MAN AND ENVIRONMENT : THE CENTRAL HIMALAYAN CASE

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ABSTRACT

The effect of man as modifier of the mountain ecosystems and the way he himself is being affected by the modified ecosystem has been described in context of the Central Himalaya. The production in the agro-ecosystems is largely at the expense of the adjacent forest ecosystems. The forest management atleast in the past has not taken into account the considerations of protective role of forests. The results are that: (i) area under forest with adequate crown-density is negligible, (ii) forests over large areas have become even-aged and predominately of one or two shade-intolerant species, (iii) accelerated landslides have resulted in increased movements of silt and floods down stream. These forms of degradation have been intensified rather than checked by various "developmental activities."

KEY-WORDS

Environment, Ecosystems, Himalayas.

INTRODUCTION

The Himalayan ranges extending in a broad arc over Pakistan, India, Nepal, Bhutan and China are among the youngest mountain systems of the world. They are supposed to have arisen from Tethys sea as a result of several successive impulses of upheaval occurring in a time span of 30-40 million years, from Oligocene to late Pleistocene. According to some geologists, the collision of the Indian Plate with the Asian Plate towards the end of the Cretaceous period and consequent underthrusting of the Indian Plate, is involved in the rise of Himalaya. Geologically, four longitudinal belts are evident (JHINGRAN, 1981); The Siwalik belt forming the southern most part of the Himalaya and flanking the Indo-Gangetic plains; Lesser Himalaya lying immediately to the north of the Main Boundary Fault where the Siwalik belt ends; Central Crystallines lying to the north of the Lesser Himalaya and separated from it by the Main Central Thrust; and Tethyan Himalaya situated north of the Central Crystallines and containing several glaciers. The topography in most parts, is dissected with deep valleys and high ridges. The Central Himalaya (Uttar Pradesh Himalaya and Nepal) shares the characters of both the flanking regions, namely western and eastern Himalaya with respect to climate, vegetation and possibly cultural attributes of the human beings. This paper primarily deals with: (i) environmental background of the Central Himalaya, (ii) effects of man, the modifier, on various ecosystems of this region, and (iii) effects of the modified resource environment on the man himself.

ENVIRONMENTAL BACKGROUND

Physical : Varying in elevation from about 250 m at the base to peaks ranging above 8000 m, this mountain range acts as a climatic divide exercising a controlling influence on the meteorological conditions over the Indian subcontinent to the south and the Central Asian highland to the north. The climate changes largely with altitude, being tropical to subtropical upto about 1000 m, monsoon warm temperate between 1000 m and 2000 m, monsoon temperate between 2000 m and 2500m, cool temperate between 2500 to 4000 m and arctic at still higher elevations, with permanent snowline at about 5400 m. Mean temperature declines at an average rate of 1°C for every 270 m rise in elevation, the decline being steeper and more rapid above 1500 m altitude. Severe frosts are usual from December to February and they occur even in lower valleys down to 1200 m. The basic patterns of weather and climate are governed by summer and winter monsoon systems of Asia (MANI, 1981). There are four main seasons : pre-monsoon or summer (March-mid June), monsoon (mid June-mid September), post-monsoon (mid September-November), and winter (December-February). The monsoon season accounts for 75-85% of the annual rainfall, which in outer ranges is seldom below 1000 mm and occasionally exceeds 2000 mm. The summer and monsoon seasons are more prolonged in the Eastern Himalaya and the winter season in the Western Himalaya. The situation is intermediate in the Central Himalaya. In winter the snow accumulates around the high peaks and the snow-line comes down to 2500 m in the western and 3000 m in the eastern Himalaya. Mean monthly temperature ranges from less than 2°C (January) to 24.4°C (June) and annual rainfall from 900 to more than 3000 mm.

