10 PARTICIPATORY REHABILITATION OF DEGRADED LANDS FOR RURAL LIVELIHOOD SUSTAINABILITY AND IMPROVED BIODIVERSITY – A Case Study from the Indian Central Himalayas

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Abstract

In the middle mountains of Uttaranchal of the Indian Central Himalayas, there is a paucity of information about the biophysical rate of recovery when degraded areas are rehabilitated through peoples' participation, and the impact that the recovery has on the livelihoods of the rural communities. This study presents an analysis of change in terms of floral communities and associated change in soil character within an area of land under rehabilitation that was previously used extensively for grazing. The time-series evaluation showed that between 1993 and 1999, the average soil moisture increased from 12.3 to 21.3%, total soil organic carbon from about 1.0 to 1.5%, and soil pH from 5.9 to 6.3. The plant species richness increased from 28 in 1993 to 54 in 1999. Although the number of C_4-type plants increased from 2 (in 1993) to 10 (in 1999), their Importance Value Index decreased from a value of 149.7 to 137.4 during the same period. The site also recorded a significant increase in grass production from 2.7t in 1993 to 8.9t in 1999, which meant increased availability of fodder for the villagers, especially during lean periods, and a reduction in the fodder-related expenditures by about IRs 1,000 [3] per household.

Introduction

Located in the Western Himalayan Ecoregion of India, the newly created mountain state of Uttaranchal (29°5'-31°25' N and 77°45'-81°E, altitudinal range 300-7,817 masl), covers an area of 53,485 km^2 and has a large human population (8,479,562 or 22% of the total in the Indian Himalayan region). The region is associated with one of the most productive agricultural zones of the planet, the Gangetic Plain, and contributes significantly towards the livelihood sustainability of nearly 400 million people. Due to extensive forest cover (3,430,038 ha) the region plays an important role in providing ecosystem services such as landscape and watershed stabilisation, including soil

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3 In 1999 US $ 1 = IRs 43

protection and regulation of hydrological processes. However, the region presently faces serious environmental threats, due to increasing population, major changes in land-use and land-cover patterns, and a rapid depletion of natural resources (Maikhuri and Rao 2002). Depletion of any resource can interrupt the flow of energy, nutrients, and water within an ecosystem, which, on account of this depletion, gradually reverts to an early stage of succession (Bradshaw 1987).

Rural communities living in the hills of Uttaranchal have diverse cultures and are mostly agrarian in nature. Because the quality and quantity of natural resources are so vital in the traditional lifestyles of these people and because of the importance of livestock, fodder, fuelwood, and timber demand in the region is very high. Fodder scarcity, in terms of quantity and quality, has become a major issue causing women, including girls, who are traditionally assigned the task of collection, to travel increasingly longer distances. Due to poor quality of fodder, livestock quality is deteriorating and there is an increase in mortality rate. Free and continuous overgrazing is reducing the water permeability of the soil and accentuating soil erosion. There is also destruction of forests for agricultural expansion to support a growing human population in the region. As a result, many of these cleared areas have reverted to secondary growth when left abandoned.

To overcome these problems, rehabilitation of degraded lands or wastelands in the fragile mountain environment of Uttaranchal is one of the potential options for sustainable development. Experiences in ecological restoration of degraded community lands in the region are limited and the ongoing alterations in the human and natural environment urgently demand the generation of effective land and water management options with people's participation as a prerequisite (Kothyari et al. 1991; Ramakrishnan et al. 1992; Kothyari et al. 1996). This time-series study (from 1993 to 2001), conducted in a remote village (Arah) of Uttaranchal, showed the potential benefits and impacts of rehabilitating degraded community lands with an approach comprising both traditional and scientific knowledge.

The Study Area

The study area, Arah Village, covers 99 ha, and is located in Bageshwar District of Uttaranchal. The region is characterised by a variety of sun-temperate-type microclimates mainly governed by geographical coordinates and altitudinal variations. The temperature of the area drops to 0°C during winter and reaches a maximum of 37°C during summer. The area receives moderate precipitation, with a mean annual value of 1,380 mm.

Arah was (and still remains) a semi-remote village, as it is not linked to a road. Based on the village survey conducted in 1993, it was found that some essential amenities were present including a branch post office, primary school, junior basic school (2 km from the village), a rural electricity supply, and a drinking water supply. Other essential amenities like health care and veterinary centres, seed and fertiliser distribution cells, and telecommunication facilities were located at least 5 km away at Garur (nearest roadhead town). The whole village was largely dependent on this town for daily needs and on farming for their 'subsistence' livelihood (Figure 10.1).

