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Comparing Growth of *Eucalyptus Camaldulensis* According to Sites in Sagarnath Forestry Development Project, Nepal

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ABSTRACT

Eucalyptus camaldulensis is one the important fast growing exotic species in Nepal but its growth performance assessment was not so far done. Thus, this research was objectively carried out to assess the growth performance and relating their growth to soil nutrients in E. camaldulensis plantation forest. Sagarnath Forestry Development was selected for the study site. Stratified random sampling was carried out to collect the samples. Altogether 60 sample plots (40 for plantation, 10 for singling and 10 for doubling) having 1 to 10 years age. Diameter and height, crown height, crown diameter, fork information of 600 plants were measured as well as spacing was recorded. The age of the plantation was noted from plantation report and age of singling and doubling from the harvesting register. Meanwhile, 120 soil samples were collected from 40 plantation site from 0-10, 10-20 and 20-30cm depths. The basal area, volume, biomass and carbon were analyzed, as well as N, P, K, C, pH and bulk density were analyzed in lab. Moreover, inferential and descriptive analysis were analyzed. The result showed that overall growth performance of Eucalyptus camaldulensis with respect to height, diameter, and volume was significantly different according to site quality. The growth of site quality I of E. camaldulensis of SFDP was shown the best performance. The average diameter, height and volume increments were 2.8cm, 3.36m and 0.027m3 respectively in site quality I. The soil N, P, K and pH varied according to depth of sites. For the greater production of timber, it was needed maximum pH (5.83 - 8.37). The maximum NPK values were 0.175%, 300.89kg/ha and 194kg/ha respectively in site quality I. The plant volume was increased till the age of 9 year and then its increment was fallen so, for the maximum growing stock in short rotation in E. camaldulensis it need to harvest at the age of 9 year. It needs to maintain the spacing to obtain the straight and healthy bole. It was found that increasing the spacing has positive effect in diameter and height increment. This study will be useful to see the effect of spacing and soil fertility on growth performance.

***Keywords:** Eucalyptus camaldulensis, SFDP, growth, plantation, singling, doubling, spacing.*

INTRODUCTION

Growth is Increase in diameter, basal area, height and volume of individual trees or stands during a given time period. (Source: Compilation of Forestry Terms and Definitions). The Performance is the action or process of performing a task or function by a living being. *Eucalyptus camaldulensis*, the river red gum, is a tree of the genus Eucalyptus. It is one of around 800 species within the genus. It has smooth white or cream-colored bark, lance-shaped or curved adult leaves, flower buds in groups of seven or nine, white flowers and hemispherical fruit with the valves extending beyond the rim. It is a plantation species in many parts of the world but is native to Australia, where it has the widest spread natural distribution of Eucalyptus in Australia. This species is cultivating in China and India also. Eucalypts planting in India started taking shape through extension activities of the state forest departments in the late sixties and early seventies.

Eucalypts were introduced some 70-80 years ago in Kathmandu by the Nepal-Australian Forestry project, where some fine avenue trees may be seen. Several trials were made; results were prominent in the Terai but above 1,000 m results were on the whole disappointing. Species selection trials by K.J. White (1981-85) showed *Eucalyptus camaldulensis* best suited on account of its adaptability to a range of sites, rapid growth, high yield and the utility of its timber in Sagarnath Forest Development Project, Nepal. However, the site is an important factor which affects the growth of this species.

Forest occupies a total of 5.96 million ha which is 40.36% of the total area of the country. Other

Wooded Land (OWL) covers 0.65 million ha (4.38%). Forest and OWL together represent 44.74% of the total area of the country (DFRS/FRA, 2014). Its Nepali name is "Masala" and "Sapeta" called in mid and eastern Terai region. It is one of the fast-growing species and mainly used for fuelwood but now a day it is using for furniture also. In Nepal about 80% of domestic and industrial energy consumed is provided from fuelwood, largely from forest, which is being depleted at an increasing and unsustainable rate. An integrated model demonstration plantation largely based on eucalyptus species in the Bhabar Terai showed that *Eucalyptus camaldulensis* was the most suitable species in terms of adaptability and productivity.

The study related to growth and its factors like nutrients have limited research in Nepal especially in Eucalyptus plantation, Sagarnath. Infarct, there is no record of mean and periodic growth of this species, which indicates the tree health and directly related to the production of good quality timber. Thus, this study will help to address the gap seen plantation of *E. Camaldulensis*. Similarly, as it is well known that the site quality depends upon the fertility of soil. Specifically, soil Carbon (C), Nitrogen (N), Phosphorus (P), Potassium (K), and pH value are the major elements which are generally used to evaluate the site quality. Therefore, this research is rational. This study was objectively carried out to show the diameter and height distribution of *E. camaldulensis* its growth performance of *E. camaldulensis* according to different site quality and relate the soil nutrients.

Materials and Methods

Study Site

The study was carried out in the Eucalyptus camaldulensis plantation of Sagarnath Forestry Development Project located in Sarlahi and Mahottari District. The study area lies at 26.9974° N and 85.6749° E (Sagarnath). The temperature ranges 10-40 (average 42°C in summer season) and rainfall around 1500 mm annually. The climate is lower tropical so natural dominant vegetation is Shorea robusta.