The region is traversed by a number of river systems: the Bhagirathi and the Alaknanda, which meet in lower elevations to form the river Ganga in Garhwal, Pinder and Kali in Kumaun, and the latter, and Ghaghar and Gandak in western and central Nepal are some of the major ones. In general, these rivers cut deep gorges across the rocks and drain down coarse particles, pebbles and stones in narrow submontane zone (BHABAR), where they subside to reappear subsequently to form wet, often marshy zone of plains (TARAI). The marshy and malarial belt of tarai has been the main barrier between the mountains of the Central region and the vast Indo-Gangetic plains until mid-1950s, when agriculture became possible. The width of tarai belt tends to decline from east to west, which possibly explains the presence of larger human settlements in bhabar belt of western part than in the eastern part during the past centuries.

Biotic : In conformity with the changes in the altitude and climate, the Central region (about 51×10^3 km^2 within India) supports a great variety of forests: tropical and subtropical broadleaf forests at elevations below 1200 m, pine forests at elevations between 1000 and 2200 m, moist temperate evergreen broadleaf and mixed coniferous forests between 1500 m and 3500 m, and subalpine forests around 3500 m. The timber line occurs at about 3600 m. The broadleaf sal (*Shorea robusta*) which has pronounced dominance below 800 m, begins to be replaced by pine (*Pinus roxburghii*) above 1000 m. The altitudinal belt 800-1000 m is a tension zone where a mixture of broadleaf species such as *Holoptelea integrifolia, Mallotus philippensis, Ehretia laevis*, and *Terminalia tomentosa* gain local preponderance forming mixed broadleaf forests but retaining *Shorea robusta* in varying proportions. *Pinus roxburghii* has maximum expression between 1000-2000 m and tends to form pure forests. Within this altitudinal belt, however, other forest types, such as pine-mixed broadleaf (*P. roxburghii, Myrica sapida, Syzygium cumini, Engelhardtia spicata, Quercus leucotrichophora*), low altitude mixed oak (*Quercus leucotrichophora, Lyonia ovalifolia, Bauhinia retusa, Rhododendron arboreum*), and oak (*Q. leucotrichophora, R. arboreum, L. ovalifolia, Aesculus indica*) are also present. Much of the area now occupied by the pine forest was once covered with the potential natural vegetation of oak (CHAMPION & SETH 1968). Around 1900 m *Q. leucotrichophora* establishes dominance and gradually gives way to *Quercus floribunda* and *Quercus lanuginosa* which form pure or mixed forests between 2000-2500 m. The high altitude oak, *Quercus semecarpifolia* begins to appear around 2400 m and approaches the timber line where it is replaced by *Betula utilis*. Conifers such as *Pinus wallichiana, Cupressus torulosa*, *Cedrus deodara*, *Picea smithiana*, and *Abies pindrow* are locally important forming pure or mixed patches above 2300 m. However, *C. deodara* forms extensive forests in western part (Garhwal) and declines in importance eastward. The subalpine stunted forests contain *Abies spectabilis*, *Betula utilis*, *Rhododendron campanulatum* and *Juniperus wallichiana*.

The population of the Indian Central Himalaya was 3.81×10^6 in 1971 and it increased to 4.81×10^6 in 1981 (ANONYMOUS, 1981). Thus the increase was at a compound rate of about 2.28%/year (SHAH 1982). About 82% of the population is rural with 90% of them being engaged in agriculture. The density of population averages 89 persons/km² and is highest (120-150 persons/km²) between 600-1800 m elevations. About 42% people are in the age group of less than 15 years and 52%in the age group of 15-59 years.

