Simple coppice management options for the sal (*Shorea robusta* Gaertn. f.) forests in the Terai of Nepal

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The paper examines simple coppice management options for sal (*Shorea robusta* Gaertn. f.) forest that maximizes total biomass production. The study is based on the data obtained from two non-replicated research blocks located at Butwal and Dharan, which were established in 1988 and 1989 respectively by the Department of Forest Research and Survey. Out of four blocks in each site, one block was of simple coppice management option. Simple coppice management option had four treatments, i.e. 1) 3 *s/s*, 2) 1 *s/s*, 3) 3-2-1 *s/s*, and 4) Control, which were designed for fodder and fuelwood production in a short rotation of four years. The analysis was done to estimate the productivity of the treatments for the four successive rotations. In on average, it was found that treatment 3-2-1 *s/s* was the best to produce maximum biomass in short rotations. Both treatments 1 *s/s* and 3-2-1 *s/s* were found best for foliage production. Local community user groups benefit from the result to choose appropriate simple coppice management option in their sal forests, if fodder and fuelwood production in short rotations is the main objectives of the forest management.

Key words: biomass, coppice, Nepal, regeneration, Sal forests.

Sal (*Shorea robusta* Gaertn. f.) forests are widely distributed and cover largest area of forests in Bhabar, Terai and Siwalik hills from east to western Nepal. Sal is the most valuable and high-price wood in Nepal. The country mainly depends on this forest to meet the timber requirement (Acharya *et.al.* 2002).

In the past, sal forests was heavily exploited both for resettlement programs and for generating state revenue. Moreover, this forest was heavily cut down to meet the forest product demand of continually increasing population. Due to this, many of such forests have either become degraded in quality and quantity or converted into agricultural land.

The forest policy of Nepal has emphasized the protection of forests in Terai during the past decades. This has led to passive management, producing overmature degraded forests and that eventually disappear (Pesonen and Rautiainen 1995). The rate of decline of the forest area is 1.3 percent per annum in the Terai in the past 12 years (FRIS 1993). Thus the total loss of forest area in the plains during that period has been found 99,000 ha. In spite of degradation, the forest resources of the Terai are substantial and offer an excellent basis for sustainable management. An estimate has shown that a total of 3654 million ha of forest area is available for improved management. Out of which sal occupies 13,20,000 ha of forest area in Nepal (Sowerine 1994, cited in Acharya *et. al.* 2002). In the absence of active management of forests, uncontrolled felling, encroachment and land clearing exist. Pesonen and Rautiainen (1995) found that, about 70 percent of production forests would be suitable for the even-aged silvicultural system in Terai.

According to the Pesonen and Rautiainen (1995), most of the sal forests are over mature, since the best option for forest management is, initiating active management of natural forests based on natural regeneration of indigenous species. The production capacity of the sal forests can be improved considerably with a change in the forest management strategy and silvicultural systems. Wood production can be enhanced threefold. Young stands produce more foliage than old ones. The management system should be selected that would boost production such that local people benefit more from the new system than from the existing one.

Nowadays, people are interested to manage sal forests for multiple products as to meet local livelihood demands of forest products. This in fact needs to identify appropriate management system or

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silviculture regime. To design silviculture regimes for multiple-product management, it is important to have knowledge of stand growth and productivity (Gautam and Devoe 2006).

Natural forest management research program mainly focus on regeneration establishment in Nepal and it studies the effect of different harvesting regimes on growth performance and biomass productivity of the stand. These long-term researches were started in the 1980s at the time when the national focus in forestry sector was on renovation of degraded sites (Acharya *et. al.* 2002). These research plots were established in Tropical Sal Forest Type in the Terai region of Nepal and the objectives were:

- to investigate best management practice to establish the natural regeneration through coppice management.
- to identify best management option that can maximize fodder and firewood production from degraded Terai forests of Nepal.

Materials and methods

Study Area

The data used in this study was taken from two research sites established by the Forest Research Division (FRD) of the Department of Forest Research and Survey (DFRS).

The experiment block was established at Jogikuti, Butwal of Rupandehi district in Western Terai as a large unreplicated block which is representative of the area. The study site is about 5 km south of Butwal town and accessible by vehicles. It is accessible from the Butwal-Bhairahawa road, which passes through Jogikuti village. The plot is situated at latitude of 27°42' and longitude of 83°28' and at altitude of 263 masl. The forest was selectively logged by the authority and the remnant mature trees were removed gradually by illegal felling until 1987. The site was highly degraded and only two trees were present at the time of plot establishment in 1988 (FRP 1989). In 1988, Forest Research Project (FRP) cleared all the existing patchy bushes by coppicing so that the resulting crop would be all the same age. There was substantial re-growth after the area was protected (previously it was a grass/grazing ground). This research site is located in a place which is near the city and surrounded by the highly crowded population. By the time very few patches of forest like this were left in the area because of deforestation and population pressure.