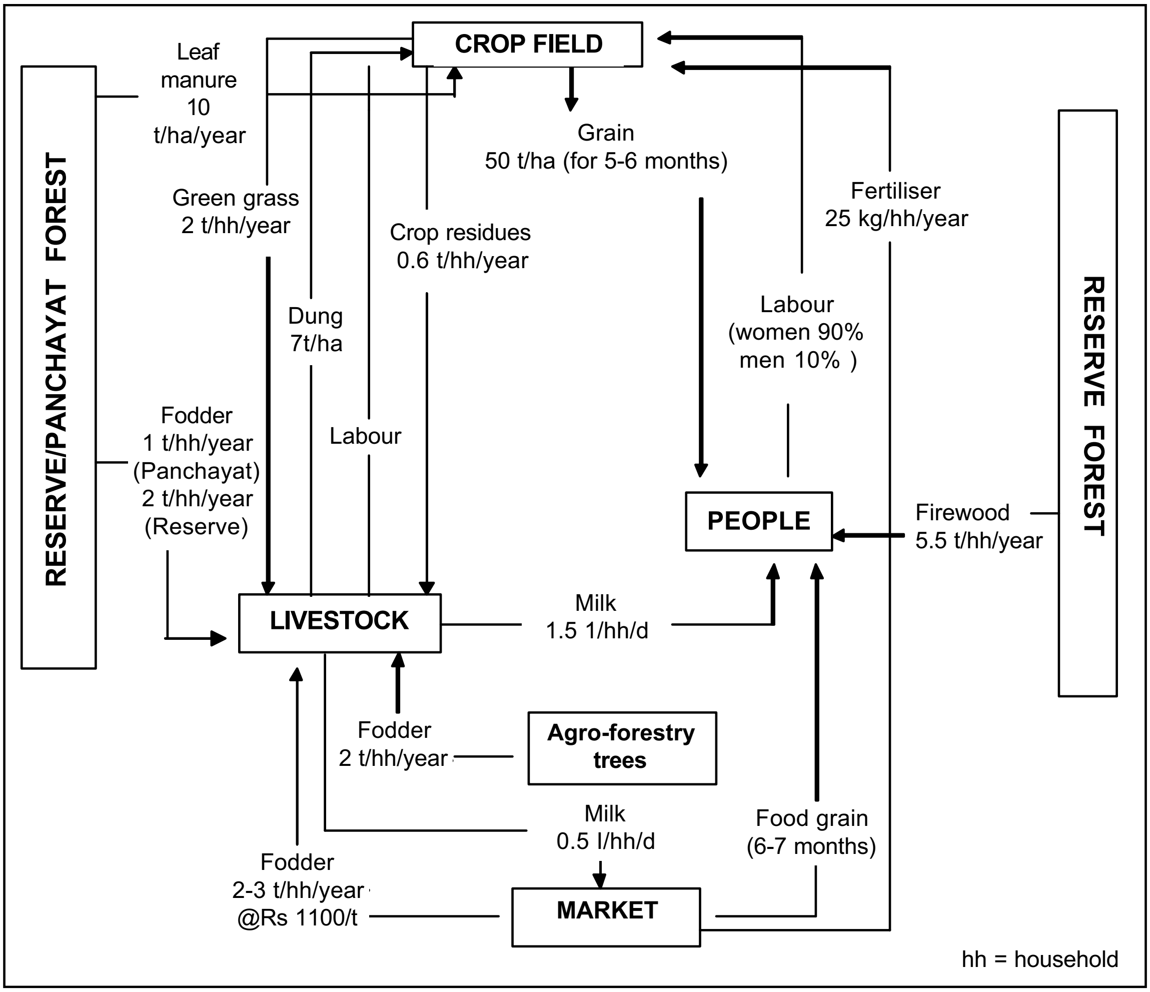

Figure 10.1: **The farming system of Arah (1993)**

The village had four social institutions actively involved in the management of the natural resources as described below.

Village Panchayat – This elected body headed by the gram pradhan (village chief) acts as a link between the State Government and the villagers for ensuring development of the village.

