Rehabilitation of degraded community land in Western Himalaya: linking environmental conservation with livelihood

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Considering the situation of resource degradation and associated livelihoods in Western Himalaya, a scientific framework for rehabilitation of degraded and waste lands was developed and executed through people's participation. The objective of the present study was to restore degraded village lands, improve local livelihoods and strengthen ecosystem services. Twelve ecologically adapted and socially valued tree species having economic potential were planted at two different sites. Survival of the planted tree species after five years was found to be excellent (53.6–87.2%) and did not show any mortality after four years. Statistical analysis revealed no significant influence of the sites on the height and circumference of common species in them; however, year of plantation significantly ($P < 0.01$) influenced increase in the growth of the species. A slight increase was observed in organic carbon whereas exchangeable calcium, exchangeable magnesium and total nitrogen increased significantly ($P < 0.01$) during successive years. Capacity building and active people's participation were the most crucial aspects of the rehabilitation programme in the present study. The outcome of the present study would be helpful for developing appropriate strategies and action plans for the management of natural resources and rehabilitation of wastelands in the Himalayan region.

Keywords: Degraded land, environmental conservation, fodder, livelihood, rehabilitation.

THE inhabitants of lower (500–800 m asl) and middle hills (800–1500 m asl) of the Western Himalayan region are largely dependent on subsistence agriculture and natural resources for their livelihood[1]. The region plays an important role in providing ecosystem services to the global communities and contributes significantly towards food and livelihood security of over 400 million people of the Indo-Gangatic plains and nearby regions[2,3]. However, the region is presently facing serious environmental threats largely due to increasing population, changes in land-use/land-cover pattern and rapid depletion of the natural resource base[4,5] resulting into degradation and abandonment of agriculture land. The degradation of the forests has been a major blow to rural residents of the area, who have suffered from the lack of firewood (the main source of energy for cooking and heating), fodder and grazing, and the adverse effects on springs which are the main water sources for villages on the slopes. Degradation and depletion of forest cover has resulted in biodiversity loss, shortage in terrestrial carbon stocks, declining farm productivity, increasing hydrological imbalance and soil erosion[1,2]. All these are interconnected problems between ecosystems health and livelihood needs and are considered to be the major causes of poor economic status of the hill people[6]. Agriculture along with animal husbandry is still the principal occupation and source of livelihood for over 70% of the population in Western Himalaya. As agriculture is dependent on forests for manure and fodder, reduction in intensity of biomass removal from forests is crucial for forest conservation. Both state and community forests are the major sources of fodder, which play a key role in crop–livestock–manure–soil nutrient cycle of farms in mountains of the Himalaya[7,8]. Degradation of land has direct impact on fodder availability and livestock production, especially during winter months when green fodder is scarcely available[9]. Crop residue is another important source of fodder in the region, but decreasing cropped area due to abandonment of agriculture practice, adoption of cash-crop cultivation, crop failure due to erratic weather conditions and crop depredation by wild animals has put fodder availability under stress[10,11]. Considering these facts, serious efforts are required to manage the natural resource base through rehabilitation of degraded or community waste and abandon agriculture

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lands to enhance ecosystem services and socio-economic development.

Materials and methods

Study area

The study was carried out in two villages, namely Dharaunj (1800 m asl) and Gumod (1000 m asl), Champawat district, Uttarakhand, Western Himalaya, India. The forest cover of the district extends over 61% of the total geographical area. Agriculture is practised in 17% of the area, while average per capita cultivated land is below 0.5 ha (ref. 12). About 22% of the area is under pasture, fallow, degraded/waste and cultivable wastelands. The land use and land cover are classified into state and community forests, settled farming on privately owned terraced slopes, degraded community wasteland (DCWL) and degraded abandoned agricultural land (DAAL). Due to the traditional, natural resource-based lifestyle, the demand for fodder, fuelwood, leaf-litter and timber is high.