The research block with the same management system and treatments was established at Chaukibari, Dharan of Sunsari district in Eastern Terai and intended to be a replication of the experimental site mentioned above. The study site is located at about 1.5 km east of Chaukibari of Sunsari district (Near Dharan) and about 3 km South of Dharan on the road to Ghopa Camp. The plot is situated at latitude of 26°49' and longitude of 87°17' and at altitude of 400 masl. It is located within the scrubland national forest of Sunsari district. The site is situated in a Dun valley of the Terai Bhabar zone of Nepal and is accessible by the vehicles. The site is gently undulating. The forest was under selective logging and the remnant mature trees gradually removed by illegal felling until 1989. At the time of plot establishment, there were very few trees present within the plot. Forest Research Project (FRP) cleared the area in June 1990 to establish the permanent silviculture research plots (FRP 1990). During plot establishment all the trees including felled trees were coppiced and after few month area got covered with profuse and vigorous regeneration.

Butwal and Dharan research blocks are situated apart at a distance of about 350 km in the Bhabar Terai area of Nepal as shown in figure 1.

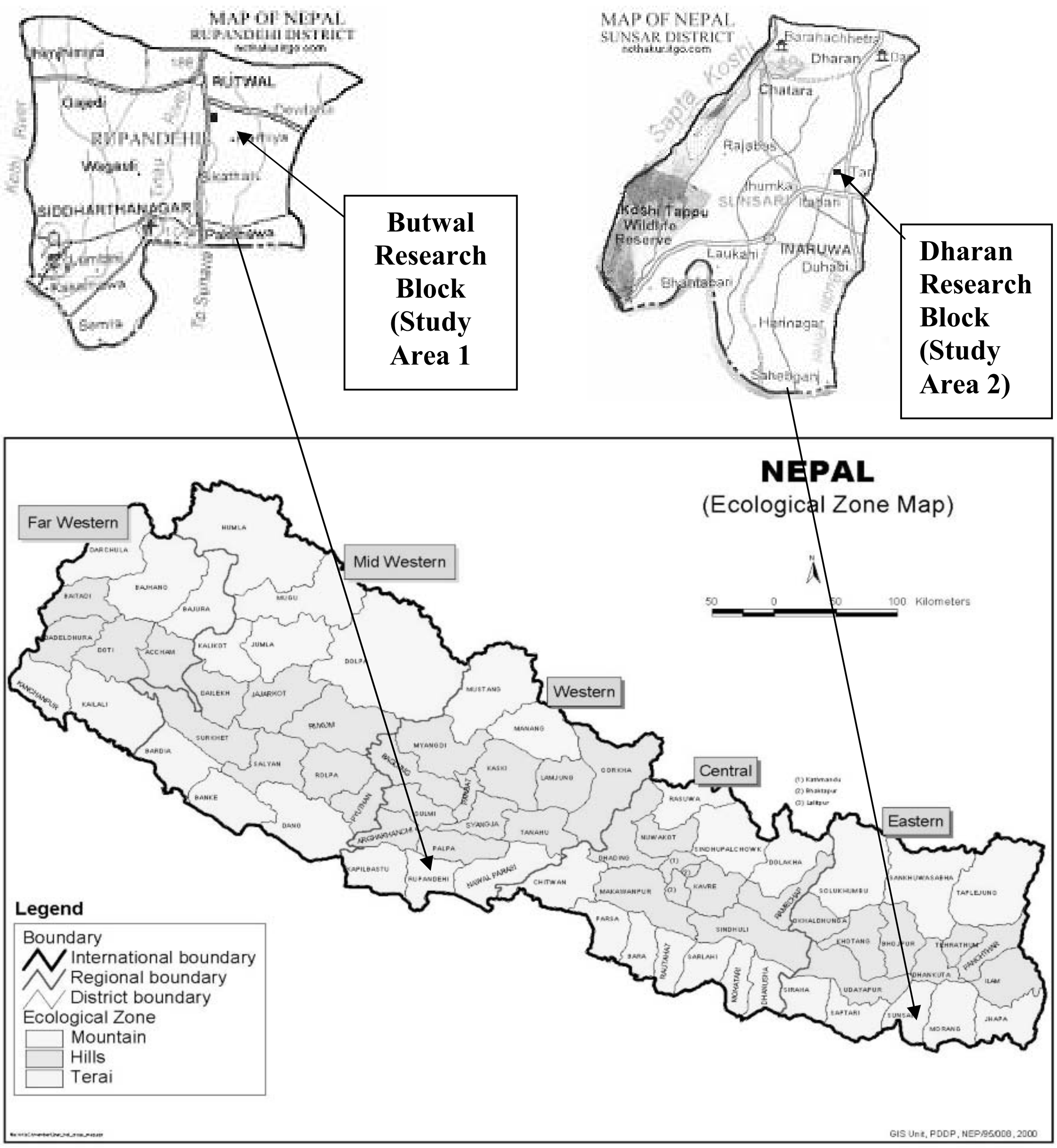
Site Conditions

Butwal Site

Soil: Butwal site is flat and fertile. The soil is loamy, deep, well drained and has adequate nutrient capability. According to the map of the Land Resource Mapping Project (LRMP), this area belongs to the class I, most suitable land for agriculture and forestry. Actual landuse for this area is shown as degraded tropical mixed hardwood forest. Soil physical and chemical properties are exceptionally good for forestry use (FRP 1989).

Climate: The climate is sub-tropical and sub-humid with regular monsoon between June-August. Frost occurs seldom and the annual average number of days with minus temperature is 0 (Jackson, 1994). Mean total annual precipitation is 2452 mm of which more than 80% falls from June to September. Monthly mean maximum and minimum temperature are 31.4°C and 17.7°C respectively with an absolute minimum of 4.3°C (Jackson 1994).