Farming systems: There are three basic farming systems; all are livestock-based and represent specific human answers to problems of climate, topography and resource base. These are, livestock farming, mix livestock-crop farming and mix crop-livestock farming; representing respectively, three different ways of life, nomadism, semi-nomadism and settled agriculture. The nomads, exemplified by *Gujjars*, have no permanent land base, their huts are scattered in high valleys where they stay in summer to graze their cattle in the lush, high altitude meadows and migrate with their herds to lower elevations in winter (BOSE, 1972). The semi-nomadic way of life is exemplified by *Gaddis*, whose permanent villages are located in the valley bottoms where they engage in agriculture. During summer, while their women and children remain behind in the villages, men roam with their sheep and goats in the higher meadows and return to the villages with the onset of winter (BOSE, 1972). A somewhat similar interseasonal, trans-elevational migration is also practiced by the *Bhotias* (BHANDARI, 1981). The crops grown by these semi-nomadic high altitude farmers are mostly pseudo-cereals (*Amaranthus* spp., *Fagopyrum esculentum*, *F. tatricum*), hulless barley (*Hordeum himalense*), and some potato (*Solanum tuberosum*) and wheat (*Triticum vulgare*).

The settled agriculture is most common between 1000-2500 m elevations. The farming is still cattle-based. A majority of cultivation is rainfed. Cropping intensity varies from three crops/year in irrigated fields to three crops per two successive years in rainfed fields. Among cereals, finger millet (*Eleusine coracana*), maize (*Zea mays*), paddy (*Oryza sativa* var. *indica*) and what are most common and among vegetables, potato is the most prevalent crop. In this region there may be 17.6 people per ha of cultivated land compared to 2.3-5.8 in the rest of the State of Uttar Pradesh (*Moddie*, 1981). Consequently, this altitudinal range (1000- 2500 m), also called the middle mountains, has experienced most severe ecologial degradation. In this article we will specifically deal with the middle mountain situation.

From time immemorial the hill population has been using the forest resources freely for its subsistence economy, the agriculture being the predominant part of it, although the practice of iron smelting and other small-scale economic activities were also known (TUCKER, 1983). Occasionally such activities used to breakdown under the military stress of Gurkhas and Rohillas. With the advent of the British Colonial System around 1820_s the agriculture area increased, and the practice of converting waste lands into agricultural land began and continued till the present. However, the interests of the organized forestry, under which reserved forests were established one-by-one (from 1880_S to mid-1910_S) and forests were exploited commercially, conflicted with the traditional interests of the people in the forest resources. Consequently a keen socio-political struggle developed between the people and the Forest Department of the State.

Agricultural production and its linkages with forest ecosystems: A case study of the agricultural production in a village, Mehragaon, located at 1450 m in Kumaun Himalaya indicates how the hill agriculture is largely dependent on the adjacent forest ecosystems (PANDEY & SINGH, 1984). In this village rain-fed crops are raised without any input of fertilizers and in a very inefficient way (Table I), for the output: input ratios are merely 0.55 and 0.18, respectively for wheat-maize and fallow-pulses cropping patterns. On average about 4 units are expended to obtain one unit of agronomic energy. And the total usable units are far less than the minimum required to support the human population. Consequently the minimum import of supplementary food amounts to 227.75×10^6 KJ per yr per ha of cultivated land. However, the actual import of foodstuffs is probably twice as much. Because of this shortage, a phenomenon called "money-order economy" has developed in the hills. It involves temporary emigration of a significant proportion of male population to other areas, and sending back of a part of their earnings to the members left in villages for the import of foodgrain and other necessities of life. Possibly this pattern started around 1950_s when after the establishment of the British Colonial System the road net-work improved.

The major portion of the input in this agronomic production is in the form of manure which is largely derived from the adjacent forests. The animals which are mainly kept for manure, (for example, bullocks work for only 30-45 days against more than 100 days in plains) derive (through grazing or stall-feeding) upto 87% of their energy requirements from the forests, the rest being met from the agro-ecosystem itself.

Table I. Some characteristics of agronomic production in village Mehragaon, Kumaun Himalaya (data from Pandey and Singh 1984).

