years. Teak yield tables show that MAI usually peaks within 20 years of plantation establishment;
- teak can produce timber of optimum strength in relatively short (e.g. 21 year) rotations; and
- fast-growing provenances/clones can be selected for teak management without reducing the specific gravity of wood. However, provenances should be matched with the site conditions. Further product requirements appear to be most crucial in tree improvement programs.

Conclusion

There is a lot of scope for promotion of teak plantations in suitable sites of Terai and Inner Terai of Nepal. The results of growth, biomass and volume production of *T. grandis* at Shankarnagar, Rupandehi District has shown its success in plantations. On one hand, demand of firewood, poles and small timber can be met from the yield in different thinning, which on the other, the remaining trees will have more growing space for diameter increment which reduces the rotation period considerably. Shorter rotations of 20-30 years as applied in other countries is crucial for teak plantations in Nepal for both veneer and saw log production to get quick returns.

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Annex 1: Regression equations for estimation of over bark volume and green wood and foliage of *Tectona grandis*

Model: Ln V or W = a+b*LnDBH where W stands for green weight of wood and foliage or V for over bark stem volume, dbh for diameter at breast height, a and b regression constants

Particular	Regression constant		R2	Standard error	Mean square error	No. of observations
	a	b				
Total Over Bark Volume	5.8958	2.2221	97.4	0.165	0.0273	31
Green Wood Biomass	-1.9276	2.5206	90.0	0.31	0.0987	29
Green foliage	-2.9556	1.9362	69.7	0.480	0.2304	29