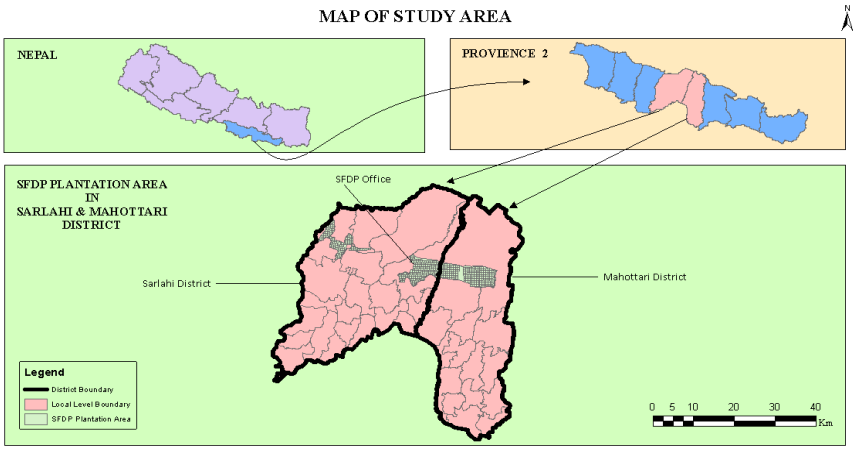

Figure1. *Map showing study area*

After selecting the study area the data specifically biophysical and soil samples were collected and they were analyzed. Based on the analyzed data the thesis draft was prepared and after presentation advices were submitted and it was finally completed.

Data Collection

Primary and secondary data were collected for the study purpose. The secondary data and information were gathered from internet surfing, books, journals, reports from department of forest and SFDP while the primary data were collected through field observation, direct measurement of plants, soil sample and laboratory analysis, as per the method described below.

For accuracy, reliability and convenience to reduce the chances of the error, 40 sample plots having 10 plants in each plot were measured in plantation and 10 plots in singling and 10 in doubling coppice. Soil samples collected from only 40 plantation sample plots from 0-10 cm, 10-20 cm and 20-30 cm depth. The plots were selected with the help of SFDP plantation and harvesting record and finalized after field visiting.

Sampling Size and Sampling Plot

Total 60 sample plots were established for the field data collection. 40 sample plots (400 plants) from plantation (Table-1) and 20 plots (200 plants) from singling and doubling coppice. (Table-2)

Table1. *Number of sampled plantation tree according to age and site class*

Site Class	Age of plant (year)										Total number	Remarks
	1	2	3	4	5	6	7	8	9	10		
I	10	10	10	10	10	10	10	10	10	10	100	
II	10	10	10	10	10	10	10	10	10	10	100	
III	10	10	10	10	10	10	10	10	10	10	100	
IV	10	10	10	10	10	10	10	10	10	10	100	
Total	40	40	40	40	40	40	40	40	40	40	400	

Table2. *Number of sampled coppice tree according to age*

Coppice	Age of plant (year)										Total number	Remarks
	1	2	3	4	5	6	7	8	9	10		
Singling	10	10	10	10	10	10	10	10	10	10	100	
Doubling	10	10	10	10	10	10	10	10	10	10	100	
Total	20	20	20	20	20	20	20	20	20	20	200	

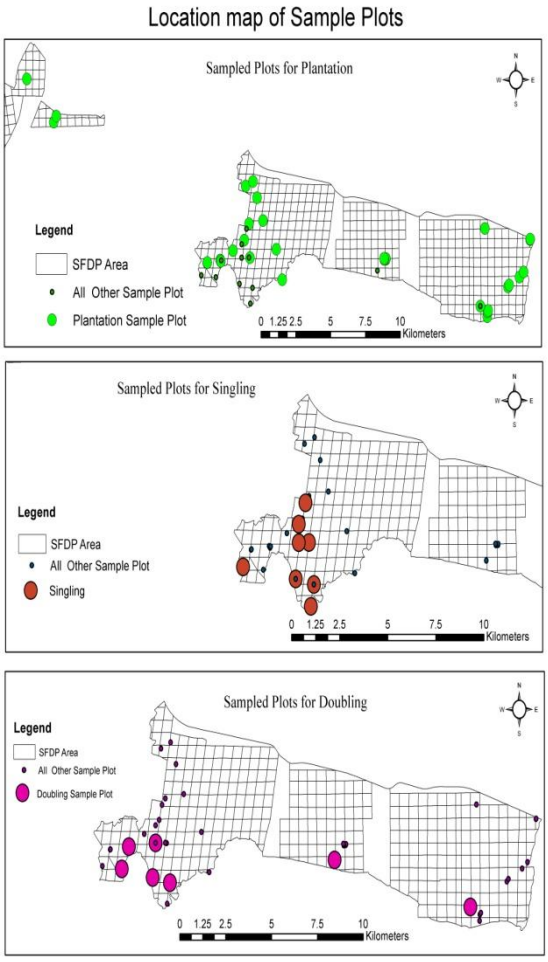

Figure2. *Map showing sample plots*

Measurement And Soil Sample

After fixing the point according to age and site class DBH and height (total height, crown height, fork height) measured with the help of linear tape and Range Finder respectively and the location were recorded by GPS. Crown diameter was also recorded of 600 plant of 60 plots. Besides this silviculture operations, other activities were listed in plot history record. The soil samples at depth 0-10cm, 10-20cm and 20-30cm were collected at 40 different sample plots from four site quality of 1 to 10 years age by using soil corer and shovel and place in labeled sample bag and the fresh weight of sample were taken in the field with the help of weighting machine. After that the collected samples

brought to the laboratory to determine the soil nutrients and carbon content. The collected soil Samples were oven dried at 1050C in the laboratory until they reached a constant weight to estimate soil bulk density.

Data Analysis

The basal area, volume, biomass and carbon were calculated. As mean of diameter, height, basal area, volume, biomass and carbon and then increment in diameter, height, basal area, volume, biomass and carbon were calculated using the mean data and present age of the species. The following formulae were used for the quantitative analysis.

$$Volume\,(V) = (\frac{\pi d^2}{4} * \text{Height} * \text{form factor})/10000$$

Where, V = Volume in m^3, d = diameter in cm, form factor = 0.5 (CFIG, 2004)

Above ground tree biomass (AGTB in kg) was calculated using Chave et al. (2005)

$$AGTB = 0.0509 * \rho * d^2 * H$$

Where, ρ = wood density of the species (gm/cm^3), d= diameter (cm), H= tree height (m)

For *Eucalyptus*, wood density=0.72 gm/cm^3 was used (Jackson, 1992)

$$Carbon\ content(C) = 0.47 * total\ biomass$$ (MacDicken, 1997).