Vegetation: Sal forest diversity consists of more than 80 percent sal (*Shorea robusta*). Other associated tree species in this forest are asna *(Terminalia alata)*, amala



http://ncthakur.itgo.com/districtmaps/rupandehi_district.htm
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Figure 1: Location of the study area in the map of Nepal.

(Phyllanthus emblica), barro *(Terminalia belerica),* bhalayo *(Semicarpus anacardium)* botdhairo *(Lagestroemia parviflora),* harro *(Terminalia chebula)*, jamun (*Syzygium cumini),* kalikath *(Myrsine semiserrata),* karma *(Adina cordifolia),* raj briksha *(Cassia fistula)* and sindure *(Mallotus philipinensis).*

Dharan Site

Soil: Dharan site is also flat and fertile. The soil is loamy, deep, well drained, and gravelly and has adequate nutrients. Capability map of the Land Resource Mapping Project (LRMP) classifies the area as class I as most suitable land for agriculture and forestry. Land use is defined as degraded tropical mixed hardwood forest. As previous site, physical and chemical properties of the soil are exceptionally good for forestry use (FRP 1990).

Climate: The climate is sub-tropical and sub-humid with regular monsoon between June-August. Frost occurs seldom and the annual average number of days with minus temperature is 0 (Jackson, 1994). Mean total annual precipitation is 2401 mm of which more than 80% falls from June to September. Monthly mean maximum and minimum temperature are 28.2°C and 17.1°C respectively with an absolute minimum of 5°C (Jackson 1994).

Vegetation: The vegetation structure and composition of this site is similar to Butwal site.

Research design and layout of the plots

The block has been divided into four different management options: i) simple coppice, ii) high forest, iii) coppice with standards 25% and iv) coppice with