General features :

Latitude	Longitude	Altitude (m)	Cultivated area (ha)	Human population	Livestock population
29° 23′ N	79° 33′ E	1,450	100	800	410

Energy input and output (The values are in $\times 10^6$ KJ per ha per yr) :

	Wheat-maize (November-June)	Fallow-pulses (June-October)	Average
Input			
Human labour	24.07	12.53	18.30
Bullock labour	13.09	5.82	9.46
Seed	31.32	6.00	18.66
Manure	688.14	344.07	516.11
Fertilizer	0	0	0
Total	756.62	368.42	562.53
Output			
Crop Production	224.66	51.62	138.14
By-products	194.60	14.54	104.57
Total	419.26	66.16	242.71
Output: Input ratio	0.55	0.18	

In addition, the dependence on forest ecosystem is for the requirement of wood fuel, which is $735.84 \times 10_s$ KJ per yr per ha of cultivated land. If to this were added the energy derived as fodder, each unit of agronomic production will entail an expenditure of about 8.5 units of energy from the surrounding forests. If only forest-floor herbage were to be used as fodder 16.7 ha of forest land would be required to support one ha of cultivated land. Similarly if only natural wood-fall were used for fuel-wood, 5.8 ha of well stocked forest would be required for each ha of cultivation. Thus the 100 ha of cultivation in Mehragaon will require about 1700 ha of well stocked forest for a sustained supply of fodder and fuel.

Commercial exploitation of forests : Table II contains a chronological summary of major phases of commercial forest exploitation, the economic activities which necessitated the exploitation of particular timber species, forest management practices and impact of these on forest structure. Following points become evident.

1. The chronology of exploitation of timber species was largely influenced by the accessability, however, the demand of the prevalent economic activities often proved to be ascendant force. For example, sal (*Shorea robusta*), a species of submontane zone was the first major species to be commercially exploited for the construction activities. However, the necessity of sleepers for the railways during 1860_s-1890_s resulted in the exploitation of deodar (*Cedrus deodara*) from remote areas of higher elevations (over 2000 m). By that time the stock of sal had depleted considerably.

2. Most of the commercial exploitation in the last one and one-half century centered upon three species, viz.; sal, deodar and chir-pine (*Pinus roxburghii*). These species make pure forests or such forests in which they share predominance. Out of these, chir-pine is an early successional species and the other two are late successionals. All the three species were over-exploited at one time or the other.

3. The sal was largely over-exploited during the pre-railway era when organized forestry had not been established, hence, its exploitation was unregulated. It was over-exploited further under the pressure of early-railways-era and military demand of the two world wars. Deodar's over-exploitation occurred when sal became inadequate to meet the demand of railway sleepers. Chir-pine was not exploited until the improved technology for resin processing was made available in the beginning of the 20th century. This species too could not escape over-exploitation particularly during the post-independence period.

4. While the regeneration of sal and deodar could not be revived adequately by silvicultural practices evolved under the organized forestry as they were late successional species, it was easier to regenerate the early successional species chir-pine.

5. The objectives of establishing the reserved forests, that they would ensure the regular, and long-term supply of commercial timber and that they would become the permanent forest cover of the hills could not be achieved. For not only the multistratal oldgrowth forests, particularly of oaks, were transformed into simpler forests, particularly of chir-pine, several reserves were transfrormed into shrub and grasslands as time elapsed.

6. Apart from over-exploitation of forests before the advent of organized forestry, under the pressure of railway and military demands, sharp increase in the revenue of Forest Department indicates that the forests were exploited after independence, at greater scale than that which would have been appropriate for their perpetuation.

7. It was not possibleto estimate the rate at which village forests (all the forest types which villages could use) became inadequate to meet the demand of subsistence economy of the villagers. It appears that they became inadequate by the beginning of the 20th century, when most of the forests in the hills had been categorized as reserved. This led

Table II. A chronological summary of major events in forest exploitation and related socio-economic and technological conditions in the Central Himalaya (based on Stebbing 1922-23; Champion and Osmaston 1962, Madras Group 1983 a, b; Tucker 1983; Singh, Pandey and Tiwari 1984; Forest Working Plans; Personal observations).