Methodology

Participatory action research framework and approaches: A scientific framework, interlinking both scientific and traditional knowledge among the communities was developed for execution and management of the present rehabilitation programme. The framework included: (i) selection of native plant species by the local stakeholders based on their perception and traditional knowledge, and the scientists by adding eco-physiological attributes of the species, (ii) simple technique for soil and water conservation; (iii) ensuring long-term benefits in terms of fuel, fodder, timber and ecological safeguards to the community, and (iv) involvement of local people in all stages of implementation and ensuring both short- and long-term livelihood opportunities. Demonstration of plantation, techniques and sharing of knowledge was adopted during the execution[4,13]. Capacity building and skill improvement programmes for local people through organizing village-level meetings and trainings were an integral part of the approach[14]. People's participation was an important step in this programme since active participation of local stakeholders has been realized as a prerequisite for the success of any land rehabilitation effort in the Himalaya[4,10].

Land and tree spices selection: To implement the participatory rehabilitation model, DCWL (14.6 ha) and DAAL (6.5 ha) were selected for developing rehabilitation models at Dharaunj and Gumod villages respectively. Ten-to-twelve-month-old seedlings were planted at regular intervals of 3 m in 45 × 45 × 45 cm size pits, providing 2 kg of farmyard manure in each pit. Mixed plantation of seven species (*Alnus nepalensis*, *Cedrus deodara*, *Cinammomum tamala*, *Juglans regia*, *Morus alba*, *Quercus glauca* and *Quercus leucotrichophora*) was planted at Dharaunj site and ten tree species (*Alnus nepalensis*, *Cinammomum tamala*, *Morus alba*, *Quercus glauca*, *Quercus leucotrichophora*, *Terminalia chebula*, *Sapindus mukrossi*, *Pittosporum eriocarpum*, *Phyllanthus emblica* and *Bauhinia purpurea*) were planted at Gumod site during August 2007, followed by gap fillings during the second year onwards. The sites were protected against open grazing according to the agreed upon terms and conditions of the Memorandum of Understanding (MoU) between the villages and project members. The species for plantation were selected based on the villagers' perceptions, species adaptability, local uses and ecological importance (Table 1). *Quercus* spp. was given preference for large-scale plantation at both the villages due to its multiple uses as fodder, timber, fuelwood and nutrient provider to commons with great water-holding capacities. *A. nepalensis* fixes nitrogen and is not much affected by soil moisture and nutrient stress; it is also capable of sequestering larger quantities of carbon. *B. purpurea* and *M. alba* were selected for their nutritious fodder quality. *C. tamala*, *T. chebula*, *S. mukrossi*, *P. eriocarpum* and *P. emblica* were included and planted at middle altitude (800–1200 m asl) due their high medicinal value and economic benefits potential to local populace. Apart from the large-scale plantation in common lands, the saplings were also provided to the villagers for plantation on nearby private or common lands. Protection of sites against open grazing, soil fertility improvement, harvesting and storage of water for irrigation were identified as the key inputs for improvement in site productivity[10,13].

Selection of simple rehabilitation techniques: Nutritious grasses like *Pennisetum purpureum* and *Thysanolaena maxima* and medicinal grasses like *Cymbopogon citratus* were introduced between the gaps in the plantation sites aiming to stabilize slopes, prevent soil erosion, reduce run-off, improve percolation and fodder availability. Since the sites have acute water scarcity, low-cost, polyethylene-lined water-harvesting ponds were constructed at suitable locations to facilitate irrigation for planted seedlings. Simple ecological technologies like terracing, bunding, gully plugging, check dams, etc. were adopted aiming to halt the ongoing process of soil erosion and to maintain the soil moisture at the planted sites following Kothyari and Bhuchar[10]. Staggered contour trenches (30–45 cm wide and 45–60 cm deep) were dug to improve water percolation for better growth of the planted tree saplings.

Growth data collection: Survival rate was assessed based on complete census of all planted individuals at the end of 2, 3 and 5 years of plantation. Twenty

Table 1. Local uses, management practices and ecological features of multipurpose tree species used in the study in Western Himalaya