MAVI = MV /Age of tree**,** Whereas, Mean Volume (MD) and Mean Annual Volume Increment (MAVI)

Lab Analysis

Soil Organic Carbon (SOC) analyzed using volumetric method (Walkley and Black, 1934).

SOC [t/ha], = ρ × d × %C,

Where, ρ (Bulk Density g/cc) = (oven dry weight of soil)/ (volume of soil in the core)

d = the total depth at which the sample was taken [cm], and %C = carbon concentration [%].

Lab Analysis of Soil for Ph, SOC, N, P And K Estimation

Soil nitrogen, carbon, potassium, phosphorus & pH were analyzed here by using Manual of Soil Testing at Central Department of Environment Science, TU Kirtipur.

Potassium was calculated using the Ammonium Acetate Method of K Determination (Hanway and Heidel, 1952). Phosphorus was analyzed using Olsen's Method (Olsen et al., 1954), pH is analyzed using pH meter.

RESULT

Volume Per Hactare According to Crop Type and Site Quality

In the doubling two plant grow from the one stump so the volume of doubling was greater than singling (Table: 3). The per hactare volume of plantation was higher than doubling since doubling had two plant at one stump.

Table3. *Volume per hactare according to crop type*

Age (Year)	Volume (m^3) of crop per hectare					
	Plantation Site I	Plantation Site II	Plantation Site III	Plantation Site IV	Singling	Doubling
1	9.894	4.471	1.465	0.172	6.509	13.017
2	18.225	5.810	2.300	3.259	30.368	60.737
3	78.064	24.363	19.902	9.516	13.199	37.074
4	29.256	49.054	50.079	8.056	19.522	63.814
5	87.841	81.569	30.822	22.232	29.040	205.754
6	279.699	79.491	19.721	26.836	60.796	140.593
7	142.295	142.295	102.773	30.069	41.673	373.662
8	252.322	121.179	112.564	82.411	54.082	81.017
9	184.063	741.431	188.316	182.809	85.574	177.849
10	348.370	316.158	175.359	137.241	79.232	130.690

Mean Annual Volume Increment (MAVI) of E. Camaldulensis According to Site Quality

In Plantation site; the MAVI was varied according to the different age and site. The highest MAVI was 0.042±0.004 m^3 at age 10 in site quality III, whereas the lowest MAVI was recorded 0.0001±2.52 m^3 at age 1 in site quality IV (Table 4). In Singling, the highest MAVI was 0.0371±0.0043 m^3 recorded at age 5 whereas age 1 recorded the lowest MAVI 0.0052±0.001 m^3. In Doubling, the highest MAVI recorded was 0.0474±0.0049 m^3 in age 9 whereas, age 1 recorded the lowest MAVI as 0.0052±0.0014 m^3.

Table4. *Mean Annual Volume Increment per stem*

Age (Year)	Volume (m^3)					
	Plantation				Singling	Doubling
	Site I	Site II	Site III	Site IV		
1	0.006±0.001	0.002±0.000	0.001±0.000	0.0001±2.52	0.0052±0.0014	0.0052±0.0014
2	0.005±0.000	0.001±0.000	0.002±0.000	0.001±0.000	0.0121±0.0023	0.0121±0.0023
3	0.020±0.002	0.004±0.000	0.003±0.000	0.002±0.000	0.0105±0.0022	0.0148±0.0016
4	0.014±0.002	0.012±0.002	0.010±0.002	0.003±0.001	0.0078±0.0015	0.0127±0.0011
5	0.017±0.001	0.013±0.002	0.009±0.001	0.003±0.0004	0.0371±0.0043	0.0308±0.0064
6	0.056±0.009	0.010±0.001	0.007±0.001	0.005±0.001	0.0121±0.0025	0.0234±0.0026
7	0.028±0.006	0.032±0.005	0.018±0.003	0.006±0.001	0.0214±0.0023	0.0266±0.0039
8	0.050±0.005	0.024±0.002	0.022±0.002	0.024±0.003	0.0162±0.0032	0.0202±0.0040
9	0.049±0.008	0.051±0.005	0.021±0.004	0.020±0.003	0.0342±0.0038	0.0474±0.0049
10	0.027±0.004	0.025±0.003	0.042±0.004	0.034±0.005	0.0285±0.0030	0.0235±0.0030

The MAVI was recorded highest in the site quality I of the plantation area then it was followed by doubling and singling within 9 year but at the time of 10 year all MAVI were decreased in the comparison of ninth year age. MAVI was less in the initial year and was increasing till ninth year.

One way ANOVA showed that there was significant differences in height growth of *E. camaldulensis* among all age and all site except ten year volume increment since $p<0.05$ at 5% level of significance as well as ten year plantation volume increment was insignificant since $p>0.05$ at 5% level of significance. At one year plantation Tukey's b test showed that, there was significant difference in volume increment between site 1 with 2, 3 and 4 as well as there was insignificant difference between site 2 and 3, as well as 3 and 4 at 5% level significant. At two, three and six year plantation Tukey's b test showed that, there was significant difference in volume increment between site 1 with 2, 3 and 4 as well as there was insignificant difference between site 2, 3 and 4 at 5% level significant. At four year plantation Tukey's b test showed that, there was significant difference in volume increment between site 1 and 2 with 4 as well as there was insignificant difference between site 1, 2 and 3 as well as 3 and 4 at 5% level significant. At five year plantation Tukey's b test showed that, there was significant difference in volume increment between site 4 with 1, 2 and 3 as well as there was insignificant difference between site 1 and 2 as well as 2 and 3 at 5% level significant. At seven year plantation Tukey's b test showed that, there was significant difference in volume increment between site 4 with 1 and 2 as well as there was insignificant difference between site 1, 2 and 3 as well as 3 and 4 at 5% level significant. At eight year plantation Tukey's b test showed that, there was significant difference in volume increment between site 4 with 1 as well as there was insignificant difference between site 2 and 3 at 5% level significant. At nine year plantation Tukey's b test showed that, there was significant difference in volume increment between site 1 and 2 with 3 and 4 as well as there was insignificant difference between site 1 and 2, 3 and 4 at 5% level significant. At ten year plantation Tukey's b test showed that, there was insignificant difference in volume increment between all site at 5% level significant.