Phases	Relevant technologies and resultant economic activities	Technologies for use of forest resources and social aspects	Species exploitation and forest management	Effect on forest resources
1	2	3	4	5
Pre-British period: before 1816 in Kumaun division; before 1849 in parts of Punjab coal.	Age-old agriculture based on forest resources; house construction; iron smelting charcoaling mining, etc. at subsistence level.	Technologies of cottage industry-size. Normal subsistence economy, broken occassionally under the military pressure of Gurkhas and Rohillas.	Oak and other broadleaf species for fodder, fuel, agricultural tools, house construction etc.; chir-pine for charcoaling. Theoretically the king-owned forests, in practice villagers exploited in order to maintain subsistence economy; no demarcation of ownership, kings' use minimal.	No marked effect, plenty of resources available for subsistence ecomomy.
British Colonial System: pre-railway era till around 1860.	*Plains:* expansion of agriculture due to construction of canal networks and cultivation of cash crops even for export, expansion of cities. Creation of urban markets. *Hills:* introduction of localized tea gardens, and expansion of agriculture in central and outer Himalaya. Mining mostly in Siwaliks; import of iron processed from England with opening of Suez Canal in 1869 destroyed iron smelting in hills.	Down-river transportation; British system of charcoaling for smelting iron, copper etc. Villagers motivated to plough more waste-lands and forests and depopulated villages rehabitated; kings used forests and source of rewards for courtiers as army personenl.	Heavy exploitation of sal and initiation of deodar exploitation by British contractors. Uncontrolled and unclassified felling for timber transportation to plains, forest resources thought inexhaustible, therefore, no preservation.	Sal and other broadleaf species exploited at large scale during 1840-1850, and regenerations weakened.
Railway Building era mid 1860s-1890s.	Use of steam engines; building of railway lines; construction of coaches; improvements of road network; limited expansion of	Creosoting system designed for the use of soft-wood conifer timber for railway sleepers, but proved unusable.	Sal, deodar, mostly for railway sleepers. First IG of forest appointed in 1865 and control of forest resources started; variety of	Deodar over-exploited and regeneration weakened.

	tea gardens in Western Himalaya but very extensive in eastern Himalaya.	Few contractors became wealthy because of timber trade. Skillled (e. g. Sawyears of foothills of Punjab) and unskilled labour forces developed; two-way shift in labour forces; outside labour included, Nepalese, Beharies and east U. P. labour.	harvesting and marketing arrangement s developed with private contractors, division of forests for management stand point; forest boundaries, compartments etc. marked; disputes negotiated.	
Beginning of 20th century through Ist world war upto 1920s	Gun power, improved communication, energy concentration and spurt in military demand.	Improved technology for the use of chir-pine resin, development of technologies at FRI for better poles for gun carriages, stock for army rifels, parts for aeroplanes, etc. Large scale army recruitment, immediately after the war relation between hill people and forest department worsened; non cooperation movement against restrictive forest laws; issue of forest politicized.	Chir pine and several species even those found rather infrequently; Establishment of reserves completed; uncontrolled felling of any accessible tree species under the pressure of war.	Forests available to villagers become inadequate for their subsistence, large scale deliberate burning of forests by the people. Further deterioration in the forest stocks.
Between two world wars	Improved road network: growth in sugar industries; improvement in war technologies-use of aeroplanes; greater concentration of energy in a few countires.	None significant expept for plywood. More politicized relations between the Forest Department and the people; army recruitments, more out-migraation.	Increased use of chir pine, over-exploitation of any species to meet the military demand. Controlled burning in chir pine at larger scale.	Further deterioration in the forest stocks.
Post-independence until 1950s	Expansion of construction works due to rapid urbanization; large sized hydroelectric project; transformation of tarai into agricultural land and subsequent expansion of human settlements across tarai into Bhabar belt; enormous growth in road network in hills and tourism activity; military establishment up to borders.	None significant. Further increase in outmigration for settled in Bhabar, women very hard pressed because of scarcity of fodder and fuel; use of grovernment aid without any perceptible improvement; mushroom growth of nongovernment organizations with or without vested interests.	All the materials available, including *Lantana camara*, an obnoxios weed for fuel. Beginning of the introduction of exotic species, partial replacement of sal by teak and *Eucaylptus*; emphasis an control of soil eroosion, Van-Mahotsav; forest co-operatives for felling and utilization.	Transformation of some originally oak forests, into chir pine forests, degradation of some reserved forests into shrubs and grasslands; even high mountain sub-alpine and alpine vegetation disturbed; good forest cover reduced to 4.4% of the total area.