Species name/family	Vernacular name	Local uses	Ecological features
Alnus nepalensis D. Don., Betulaceae	Utis	Fuelwood, timber, litter	Deciduous forms, nearly mono-specific patches at newly exposed moist soils at 1000–2500 m asl. It is predominant in both managed and natural ecosystems and is a successful colonizer of landslide-affected or freshly exposed rocky, eroded slopes.
Bauhinia purpurea Linn., Fabaceae	Guriyal	Fodder, vegetable	Deciduous trees, small twigs falling together with the leaves. Common in the drier, open forest.
Cedrus deodara Roxb. G.don, Pinaceae	Sisham	Fuelwood, timber	Deciduous, rare occurrence in farms up to 1500–1800 m asl and forests on slopes; dominant species of riverine vegetation.
Cinnamomum tamala Nees and Eberm, Lauraceae	Tejpat	Medicinal, leaves as spice	*Cinnamomum* is a genus of evergreen aromatic trees found in tropical and subtropical Himalaya in shady moist habitats. The tree species grows to high-altitude forests between 1000 and 2000 m asl.
Juglans regia L., Juglandaceae	Jangali Ankhrot	Medicinal, fuel, fodder	*Juglans regia* is a large, deciduous tree attaining heights of 25–35 m and is native to the mountain ranges of Central Asia.
Morus alba Linn., Moraceae	Sahtut	Fuelwood, fodder	It is short-lived, fast-growing, small to medium-sized grows to 10–20 m height between 200 and 1000 m asl.
Phyllanthus emblica Linn. Euphorbiaceae	Anwala	Medicinal, fodder	It is a medium-sized deciduous tree found from 200 to 1300 m asl.
Pittosporum eriocarpum Royle, Pittosporaceae	Agni	Medicinal, fodder	It is an endangered plant species endemic to India. This taxon is threatened by habitat loss. Bark is aromatic and used in the treatment of narcotic, expectorant and bronchitis.
Quercus glauca Thunb, Fagaceae	Faliyat	Fuel, timber, fodder, litter	It is naturally found in moist temperate forests of the western Himalayas in the elevation range of 1500–3200 m asl.
Quercus leucotrichophora A. Camus, Fagaceae	Baanj	Fuel, timber, fodder, litter	*Q. leucotrichophora* ranging from the subtropical to the sub-alpine zones.
Sapindus mukorossi Gaertner, Sapindaceae	Reetha	Medicinal, fodder	It is a fairly large, deciduous tree much cultivated in northern India, especially in the moister tracts along the foot of the Himalaya.
Terminalia chebula Retz. Combretaceae	Heda/harad	Medicinal, fuel, fodder	It is a medium to large tree found in the deciduous forests of the Indian subcontinent and dry slopes up to 900 m elevation.

random individuals of each species in each site were selected for growth parameters following Maikhuri *et al.*[4,13]. Height and stem circumference (circumference of main axis at a height of 10 cm above ground level) were measured during 2009–2012. Twenty random individuals of each species in each site were selected for measuring morphometric parameters following Maikhuri *et al.*[4,13].

Soil data collection: Soil samples were collected from different depths of soil layer, viz. 0–10 and 10–20 cm randomly from the planted sites and mixed for making a composite sample to calculate organic carbon. Soil pH was measured in soil : water suspension (1 : 5) in fresh samples. Samples were air-dried and passed through a 210 mm sieve. Organic carbon was determined using the Walkley–Black method[15], total nitrogen by the Kjeldahl method[16] and cations (calcium and magnesium extracted in 1 N potassium chloride solution and potassium in 1 N ammonium acetate solution) by atomic absorption spectrophotometer. Soil was digested in perchloric acid to determine total phosphorus by the molybdenum blue method[17] during 2007, 2009 and 2012.

Economics of biomass harvesting: Five year of plantation onwards, about 30–50% branches of fodder species planted in both sites were lopped and 10–20% of other grass species (*Imperata cylindrica*, *Chrysopogon* serrulatus, *Arundinella nepalensis*, *Setaria glauca*, etc.) growing naturally were harvested from the second year onwards. The harvested grasses were left for 20 days in the plots for sun-drying. The dried grasses were collected by each household of the studied villages and the total weight calculated by adopting weight survey method[18]. The quantum of fodder collected (head load) during each trip by an individual was weighed using spring balance. The economic valuation of fodder biomass was made using contingent valuation method (CVM) following Mitchell and Carson[19], which is an economic, non-market-based valuation method especially used to infer an individual's preference for public goods. It was basically done through a survey about people's willingness to pay for a benefit and the commodity they wish to accept by way of compensation. Price of the fodder was fixed on local/regional market basis and individual's preference. The survey was done through questionnaire as well as by personal interviews and group discussions.

