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Natural resource enhancement through silvipastoral establishment in western Himalayan region

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ABSTRACT

Livestock rearing is an integral part of rural livelihood in the Himalayan region. In spite of abundance of pasture resources, total biomass is insufficient to meet the forage demand. Indiscriminate grazing has caused an alarming decline in the carrying capacity of grazing lands and has caused severe land degradation. This study was carried out with the objective of increasing biomass potential, improving livestock productivity and to arrest environmental degradation. The study was conducted at Ghanetta and Dagoh (Kangra) and Jogindernagar (Mandi) districts in Himachal Pradesh through silvipastoral intervention in conjunction with soil and water conservation measures. Grasslands of the study area were of alluvial–loamy soil with shallow depths. Soil organic matter was 0.72 (Ghanetta), 0.76 (Dagoh) and 0.80% (Jogindernagar). Organic carbon content in the subsurface (15–45 cm) layer was only 30 to 39% of the surface layer (0–15 cm). *Chrysopogon* (20%) was found the most dominant species, followed by *Heteropogon* (13%). Average herbage production was 5.613 DM tonne/ha (Ghanetta), 5.458 DM tonne/ha (Dagoh) and 5.233 DM tonne/ha (Jogindernagar). Leaf biomass of different fodder trees ranged from 0.23–0.60 DM tonne/ha (Ghanetta), 0.16–0.51 DM tonne/ha (Dagoh) and 0.21–0.59 DM tonne/ha (Jogindernagar). Maximum biomass of 9.17 DM tonne/ha was obtained at Ghanetta followed by 8.26 DM tonne/ha and 8.23 DM tonne/ha at Dagoh and Jogindernagar, respectively, showing substantial improvement in total biomass potential with silvipastoral intervention in conjunction with soil and water conservation measures.

Key words: Fodder, Herbage, Livestock, Nutrition, Silvipasture

Livestock rearing is an important pursuit in western Himalayan region. Pastures, available in the mid-hills, subalpine and alpine regions are the major sources of feed, while crop residues and grazing in the forests and wastelands are other major feed sources. In spite of abundance of these resources, total available biomass is insufficient to sustain the livestock population. To meet this feed shortage, farmers extensively use fodder trees and their use is maximum during lean period. The Himalaya supports 84 species of fodder trees and 40 shrubs, yet not more than 20 of these are used by the farmers (Misri 1997). Looking to the various competing land uses, the increased productivity per unit area and integration of fodder crops in the cropping system are only viable options to meet the fodder needs (Sunil Kumar *et al.* 2012). Grazing, feeding of crop residues and use of fodder tree leaves are the major feed resources in descending order of extant use. The productivity of fodder in community property resources (CPR) lands is very low due to pine trees and invasion of *Lantana* and other obnoxious weeds (Pathania and Dev 2011). There is a gap of about 26 and 54% for green and dry fodder availability in western Himalayan state of Himachal Pradesh (Dev *et al*. 2006). The perpetual dependence and indiscriminate grazing has caused alarming decline in the carrying capacity of these grazing lands and has caused severe land degradation. The sparse vegetation cover coupled with overgrazing has resulted in tremendous soil and water loss, rendering the entire system ecologically fragile. Silvipastoral system was found to be one of the most viable options for obtaining a high biomass per unit area. Ibrahim *et al.* (2010) reported that silvopastoral systems in Costa Rica and elsewhere lowered GHG emissions from livestock-based systems and improved income levels. A large number of tree species are available

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for planting, however, the choice of species from the farmers' perspective is always a better option. This study, "Natural resource enhancement through silvipastoral establishment in western Himalayan region" was carried out with the objective to increase biomass potential, improve livestock productivity and to arrest environmental degradation.

MATERIALS AND METHODS

Ghanetta and Dagoh villages in Kangra district and Jogindernagar in Mandi district in western Himalayan state of Himachal Pradesh in India were selected through multistage stratified sampling methods for silvipastoral intervention with active participation of native beneficiaries on the community lands. Farmers were classified into different farm size, i.e. marginal (0–1 ha), small (1–2 ha) and large (>2 ha). The preference of fodder trees for silvipastoral establishment was done through focused group discussion (FGD) and matrix scoring. Information on role of farmers and farm women were also gathered through FGD. The fodder trees identified through PRA were analyzed for proximate composition. The establishment of the project was preceded by conducting several participatory rural appraisal (PRA) exercises at the study sites. The silvipastures were laid out at 3 sites, viz. Ghanetta, Daghoh and Jogindernagar with active participation of the native beneficiaries at the community lands during 2000–2003. The site details are discussed here.