Table II—(*Contd.*)

1	2	3	4	5
Present 1970s and thereafter	As above.	Forest problems became matter of concern for ecologists, social workers, politicians and administrators; Chipko movement, emergence of the centres of study on forest management, and forest ecology beyond the control of Forest Department; establishment of Central Department of Environment; beginning of cases of physical assaults on foresters.	Initiation of social forestry, control on forest department in the management of forests; blanket-ban on felling of trees above about 1300 m; beginning of the exotic pines; harvest of first plantations of *Eucalyptus* spp., Replacement of contractor system for the tree cutting by the corporation system; ban on oak felling.	As above.

to a keen and perpetual struggle between the people and the Forest Department,and politicised movements against the restrictions on the use of forest resources were launched by the people in different parts of the Central Himalaya. The latest being the "Chipko Andolan". In the forest available to villagers no silvicultural practices were used before Independence, and after Independence only a few attempts, albeit unsuccessful, were made to revive them.

8. There are evidences to indicate that a number of broadleaf species, particularly oaks (*Qeurcus* spp.), which supported the subsistence economy of the villages, were disfavoured under the organised forestry, and commercial species particularly pine and deodar were promoted through protection and plantation. Instances are there to indicate that activities such as lopping and girdling of oaks were allowed even in reserved forests so that the conifers could preponder in the original oak forests (Guha, 1983). The Forest Research Institute, Dehradun right from the beginning was mainly concerned with improving the products of commercial uses. If the research papers published by the personnel of the Forest Department were any indicative of the policy, it is apparent that most of the emphasis was on the revival of sal and deodar in the earlier phase and that of spruce and fir (species of higher elevations), commercially exploited after independence, in the later phase. Almost all research papers on regeneration, available to the authors were related to these commercial species rather than oaks and other broadleaf species.

Currently a situation has reached when it has became difficult to plant any species and to save the forest resources under the increased biotic stress and it appears that things have gone beyond the control of the present administrative and socio-economic system as far as the revival of the vegetal cover in the Himalaya is concerned.

OTHER MODIFYING FACTORS

Apart from the two major forces of biotic pressure, tea plantations, mining and road-building have also played a significant role in destroying the original habitats in the Himalaya. In Central Himalaya, the tea plantation has been practiced at much lower scale than in the eastern Himalaya. However, as early as 1840_s entrepreneurs began speculating on tea plantation in the outer hills of the Central Himalaya (Tucker, 1983). Dehradun in Garhwal and Berinag in Kumaun became the main centres, and by 1911 a total of 6,880 ha were under the tea bushes. No other plantation crop even approximated that extent before Independence (Tucker, 1983). Although tea plantation did not progress as the planners had envisaged, it destructed the forest habitats substantially.

Mining destructs the vegetal cover both directly by destroying the habitat and by consuming the wood fuel from the forests. In this part of the Himalaya the people have been quarrying slates for their roofs and building-stones from the time immemorial. Iron-smelting, which required charcoal was well developed in Kumaun and Garhwal before the establishment of the British Colonial System. However, the import of cheaper iron and the unavailability of easy supply of chir-pine wood fuel gradually led to the abandonment of this cottage industry.