Van Panchayat – The second highest elected body in the village is the van panchayat (forest panchayat), headed by the surpanch, which manages community land and other natural resources such as forest, grassland, and springs. Approximately 16.5 ha of panchayat van land was being managed by this body, whose main function was to ensure equitable distribution of different usufructs, for example, fodder and leaf litter. This institution took the lead in facilitating the smooth operation of the rehabilitation project.

Dairy Cooperative – A 'parag', a government-sponsored cooperative, along with a number of its units (village milk collection units), was partially functional within the village. However, daily collection of milk from the village was extremely low (10-15 l/day during winter and 30-45 l/day during the rainy season).

Yuva Mangal Dal – This informal group of young people (below 35 years) was actively involved in executing various social and religious functions within the village. Their services were also efficiently utilised during the implementation of the rehabilitation project.

The Study Site and Land Use History

The study site (Balgara, about 9 ha) was located about 1 km from the main settlement, more than 60% households of Arah had customary rights in it. The per-capita landholding size varied, but not significantly. According to the villagers the site had an interesting land use history before the initiation of the project.

Until 1950:	under forest, dominated by *Pinus roxburghii*
During the 1960s:	site cleared for agricultural activities
Until 1975:	agriculture practised, partially under irrigation
Between 1975 and1993:	area abandoned as a result of fragmentation of land holdings, distant location from the main village, increase in the out-migration of men from the village, scarcity of water for irrigation, and destruction of crops by monkeys. The area reverted into grassland and then became an open grazing area.

From 1993 onwards, because of the interest shown by the villagers in carrying out rehabilitation activities, the site was selected for a rehabilitation project with funding from the International Development Research Centre (IDRC, Canada) and ICIMOD (Nepal). The GBPIHED (India) implemented the project. The concept of degraded land consolidation and subsequent community-based development was introduced for the first time in this part of Uttaranchal. The project promoted plantations of different fuelwood, fodder, nitrogen-fixing and timber species, based on the preferences of women as well as GBPIHED research findings in the area of land rehabilitation. Initially, open grazing within the site area was completely checked with the help of the Van Panchayat and the villagers. From 1997 onwards the site was managed by the village community and jointly monitored by PARDYP, India; PARDYP, ICIMOD; and the villagers of Arah.

Methodology

In 1992, during the general meeting of the Van Panchayat, a proposal was passed by the villagers of Arah for rehabilitation of the site. The villagers themselves clearly defined their contributions towards the project goal as follows.

- Open grazing would be stopped at the site.
- Villagers would provide an abandoned house at no cost to the team.
- The community would plant broad-leaved species, mainly fodder species.
- Initially, harvesting and distribution of grasses (ground vegetation) would be as per the norms fixed by the village Van Panchayat.
- Before the project withdrawal in 1996, a village society would be formed for future management and development of the site.

Other activities carried out at the site aimed at sustaining the plantation-related activities and promoting similar programmes elsewhere by different groups of people are described below.

Water harvesting

Scarcity of water was identified as one of the basic causes of land abandonment. Therefore, two polyethylene-lined underground tanks were constructed, with local people's participation, at relatively low cost. The main focus was on harvesting wastewater. The water collected proved to be sufficient for the nursery and newly planted trees. Irrigation was applied through plastic pipes (siphon method).

Soil amendment

Considering the requirements of the site, soil amendments were made with limited mechanical and biological means. Renovation of damaged terraces, pitting for planting desired tree and grass species, and digging and ploughing of terraced areas, were some of the mechanical activities. For improving the soil fertility, nitrogen-fixing crops and tree species were planted and compost preparation was done by vermiculture and bio-composting methods.

Soil erosion control measures

Over the years, a few gullies had formed at the site and, therefore, small check dams were constructed using local stones. However, there are now reports of effective bio-engineering methods to replace such mechanical methods (Agrawal and Rikhari 1998). The run-off from higher sensitive locations at the site was diverted to permanent rivulets.

Nursery development and plantation

To reduce the cost and the damage associated with transportation of planting material from distant locations, nurseries of the required species were set up at the site. The species selected (as per the participatory matrix developed) were *Alnus nepalensis, Albizia lebbeck, Bauhinia retusa, B. verigata, Dalbergia sissoo, Dendrocalamus hamiltonii, D. strictus, Ficus nemoralis, F. macrohylla*, *Debregeasia longifolia, Grewia optiva, Quercus glauca, Q. leucotrichophora,* and *Thysanolaena maxima* (broom grass). In the first year, nitrogen-fixing crops, such as soybean, lentils, and gram, were introduced along the margins as a soil fertility improvement measure.