Statistical analysis: Analysis of variance (ANOVA) and least significant difference (LSD) were applied to evaluate the effect of age on tree growth and circumference at different sites. Mean values of the age and species on tree growth were subjected to ANOVA using SPSS version 7.5. The significance level was determined at $P < 0.05$ and the means were separated using Duncan's Multiple Range Test (DMRT) if the values were significantly different.

Results

Survival percentage

A complete census of planted trees was undertaken to assess survival and growth performance. Most of the species planted at the DAAL site showed better survival (57.7–92.2%) as compared to the DCWL site (53.6–87.2%), with an average of 66.32% for total saplings introduced at both the sites. *A. nepalensis* showed maximum survival percentage (87.2–92.2) at both sites followed by *Q. leucotrichophora* (69.7–82.4), whereas minimum survival percentage (57.7–62.5) was observed for *B. purpurea* at the DAAL site (Figure 1).

Growth performance

Knowledge on survival and growth of multipurpose tree species in tropical mountain regions and other developing regions is confined to only a few species and, that too, regarding their early growth. Growth of all the species was remarkably better at DAAL compared to DCWL. *A. nepalensis* showed maximum height ($P < 0.05$) at both the sites (205.1 cm at DAAL and 133.8 cm at DCWL) after the fifth year of plantation (Table 2). Stem circumference was maximum 26.42 ± 1.88 and 28.56 ± 6.85 cm for *A. nepalensis* at the DCWL and DAAL sites respectively, whereas it was lowest ($P < 0.05$) for *C. tamala* at both the sites (Table 3). *Quercus* spp. showed better stem growth performance ($P < 0.05$) at higher elevation compared to lower elevation, which was found to be maximum (78.25 cm) in *Q. leucotrichophora* compared to *Q. glauca* (68.10 cm) at higher elevation.

Soil characteristics

Significant changes ($P < 0.05$) in soil pH were observed with regard to the time-period (2007–2012). A gradual increase in soil organic carbon and total nitrogen was recorded during successive years at both the sites, while DAAL showed comparatively better results for both the parameters (Table 4). Considering initial and five years of treatment, soil at the DAAL site had higher concentration of organic carbon (0.95 ± 0.01%) and nitrogen (0.17 ± 0.01%) compared to the DCWL site (0.75 ± 0.01 and 0.15 ± 0.00 respectively). The total phosphorus content did not show significant variation among sites and was also not altered during successive years. Exchangeable calcium, exchangeable magnesium and total nitrogen increased significantly ($P < 0.01$) each year, while no significant difference was found between the sites. There was no significant difference in exchangeable potassium between the two sites. The exchangeable potassium increased significantly ($P < 0.05$) during the successive year (Table 4). Factorial analysis exhibited significant impact ($P < 0.05$) of sites plantation in successive year (Table 5).

Biomass production and monetary equivalent

The branches of fodder species were lopped up to 30–50% from five years of plantation and 10–20% of other species growing naturally during winter season and local grasses were harvested from the second year onwards. At both sites, farmers harvest grasses during the dry season serving three purposes: better growth of transplants as a result of reduction in competition, avoidance of mortality due to fire and availability of fodder for stall-feeding. Fodder biomass, particularly of naturally growing grasses, viz. *Imperata cylindrica*, *Chrysopogon serrulatus*, *Arundinella nepalensis*, *Setaria glauca* and *Cyperus compressus* increased four to five times within a period of five years at both the sites, 345–1280 t/ha (worth Rs 10,483–52,964) at DAAL site and from 104 to 636 t/ha (worth Rs 14,379–67,882) at DCWL site. The increased grass production generated additional opportunity of income to the locals and reduced the distance for people to collect fodder. These households are now getting sufficient grass from the site and also marketing dry grass to nearby areas. On an average, households in Gumod village save