Site details of silvipastoral project

Site	Location from Palampur	Elevation and slope	Remarks
Ghanetta	On NH-20.28 km from Palampur towards Pathankot (NH- 20)	1100 m above msl 15-35% slope	West; Dominant landuse: Good agriculture. Defined by natural ridge. Perennial channel. Excellent scope for water harvesting, farming, aquaculture. Very good access.
Dagoh	On SH-7.26 km from Palampur on Palampur - Jaisinghpur road	1020 m above msl l 25-60% slope	East; Dominant landuse: Good agriculture. Natural ridge, part highway located on top of the slope. Excellent access.
Jogindernagar	On NH-20.35 km from Palampur towards Mandi (NH-20)	1175 m above msl 15-30% slope	West-South; Dominant landuse: Good agriculture. Highway as artificial ridge. Located half way in lower portion. Excellent access

One paddock measuring 1.0 ha was divided into 4 parts, viz. fodder trees + introduced grasses + soil and water conservation measures and cut and carry (Block-B_1); fodder trees + introduced grasses + soil and water conservation measures and animal grazing (Block-B_2); soil and water conservation measures + grasses (Block B_3); control (farmers' practice) (Block B_4). Three parts were utilized for rotational grazing, while 1 part was used for conservation of fodder during lean period. The treatments were replicated 4 times. *Albizia lebbeck, Artocarpus chaplasha, Bauhinia variegata, Grewia optiva* and *Morus alba* were the fodder trees planted at all the 3 sites. *Cenchrus, Guinea, Congosignal* and Riversdale (grasses) and siratro, stylo, lotus and white clover (legumes) were sown in the area. Gauging stations were established at all the sites to measure soil and water runoff and its control by the silvipastures. The site details of the watershed intervention are presented in Fig. 1.

RESULTS AND DISCUSSION

Natural resources of the area: Most of the grasslands situated in the study area were of alluvial–loamy soil with shallow depths at the slopes. The soil composition was highly variable vertically as well as horizontally, the pH of the soil ranged between 6.21 to 6.57. Organic carbon was medium to high. Available nitrogen was medium to high (20–50 kg nitrates/ha), while ammonical nitrogen varied between 72 and 201 kg/ha. Potassium content was poor (<112 kg/ha), while phosphorus content ranged between 56 and 72 kg/ha. The critical aspect was fragility of the resources, which is evident from the data presented in Table 1. Soil organic matter was 0.72 (Ghanetta), 0.76 (Dagoh) and 0.80% (Jogindernagar). Organic carbon in subsurface (15–45 cm) layer was only 30 to 39% of the surface layer (0–15 cm). On an average, soils were having 209 (Ghanetta), 219 (Dagoh), 222 N kg/ha (Jogindernagar); 14.47 (Ghanetta), 11.64 (Dagoh), 15.21 P kg/ha (Jogindernagar);

Table 1. Soil characteristics of different locations

Location	Soil depth (cm)	pH	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Ghanetta						
Surface	0-15	6.22	1.04	274	16.71	174.72
Sub-surface	15-45	6.24	0.41	145	12.23	79.52
Dagoh						
Surface	0-15	6.28	1.16	282	12.54	178.08
Sub-surface	15-45	6.57	0.35	156	10.75	106.40
Jogindernagar						
Surface	0-15	6.24	1.17	263	13.71	201.60
Sub-surface	15-45	6.21	0.43	181	16.71	79.52