Total Carbon Per Ha of E. Camaldulensis According to Site Quality

In Plantation site; the Average carbon was varied according to the different age and site. The highest average carbon was 135.449±14.702 ton/ha at age 9 in site quality II whereas the lowest average carbon was recorded 0.033±0.005 ton/ha at age 1 in site quality IV which was highest and lowest data within plantation, singling and doubling (Table: 5). In Singling, the highest average carbon was 90.043±10.11 ton/ha recorded at age 9 whereas age 1 recorded the lowest average carbon 1.518±0.409 ton/ha. In Doubling, the highest average carbon recorded was 124.762±12.916 ton/ha in age 9 whereas, age 1 recorded the lowest average carbon as 1.518±0.409 ton/ha.

Table5. *Carbon Stock per ha according to site quality*

Age	Plantation (ton/hac)				Singling (ton/hac)	Doubling (ton/hac)
	Site I	Site II	Site III	Site IV		
1	1.805±0.343	0.813±0.155	0.268±0.033	0.033±0.005	1.518±0.409	1.518±0.409

2	3.328±0.526	1.062±0.118	1.076±0.103	0.597±0.132	7.097±1.372	7.102±1.372
3	18.25±2.453	3.558±0.555	2.909±0.536	2.223±0.588	9.259±1.96	13±1.452
4	17.103±3.21	14.335±2.341	11.708±3.431	3.768±0.968	9.127±1.833	14.923±1.344
5	25.676±2.815	19.073±2.839	13.513±2.402	5.198±0.635	54.323±6.359	45.106±9.466
6	98.103±17.216	18.584±2.148	13.832±2.844	9.409±1.861	21.324±4.427	41.092±4.667
7	59.037±13.137	66.547±11.21	37.548±7.685	14.062±1.988	43.851±4.794	54.609±8.07
8	118.003±12.82	56.673±5.922	52.64±5.786	57.81±7.887	37.938±7.633	47.362±9.555
9	129.123±22.96	135.449±14.702	55.042±11.684	53.434±9.898	90.043±10.11	124.762±12.916
10	81.46±13.893	73.926±10.251	123.013±13.414	100.289±16.666	83.373±8.939	68.761±8.954

Mean Annual Carbon Increment (MACI) of E. Camaldulensis According to Site Quality

In Plantation site; the MACI was varied according to the different age and site. The highest MACI was 16.347±2.867 at age 6 in site quality I, whereas the lowest MACI was recorded 0.028±0.007 at age 1 in site quality IV. In Singling, the highest MACI was 10.002±1.123 recorded at age 9 whereas age 4 recorded the lowest MACI 2.28±0.456. In Doubling, the highest MACI recorded was 27.721±1.33 in age 9 whereas, age 1 recorded the lowest MACI as 3.041±1.142.

Table6. *Mean Annual Carbon Increment*

Age	Plantation				Singling	Doubling
	Site I	Site II	Site III	Site IV	Site I	Site I
1	1.805±0.334	0.813±0.155	0.263±0.033	0.028±0.007	1.518±0.409	3.041±1.142
2	1.664±0.263	0.526±0.056	0.536±0.052	0.296±0.061	3.549±0.686	7.097±0.898
3	6.082±0.818	1.184±0.183	0.968±0.179	0.738±0.193	3.083±0.653	8.667±1.17
4	4.272±0.799	3.581±0.583	2.923±0.855	0.94±0.24	2.28±0.456	7.459±0.606
5	5.132±0.559	3.812±0.564	2.703±0.479	1.039±0.127	10.862±1.269	15.689±0.545
6	16.347±2.867	3.097±0.357	2.303±0.47	1.565±0.282	3.553±0.738	13.696±1.213
7	8.432±1.875	9.503±1.598	5.363±1.095	2.007±0.282	6.26±0.682	15.599±2.876
8	14.749±1.598	7.083±0.738	6.58±0.719	7.224±0.982	4.742±0.954	11.839±2.933
9	14.344±2.547	15.049±1.631	6.115±1.297	5.936±1.1	10.002±1.123	27.721±1.33
10	8.145±1.387	7.388±1.025	12.3±1.34	10.025±1.664	8.333±0.893	13.748±2.519

Relation Between Crown Height and Tree Height

The relation between Crown heights with total height, Spacing with diameter, Age of tree with forked percent were directly proportional with each other. The linear equation was y = 0.6901x - 0.3877 to find the crown height (Figure: 3)