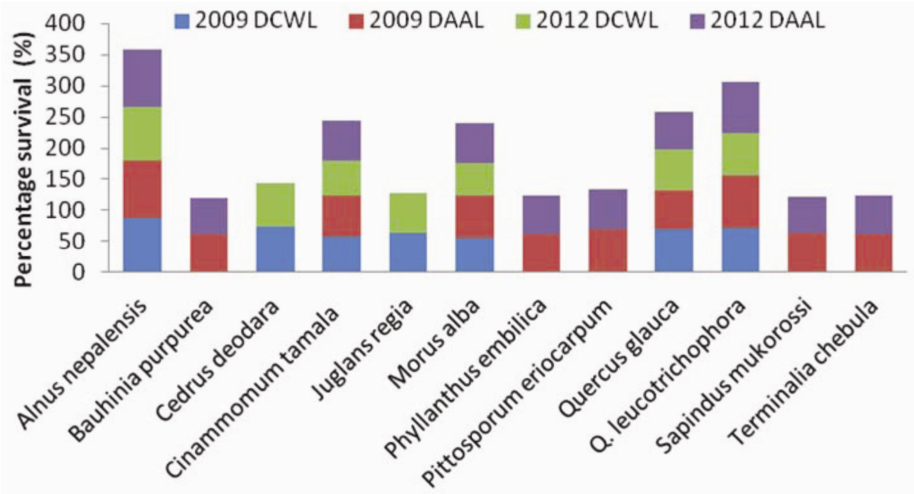

Figure 1. Percentage survival of planted tree species in 2009 and 2012 at DAAL and DCWL sites, Western Himalaya.

Table 2. Height (cm) of planted tree species in 2009, 2010 and 2012 at DAAL and DCWL sites, Western Himalaya

	Site					
	DCWL			DAAL		
Species	2009	2010	2012	2009	2010	2012
A. nepalensis	76.45 ± 4.04^a^	104.75 ± 7.62^b^	128.15 ± 4.89^c^	80.90 ± 14.01^a^	106.05 ± 22.97^b^	134.70 ± 35.09^c^
B. purpurea	–	–	–	43.75 ± 1.55^a^	50.45 ± 1.75^b^	56.10 ± 1.95^c^
C. deodara	34.55 ± 1.53^a^	42.05 ± 1.85^b^	55.25 ± 3.47^c^	–	–	–
C. tamala	27.50 ± 1.27^a^	33.95 ± 1.47^b^	43.85 ± 1.48^c^	26.75 ± 0.99^a^	35.80 ± 1.31^b^	49.30 ± 2.77^c^
J. regia	36.95 ± 2.11^a^	41.85 ± 2.24^b^	61.15 ± 3.93^c^	–	–	–
M. alba	68.35 ± 4.09^a^	78.05 ± 5.36^b^	93.45 ± 6.01^c^	73.00 ± 2.93^a^	89.30 ± 6.08^a^	105.45 ± 8.32^b^
P. emblica	–	–	–	67.80 ± 3.00^a^	77.25 ± 4.05^ab^	86.45 ± 4.61^c^
P. eriocarpum	–	–	–	41.85 ± 1.76^a^	50.20 ± 2.99^b^	69.35 ± 2.49^c^
Q. glauca	53.15 ± 3.15^a^	61.8± 4.20^a^	68.10 ± 3.32^b^	47.10 ± 2.29^a^	56.86 ± 3.04^b^	61.81 ± 3.70^c^
Q. leucotrichophora	43.40 ± 1.89^a^	66.15 ± 2.03^b^	78.25 ± 4.23^c^	44.8 ± 2.30^a^	61.65 ± 2.40^b^	70.05 ± 3.36^c^
S. mukorossi	–	–	–	49.80 ± 1.85^a^	57.20 ± 1.39^b^	67.05 ± 1.56^c^
T. chebula	–	–	–	42.15 ± 4.01^a^	48.35 ± 4.13^ab^	55.80 ± 4.51^a^

Values are mean ± standard error ($n = 20$); Mean values followed by the same letter(s) in a column are not significantly different ($P < 0.05$) based on DMRT.

