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Vegetation Patterns in Tehri Dam Submergence Zone, Uttaranchal, India

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Abstract

The present study deals with structure and composition of plant communities in Tehri dam submergence zone in Garhwal, west Himalaya, Uttaranchal. The submergence zone comprises of two valleys, i.e. Bhagirathi submergence zone and Bhilangna submergence zone. Four major plant communities were identified in both the submergence zones with varied associations through TWINSPAN. The species richness and diversity was high in most of the sites in Bhagirathi SZ compared to Bhilangna SZ, where species richness and diversity were more or less similar in most of the sites. The evenness values in most of the sites indicate that species were distributed evenly in Bhagirathi SZ, while heterogeneously in most of the sites in Bhilangna SZ. However, the rate of species change, i.e. beta-diversity was higher in Bhilangna SZ compared to Bhagirathi SZ. The biomass of *Lantana* (74.5%) was high for entire submergence zone compared to *Carissa* (25.4%), of the total available biomass for both species. However, the extraction was more for *Carissa* (2.2%) as compared to *Lantana* (1.2%), of the total biomass of each species.

Key words: Biomass, Diversity, Plant community composition, Submergence zone, Tehri dam

Introduction]]b-]] Tehri, a hill town in Garhwal Himalaya, is situated at the confluence of rivers Bhagirathi and Bhilangna. According to Atkinson (1882) the population of Tehri town at that time was about 2000. This has now increased approximately twenty times since then. Atkinson described Tehri town as very hot place devoid of trees and surrounded by bare hills. At many points along the course of Bhagirathi taking the advantage of sheer drops in height and high velocity of river, Government of India proposed to construct a dam nearly 1 km downstream of Tehri town. The Geological Survey of India conceived the Tehri Hydro Electric Project in 1949. Apprehensions were expressed with regard to the geologically vulnerability of the area around the site, the instability of the hill slopes which would constitute the reservoir rim areas and the proneness of the site to seismicity. Considering the above site features, the decision was made by Planning Commission, Government of India in 1972 to construct a clay-core rock-fill dam which would allow more flexibility to its structure. The salient features of the Tehri Hydro-Electric project are:

Type of dam	**Earth and Rock fill**
Extent of dam	**44 km in Bhagirathi valley and 25 km in Bhilangna valley**
Height of the dam	**260.5 m (from the deepest foundation)**
Height of the dam	**239.5 m (from the bed of the river)**
Installed capacity	**2000 MW**
Minimum reservoir level	**740 m**
Full reservoir level	**830 m**
Dead storage level	**720 m**
Water spread area	**42.5 km2**
Water impound capacity	**3.2 million m3**
Area to be irrigated	**6.7 Lakh acre**

The hydro-electric project was initially being executed by the irrigation department of U.P. but later, (July 1988) it was handed over to a joint venture company of the Government of India and Government of U.P., viz., Tehri Hydro Development Corporation (THDC). Features of the Tehri dam project reveal that the magnitude of the impacts of the project are likely to be more significant and it is for this reason that more controversies revolving around the project have been in news since the past few decades and some are still in the process. On November 9, 2000 the state of Uttarankhand has come into existence as the 27th state of Republic of India, which was carved out from the erstwhile Uttar Pradesh.

Several extensive studies have been conducted in Tehri dam project area (Paranjpye 1988, Anon. 1969, Bhattacharya and Goel 1982, Gaur 1986, Goverdhan 1993) to study the impacts of Tehri dam on people, vegetation, climate and geology of the area. No such study was made on the ecological aspects of vegetation; therefore, the present study was conducted with following objectives, a) vegetation structure and composition within and between the submergence zones, b) diversity patterns in different communities, and c)

conservation issues related to Tehri dam submergence zone.

Materials and Methods

Study area'

The submergence zone consists of two areas, viz., Bhagirathi submergence zone and Bhilangna submergence zone

[IMAGE]

Figure 1. Map showing the location of Tehri dam submergence zone.

. As the Bhagirathi and Bhilangna rivers pass through the submergence zone, the deep gorges open into broad valleys which represent subtropical climate. The summer is very hot due to low elevation and topographic features. These submergence zones (hereafter referred as Bhagirathi SZ and Bhilangna SZ, respectively) lie between 30020'-30040' N and 78015'-78040' E along an altitudinal range from 569.5 to 830m asl. The characteristic features of both the submergence zones are given below (Table 1). With the submergence of vast tract of land, people of the area are the most affected once. A total of 22 villages fully, 69 villages partially and the Tehri town itself are going to submerge after the impoundment of water. According to Adhikari et al. (1997) the faunal wealth of the submergence zone is as follows: mammals (9 species), reptiles (2 species) and birds (72 species).