Figure 2. Layout design of the research Block at Dharan

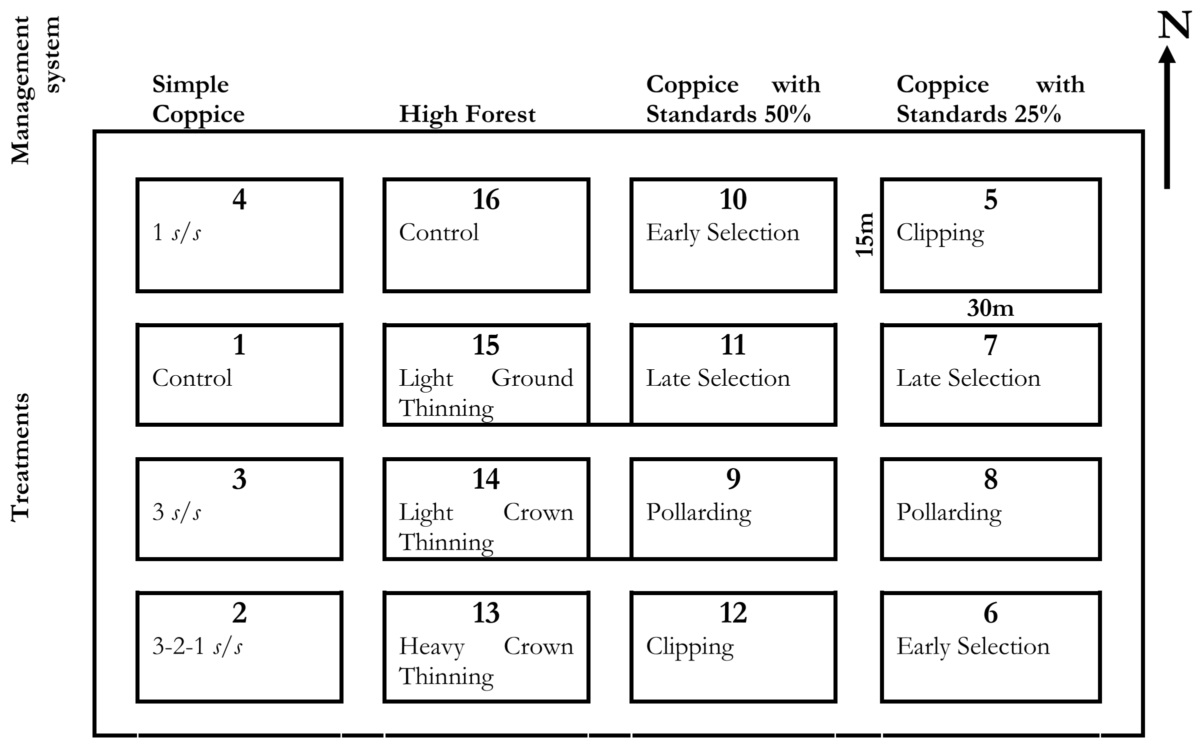
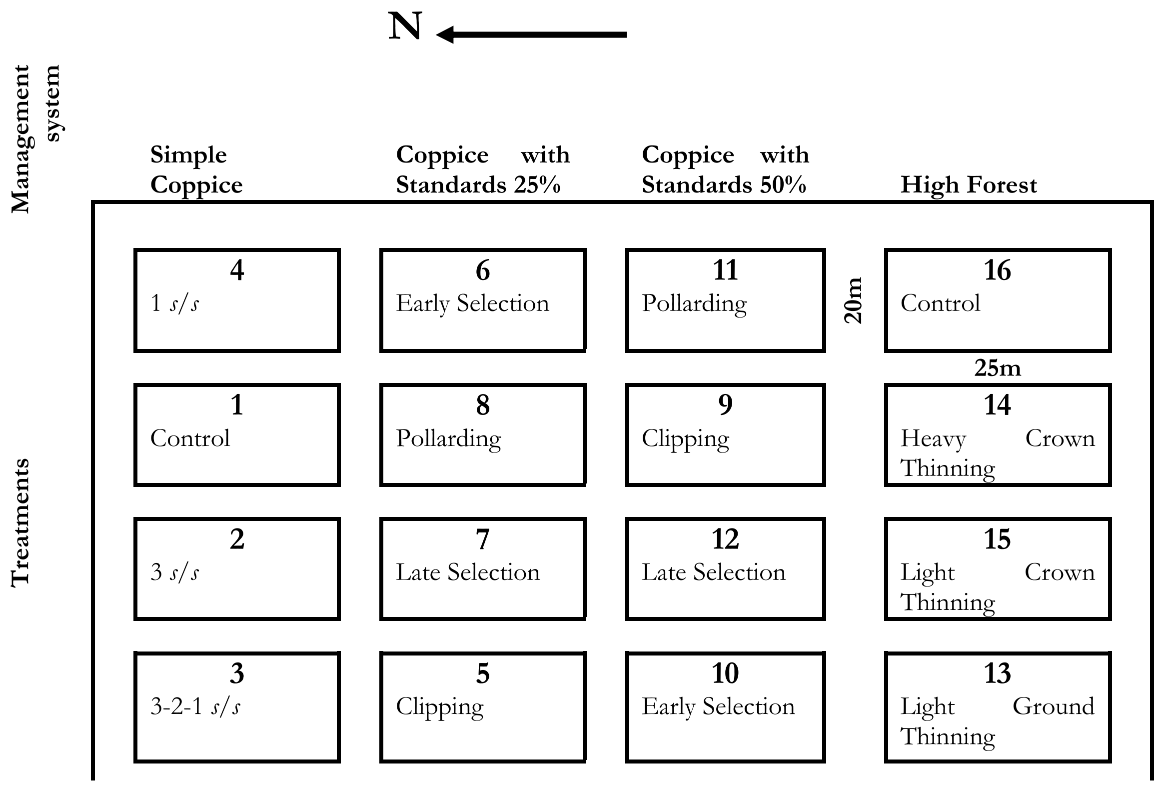