During the post-independence period, limestone-mining flourished throughout the Himalayan region, and in 1977 about 25% of the total mines of India were in these mountains (Negi, 1982). Apart from limestone, magnesite and phosphorite exploitations are significant. And in 1978, nearly 5000 ha area was under mining lease in Uttar Pradesh Himalaya (Negi, 1982).

These mining activities do not involve massive consumption of wood fuel, but they directly destroy the forests and trigger a host of environmental problems, such as, enrichment of waterways with one or other chemicals which destroy biotic life of water bodies adapted to the original water conditions. Mineral transports render the vegetated areas vulnerable to road construction activities, and to the activities related to temporary human settlements in the adjacent areas. Quarrying of limestone releases CO_2, thus increasing the level of atmospheric CO_2 further.

Soil loss : These young mountains which continue to rise, are susceptible to land-slips and soil erosion even without the interference of man, because of high energy environment. However, man accelerates this by his one or other modifying activities such as, deforestation, road and dam construction etc. It is estimated that the current rates of erosion in the Himalayan catchments are five times greater than those prevailing in the geological past (K. S. VALDIYA, PERS. COMM.).

Recently, SINGH, PANDEY & PATHAK (1983), suggested that the Himalayan catchments are subsurface-flow systems and that the major pathway of soil loss from them is by landslide i.e., the sudden detachment of bodies of soil, with or without rock and their movement down the slope. Results from as many as 13 sites, located in the Kumaun Himalaya indicated (i) that the overland flow accounted for an insignificant (0.3-1.3%) part of the rainfall, and the soil loss through siltation varied between 14-81 kg ha^1 , at 10 of the sites it being 40 kg or less; and (ii) generally the values for overland flow and sediment output were higher for the non-forested than for the forested sites. Because these are subsurface flow systems with shallow soil-cover, and in large areas rocks are soft and rapidly weathering, it was suggested that the hills are very prone to landslides. They (SINGH, PANDEY & PATHAK, 1983) emphasized that the actions which generate large quantities of overland flow (e.g. roads and deforestation) are to be evaluated for their impact cautiously. Road construction may impede the lateral downslope subsurface flow, lead to its explosive emergence, to over-saturation of the soil and to subsequent landslide. Further, it may obliterate the springs, particularly in areas devoid of forest cover, where deeper root channels are scarce. Such causes result in massive sediment load of the Himalayan rivers and are largely responsible for the siltation of the reservoirs and natural water bodies (Table III).

Table III. Sediment data for some Himalayan Reservoirs (Anonymous 1974)

Reservoir (Related River)	Year of impounding	Catchment areas (km^2)	Rate of sedimentation ha m/100 km^2 /yr		Percent loss of capacities upto 1975	
			Assumed	Observed	Total	Annual
Mayurakshi (Mayuralr R.)	1955	1792	3.57	16.43	10.24	0.50
Bhakra (Sutlej R.)	1959	56876	4.29	6.14	5.60	0.65
Beas Unit (Sutlej R.)	1974	6825	4.29	14.29	0.25	0.13
Tehri (Bhagirathi R.)	—	7511	—	—	—	—

Eutrophication of lakes : The lake town of Naini Tal has been one of the most important tourist centres of the Himalya. Apart from the most well known lake, Naini Tal, numerous lakes are located in this part of Kumaun Himalaya (as many as 60 in the past, ATKINSON 1882), of which two major ones are Bhim Tal and Naukuchiya Tal. During 1968-1972, on average about 0.36 million tourists visited Naini Tal, and some of them temporarily visited the adjacent two lakes also. Obviously, these lakes are of great economic importance to the local economy. However, the lake Naini Tal is rapidly losing its aesthetic values, as a result of increasing level of eutrophication. SINGH *et al.* (1982), showed that the level of eutrophication in these major lakes, was directly proportional to the size of the effective population (permanent plus tourist population) of their catchment. Thus, Naini Tal lake is characterized by near-opaque water, restriction of autotrophic activity to a narrow sheet of water (5 m deep), a NO_3-N level indicating exceptionally high loading of wastes, frequent algal blooms and high between-month beta-diversity of phytoplankton, high community respiration relative to net production, preponderance of pollution-philic submergent species, *Potamogeton pectinatus*, and relatively greater biomass of copepods in zooplankton community. All these features are attributed to a highly eutrophic water body. In contrast, Naukuchiya Tal shows all the characters of an oligotrophic water body: high transparency, low bicarbonates and NO_3-N levels, preponderance of diatoms in relatively small phytoplankton population, low between-month beta-diversity of phytoplankton, colonization of exceptionally great water depths by macrophytes etc.