Bio-composting

Compost prepared from a mixture of weeds, agricultural waste, cow dung, mud, and leaf litter in deep underground pits covered in polyethylene supplemented traditionally composted organic manure. The chopped leaf litter, weeds, and agricultural by-products, mixed with cow dung (when available), mud, and waste paper, were tightly packed into the underground pit and covered with a polyethylene sheet to protect against rain water and surface run-off. By this method, not only was there complete decomposition of weeds and other bedding material, but also the time requirement for preparing manure of the usual quality was reduced by about 2 months; by traditional methods the time required for complete decomposition of the raw material (chir pine leaves) is approximately 1 year.

Meetings, training, and awareness activities

Apart from development and research activities, formal and informal meetings and training camps were organised for the farmers, women, school children, non-government organisations, army personnel, and other government officials. For example, the Garur Block and the Soil and Water Conservation Department were interested in nursery development, plantation technologies, and new approaches for community-based natural resources conservation and management practices.

Key Results

Soil characteristics

A significant increase in average soil moisture content (from 12.3 to 21.3%) was recorded during the study period (1993-1999), while pH showed a small but significant improvement (from 5.9 to 6.3). A gradual increase in organic carbon (C) (from 1.02 to 1.48%) was a positive indication of improvement in soil fertility as was the increase in total nitrogen (N), and available phosphorous (P) and potassium (K) during the same period (Table 10.1). Soil moisture content has a positive correlation with the soil microbial population responsible for the decomposition of organic matter in the soil, therefore enabling plants to have increased access to nutrients (Kothyari and Dhyani 1995).

Table 10.1: **Temporal changes in the soil characteristics of Balgara during the study period**

Years	Moisture (%)	pH	Organic C (%)	Total N (%)	Available P (kg/ha)	Available K (kg/ha)
1993	12.3	5.9	1.02	0.0119	7.2	134
1994	19.9	6.2	1.08	0.012	8.9	157
1995	20.1	6.3	1.12	0.0216	9.2	189
1996	20.6	6.4	1.44	0.0191	9.2	181
1997	21.2	6.4	1.44	0.0205	11.1	190
1998	21.4	6.3	1.45	0.0213	11.4	192
1999	21.3	6.3	1.48	0.0257	11.7	183

Overland flow and sediment output

This study was carried out between 1995 and 1999 by establishing erosion plots (5x2m, n=3) at the site. The total overland flow of 41.01 m^3/ha in 1995 gradually decreased to 27.09 m^3/ha in 1999. Sediment loss also decreased from 0.43 t/ha to 0.37 t/ha. Gradual reduction in overland flow and sediment losses was possibly due to improvement in vegetation cover (ground as well as canopy) as found in similar studies in the Indian Central Himalayas by Pandey et al. (1983) and Pathak et al. (1984).

Soil microorganisms

Soil microbial studies conducted at the site following the methods of Warcup (1950) and Subba Rao (1977) showed a gradual increase in microorganism density (Table 10.2). Microorganisms play a key role in breaking down non-available forms of nutrients into forms that plants can take up (Aune 1995; Aune and Lal 1995; Mishra 1966). Thus the gradual increase in soil microorganisms might have helped increase the soil fertility of the site.

Table 10.2: **Temporal changes in the fungal species' colony-forming units (per gram of dry soil) identified from the study site**