Methods

We have developed different methods for the rapid assessment of vegetation and faunal component in the submergence zone of Tehri dam for the above mentioned objectives. The Systematic sample plots were used to quantify various parameters of vegetation following Misra (1968). In both the submergence zones, well established motor roads were used as a curvilinear transect to decide sampling point and at every one km distance sites were selected on either side of the road. The road passes roughly through the submergence zone along the contour of 569.5 to 830m asl. At each sampling site, which was representative of submergence zone, ten, 10x10m quadrats for trees and ten, 5x5m quadrats were laid for shrubs. The sample plots falling in cultivated fields close to a household were excluded.

The data was analyzed for density, frequency, species richness, evenness and species diversity (Misra 1968; Shannon and Weaver 1963). For community classification the data was subjected to TWINSPAN (Hill 1979). For biomass, ten representative individuals of different girth classes were harvested for two most common shrubs, viz., *Lantana camara* and *Carissa opaca* and fresh and dry (sun dried material after 15 days) weights were determined. The regression equations for both the shrubs were developed. The girth of 25 individuals each of Lantana and *Carissa* were measured at ground level (10cm above the ground level) to get the mean girth in each site. In order to estimate the total shrub biomass (mainly *Lantana* and *Carissa)* , the mean biomass and total density of species was multiplied for each site.

Result and DiscussionIn general, 177 sites were selected for the quantification of vegetation in Tehri dam submergence zone (105 and 72 sites in Bhagirathi SZ and Bhilangna SZ, respectively).

Vegetation

Of the total trees and shrubs reported from the study area (Uniyal et al. 1995), approximately 80% were encountered in the sites during the present survey (*Appendix I*). The comparison of vegetation between Bhagirathi SZ and Bhilangna SZ is given in Table 2. The community and its associations are comparable with each other.

Distribution of major species

The frequency distribution in Bhagirathi SZ indicates that *Lantana* and *Carissa* were distributed throughout the zone followed by *Euphorbia*. However, within the sites, *Lantana, Carissa* and *Euphorbia* were distributed frequently (Table 3). In Bhilangna SZ *Lantana, Dalbergia, Carissa* and were frequently distributed. Species like *Carissa, Lantana, Adhatoda, Eupatorium, Artemisia* and *Grewia* are frequently distributed within the sites in which they occur (Table 3).

Since the land in both the sides of the river is agricultural, it seems that cultivation and exploitation of selected plant species have or may have modified the vegetation, though naturally occurring forests area are difficult to be marked in this area. Most of the species in the area were planted having either economic or religious importance. *Ficus* species

usually occur near religious shrines or on the road sides to provide shelter to the people from the virulent summer and also to wild fauna. *Dalbergia* near riverine area and *Melia, Grewia* and *Pyrus* near habitation and agricultural fields were protected by villagers. Within Tehri dam submergence zone, the species richness was high in Bhilangna SZ (64) as compared to Bhagirathi SZ (33) for trees and shrubs (based on quantitative data).

In general, the micro-climate of the Bhilangna SZ supports a good population of trees in riverine sites followed by degraded lands where the soil layer was thin, dry with coarse sand and gravels, along the margins of agricultural fields and poor on the margins of the agricultural fields, respectively. *Dalbergia* was sown in both the submergence zone, however, the growth of *Dalbergia* was quite good on degraded sites, while on marginal lands it was less abundant and growth was poor. Generally locals have developed their marginal lands with fodder species like *Grewia* and *Ficus*. The tree species like *Grewia* and *Melia* were becoming less prominent on those sites from where villages have been shifted due to fast proliferation of *Lantana* and *Euphorbia*. In both the regions *Fumaria indica* (Fumaraceae), *Aspidopteris wallichii* and *Hiptage benghalensis* (Malphigiaceae) were the common species. Though, most of the families were common to both the regions. The plants of present study site shows affinity with the plants of Indus plain, such as *Bombax ceiba, Ficus palmata* and *Aegle marmelos*, with hill top plants such as *Berberis* and *Pyrus pashia* in Sarjuga (M.P.), *Berberis* and *Rhus parviflora* in Pachmarhi hills and *Rubus ellipticus* and *Pyrus pashia* in Parasnath hills, Orissa. However, out side India such as *Mallotus, Rubus* and *Rhus* (common Malayasian type) and *Euphorbia* and *Zizyphus* (common African type).

Community Composition

Based on TWINSPAN analysis four major communities were identified in Bhagirathi SZ as well as Bhilangna SZ

[IMAGE]

Figure 2. Vegetation communities/associations in Bhagirathi (a) and Bhilangna (b) submergence zones through TWINSPAN analysis

, however, similar community had different associations in the submergence zones.