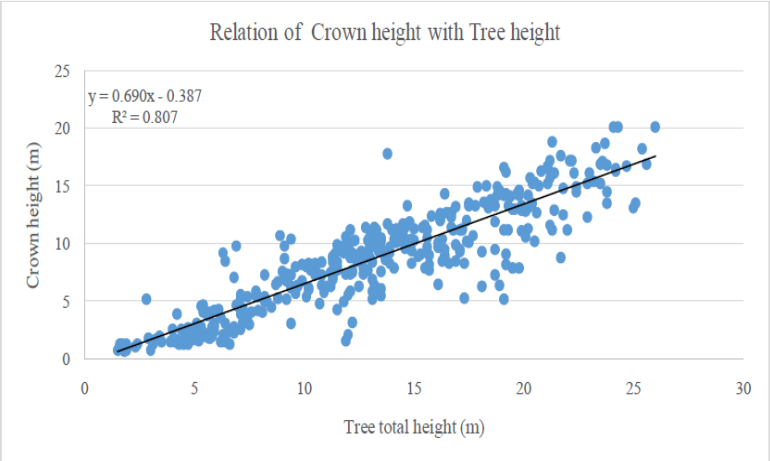

Figure3. *Relation of crown height with tree height*

Relationship Between Crown Diameter and Plant Spacing

The crown diameter was greater as the spacing increased. It was 2m crown diameter at spacing 7 m^2, 2.5m at spacing 7 m^2, and 5m at spacing 25m^2. There was a linear equation y = 0.169x + 0.8426 as the relation of crown diameter with spacing (Figure:4)

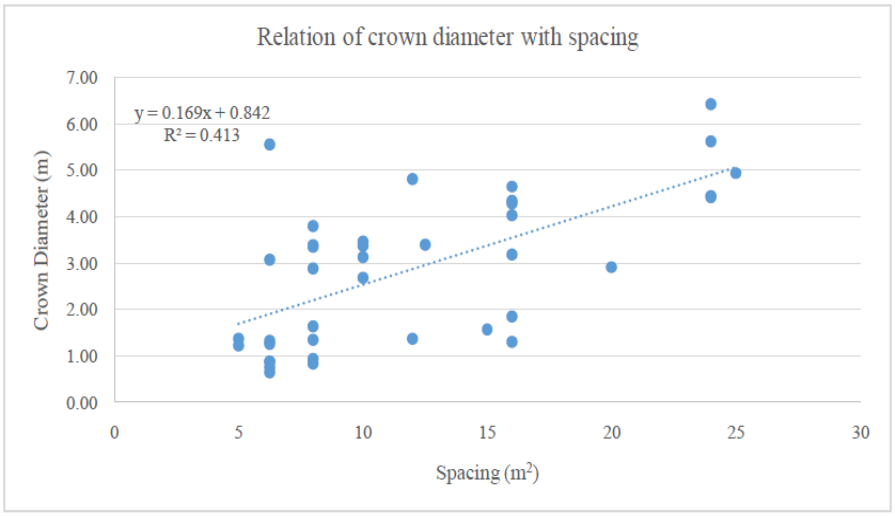

Figure4. *Relation of crown diameter with spacing*

Relationship between Crown Diameter and Crown Height

It was in increasing trend of crown diameter as the crown height increased. To find the crown diameter by crown height, y = 0.2912x + 0.4144 was the linear equation (Figure:5).

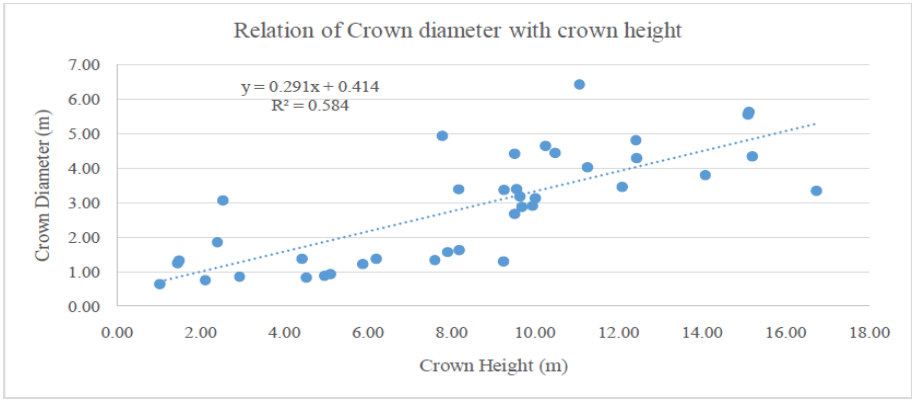

Figure5. *Relation of crown diameter with crown height*

Relation between Volume of E. Camaldulensis and Nitrogen

There was positive correlation between volume and nitrogen% since r2=0.4016 and equation was y = 0.4842ln(x) + 1.2085. ANOVA showed that there is significant relation between Nitrogen% and plant's volume at 95% confidence level (Figure:6). At the same time t-test showed constant and variable were significant at 5% level of significant with standard error 0.04 and 0.089 respectively. Here, in the figure shows that Nitrogen from 0.15% to 0.165% is best for the better production of volume in SFDP. volume.