Species	1993	1994	1995	1996	1997	1998
Absidia sp.	0.13	0.33	0	0	0	0
Alternaria alternata	0.51	0.55	0.61	0	0.25	0.63
Aspergillus niger	0.13	0.64	1.35	1.76	2.39	2.29
Aspergillus flavus	0	0.66	0.37	0.23	0.12	0
Aspergillus fumigatus	0.64	0.64	0.73	1.06	0.37	0.25
Aspergillus sp.	0	0	0	0.23	0.88	0.88
Botrytis sp.	0.38	0.93	0	0	0	0
Cladosporium sp.	0.25	0.66	0.87	0.95	0.62	0.5
Colletrotricum sp.	0.25	0	0	0	0	0
Curvularia sp.	0	0.11	0	0	0	0.12
Drechslera sp.	0	0	0.24	0	0	0
Fusarium sp.	0	0	0	0	0.12	0.25
Gliocladium sp.	0	0.33	0	0	0	0
Helminthosporium sp.	0.38	0.44	0	0	0	0
Hormodendrum sp.	0	0.11	0	0	0	0
Mucor sp.	0.13	0.11	0.12	0.58	0.62	0.55
Penicillium expansum	2.19	1.21	2.69	2.84	2.27	2.29
Penicillium chrysoginium	0	0.11	0.75	0.12	0	0
Penicillium sp.	0	0.87	0.12	0.58	0.75	1.26
Paecilomyces sp.	0	0	0	0	0.5	0.76
Rhizopus sp.	0	0	0.12	0.58	0.37	0.25
Trichoderma koningi	0.88	0.55	1.24	1.41	1.26	1.52
Trichoderma harzianum	0.64	0.33	0.36	1.06	0.5	0.13
Monila sp.	0	0.11	0	0	0	0
Verticillium sp.	0.25	0	0	0	0	0
*White sterile mycelia**	0.64	1.22	1.86	1.65	2.51	2.29
*Grey sterile mycelia**	0	0.37	0.75	0.83	0.37	0.88
*Black sterile mycelia**	0	0	0	0	0.75	0.38

* Specific identification was not possible because there was no sporulation. The study was only carried out up to 1998

Changes in natural vegetation composition

Phytosociological studies conducted following Misra (1968) and Saxena and Singh (1982) showed that the species richness of the Balgara site increased from 28 in 1993 to 54 in 1999 (Table 10.3). Also, the number of C_4-type species increased from 2 to 10 during the same period. However, the importance value index (IVI) of C_4 plants decreased from 149.7 to 137.4 (Table 10.4). The predominant species at the site was *Imperata cylindrica* (C_4 grass species, local name siro) with an IVI range of 102.2-128.4, the highest value was recorded in 1993. In contrast, the total IVI of C_3 species increased from 150.3 to 162.6, and their number from 26 to 40 during 1993-1999.

Table 10.3: **Time series changes in the IVI of the species recorded at the Balgara site**