Figure 3. Layout design of the research Block at Butwal



standards 50% (Figure 2 and 3). Each of these management options has four treatments. Each treatment-plot was randomly located and demarcated apart with a buffer between them. All plots have equal size and dimension. Each plot in Dharan has an area of 450 m² (30 m * 15 m) and in Butwal has an area of 500 m² (25 m * 20 m). Fire-line around the block and buffers in-between the plots have width of 5 m. This paper analyses the simple coppice management option only.

Measurements

Total enumeration was carried out over plots during biomass measurement. Field measurements were carried out mostly between November to March every year. The harvested biomass (foliage and wood) each year from the plots under the various treatments was weighed and recorded. A weighting apparatus was used to weight the green biomass.

Simple coppice management option

Regeneration of the crop in coppice systems is based on coppicing. This management system produces maximum productivity from the harvested stumps. The simple coppice option had the shortest rotation of four years. In the fourth year, re-growth of coppice was so vigorous that the plot was covered in a dense stand of sal trees reaching a height of four meters or more. Coppices were either annually harvested or protected. The entire crop was harvested (clear felled) at the rotation age. The cycle was repeated for 4 rotations.

The treatments are as follows (Tamrakar, 1994)

1. 3-shoots per stool treatment (3 *s/s*)
   In the first year after clearfelling, the multiple shoots regenerated from the stump were singled to three best shoots per stump and the rest were harvested. These three shoots were maintained in the following years and new shoots were removed if there were any. Clearfelling was carried out at the rotation in the fourth year.

2. 1-shoot per stool treatment (1 *s/s*)
   In the first year after clearfelling, this treatment involved singling to one shoot per stump and the rest were harvested. This one shoot was maintained in the following years. Harvesting any new shoots was carried out every following year until the canopy closes and clearfelling was carried out in the fourth year.

3. 3-2-1 shoots per stool treatment (3-2-1 *s/s*)
   This treatment maintained three best shoots per stump for the first years. These were reduced to two shoots per stump in the second year and further reduced to one shoot per stump in the third year. The canopy closed at four years then the stand was clearfelled.

4. Control plot, no treatment
   In this treatment only weeding is done to facilitate coppice growth for initial three years. The plot was harvested on the fourth year.

Silviculture history of the of the treatment plots from year 1988 to 2005 is presented in Annex 1.

Results and discussion

Total biomass production

The total biomass production from the treatment plots during four rotations in Butwal and Dharan is shown in figure 4 and 5 respectively (also in Annex 2 and 3). The findings show that the management intervention increases biomass production. In both Butwal and Dharan, the biomass production in all treatment plots is increased in second, third and fourth rotations compared to the first rotation.

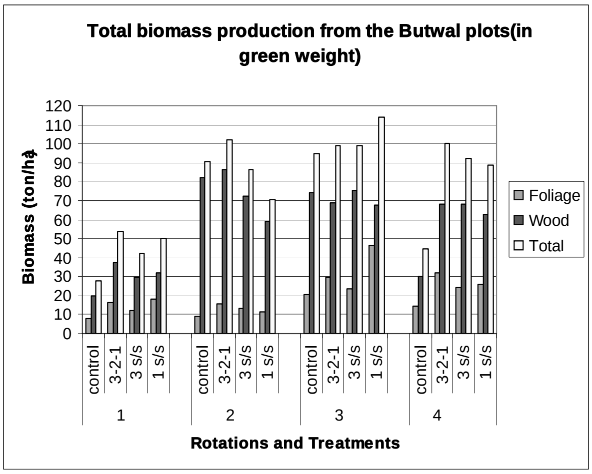


Figure 4: Total biomass production from the Butwal plots.

