correlated with the enhancement of gap junctional cell-to-cell communication in cultured mouse fibroblasts[26–28] and with parallel up-regulation of the connexin 43 gene[29,30]. Accordingly, it is worth investigating the role of gap junctional cell-to-cell communication and connexin 43 gene during chemoprevention by carotenoids. Further study is in progress from this point of view.

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GIS and remote sensing-based study of the reservoir-induced land-use/land-cover changes in the catchment of Tehri dam in Garhwal Himalaya, Uttaranchal (India)

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Large dams, though necessary for national growth, adversely affect the life-support strategy of a large number of people living in the submergence zone and the hinterland of the reservoir. With the help of GIS-based techniques and land-use/land-cover map prepared with the help of satellite remote sensing tools, it is estimated that the Tehri reservoir in the upper catchment of Ganga river would directly affect 2687 ha of agricultural land and another 3347 ha around the reservoir rim would be rendered unfit for cultivation.

THE importance of water resources has increased with industrialization and growth of population, as these are needed for sustaining crop productivity, meeting the ever-increasing needs of the domestic, industrial and power sector. Dams are therefore being constructed for harnessing water resources.

The Himalayan terrain provides cost-effective conditions for dam construction – deep gorges with wide valleys on the upstream; but the inherent fragility and proneness of the terrain to seismic tremors is the bone of contention between environmentalists and policy implementers. Whatever the concerns, water resources need to be tapped because, despite being endowed with vast land and water resources, India faces severe scarcity of water in relation to agriculture, municipal and industrial needs, as also for power generation.

The present study concentrates upon the reservoir rim area of Tehri dam that is coming up in the catchment of Ganga river a little downstream of the confluence of Bhaghirathi and Bhilanganga rivers (Figure 1). The Tehri dam site is located in a narrow and deep gorge (Figure 2) and has a wide valley with extensive fluvial terraces on the upstream side. Work on this dam started in 1978 and is envisaged to produce 2000 MW of electricity, besides irrigating 270,000 ha of land and providing drinking water to the tune of 500 cusecs to the Indian capital, New Delhi.

The Tehri dam is approaching its final stages and with the closure of the lower level diversion tunnels, the water

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level has started to rise; therefore it is important to study the land-use/land-cover changes in the area due to the reservoir and its overall impact upon the life-support system of the masses.

Land-use/land-cover pattern is the result of anthropogenic interaction with the natural environment. Besides affecting the quality of life of the people living in the area, it also affects surface run-off as also erosion intensity that control the reservoir life.

The inhabitants of the area traditionally maintained a large number of animals. Increasing restrictions upon forest resources in the previous decades have, however, led to substantial reduction in cattle headcount. This at the same time has increased human pressure upon land. Marginal lands, traditionally left barren hitherto, have therefore been terraced with 65% of the total area under agricultural activity falling under slopes steeper than 20°.

Remote sensing techniques are particularly suited for providing reliable, up-to-date and comprehensive data on land-use/land-cover. Apart from the field investigations, IRS LISS III multispectral and PAN data were used for preparing the land-use map of the area (Figure 3).

Forest types identified along the slopes of the Bhaghirathi and the Bhilanganga valleys are classified into (i) dense/fairly dense mixed, (ii) open mixed, and (iii) scrub. The dense mixed forest accounts for 71% of the total forest cover delineated in the area, while open forest accounts for another 26% (Figure 4).

Southerly slope aspects have less of dense and open forest, but majority of the scrub forest. This observation is in keeping with the vegetation distribution pattern in the Himalayan terrain and reflects differential solar insolation on the two slopes. With the gentler slopes being cleared for cultivation, forests are mainly confined to the higher reaches; high (20–30°), very high (30–40°), and steep (> 40°) slope class accounting for 30 and 25, 15% of the forest cover respectively.

Chir (*Pinus roxburghii*) is the predominant species of the region, while the other communities include banj (*Quercus leucotrichophora*), kaphal (*Myrica esculenta*), burash (*Rhododendron arboreum*), and deodar (*Cedrus deodara*). In the Bhaghirathi valley, barring a few pockets, there is mostly open forest between Tehri and the confluence of Jalkur with Bhaghirathi. Beyond this the steeper slopes are clad with dense mixed forest that is well developed on the left bank. Open forest is observed to border the dense forest along the right bank. In the Bhilanganga valley between Tehri and Dewal, a similar situation prevails as between Tehri and the Jalkur confluence in the main valley. However, occurrence of dense and open forests is encountered in this valley. The slopes are not bare continuously, but are randomly covered with vegetation patches of mixed varieties. Beyond Pilkhi the area is thickly wooded, but the Dewal–Pilkhi sector is intercepted with open and dense forests and scrub forest.