Table 3. Stem circumference (cm) measured at 10 cm above ground level of multipurpose tree species in 2009, 2010 and 2012 at DAAL and DCWL sites, Western Himalaya

	Site					
	DCWL			DAAL		
Species	2009	2010	2012	2009	2010	2012
A. nepalensis	8.29 ± 0.47^a^	13.84 ± 0.82^b^	26.42 ± 1.88^c^	9.88 ± 1.86^a^	18.29 ± 5.57^b^	28.56 ± 6.85^c^
B. purpurea	–	–	–	5.96 ± 0.18^a^	7.46 ± 0.27^b^	8.68 ± 0.35^c^
C. deodara	3.73 ± 0.12^a^	4.91 ± 0.10^b^	6.44 ± 0.45^c^	–	–	–
C. tamala	2.13 ± 0.17^a^	3.34 ± 0.21^b^	5.86 ± 0.33^c^	2.39 ± 0.24^a^	3.84 ± 0.33^b^	6.51 ± 0.34^c^
J. regia	6.07 ± 0.31^a^	7.56 ± 0.34^b^	10.51 ± 0.60^c^	–	–	–
M. alba	4.73 ± 0.37^a^	7.22 ± 0.43^b^	10.32 ± 0.48^c^	7.26 ± 0.69^a^	9.64 ± 0.64^b^	12.88 ± 1.02^c^
P. emblica	–	–	–	9.58 ± 0.51^a^	11.66 ± 0.63^b^	13.78 ± 0.85^c^
P. eriocarpum	–	–	–	5.35 ± 0.40^a^	7.68 ± 0.42^b^	9.63 ± 0.28^c^
Q. glauca	3.99 ± 0.26^a^	5.78 ± 0.32^b^	8.81 ± 0.29^c^	3.53 ± 0.19^a^	5.45 ± 0.38^b^	9.86 ± 0.63^c^
Q. leucotrichophora	5.19 ± 0.65^a^	8.98 ± 0.81^b^	13.11 ± 0.72^c^	7.40 ± 0.53^a^	10.86 ± 0.89^b^	14.63 ± 1.29^c^
S. mukorossi	–	–	–	6.52 ± 0.25^a^	8.06 ± 0.26^b^	9.19 ± 0.28^c^
T. chebula	–	–	–	5.47 ± 0.52^a^	6.76 ± 0.66^ab^	8.62 ± 0.80^c^

Values are mean ± standard error ($n = 20$); Means values followed by the same letter(s) in a column are not significantly different ($P < 0.05$) based on DMRT.

Table 4. Soil physico-chemical characteristics and factorial analysis within years and between different sites in Western Himalaya

	Before plantation (2007)		Two years after plantation (2009)		Five years after plantation (2012)		*F*-value		
Parameter	DCWL site	DAAL site	DCWL site	DAAL site	DCWL site	DAAL site	Year	Site	Year × site
pH	6.50 ± 0.06	6.17 ± 0.09	6.49 ± 0.01	6.31 ± 0.01	6.53 ± 0.91	6.50 ± 0.01	5.7518*	2.8814^{ns}	20.0700**
Organic carbon (%)	0.56 ± 0.01	0.63 ± 0.03	0.62 ± 0.01	0.75 ± 0.01	0.75 ± 0.01	0.95 ± 0.01	132.0962**	12.6920**	52.0802**
Total nitrogen (%)	0.11 ± 0.01	0.13 ± 0.01	0.11 ± 0.01	0.15 ± 0.00	0.15 ± 0.00	0.17 ± 0.01	27.6946**	0.04300^{ns}	4.7390*
Total phosphorus	0.05 ± 0.01	0.03 ± 0.00	0.05 ± 0.00	0.04 ± 0.00	0.06 ± 0.00	0.05 ± 0.00	2.1033ns	2.7929^{ns}	10.6550**
Exchangeable potassium (mg/100 g)	4.33 ± 0.15	4.10 ± 0.12	4.57 ± 0.09	4.20 ± 0.06	5.30 ± 1.01	5.15 ± 1.02	4.9961*	0.0056^{ns}	78.3440**
Exchangeable calcium (mg/100 g)	40.80 ± 0.79	46.32 ± 1.48	44.73 ± 0.70	50.53 ± 0.43	50.55 ± 0.34	52.61 ± 0.80	56.2201**	0.7505^{ns}	12.9079**
Exchangeable magnesium (mg/100 g)	4.15 ± 0.03	4.61 ± 0.15	4.73 ± 0.09	4.93 ± 0.2	5.63 ± 0.1	5.23 ± 0.02	52.7666**	0.5430^{ns}	65.9212**

*P < 0.05; **P < 0.01; ns, Not significant at P < 0.05.