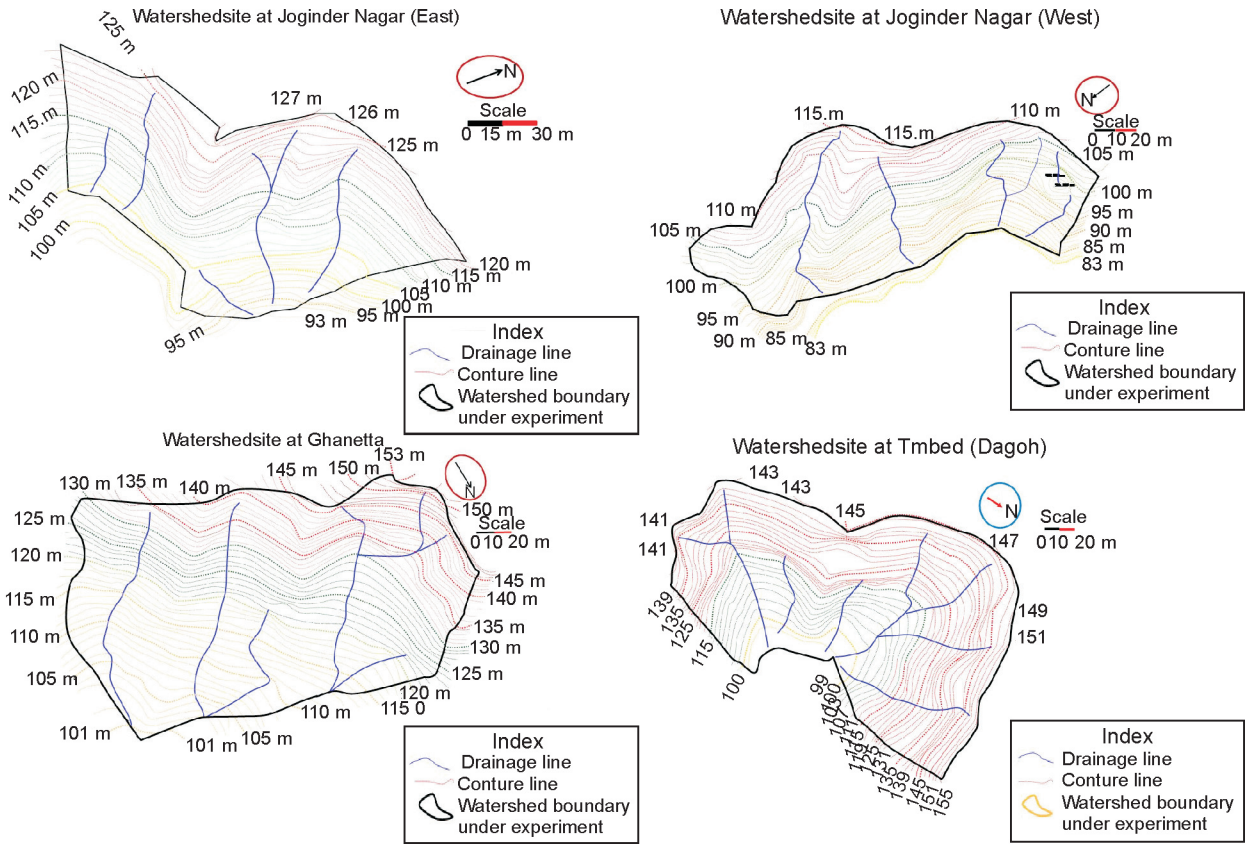

Fig. 1. Watershed sites at Ghanetta, Dagoh and Jogindernagar in Himachal Pradesh.

127.12 (Ghanetta), 142.24 (Dagoh) and 140.56 K kg/ha (Jogindernagar). The fragility was evident from sharp decline of organic matter to only 30–39% in 15–45 cm layer in the grasslands. There was sharp decline in the N and K content in the subsurface layers at all the 3 sites. This indicated that the loss of surface soil due to erosion will expose the poor sub surface layer and severely affect the productivity. Burning, annual scraping and managed grazing by community were common practices in the selected area.

Composition of dominant grasses: Composition of grasses was studied at the initiation of the study and it was observed that *Chrysopogon* (20%) was the most dominant species, followed by *Heteropogon* (13%) and other grasses (19%) at Ghanetta. Similarly, *Chrysopogon* (18%), *Heteropogon* (9%) and other grasses (22%) were the dominant grass species at Dagoh. At Jogindernagar, *Chrysopogon* (16%) was the most dominant species followed by *Heteropogon* (11%), *Dichanthium annulatum* (10%) and other grasses (19%) (Table 2).

Growth and pasture biomass potential: The data on average height gained by grasses/legumes/forbes is presented in Table 3. The data revealed that by and large there was no significant difference observed in different blocks. At the harvest stage, average height gained by pasture components namely grasses, legumes and forbes was 68.20, 25.40 and 47.78 cm, respectively, at Ghanetta. At Dagoh, average height gained by the pasture components grasses, legumes and forbes, was 63.55, 29.05 and 35.30 cm, respectively. Similarly, average height gained by pasture components namely grasses, legumes and forbes was 73.10, 11.65 and 29.65 cm, respectively, at Jogindernagar.