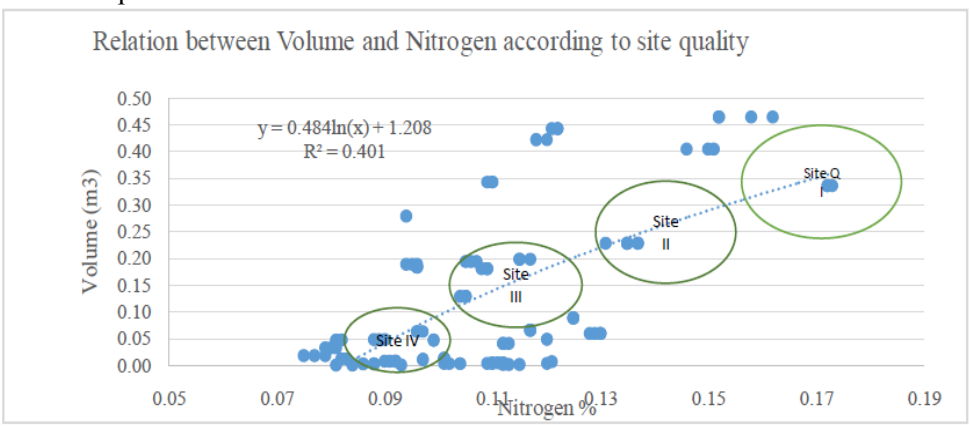

Figure6. *Relation of volume with Nitrogen*

Relation Between Volume Of E. Camaldulensis And Phosphorus

There was positive correlation between volume of plant and Phosphorus since r^2=0.368 and equation was y = 0.2677ln(x) + 0.5308. ANOVA showed that there is significant relation between Phosphorus (kg/ha) and plant's volume ($m^{3)}$ at 95% confidence level (Figure: 7). At the same time t-test showed constant and variable were significant at 5% level of significant with standard error 0.019 and 0.037 respectively. Here, in the figure shows that Phosphorus from 0.4kg to 0.5kg is best for the better production of volume in SFDP.

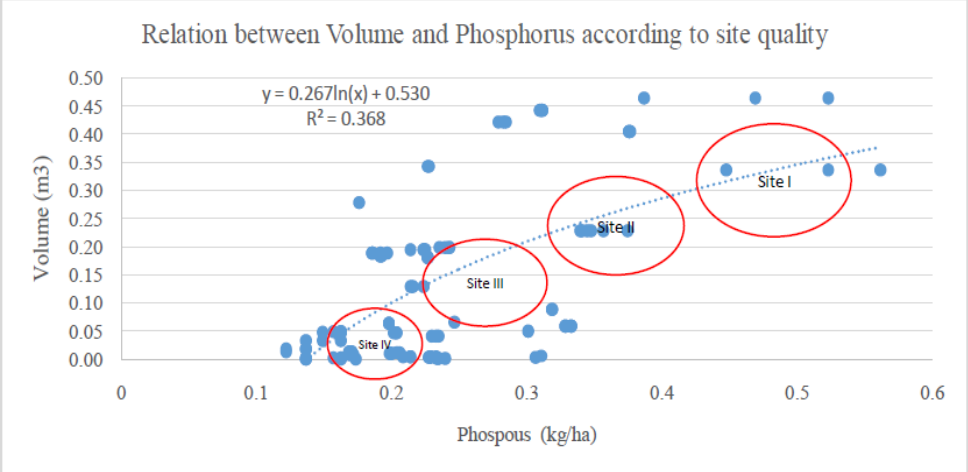

Figure7. *Relation of volume with Phosphorus*

Relation between Volume of E. Camaldulensis and Potassium

There was positive correlation between volume of plant and Potash since r^2=0.032 and equation was y = 0.2535ln(x) - 1.0181. ANOVA showed that there is significant relation between Potassium **(**Potash) (kg/ha) and plant's volume ($m^{3)}$ at 95% confidence level (Figure: 8). At the same time t-test showed constant and variable were significant at 5% level of significant with standard error 0.019 and 0.037 respectively. Here, in the figure shows that Potash from 130kg to 175kg is best for the better production of volume in SFDP.

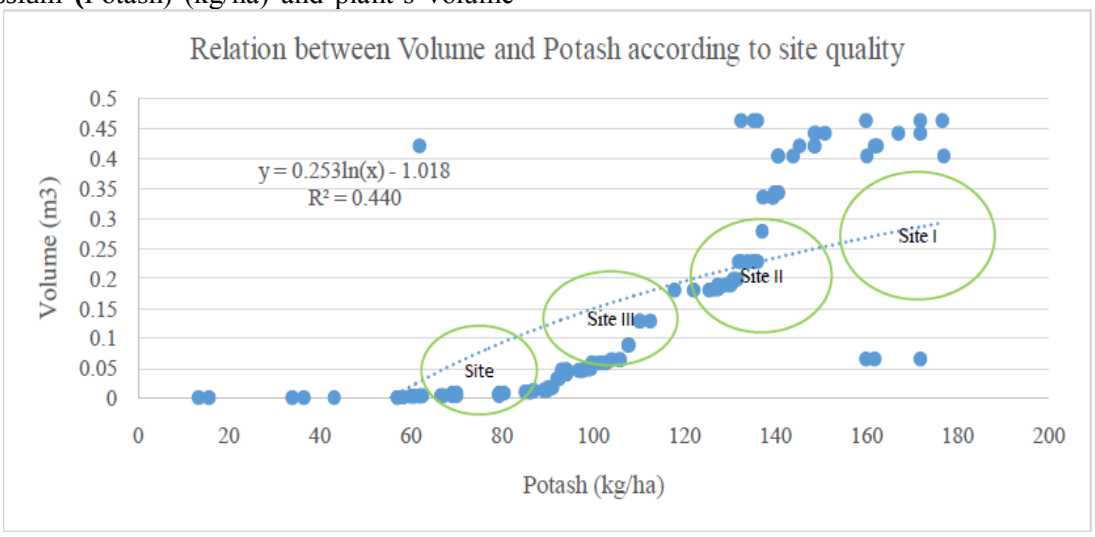

Figure8. *Relation of volume with Potassium*

Relation between Volume of E. Camaldulensis and Soil Ph

The pH value was smallest (5.53) in site quality IV at 20-30cm depth soil but it was greatest (8.41) in site quality I at 10-20cm depth soil. There was positive correlation between mean annual volume increment (MAVI) of plant and soil pH since r2=0.1659 and equation was y =48.918ln(x)-73.59 within soil pH 5.53 to 8.41. ANOVA showed that there is significant relation between pH value and plant's MAVI percent at 95% confidence level (Figure: 9). Here, in the figure shows that pH from 8.1 to 8.4 is best for the better production of volume in SFDP.