In Butwal, the biomass production from all treatment plots is significantly higher in the second rotation than in the first rotation. Biomass production for all treatments except treatment 3-2-1 *s/s* is found higher in third rotation compared to second rotation. Biomass production from all treatment plots except 3-2-1 *s/s* plot is lower in fourth rotation in comparison to the third rotation. However, decreased biomass production in fourth rotation compared to third rotation could have happened due to unfavorable weather and livestock disturbances in the period. The treatment 3-2-1 *s/s* has produced higher biomass compared to other treatments in the first, second and fourth rotations. However, due to highest foliage production, the treatment 1 s/s has produced higher biomass compared to other treatments in the third rotation.

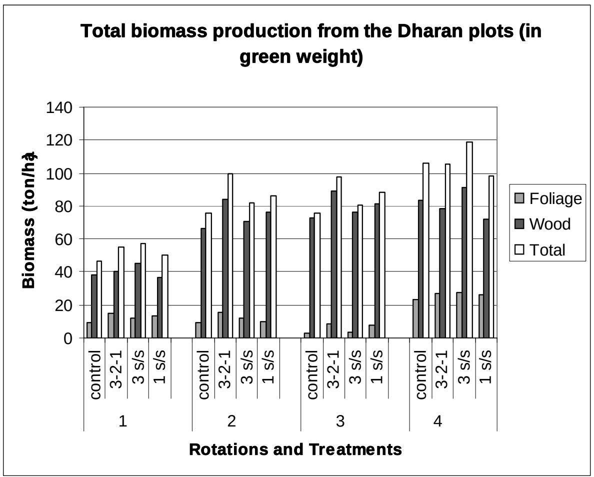


Figure 5: Total biomass production from the Dharan plots.

In Dharan, the biomass production from the treatment plots except 1 *s/s* plot is found lower in third rotation compared to second rotation. This is due to the lower foliage biomass production in all treatment plots in the third rotation compared to second rotation. This could have happened due to late measurement of the plots where already leaf shedding has been started. Biomass production for all treatments is higher in fourth rotation in comparison to the third rotation. The treatment 3-2-1 *s/s* has produced higher biomass compared to other treatments in the second and third rotations. However, the treatment 3 *s/s* has produced higher biomass compared to other treatments in the first and fourth rotations.

The lowest biomass production in first rotation compared to succeeding rotations could be due to unfavorable growing condition at the beginning of the first rotation. These degraded forests were under severe stress due to grazing, forest fire and human disturbances in the past. The protection of the site and development of root system with time could have increased biomass production. The study shows that wood biomass production was significantly higher compared to foliage in all treatments for each rotation. About 80 percent of the foliage produced was in the form of fodder.

Mean biomass production

Mean biomass production from the treatment plots for four rotations in Butwal and Dharan is presented in table 1. It is found that the mean foliage biomass production from the treatment 1 *s/s* is higher compared to other treatments in Butwal. But, the treatment 3-2-1 *s/s* produced the higher mean foliage biomass compared to other treatments in Dharan. The treatment 3-2-1 *s/s* produced the highest mean fuelwood biomass and mean overall biomass in both Butwal and Dharan. The value of standard error shows the extent of variation of biomass production in the rotations.

The study reveals that, for maximum biomass or for maximum fuelwood production in short rotations under simple coppice management, 3-2-1 *s/s* treatment is the best among the tested ones.

Conclusion

Simple coppice management is one of the most suitable forest management options to produce fuelwood and fodder from sal forest in short rotations. In overall, the treatment 3-2-1 *s/s* is found better than other treatments for maximum biomass production. Simple coppice management option is not suitable for timber production. However, it can

Table 1: Mean biomass production from the treatment plots in four rotations (Butwal and Dharan)

Site	Treatments	Rotations	Foliage		Wood (green weight, ton/ha)		Total	
			Mean	S.E.	Mean	S.E.	Mean	S.E.
Butwal	control	4	12.89	2.90	51.69	15.50	64.57	16.66
	3-2-1 *s/s*	4	23.38	4.30	65.26	10.11	88.64	11.71
	3 *s/s*	4	18.33	3.15	61.53	10.71	79.85	12.88
	1 *s/s*	4	25.56	7.59	55.14	7.97	80.69	13.57
Dharan	control	4	11.04	4.32	65.20	9.74	76.24	12.14
	3-2-1 *s/s*	4	16.44	3.87	73.13	11.13	89.57	11.50
	3 *s/s*	4	13.77	5.00	71.04	9.55	84.81	12.71
	1 *s/s*	4	14.29	4.12	66.47	10.17	80.76	10.60

produce some wooden weaving materials (*Bhata*) which can be used for house construction. The information produced in this study gives information to the forest user groups about the productivity of sal forest managed under different simple coppice management options in short rotations.