Table 5. Factorial analysis of soil parameters within years and between different sites in Western Himalaya

		pH		Organic carbon (%)		Total nitrogen (%)		Total phosphorus		Exchangeable potassium		Exchangeable calcium		Exchangeable magnesium	
	d*f*	MSS	*F*-value	MSS	*F*-value	MSS	*F*-value	MSS	*F*-value	MSS	*F*-value	MSS	*F*-value	MSS	*F*-value
Year (A)	2	0.0335	5.7518*	0.1020	132.0962**	0.0035	27.6946**	0.0001	2.1033^{ns}	0.1153	4.9961*	119.5104	56.2201**	0.8689	52.7666**
Sites (B)	1	0.0168	2.8814^{ns}	0.0098	12.6920**	0.0001	0.04300^{ns}	0.0001	2.7929^{ns}	0.0001	0.0056^{ns}	1.5955	0.7505^{ns}	0.0089	0.5430^{ns}
A * B	2	0.1168	20.0700**	0.0402	52.0802**	0.0006	4.7390*	0.0004	10.6550**	1.8084	78.3440**	27.4392	12.9079**	1.0855	65.9212**
Error	12	0.0058		0.0008		0.0001		0.0000		0.0231		2.1258		0.0165	

d*f*, Degree of freedom; MSS, Mean of sum of square; *P < 0.05; **P < 0.01; ns, Not significant at P < 0.05.

up to Rs 4426 per annum and those in Dharaunj up to Rs 2248. The women of the village have formed a Mahila Mangal Dal (MMD; women's welfare group), collecting minimal charge of Rs 15/head load of harvested grass from the villagers and utilizing the collected money for maintenance and protection of the rehabilitation site.

Capacity building and social awareness

Adoption of any technology by farmers largely depends on demonstration and training, transfer of knowledge, awareness generated and level of strengthening of capacity. Apart from the informal meetings and discussions, 42 formal meetings and 29 training programmes were organized to promote activities of the programme among the wider range of stakeholders; a total of 820 participants from both the villages covering 100% inhabitant were trained to improve their skills. The participants were trained on simple technologies of land rehabilitation, followed by subsequent demonstration of these technologies in the field. The rehabilitation activities are directly linked to the village farming system and particularly with integrated livestock management through quality forage production and soil/water conservation. The programme facilitated regular interactions among scientists and farmers during the entire study period, ensuring to establish close linkages with the community for transfer of necessary technical know-how on rehabilitation of degraded lands under the prevailing conditions. As a result, active participation of the local stakeholders was achieved not only up to the implementation of the programme, but also seen as an adoption and extension of the activities in their private agricultural lands through plantation of fodder and plants of known medicinal values.

Discussion

Participatory action research framework and approaches for rehabilitation of degraded/wasteland to promote farmers participation in community-based natural resource management programme was followed with an understanding that farmers and scientists have different types of knowledge and skills, but by working together may deliver better results than working in isolation. Local people combine their indigenous knowledge with the scientific knowledge of extension workers that can provide local people with satisfactory livelihoods and deliver environmental services downstream. Local inhabitants have selected multifarious tree species and grass species for plantation under this programme, instead of giving priority to monoculture. Conversion of degraded land through mixed tree plantation rather than monoculture plantation may be better for meeting the diverse products needs of local people and environmental amelioration[20]. Tree planting in degraded lands, apart from enhancing ecosystem functions of the treated areas, contributes to conservation of the remaining forests[1]. The introduced sapling takes at least one year to establish under such degraded conditions and normally growth starts at the second year onwards. The establishment of saplings largely depends on the ability of the species to survive in a wide environmental gradient[21]. *Quercus* species performed well at higher elevation due to its natural habitat within the elevation range 1500–3200 m asl while *A. nepalensis*, *B. purpurea*, *M. alba* and *C. tamala* performed better at lower altitude (1000–1500 m asl). The magnitude of difference in growth between two altitudes could be viewed as an indicator of the response of species to soil moisture, nutrient conditions and suitable habitat of a particular species. The higher growth of plant species recorded in 2012, compared to the previous years, may be due to application of simple techniques like terracing, bunding, gully plugging and check dams, which have contributed towards increase in soil moisture, increased availability of organic carbon and essential nutrients for growth.