The entire Bhaghirathi catchment area is mountainous and rugged, with poor infrastructure development. The area is therefore sparsely populated, with the population being concentrated in the river valleys where agriculture is being practised in river terraces.

Apart from the increasing anthropogenic pressure upon the forests, the region until recently witnessed large-scale

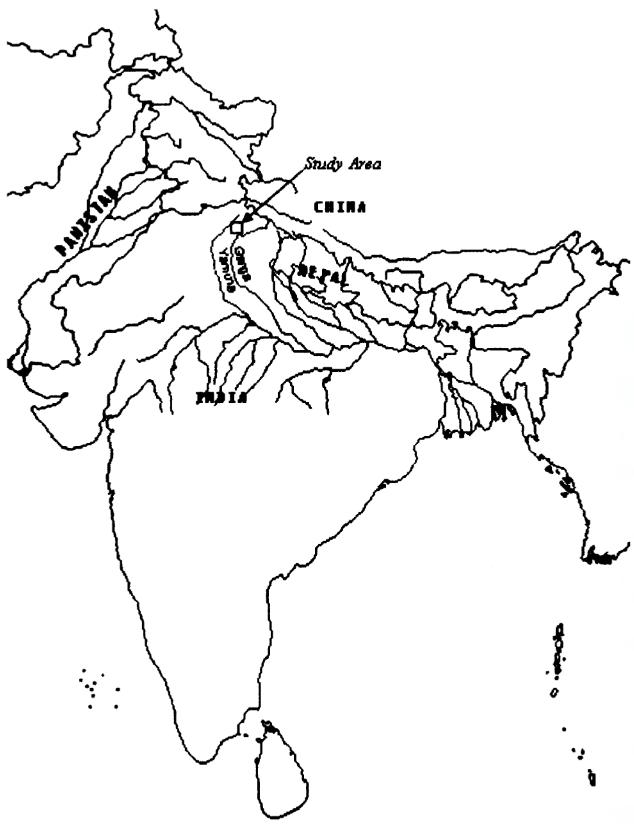

Figure 1. Location map of the study area.

Figure 2. View of the deep gorge of Bhaghirathi river.