Species	1993	1994	1995	1996	1997	1998	1999
Euphorbia prolifera	11.24	10.80	5.35	5.32	4.11	3.21	1.24
Indigofera dosua	38.76	43.80	45.47	44.64	44.74	44.98	43.00
Gnaphalium hypoleucum	4.20	2.10	1.48	1.44	1.19	1.08	1.22
Erianthus rufipilus	19.11	17.70	17.21	16.21	16.26	16.34	17.00
Imperata cylindrica	128.45	122.10	121.76	112.74	110.24	108.23	102.24
Chrysopogon serrulatus	21.27	20.10	14.54	11.71	11.05	9.15	9.80
Adiantum lanulatum	1.00	2.20	2.53	2.79	3.84	3.46	3.78
Origanum vulgare	3.00	2.00	3.66	4.20	3.94	3.90	2.19
Cheilanthus albomarginata	1.27	1.30	2.18	2.73	3.94	3.89	3.00
Gloriosa superba	2.00	1.90	1.40	1.14	1.98	1.79	2.24
Oxalis corniculata	6.00	7.80	8.46	7.53	7.56	7.89	7.54
Potentilla fulgens	4.06	5.02	6.47	5.16	5.21	5.01	4.96
Crotalaria semialata	3.23	5.30	3.83	5.58	4.16	4.90	3.80
Micromeria biflora	8.00	8.60	8.26	8.49	9.94	8.56	6.60
Phyllanthus simplex	2.00	2.00	2.64	1.05	1.04	1.21	1.64
Calamintha umbrosa	3.00	2.08	2.26	2.57	2.96	2.89	2.10
Craniotome furcata	1.00	1.00	0.00	1.14	0.00	0.00	0.00
Cassia mimosoides	7.60	11.45	11.31	11.22	9.45	9.46	8.76
Flemingia sambuense	1.00	1.10	0.00	1.20	0.00	0.00	0.00
Pareitaria debilis	2.00	2.30	3.86	3.18	1.61	0.78	1.45
Desmodium triquetrum	10.00	11.30	14.07	10.74	8.14	8.67	9.40
Begonia picta	3.56	3.30	4.06	4.29	4.40	3.56	3.54
Drosera peltata	6.21	4.30	1.23	0.18	0.16	0.12	0.00
Artemisia parviflora	2.04	2.10	2.35	1.26	0.15	0.34	0.29
Erigeron canadensis	4.00	4.70	3.66	3.78	2.94	2.99	3.44
Polygala abyssinica	1.00	1.50	0.85	0.24	1.89	1.34	2.78
Scrophularia calycina	3.63	1.01	1.13	1.80	1.08	1.34	2.98
Crotalaria sessilifera	1.00	2.00	1.38	2.19	1.90	1.07	1.56
Barlaria cristata	0.00	0.00	1.38	1.89	1.64	1.34	1.60
Centranthera nepalensis	0.00	0.00	1.42	1.47	1.49	1.34	2.20
Fimbristylis miliacea	0.00	0.00	2.15	1.98	0.87	1.34	3.90
Erigeron bonariensis	0.00	0.00	1.53	0.66	0.94	0.90	1.62
Androsace rotundifolia	0.00	0.00	2.63	1.95	1.42	0.90	2.90
Dicanthium annulatum	0.00	0.00	0.00	1.86	2.94	2.34	3.60
Arundinella nepalensis	0.00	0.00	0.00	0.36	1.89	1.67	2.74
Bothriochloa pertusa	0.00	0.00	0.00	0.90	1.90	1.78	2.90
Setaria glauca	0.00	0.00	0.00	1.08	1.25	2.89	3.40
Cyperus compressus	0.00	0.00	0.00	2.40	2.42	2.23	3.20
Fimbristylis ovata	0.00	0.00	0.00	0.48	1.19	1.90	2.84
Cynoglossum zeylanicum	0.00	0.00	0.00	1.20	0.00	0.00	0.00
Valeriana wallichi	0.00	0.00	0.00	1.44	1.96	2.09	2.80
Justicia pubigera	0.00	0.00	0.00	0.93	0.00	0.00	0.00
Polygonum nepalensis	0.00	0.00	0.00	0.84	1.38	1.01	1.03
Cyanotis vaga	0.00	0.00	0.00	1.05	1.06	0.56	1.08
Lindernia sessilis	0.00	0.00	0.00	0.90	1.84	0.34	1.46
Euphorbia hirta	0.00	0.00	0.00	0.21	0.00	0.00	0.00
Zornia gibbosa	0.00	0.00	0.00	1.65	2.94	1.98	2.44
Evolvulus alsinoides	0.00	0.00	0.00	1.86	3.36	2.32	2.14
Justicia simplex	0.00	0.00	0.00	0.42	0.00	0.00	0.82
Lindernia crustacea	0.00	0.00	0.00	1.68	2.74	0.89	1.00
Heteropogon contortus	0.00	0.00	0.00	0.00	3.36	3.98	4.40
Bidens pilosa	0.00	0.00	0.00	0.00	2.96	3.13	2.46
Conyza stricta	0.00	0.00	0.00	0.00	0.00	0.67	1.44
Crotalaria albida	0.00	0.00	0.00	0.00	0.00	0.12	0.24
Arthraxon nudus	0.00	0.00	0.00	0.00	0.00	0.15	0.00
Lespedaza gerardiana	0.00	0.00	0.00	0.00	0.00	0.78	0.00
Antirhinum orontium	0.00	0.00	0.00	0.00	0.00	0.56	0.00
Apluda mutica	0.00	0.00	0.00	0.00	0.00	0.23	1.20
Pacteilis triflora	0.00	0.00	0.00	0.00	0.00	0.00	0.04

Table 10.4: **Comparison of the changes in the IVI of C_4 and C_3 species reported from Balgara (Arah)**							
Species	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Imperata cylindrica	128.45	122.10	121.76	112.74	110.24	108.23	102.24
Chrysopogon serrulatus	21.27	20.10	14.54	11.71	11.05	9.15	9.80
Fimbristylis miliacea			2.15	1.98	0.87	1.34	3.90
Dicanthium annulatum				1.86	2.94	2.34	3.60
Arundinella nepalensis				0.36	1.89	1.67	2.74
Bothriochloa pertusa				0.90	1.90	1.78	2.90
Setaria glauca				1.08	1.25	2.89	3.40
Cyperus compressus				2.40	2.42	2.23	3.20
Heteropogon contortus					3.36	3.98	4.40
Apluda mutica						0.23	1.20
Total IVI C_4 plants	149.72	142.2	138.45	133.03	135.92	133.84	137.38
Total IVI C_3 plants	150.28	157.8	161.55	166.97	164.08	166.16	162.62

Species composition within any ecosystem is strongly influenced by multiple factors, including soil characteristics (Tilman and Wedin 1991), grazing (Rana and Rikhari 1994), and climate (Teeri and Stowe 1976). This investigation provided important information about changes that occur due to overgrazing and land degradation. The dominance of C_4 plant species and their changing status from 1993 to 1999, associated with changes in edaphic characteristics, conforms with other reports, which compared plant community differences in relatively productive and unproductive sites (Piper 1995).