Table 2. Composition of dominant grasses at different locations

Species	Composition (%)		
	Ghanetta	Dagoh	Jogindernagar
Arundinella nepalensis	6	9	4
Bothriochloa intermedia	9	7	12
Chrysopogon gryllus	20	18	16
Cynodon dactylon	4	3	6
Dichanthium annulatum	6	8	10
Eragrostis sp.	4	7	6
Heteropogon contortus	13	9	11
Imperata cylindrica	6	6	7
Saccharum spontaneum	6	5	3
Themeda triandra	7	6	9
Other grasses	19	22	16

Data on biomass potential of pasture component is presented in Table 4 and depicted in Fig. 2. A perusal of the data reveals that average herbage production was 5.613 DM tonne/ha (Ghanetta), 5.458 DM tonne/ha (Dagoh) and 5.233 DM tonne/ha (Jogindernagar). It is evident from the data that under overall conditions maximum biomass was harvested undercut and carry system (B_1) followed by animal grazing (B_2), soil and water conservation + grasses

Table 3. Average height (cm) of pasture component at harvest stage

Location	B_1	B_2	B_3	B_4	Average
Ghanetta					
Grasses	70.1	69.0	72.9	60.8	68.20
Legumes	32.8	21.9	25.4	21.5	25.40
Forbes	56.2	50.1	42.9	41.9	47.78
Dagoh					
Grasses	81.6	52.3	62.2	58.1	63.55
Legumes	36.4	33.3	31.3	15.2	29.05
Forbes	34.8	40.1	36.1	30.2	35.30
Jogindernagar					
Grasses	79.0	70.1	80.9	62.4	73.10
Legumes	12.9	9.7	10.3	13.7	11.65
Forbes	10.2	48.3	23.0	37.1	29.65

B_1, Fodder trees + introduced grasses + soil and water conservation and cut and carry; B_2, fodder trees + introduced grasses + soil and water conservation and animal grazing; B_3, soil and water conservation + grasses; B_4, control (farmers practice).

Table 4. Herbage production (DM tonne/ha) at different locations

Location	B_1	B_2	B_3	B_4	Average
Ghanetta					
Grasses	5.21	3.95	4.73	2.02	3.978
Legumes	0.73	0.54	0.88	0.32	0.618
Forbes	1.16	1.24	0.92	0.75	1.018
Total	7.10	5.73	6.53	3.09	5.613
Dagoh					
Grasses	4.82	4.16	4.90	1.97	3.963
Legumes	0.85	0.72	0.74	0.42	0.683
Forbes	0.76	0.92	0.82	0.75	0.813
Total	6.43	5.80	6.46	3.14	5.458
Jogindernagar					
Grasses	4.61	3.72	4.65	1.68	3.665
Legumes	0.65	0.52	0.74	0.43	0.585
Forbes	1.22	0.95	0.92	0.84	0.983
Total	6.48	5.19	6.31	2.95	5.233

B_1, Fodder trees + introduced grasses + soil and water conservation and cut and carry; B_2, fodder trees + introduced grasses + soil and water conservation and animal grazing; B_3, soil and water conservation + grasses; B_4, control (farmers practice).

(B_3) and lowest biomass was obtained under farmers' practice (B_4). Therefore, inference can be drawn that introduction of fodder trees, grasses/legumes and intervention of soil and water conversation measures enhanced the biomass potential of the pasture component substantially.

Survival (%): Data presented in Table 5 revealed that during seventh year of silvipastoral establishment, intervention of grass, soil and water conservation measures did not influence the survival (%) significantly. The highest survival (%) was recorded in *B. variegata* at all the three sites. *Bauhinia variegata*, *Grewia optiva* and *Morus alba*

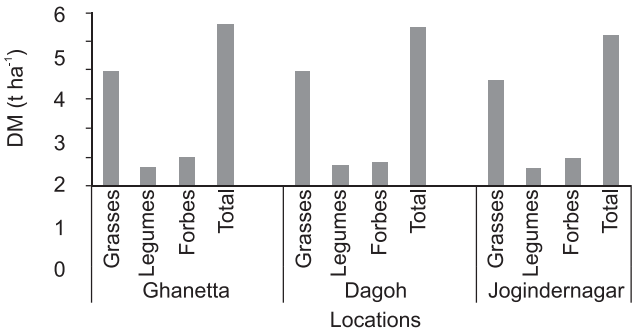

Fig. 2. Biomass production (DM tonne/ha) at different locations.

had >80% survival in block B_1 and B_2. *Artocarpus chaplasha* at Ghanetta, Jogindernagar and *Albizia lebbeck* showed least survival (%) at Dagoh.