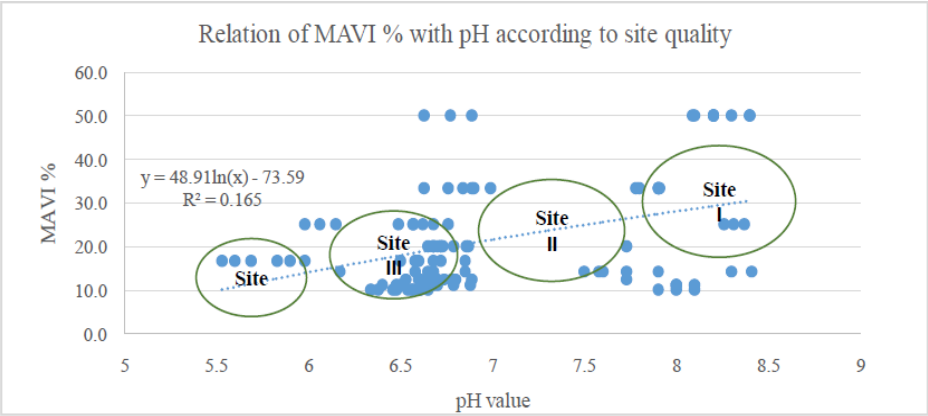

Figure9. *Relation of volume increment percent with soil pH*

DISCUSSION

Diameter And Height Distribution Of E. Camaldulensis According To Site Quality

The DBH of 10 years *Eucalyptus camaldulensis* was 17.3cm and height was 21.65m in quality site 1 because this site is very favorable. The regular weeding, cleaning and thinning may be other cause of high growth in this site in the SFDP. Amsterdam (1991), showed that the highest DBH at 18 year was 22.20cm and height was 24.6m and the smallest DBH was 13.18cm and height was 14.46m among ten sites. This DBH and height are about similar with our research finding. Bhatt (2009), reported that *Eucalyptus camaldulensis* growth in SFDP by intercropping was more than without inter cropping. DBH and height of four year crop in the intercropping was 12.65cm, 18.66m and without intercropping was 4.07cm and 9.62m respectively which are quite similar with our research result finding. The DBH of *Eucalyptus camaldulensis* from the age with 2 year to 10 year old was 3.84 cm, 7.57 cm, 9.53 cm, 10.35 cm, 11.76 cm, 13.7 cm, 15.72 cm, 17.79 cm and 19.68cm respectively. (Dhakal, 2008). This findings were quite similar with our research work because the DBH of this spp was 6.16cm, 10.18cm, 10.1cm, 12.53cm, 20.2cm, 15.72cm, 21.09cm, 21.74cm and 17.34cm in the site one and 3.15cm, 4.9cm, 5.6cm, 06.0cm, 8.3cm, 9.8cm, 17.6cm, 15.9cm and 20.9cm at the site four from age 2-10 years of plantation crop of *Eucaluptus camaldulensis.*

Pakistan Grey (2003) showed that overall mean height at age 60 months was 8.7 m. This height is quite similar to our result because our research found the mean height 12.53m in site one and 6.07m in site four. Intercropping for 3 years plants' height 15.2m, intercropping for two years was 12.6m, intercropping in first year only was 6.0 m and only 1.8m height where there no intercrops.(Khanal, 1993) which are similar as our study.

The mean height of *E. camaldulensis* at the age of 0.6, 1.5, 2.5 and 3.5 years were 2.2m, 7.1m, 8.9m and 12.0m in the plantation area in the Tarahara Sunasari. It was 5.3m, 7.0m, 9.5m, 7.7m and 14.7m at the age of 4.5yr, 5.5yr, 6.5yr, 9.5yr and 10.5yr in the coppice shoot (Thapa and Subedi, 2011). The mean height of *E. camaldulensis* at Puttalum in dry zone of Sri Lanka at the age of six years was 8.4m (Ranasinghe and Mayhead1991) which was better than Tarahara. The mean DBH was 8.7cm at the age of 2.5 year and 9.5cm at the age of 3.5yr at the Tarahara in plantation crop. The mean DBH in the coppice crop was 3.3cm, 4.8cm and 7.2cm at the age of one to three year. The result was quite similar to 4.8cm, 6.1cm and 10.1cm in site quality one and 1.1cm, 3,1cm and 4.9 cm in site four. The Basal Area per hectare according to age of 2 and recorded until 10 year was 1.9 m^2, 7.5 m^2, 11.4 m^2, 14 m^2, 18.1 m^2, 24.7 m^2, 32.3 m^2, 41 m^2 and 50,7 m^2. These were recorded in 2*3 m^2 spacing in private forest (Dhakal ,2008). Mean basal area of *E. camaldulensis* planted at a spacing of 2mx2m was 9.25 m^2/ha i.e. 19.4% lower than that of Tarahara (Prasad et al. 1984). The result of our study was near with current study to 4.95 m^2/ha, 11.39 m^2/ha, 4.29 m^2/ha, 12.5 m^2/ha, 27.93 m^2/ha, 16.09 m^2/ha, 22.26 m^2/ha, 16.4 m^2/ha and 30.67 m^2/ha at the age of 2-10year which are quite similar with previous results.

Growth Performance of E. Camaldulensis According to Site Quality

According to current study 5 year age increment was 17.57 m^3/ha in good site and 4.45 m^3/ha in poor site which data was between previous study. In community plantation, the mean stem

volume per ha was found to be 171.46 m³/ha which was nearly doubled than the mean stem volume from private plantation and higher by about 10 m³ than total stem volume for Tarai region of Nepal (FRA, 2015). Meanwhile, the mean annual volume increment per ha was 10.2 m³/ha and higher by 1.4m³/ha in private land than community land. ADB Post-Evaluation Office (1993) published a report. It was 12.7m^3 /ha under good management in site class I and 8.5 m3/ha in site class II. The actual harvest of first 40 ha in 1991/92 indicated MAI of 9.0 m^3/ha. In the study the crown height with total height, crown diameter with spacing and crown diameter with crown height were proportional to each other.