The main limitation in this research design was the lack of replication of the treatments. Due to this, advance statistical analysis such as testing the significance of difference between the treatments or analysis of variance was not possible. Therefore, principles of experimental research design should be followed during further scientific research designing and planning.

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Annex 1: Silviculture history of the plots from year 1988 to 2005

Dharan				Butwal				Age (yr)	Treatments				Remarks
Rot 1	Rot 2	Rot 3	Rot 4	Rot 1	Rot 2	Rot 3	Rot 4		Control	1 *s/s*	3 *s/s*	3-2-1 *s/s*	
1989				1988				0	complete clearfell	complete clearfell	complete clearfell	complete clearfell	Green biomass weighed everyyear after harvesting.
1990	1994	1998	2002	1989	1993	1997	2001	1	weeding	singling to leave 1 shoot per stool	singling to leave 3 shoots per stool	singling to leave 3 shoots per stool	
1991	1995	1999	2003	1990	1994	1998	2002	2	weeding	1 shoot per stool	3 shoot per stool	2 shoots per stool	
1992	1996	2000	2004	1991	1995	1999	2003	3	weeding	1 shoot per stool	3 shoot per stool	1 shoot per stool	
1993	1997	2001	2005	1992	1996	2000	2004	4	complete clearfell	complete clearfell	complete clearfell	complete clearfell	

Rot: Rotation

Annex 2: Biomass production, Butwal

Treatments	First rotation				Second rotation				Third rotation				Fourth rotation				Total Biomass production up to 4th rotation
	Year	foliage	wood total	Total	Year	foliage	wood total	Total	Year	foliage	wood total	Total	Year	foliage	wood total	Total	
		Green weight, ton/ha				Green weight, ton/ha				Green weight, ton/ha				Green weight, ton/ha			
control	1989	0	0	0	1993	0	0	0	1997	0	0	0	2001	0	0	0	
	1990	0	0	0	1994	0	0	0	1998	0	0	0	2002	0	0	0	
	1991	0	0	0	1995	0	0	0	1999	0	0	0	2003	0	0	0	
	1992	7.94	20.01	27.95	1996	8.78	81.89	90.67	2000	20.46	74.4	94.86	2004	14.36	30.44	44.8	
	Total	**7.94**	**20.01**	**27.95**	**Total**	**8.78**	**81.89**	**90.67**	**Total**	**20.46**	**74.4**	**94.86**	**Total**	**14.36**	**30.44**	**44.8**	**258.28**
3-2-1 *s/s*	1989	2.1	1.1	3.2	1993	3	1.2	4.2	1997	4.5	4.2	8.7	2001	5.08	1.58	6.66	
	1990	1.4	1.3	2.7	1994	1.22	1.09	2.31	1998	3.58	6.8	10.38	2002	3.56	2.62	6.18	
	1991	2.9	5.6	8.5	1995	2.54	3.85	6.39	1999	4.26	10.64	14.9	2003	4.56	6.56	11.12	
	1992	9.64	29.52	39.16	1996	9.1	79.9	89	2000	17.5	47.4	64.9	2004	18.56	57.68	76.24	
	Total	**16.04**	**37.52**	**53.56**	**Total**	**15.86**	**86.04**	**101.9**	**Total**	**29.84**	**69.04**	**98.88**	**Total**	**31.76**	**68.44**	**100.2**	**354.54**
3 *s/s*	1989	2.3	1.1	3.4	1993	3.8	1.04	4.84	1997	3.5	3.8	7.3	2001	4.4	1.34	5.74	
	1990	0.7	0.3	1	1994	0.48	0.19	0.67	1998	2.5	1.06	3.56	2002	0.82	0.1	0.92	
	1991	0.4	0.1	0.5	1995	0.108	0.004	0.112	1999	0.08	0.02	0.1	2003	0.24	0.06	0.3	
	1992	8.92	28.23	37.15	1996	9.08	71.32	80.4	2000	17.24	70.78	88.02	2004	18.74	66.66	85.4	
	Total	**12.32**	**29.73**	**42.05**	**Total**	**13.468**	**72.554**	**86.022**	**Total**	**23.32**	**75.66**	**98.98**	**Total**	**24.2**	**68.16**	**92.36**	**319.412**
1 *s/s*	1989	6.7	3.6	10.3	1993	4.71	1.75	6.46	1997	12.8	10.3	23.1	2001	6.36	1.98	8.34	
	1990	1.2	2	3.2	1994	1.53	0.97	2.5	1998	4.56	3	7.56	2002	2.38	0.72	3.1	
	1991	1.2	0.6	1.8	1995	0.49	0.29	0.78	1999	0.34	0.04	0.38	2003	1.32	0.2	1.52	
	1992	9.2	25.6	34.8	1996	4.69	55.89	60.58	2000	28.82	54.09	82.91	2004	15.92	59.52	75.44	
	Total	**18.3**	**31.8**	**50.1**	**Total**	**11.42**	**58.9**	**70.32**	**Total**	**46.52**	**67.43**	**113.95**	**Total**	**25.98**	**62.42**	**88.4**	**322.77**