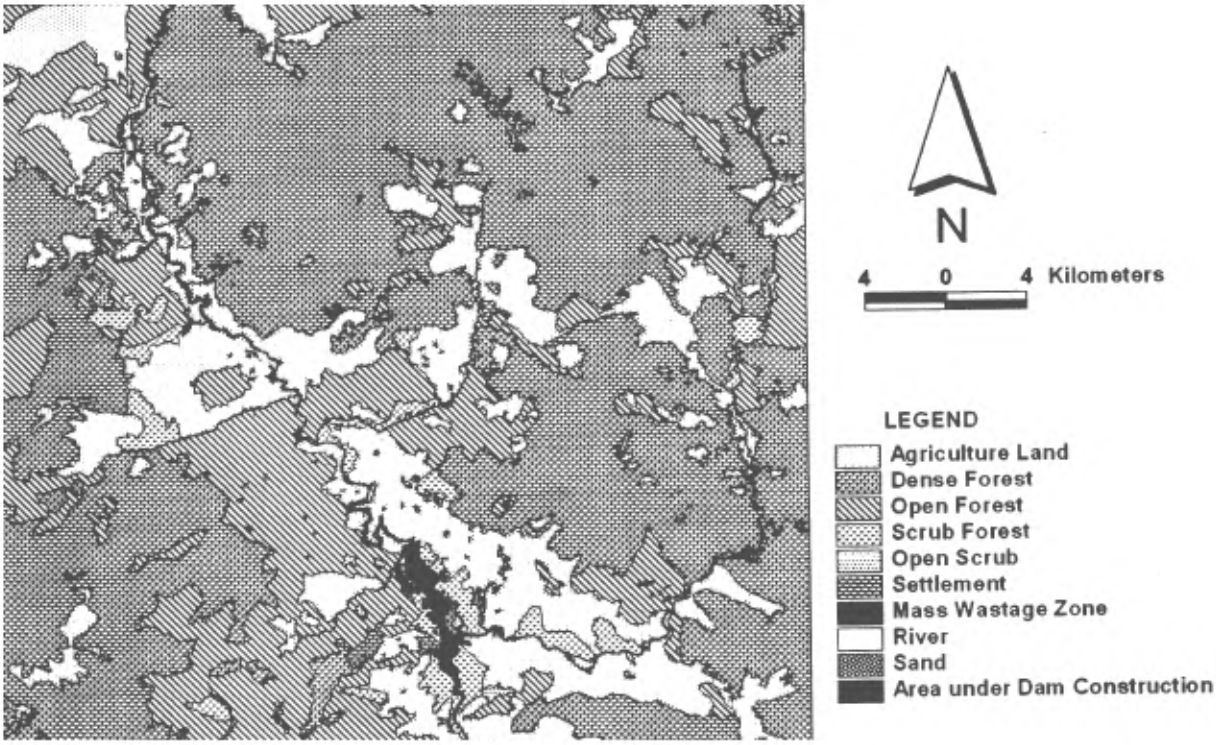

Figure 3. Land-use/land-cover map of Tehri dam reservoir rim.

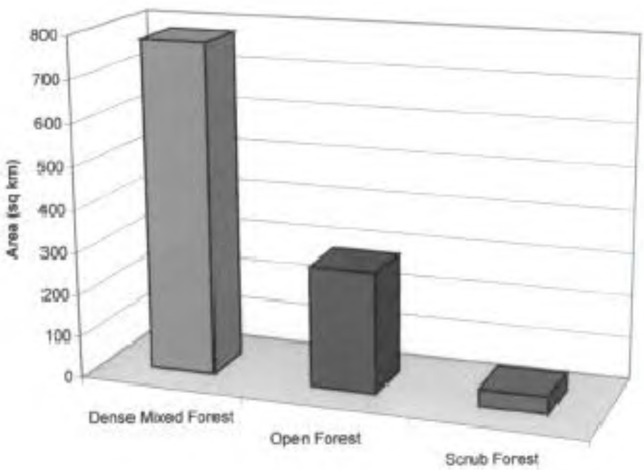

Figure 4. Statistics of forest distribution in the area.

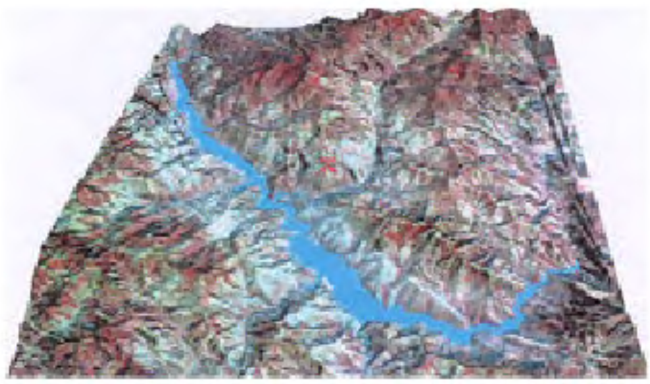

Figure 5. Water layer draped over the digital elevation model showing impoundment of the area.

commercial felling of forests and there is no system of counter-treatment of used-up forests. Thus, one-way traffic of deforestation, soil erosion and degradation of environment has been going on unabated. This is reflected in the following parameters that affect the quality of life of the masses in the region: reducing forest cover; degrading pastures; increased use of steep slopes for agriculture and low agriculture yield; uncontrolled torrent and streams; frequent landslides; soil moisture deficiency during dry period and communication failure.

The Tehri dam is designed to be 260.5 m high and would submerge everything below the critical 840.5 m level on the upstream side. Digital elevation model (DEM) of the area together with the land-use/land-cover map (Figure 3) prepared with the help of satellite data have been utilized for studying the likely land-use changes in the area.

Under the GIS environment, a dam with 260.5 m height was simulated to assess the storage capacity of the reservoir as also the extent of the area that is likely to be impounded (Figure 5). This submergence zone layer was then used for assessing the various land-use/land-cover

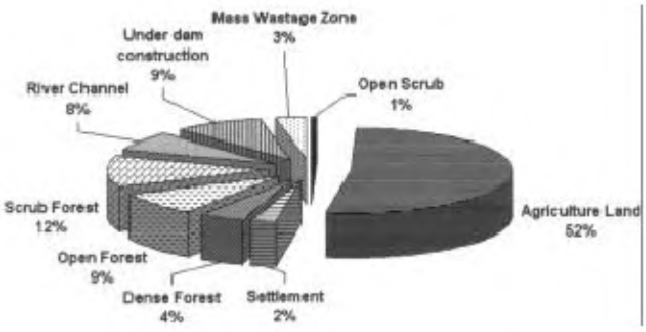

Figure 6. Statistics of the land-use types likely to be impounded by Tehri reservoir.