Soil Nutrients and Growth Performance of E. Camaldulensis

Study of the yield tables of the *Eucalyptus hybrid* shows that its current annual increment peaks in the fifth year and then drops (Chaturvedi 1983).The mean annual increment peaks in the sixth or seventh year. During this period, growth rates are high, and trees demand more moisture and nutrients. Growth rates begin to decline after the sixth year, and the demand for moisture and nutrients also decreases. During periods of fast growth, sites do not increase appreciably in nutrient and moisture status. Once the growth rate slows the nutrient uptake decreases and its recycling increases. If trees are harvested before maximum growth is reached, the sites will be poorer in moisture and nutrient status. This author carried out studies on chemical changes brought about by some tree species in saline alkaline soils. Four years after being planted, the Eucalyptus hybrid improved the sites by reducing the pH, increasing the organic carbon, and reducing the percentage of sodium and potassium. However, *Prosopis juliflora* had a greater beneficial effect. (Chaturvedi 1983).SOC in community forest was 66.38 t/ha, 52.62 t/ha in leasehold forest and 73.42 t/ha in agriculture. (Kathmandu University 2014). Maximum SOC pool was recorded under forests (51.05 t ha^{-1}) followed by plantations (35.52 t/ ha), horticulture (33.58 t/ha) and the least under agroforestry (29.22 t/ha), which was 44.54 %, 52.03% and 74.71% higher, respectively. Soil C is lost during the initial years of tree crop establishment, but increase of 1.6 t/ha per year over an 18 year study have been recorded for hybrid poplars by Hansen (1993). The highest soil organic carbon stock (114.03 t/ha) was estimated in High Mountains and High Himal regions. SOC was the lowest in Churia region with an average of 31.44 t/ha. The results from Middle Mountains region showed an average SOC stock of 54.33 t/ha. SOC stock in the forests of the Terai was found 33.66 t/ha which was slightly higher than in Churia (FRA 2015). Our study in SFDP has slightly less SOC than the average in Terai region.

NPK fertilizer was applied three times in spade-slit dressings at 9, 18 and 27 months from planting at a zero rate, a medium rate and a rate four times that. Over the life of the trial N was applied at the rate of 0, 80 or 320 kg/ha; P was applied at the rate of 0, 7.5 or 30 kg/ha and K at 0, 25 or 100 kg/ha.(ELSEVIER, 2002). The manual of afforestation in Nepal by Jackson (1994) has highlighted that the acidity or alkalinity of soils is expressed in the pH value, which is the logarithm of the reciprocal of the hydrogen ion concentration. A pH value of 7 is neutral, so that soils with a pH of less than 7 are acid, and those with a pH higher than 7 are alkaline. The writer also mentioned that low altitude soils of the Terai and Bhabar zones have pH values varying around the neutral point of pH 7, often with higher levels in the subsoil than in the topsoil. In the Middle Hills, between 1000 and 2000 m, most soils have pH values between 5 and 6; the average is about 5.4. At higher elevations still pH values of between 4 and 5 are found. These are generalizations and locally soils may differ considerably from these values.

Soil nutrients were found to be positively correlated. However, BD showed a negative correlation with C, N, K and P. According to Salim,et. al.(2018), high BD means low organic matter (i.e. low soil nutriens) and viceversa. The macronutrients; nitrogen (N), phosphorus (P) and potassium (K) frequently are the first to become deficient in the soil because they, especially N and K are required by plants in the largest quantities (Bandel et al, 2000). The height and basal area of *E. grandis* seedlings were enhanced by 12% and 30%, respectively by N fertilization at age 1 year. Inter-specific competition led to a stratified canopy in Brazil, (ELSEBIER,2007)

The entire study showed that the mean annual increment peaks in the sixth or seventh year and growth rates are high and trees demand more moisture and nutrients and decrease the moisture and nutrients. Once the growth rate slows, however, nutrient uptake decreases and their

recycling increases. If trees are harvested before maximum growth is reached, the sites will be poorer in moisture and nutrient status. Four years after being planted, the Eucalyptus hybrid improved the sites by reducing the pH, increasing the organic carbon, and reducing the percentage of sodium and potassium. The SOC in community forest was 66.38 t/ha, 52.62 t/ha in leasehold forest and 73.42 t/ha in agriculture. Maximum SOC pool was recorded under forests (51.05 t ha^{-1}) followed by plantations (35.52 t/ ha). . SOC stock in the forests of the Terai was found 33.66 t/ha.

According to the study of SFDP it was found that there was more nitrogen%, Phosphorus (kg/ha) and Potassium (kg/ha) in site quality one which had more volume and least quantity of nutrients in site quality four which had least volume. The minimum value of NPK was 0.075%, 62.06kg/ha and 5.7kg/ha respectively and maximum was 0.175%The minimum value of soil pH was not so fluctuated but there were decreased in pH range from site quality one to four. The pH range found between 5.53 to 8.41 on whole sample plot, so the greater the pH value better the *Eucaluptus camaldulensis* production.

CONCLUSION AND RECOMMENDATIONS

- The overall growth performance of *Eucalyptus camaldulensis* with respect to volume was significantly different according to site quality.
- The growth of site quality I of *E. camaldulensis* of SFDP was shown best performance.
- The soil N, P, K and pH were varied according to sites for the greater production of timber,
- Plant volume was increased till the age of 9 year and then its increment was fallen so, for the maximum growing stock in short rotation in *Eucalyptus camaldulensis* it need to harvest at the age of 9 year.
- Spacing also should considered during plantation activities.
- Further studies should be carried out to extend the status and relation of soil nutrients with growth.

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