A significant improvement in soil carbon and nutrients was observed in both the sites, though the magnitude of change varied between the sites. The degree of soil fertility changes may vary depending upon the microbial/biochemical activities in the soil, eco-physiological attributes of the plated species and management practices[22,23]. The slight increase in soil nutrients pool (total nitrogen and phosphorus) at lower elevation is due to comparatively high temperature and high relative humidity, accelerating nutrient mineralization. The low rate of increase in soil organic carbon at higher elevation indicates low temperature, low relative humidity and high soil moisture favouring high organic matter accumulation and low rate of nutrient mineralization. The soil aggregate protection function is probably highest for the protected plantations due to high mulch cover and the multistoried vegetation structure during progressive years of plantation. The techniques applied during the process have contributed towards soil/water conservation, increase in soil moisture and organic carbon within the rehabilitation sites and ultimately increase in grass biomass and better growth of planted species. The rehabilitation sites located above agriculture land also contribute towards enrichment of nutrient status of agriculture land. Any amount of moisture conserved within the sites also influences the moisture regime of the cropped land for recharging soil moisture and utilization of organic material deposited by run-off due to rain water from a higher landscape.

Livestock is the major source of income generation by providing a wider range of products and is attributed to enhancement of livelihood apart from sustaining the agriculture system. The inhabitants were made aware about the fact that the proposed rehabilitation programme will produce quality fodder, fuelwood, leaf-litter as well as better environment and all the benefits will go to the villagers. As a result, the villagers have contributed on pitting, transportation of saplings, plantation and one-third of the total development costs in the form of labour and composted manure. People are now ready to recognize grazing as an offence in the treated area. Fodder biomass, particularly of naturally growing grasses, increased five times within a period of five years at both the sites. Planting of grasses and shrubs suitable for fodder increases fodder availability and reduces erosion and landslides that prevail in these areas. The MMD has established effective control over the collection of fuel wood, leaf-litter and fodder from the developed sites, which has considerably reduced the working hours and overall work load for collection of fodder and fuel wood and the pressure of harvesting from the forest. Therefore, strengthening linkages between knowledge systems using 'community' participatory management approaches is now seen as critical for sustainable forestry, rehabilitation, restoration and agroforestry system[4,24], and when an active tree planting culture exists in rural communities, hundreds of indigenous tree species can be found conserved *in situ* on farmlands[25]. Among the direct benefits from the sites, the local communities value fodder as most important for strengthening animal husbandry and indirectly, the agriculture system. Lack of good quality fodder often limits not only the productivity of livestock, but also reduces the nitrogen content of animal dung[18]. With the initial success of the rehabilitation programme at both villages, people from neighbouring villages have also started such activities on their private and community lands. A considerable impact could be observed not only on the field, but also positive changes in their perception regarding conservation and management of the natural resources, which will also help reduce forest degradation, women drudgery and simultaneously meet the national and global targets of deforestation and rehabilitation in the Himalayan region. The models are replicable, provided necessary inputs are ensured. This type of approach has also been adopted by the Government under the Mahatma Gandhi National Rural Employment Guarantee programme (MNREGA) and Integrated Watershed Management Plan (IWMP) of the state, where at least 40% of the total financial resources is to be utilized on soil/water conservation and wasteland rehabilitation.

Conclusion

The present study was initiated for rehabilitation of degraded waste and abandoned agriculture land to improve the availability of fodder, fuelwood and leaf-litter with additional livelihood options in the near future, besides restoring ecosystem services. Within a short period of five years, the plantation of selected species is growing well with significant improvement in ecological health and providing local benefits. Availability of fodder, fuelwood and timber from the degraded community lands would reduce threats of degradation to existing forests together with improvement in the livelihood of local communities and global environmental benefits. Proper management of such rehabilitated sites will certainly provide highest reimbursement both in terms of tangible as well as intangible benefits to the mountain and downstream communities in the region.

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