Growth performance of the planted species

Despite land being degraded, the planted species had a high survival rate (more than 90%) and a good growth (Table 10.5). This was evident from the fact that the villagers started to harvest *Grewia optiva (*bhimal*), Bauhinia vahlii, and Thysanolaena maxima* from the fourth year onwards.

Biomass production (natural grass)

Grass production from the site increased many fold during the period (Table 10.6). Before 1993, grass production was negligible due to open grazing and low nutrient and moisture status. A total of 2.7t (worth IRs 4,050) of grass was harvested during the post-monsoon period in 1993, which increased up to 8.9t (worth IRs 17,800) during 1999, (rates correspond to the value of the same quality of grass in the open market in that year).

Green leaves harvested from the planted species also increased from 12 head loads/year (in 1996) to 60 head loads/year (in 1999). The value of green leaves (head load) were also evaluated (Table 10.7) based on the money or butter that the villagers would pay or exchange for a known amount of green leaves of the same quality. Due to this increased grass production, most of the participating families could save up to IRs 1,000 per year, as they did not have to buy grass from other sources during the lean periods. Women's workload was also reduced due to this increased fodder availability from a nearby source.

Table 10.5: **Growth performance (height and girth) of species planted at Balgara**

Species	1993	1994	% change	1995	% change	1996	% change	1997	% change	1998	% change	1999	% change
Quercus incana													
Diameter (mm)	7.36	10.14	37.6	13.17	29.38	20.05	52.24	29.27	46	29.72	1.53	32.4	9.09
Height (cm)	12.3	29.9	143	62.36	108.56	112.8	80.8	142.4	26	175	22.8	204	15.57
Quercus glauca													
Diameter (mm)	7.31	9.49	29.82	13.04	37.41	21.29	53.26	31.28	46	33.45	6.93	35.4	5.8
Height (cm)	19.5	38.1	95.3	80.33	110.34	181.5	125.9	189	4	220	16.4	269	22.27
Grewia optiva													
Diameter (mm)	5.16	11.36	120.15	19.52	71.33	36.83	39.68	43.7	18	47.11	7.8	54.9	16.56
Height (cm)*	23.4	80	181.89	159.93	99.91	300.34	36.51	329.57	9	400	21.37	320*	
Ficus macrophylla													
Diameter (mm)	8.91	13.01	46.01	18.98	46.38	21.04	10.85	24.65	17	28.91	17.28	36	24.56
Height (cm)	21	40	9.04	69.14	72.35	90.31	30.62	173	91	210	21.8	248	18.09
Ficus nemoralis													
Diameter (mm)	10.13	15.48	52.81	21.73	40.56	35.65	52.68	38.25	8	41.24	7.81	45.6	10.6
Height (cm)	24.9	58	133.33	92	58.34	154	67.74	215	39	240	11.63	267	23.75
Debregeasia longifolia													
Diameter (mm)	9.21	13.41	45.6	20.26	51.09	31.68	57.84	40	26	51.9	22.92	67.34	29.17
Height (cm)	25.1	60	139.04	100.42	67.36	152	51.36	177.5	16	245	38.02	305	24.48
Ougeinia dalbergioides													
Diameter (mm)	7.19	14.23	97.91	18.72	31.55	23.35	24.73	26.78	14	37.08	38.46	45.8	23.46
Height (cm)	25.3	52	105.53	91.89	76.71	140	52.36	192.3	37	200	4.04	232	16
Bauhinia retusa													
Diameter (mm)	8.1	17.25	112.9	24.87	48.01	29.22	18.44	34.76	18	35.49	2.1	49.3	38.87
Height (cm)*	40	79.5	98.75		88.05	266	71.24	359.66	44	460	21.73	370*	
Albizia lebbeck													
Diameter (mm)	6.62	12.19	84.14	19.01	55.94	21.42	12.67	29.1	35	34.01	16.87	36.8	8.2
Height (cm)	36	69.5	93.05	143.5	106.47	181.75	26.65	230.13	10	240	19.92	286	19.16
Dalbergia sissoo													
Diameter (mm)	8.42	13.67	62.35	22.83	65.54	39.83	76	47.87	20	49.28	2.94	54.09	9.71
Height (cm)	30.5	102.1	234.74	207.36	103.09	312.33	50.62	336	7	372	10.71	437	17.47
Thysanolaena maxima													
Diameter (mm)						7.01		7.96	13	8.01	0.63	8.56	6.86
Height (cm)						90.11		95.23	5	140	47.9	147	5
Dendrocalamus													
Diameter (mm)										35.01		38	8.54
Height (cm)										465		513	3.63