Annex 3: Biomass production, Dharan

	First rotation				Second rotation				Third rotation				Fourth rotation			
Treatments	Year	foliage total	wood total	Total	Year	foliage total	wood total	Total	Year	foliage total	wood total	Total	Year	foliage total	wood total	Total
		Green weight in ton per ha				Green weight in ton per ha				Green weight in ton per ha				Green weight in ton per ha		
control	1990	0.00	0.00	0.00	1994	0.00	0.00	0.00	1998	0.00	0.00	0.00	2002	0.00	0.00	0.00
	1991	0.00	0.00	0.00	1995	0.00	0.00	0.00	1999	0.00	0.00	0.00	2003	0.00	0.00	0.00
	1992	0.00	0.00	0.00	1996	0.00	0.00	0.00	2000	0.00	0.00	0.00	2004	0.00	0.00	0.00
	1993	9.03	37.87	46.90	1997	9.38	66.50	75.88	2001	2.63	73.18	75.81	2005	23.13	83.24	106.38
	Total	**9.03**	**37.87**	**46.90**	**Total**	**9.38**	**66.50**	**75.88**	**Total**	**2.63**	**73.18**	**75.81**	**Total**	**23.13**	**83.24**	**106.38**
3-2-1 *s/s*	1990	0.71	0.31	1.02	1994	0.79	1.11	1.90	1998	0.76	0.97	1.73	2002	3.00	1.11	4.11
	1991	1.57	2.23	3.79	1995	1.10	1.06	2.16	1999	0.91	0.27	1.18	2003	0.29	0.36	0.64
	1992	3.01	4.05	7.06	1996	1.68	11.84	13.52	2000	1.68	8.26	9.93	2004	0.18	1.31	1.49
	1993	9.77	33.80	43.57	1997	12.02	70.20	82.22	2001	4.87	79.80	84.66	2005	23.44	75.87	99.30
	Total	**15.05**	**40.38**	**55.43**	**Total**	**15.58**	**84.22**	**99.80**	**Total**	**8.21**	**89.29**	**97.51**	**Total**	**26.90**	**78.64**	**105.55**
3 *s/s*	1990	0.97	0.33	1.30	1994	0.80	0.82	1.63	1998	0.69	0.70	1.40	2002	2.70	1.17	3.87
	1991	0.80	0.66	1.46	1995	0.40	0.23	0.63	1999	0.05	0.04	0.10	2003	1.07	1.87	2.93
	1992	0.29	0.26	0.55	1996	0.02	0.03	0.04	2000	0.08	0.09	0.16	2004	2.29	8.69	10.98
	1993	9.95	44.31	54.26	1997	10.47	69.52	79.99	2001	2.90	75.79	78.69	2005	21.58	79.67	101.24
	Total	**12.01**	**45.56**	**57.57**	**Total**	**11.70**	**70.60**	**82.29**	**Total**	**3.72**	**76.62**	**80.35**	**Total**	**27.63**	**91.39**	**119.02**
1 *s/s*	1990	1.64	0.31	1.95	1994	2.45	3.09	5.54	1998	2.30	3.03	5.33	2002	5.66	3.74	9.40
	1991	1.99	2.57	4.56	1995	1.40	0.86	2.26	1999	1.60	7.00	8.60	2003	1.27	1.20	2.47
	1992	1.10	0.70	1.80	1996	0.14	1.69	1.84	2000	0.12	1.56	1.68	2004	0.56	2.33	2.89
	1993	8.68	32.89	41.57	1997	6.11	70.67	76.77	2001	3.50	69.55	73.05	2005	18.63	64.70	83.33
	Total	**13.42**	**36.48**	**49.89**	**Total**	**10.10**	**76.31**	**86.41**	**Total**	**7.52**	**81.13**	**88.65**	**Total**	**26.11**	**71.98**	**98.09**