Plant height: Data on height gained by fodder trees is presented in Table 5. *Albizia lebbeck* gained maximum height followed by *Artocarpus chaplasha.* Average height gained by different fodder trees in block B_1 and B_2 ranged between 5.15–9.39 m (Ghanetta), 5.29–8.48 m (Dagoh) and 5.29–7.93 m (Jogindernagar).

Leaf biomass: Leaf biomass from the fodder trees was harvested during the lean period, which is the most appropriate time for feeding the livestock with fodder tree leaves. Data presented in Table 5 reveals that the leaf biomass obtained from different fodder trees ranged from

Table 5. Survival, growth and leaf biomass production of fodder trees

Site/Trees	Survival (%)		Average plant height (m)		Leaf biomass (DM tonnes/ ha)	
	B_1	B_2	B_1	B_2	B_1	B_2
Ghanetta						
Albizia lebbeck	75.4	71.6	9.39	8.25	0.25	0.23
Artocarpus chaplasha	76.8	70.4	8.18	7.27	0.60	0.56
Bauhinia variegata	83.2	81.3	6.67	5.68	0.42	0.45
Grewia optiva	80.4	82.1	6.37	6.02	0.35	0.32
Morus alba	81.3	79.4	5.15	5.85	0.45	0.42
Dagoh						
Albizia lebbeck	65.7	68.7	8.48	7.62	0.19	0.16
Artocarpus chaplasha	72.3	70.4	7.24	7.76	0.510.49	
Bauhinia variegata	90.4	86.5	7.62	6.64	0.40	0.37
Grewia optiva	85.7	82.8	7.06	6.37	0.34	0.32
Morus alba	87.9	85.4	5.29	6.02	0.39	0.37
Jogindernagar						
Albzia lebbeck	71.7	70.6	7.93	6.80	0.21	0.23
Artocarpus chaplasha	68.3	65.2	6.18	5.82	0.550.59	
Bauhinia variegata	87.6	84.3	5.29	5.95	0.36	0.32
Grewia optiva	88.1	82.6	7.52	6.87	0.29	0.26
Morus alba	84.3	82.3	6.43	7.01	0.34	0.31

0.23–0.60 (Ghanetta), 0.16–0.51 (Dagoh) and 0.21–0.59 DM tonne/ha (Jogindernagar). Data also indicated that 2.07 (B_1) and 1.98 DM tonne/ha (B_2) (Ghanetta); 1.83 (B_1) and 1.71 DM tonne/ha (B_2) (Dagoh) and 1.75 (B_1) and 1.71 DM tonne/ha (B_2) (Jogindernagar) leaf biomass was obtained from different fodder trees.

Total biomass (leaf+herbage): As B_1 and B_2 had the intervention of fodder trees and introduced grasses/legumes, they produced maximum biomass per unit area. Maximum biomass of 9.17 DM tonne/ha was recorded (Fig. 2) at *Ghanetta* followed by 8.26 DM tonne/ha and 8.23 DM tonne/ha at Dagoh and Jogindernagar, respectively. By and large similar trend was observed in B_2 and B_3. It is evident that cut-and-carry system (B_1) was better as compared to open grazing (B_2). Soil and water conservation had also improved biomass potential substantially in B_1, B_2 and B_3 as compared to farmers' practice (B_4). Biomass potential under cut-and-carry system (B_1) was 297 (Ghanetta), 263 (Dagoh) and 279% (Jogindernagar) higher as compared to farmers' practice (Fig. 3), whereas under grazing practice (B_2), the biomass potential was 249 (Ghanetta), 239 (Dagoh) and 234% (Jogindernagar) higher as compared to farmer's practice. By and large similar trend was observed in B_3. Results from several studies document the importance of silvipastoral systems (e.g. pastures with high tree densities) for the conservation of biodiversity (Ibrahim *et al*. 2001). Therefore, it can be stated that intervention of soil and water conservation measures, introduction of grasses/legumes and fodder trees improved the total biomass potential substantially.