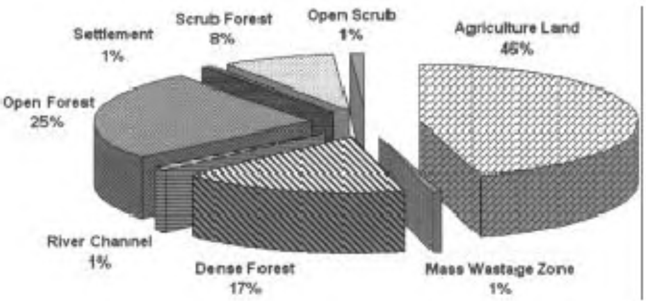

Figure 7. Details of the land-use types falling within the buffer zone of 500 m around the reservoir.

types likely to be affected by the impoundment of water in the lake. These studies show that the Tehri reservoir would cover an area of 5170.21 ha and would have a storage capacity of 4345.44 million m^3. Agricultural land accounts for almost 52% (2687 ha) of the total area likely to be submerged (Figure 6) by this dam. A number of habitations in the river valley, including the township and erstwhile district administration centre at Tehri would be submerged by the reservoir waters.

The reservoir would affect the land around the reservoir rim. The introduction of a huge reservoir would be disturbing the delicate balance between soil, water and plants through rise in groundwater table (water-logging), and disturbing the natural salt distribution in the soil, thereby affecting the biomass productivity in coming years; and the agricultural fields around the reservoir rim would be rendered unfit for cultivation. For the purpose of the present study, with conservative estimates, the area falling within a distance of 500 m from the reservoir level is being considered most likely to be rendered unfit for cultivation. A buffer zone of 500 m is thus created around the reservoir and with the help of the land-use/land-cover map, various-types of land-use, falling within this zone, have been marked out (Figure 7). It is observed that 3347 ha of prime agricultural land (46% of the total area within the buffer) on the upper terraces falls within this zone. This land would have to be left barren even if not affected by salinity or water-logging, and the marginal farmers owning these lands would have to be rehabilitated. To add to it, 42% of the area within the buffer zone falls in dense mixed forest and open forest categories.

Water sources of a large number of habitations on the reservoir rim are likely to be flooded by reservoir waters and this poses a threat of an epidemic in the region. The civic authorities have not cared to clear the debris and garbage dumps around Tehri, and this would further deteriorate the water quality of the reservoir.

The reservoir would be providing a vast area (5170.21 ha) for atmosphere–water interaction that would induce microclimatic changes in the region by way of increasing the humidity levels. The evaporation rates in the surroundings are quite high (~ 2.7 mm daily averaged over two years; Data Hill Campus, Ranichauri) and on an average 0.14 million m^3 of water would be evaporating daily from the reservoir. This would influence the biomass availability of the region besides enhancing mass wastage rates in the catchment area and adversely affecting the stipulated reservoir life.

Besides this, regional-level effects include: (a) Displacement of labour from agriculture; (b) Widening income disparities; (c) Declining sustainability of secondary and tertiary sectors; (d) Enhanced ecological pressure upon the catchment due to the migration of people; (e) Increased erosion due to engineering activities; (f) Scarcity of drinking water due to water sources getting inundated and (g) Invasion of new pathogens due to enhanced moisture.

At present agriculture is the mainstay of economy in the region and the studies show that the reservoir would affect 6034 ha of prime agricultural land (mostly irrigated) of the river valleys. The dam would affect 3663 ha of mixed and open forests, with 2990 ha falling in the buffer zone of 500 m. With increased humidity, biomass availability in the region would increase together with increased incidences of water-borne diseases. Anthropogenic pressure upon the available natural resources would at the same time be increasing and the displaced people may resort to terracing of the steeper slopes hitherto under forest cover.

There is an urgent need of promoting non land-based economic activities in the region apart from promoting the industrial infrastructure, so that the affected people could easily find suitable economic rehabilitation.

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