The Bhim Tal lake is a mesotrophic one, sharing the characters intermediate between the sets of characters described for the afore-cited two lakes.

STRATEGIES FOR ENVIRONMENTAL REVIVAL

It is evident from the foregoing that the age-old dependence of the hill agriculture on forest resources, over-exploitation of forests under the commercial demand and several other activities such as road and dam construction, mining, etc. have caused severe depletion of forest cover in the hills, so much so, that area under well-stocked forest is below 5% of the total areas. Further, over large areas the original forest structure has been modified to a form which has lesser protective roles and is not compatible with the needs of the villagers. For example, broadleaf species used for fodder are increasingly replaced by conifers and other sundemanding species and oldgrowth forests are becoming scarcer and scarcer (SINGH & SINGH, 1984). It is becoming increasingly difficult to stem the rate of deterioration, leave aside the initiation of revival of the vegetal cover. Assuming that the dependency of agriculture on forests in Mehragaon is typical of Uttar Pradesh hills, we calculate that for about 0.6 million ha (actual value 591513 ha) net area sown, about 10 million area of well-stocked forest would be required. However, the area of forests available to the villagers is merely about 0.9 million ha, i.e. each hactare of cultivation will have to depend on 1.5 ha of poorly-stocked forests (forests other than those under the control of the Forest Department). Obviously, the forest area available for the agriculture has been too small, consequently not only these forests were decimated in most areas, the pressure on reserved forests (managed by the Forest Department) increased with the lapse of time. The reserved forests (about 2.4 million ha), which account for 78.8% of the total forest area (about 3.25 million ha,), and about 38% of the total area of Uttar Pradesh Himalaya (GUPTA, 1983), were supposed to provide the permanent biomass cover, apart from providing the materials of commerce. However, only 4.4% of the total hill area (SINGH, PANDEY & TIWARI, 1984), which would account for 9% of the area under reserved forests, have crown-density more than 60%. This comes out to be only about 0.229 million ha.

Even if all the forest resources were to be used to support the agriculture, only about 4 ha forest instead of 17 ha, the required sustainable size, would be available. And most of it is poorly stocked. Singh, Pandey & Tiwari (1984) have estimated that 1.33 ha forest is available per ha of agricultural land. Thus despite the best form of the forest management the hill agriculture of the present size, perhaps, cannot be maintained without the continuous depletion of the forest resources. It is doubtful that this type of agriculture could be sustained for long, even if all the lands, other than under cultivation, were under well-stocked forests.

Thus, there is case for replacing the present agricultural pattern, which is capable of producing foodgrains sufficient only for about half of the year for the hill population, and which is not sustainable for long even if all the forest resources were to be utilized.

The farm forestry alongwith a minimal level of animal husbandary can make a viable alternative, provided a substantial amount of foodgrains is made available to the hill people as subsidy initially. The hill people in return may allow the revival of reserved forests, as a consequence of which the water bodies of plains may receive reduced levels of sediments and floods.

However, the commercial exploitation of forests must also be restrained, keeping in view the ecological constrains so that not only the density of cover is maintained, the desired species composition is also revived.

In order to adopt this model, the entire system, including administrative, legal and developmental components need to be retuned accordingly. All forests other than reserves would be put under private farm forestry with the help of know-how of various developmental agencies.

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