Soil and water conservation: Soil and water conservation measures indicated that runoff (% of rainfall) was highest at Jogindernagar (32.6%) followed by Dagoh (29.8%) and Ghanetta (22.3%) owing to their land slopes of 124, 106 and 81%, respectively. Trenching in combination with vegetative barrier allowed only 10.2% of rain as runoff compared to 40.5% under control (no measure). Sediment retention was highest at Dagoh (17.9 cm) followed by Jogindernagar (15.8 cm) and lowest at Ghanetta (13.8 cm). Therefore, silvipasture systems in combination with suitable soil and water conservation measures were found to arrest the environmental degradation. Dev *et al.* (2014) reported

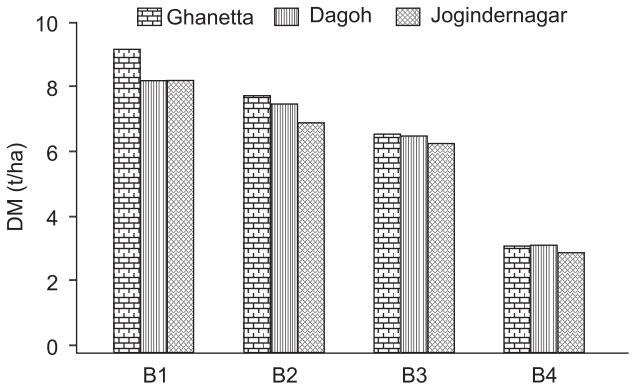

Fig. 3. Biomass potential (DM tonnes/ha) of silvipastoral system.

Table 6. Nutritive value of pasture herbage (% age in dry matter)

Parameter	July	August	September	Average
Ghanetta				
Crude protein	6.76	6.93	5.81	6.50
NDF	71.52	71.92	74.53	72.66
ADF	42.13	45.22	47.12	44.82
Calcium	1.35	1.13	1.29	1.26
Phosphorus	0.12	0.15	0.14	0.14
Dagoh				
Crude protein	8.59	9.32	9.87	9.26
NDF	70.36	72.62	73.44	72.14
ADF	36.33	37.49	39.12	37.65
Calcium	1.39	1.45	1.52	1.45
Phosphorus	0.12	0.16	0.17	0.15
Jogindernagar				
Crude protein	11.15	10.89	11.23	11.09
NDF	63.14	65.51	66.12	64.92
ADF	34.09	37.17	39.14	36.80
Calcium	0.85	0.92	1.05	0.94
Phosphorus	0.20	0.15	0.15	0.17

that among the resource conservation measures, trenching in combination with vegetative barrier allowed only 8.2% of rain as runoff as compared to 41.5% under control (no measure).

Nutritional parameters of the herbage: The herbage harvested every month exhibited almost a continued availability of high quality herbage, thereby suggesting that the fresh growth improves nutritional quality of herbage. Data indicated (Table 6) that crude protein varied from 5.81 to 6.93 % (Ghanetta), 9.32 to 9.87% (Dagoh) and 10.89 to 11.15% (Jogindernagar). Presence of legume component in the pasture at Jogindernagar has led to the higher protein content in the pasture as compared to the other 2 sites.

Proximate composition of selected tree forages (% DM): The proximate composition in the fodder tree leaves revealed that the crude protein content in various fodder tree leaves ranged between 11.3 and 17.8%. The crude protein content was highest in *Grewia optiva* (17.8%) followed by *Albizia lebbeck* (16.9%), and lowest in *Morus alba* (13.2%). The crude fibre, varied in the range of 25.3 to 36.9% in different fodder tree leaves. Depending upon the crude fibre, the fodder trees, viz. *Grewia optiva* and *Morus alba* were easily digestible. Ash content was highest in *Morus alba* (14.3%). These fodder trees were found to be the good source of protein, mineral content and which substantiated the farmers' perception.

It can be concluded that the cut-and-carry system was better as compared to open grazing. Soil and water conservation measures also improved the biomass potential of the area. It can be stated that silvipastoral intervention in conjunction with soil and water conservation measures not only enhances the quality pasture production but also reduces the environmental degradation.

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