* These species were lopped, a traditional practice.

Table 10.6: **Natural grass biomass (dry weight) at the rehabilitation site (Balgara)**			
Year	**Quantity (t) ***	**Rate/t (IRs)****	**Total amount (IRs)**
1993	2.7	1,500	4,050
1994	4.8	1,500	7,200
1995	6.4	1,800	11,520
1996	7.8	1,850	14,430
1997	8.4	2,000	16,800
1998	8.8	2,000	17,600
1999	8.9	2,000	17,800
*Average weight of a heap is 300 kg; **Rate of dry grass fixed by the community; in 1993 US$ 1 = IRs 31, in 1999 US$1 = IRs 43			

Table 10.7: **Green grass from planted species (leaves of *Grewia, Bauhinia*, and *Thysanolaena*) harvested by the farmers**			
Year	**Quantity (head loads)**	**Value (IRs)/head load (equivalent to 1 kg butter)**	**Total value* (IRs)**
1996	12	140	1,680
1997	17	140	2,380
1998	45	150	6,750
1999	60	150	9,000
* Value calculated as per the traditional market system			

Impact on rural livelihoods

The programme was assessed on the basis of the sustainable livelihood (SL) framework (Scoones 1998; Turton 2000). The participatory rehabilitation activities had implications for all the five types of assets defined in the SL framework.

Human capital

The capacity and knowledge of the Van Panchayat and the villagers – including women – belonging to Arah as well as other villages of the Gurur-Ganga Watershed, in terms of new approaches to efficient land and water management, were increased. Similar approaches and technologies have been replicated by many other villages, for example, Khaderiya, Doba, and Majherchaura (Kothyari et al. 2001, 2002).

Social capital

In 1996 the villagers formed a society comprising women and men of different ages for the management and monitoring of the site.

Financial capital

A fund was established at the post office (Arah) by the participating households for the maintenance of the site and for raising a nursery of preferential species. In 1997, about 40 households bought saplings of quality fodder species from the nursery for planting on their private land. Further, a survey conducted in 1999 showed that on average each participating household saved up to IRs 1,000 by purchasing less fodder from the market.

Natural capital
There was a significant increase in plant and microbial biodiversity, and in soil fertility. Soil erosion and water run-off was reduced. Due to increased availability of quality fodder, the productivity of livestock was higher; in 1999 the total amount of milk being sold from Arah through 'Parag' was about 120 l/day, as compared to about 20 l/day in 1993.

Physical capital
About 9 ha of degraded land was rehabilitated.

Other impacts

The project provided important feedback to the main executing agency (ICIMOD) and its regional partners (for example, GBPIHED) for developing guidelines and policy-related briefs for enabling effective land utilisation practices in the Hindu Kush-Himalayas. The project findings also gave field-based information about the causes and impacts of land degradation in mountain ecosystems, which helped in the formulation of a regional watershed project for the mountains of the Hindu Kush-Himalayas (PARDYP).

Conclusions

In recent years India, including Uttaranchal, has looked to watershed development as a way to realise its hopes for sustaining natural resources and improving the livelihood of rural communities. In the Central Himalayan region, the failure of afforestation and reforestation efforts on degraded land, a vital component of any mountain watershed, is attributed to wrong policies, which ignore people's essential needs and hence leads to their non-cooperation. This assessment showed that by taking a participatory approach, rehabilitation of degraded lands in the region, and elsewhere, has the potential to create conditions conducive to enhanced rural livelihoods, while conserving natural resources.

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