Bhagirathi Submergence zone:

(A) *Dalbergia-Carissa-Murraya-Adhatoda* community: This community occurs on flat areas with moist soil. *Dalbergia* and *Psidium* in the sites were planted and contributed 34% and 4% to the vegetation, respectively. The shrub element was dominated by *Carissa* that contributed nearly 26% to the community vegetation. The tree density ranged from 30 (*Psidium guajava*) to 276 trees ha-1 (*Dalbergia*) and the shrub density ranged from 37.3 (*Adhatoda vasica*) to 160 individuals 100 m-2 (*Carissa opaca*).

(B) *Melia-Ficus* community: This community was poorly represented near habitation. The trees like *Melia* and *Ficus* which have local importance (religious) occur at the site. The density of tree varied from 8 (*Ficus religiosa*) to 108 trees ha-1 (*Melia azedarach*).

(C) *Carissa-Euphorbia-Bombax-Pinus* community: It is further divisible into six associations.

(a) *Euphorbia-Carissa-Agave* association: This association occurred in places from where the villages have been rehabilitated in the past. The tree layer mainly consisted of *Grewia* and *Melia*, both of which were locally important then. Now *Euphorbia* and *Agave* occur on the sites. The tree density ranged from 3 (*Melia azedarach*) to 171 trees ha-1 (*Grewia* and *Dalbergia*) and shrub density varied from 53.3 (*Agave cantula*) to 414 individuals 100 m-2 (*Euphorbia royleana*).

(b) *Carissa-Agave* association: The dominance of *Carissa* throughout the submergence zone was peculiar and contributed 89% and *Agave* contributed 9% to the overall association. The tree species were very less and represented by *Bombax, Grewia* and *Ficus*. The soil in the area was generally dry and shallow. The tree density varied from 4 (*Ficus religiosa*) to 21 trees ha-1 (*Bombax*) and shrub density varied from 66.8 (*Agave*) to 626.6 individuals 100 m-2 (*Carissa*).

(c) *Carissa-Euphorbia-Bombax* association: *Euphorbia* generally grows on degraded slopes and contributed about 14% as associate species, however, *Carissa* dominated the sites with 80% representation. The tree layer was occupied by *Bombax, Grewia* and *Pinus*.

The tree density varied from 4 (*Dalbergia*) to 10 trees ha-1 (*Bombax*) and shrub density varied from 50 (*Agave*) to 596 individuals 100 m-2 (*Carissa*).

(d) *Carissa-Euphorbia-Pinus* association: Most of the sites were dominated by *Carissa* with a change in the order of co-dominant species. In this association, *Carissa* contributed 74%. The community prefers habitats like landslide prone areas where soil was dry with rocks. The tree density varied from 1 (*Ficus religiosa*) to 6 trees ha-1 (*Pinus*) and shrub density from 5.8 (*Rhus parviflora*) to 798.2 (*Carissa*) individuals 100 m-2.

(e) *Carissa-Euphorbia-Mimosa* association: Although, the dominant species were still *Carissa* and *Euphorbia*, they were followed by *Mimosa himalayana* which contributed 12% to the association. The tree layer was represented by *Pinus* (6 trees ha-1). The shrub density varied from 60 (*Mimosa*) to 256 individuals 100 m-2 (*Carissa*).

(f) *Lantana-Carissa* association: This association occurs on sites where soil was deep and dry. The dominant shrub was Lantana which contributed 48%. The tree species were *Pinus* and *Bombax*. The tree density varied from 4 (*Bombax*) to 6 trees ha-1 (*Pinus*) while shrub density varied from 60 (*Mimosa*) to 720 individuals 100 m-2 (*Lantana*).

(D) *Lantana-Carissa-Rhus-Euphorbia-Pyrus* community: This community is further divisible into six associations.

(a) *Lantana-Carissa-Agave-Euphorbia* association: *Lantana* and *Carissa* were the dominant species and contributed about 40% and 30%, respectively to the association. However, co-dominant species were *Agave* (14%) and *Euphorbia* (7%). The tree layer was formed by *Pinus* and *Dalbergia*. The tree density varied from 1 (*Bombax*) to 5 trees ha-1 (*Pinus*) and shrub density from 1.2 (*Adhatoda*) to 643.2 individuals 100 m-2 (*Carissa*).

(b) *Lantana-Carissa-Pyrus-Grewia* association: This association occurs near fields where the tree species have been planted. *Lantana* contributed about 56% whereas *Pyrus* only 4% to the association. The soil was moist and deep. The tree density varied from 15 (*Grewia*) to 57 trees ha-1 (*Pyrus*) and shrub density from 233 (*Lantana*) to 314 individuals 100 m-2 (*Carissa*).

(c) *Lantana-Carissa-Euphorbia* association: This association consists of most of the species in the submergence zone. The soil was dry with rocky out crops. The tree density varied from 1 (*Melia, Bombax, Ficus* and *Pyrus*) to 3 trees ha-1 (*Grewia*). The shrub density in this association varied from 2.8 (*Mimosa*) to 607.3 individuals 100 m-2 (*Lantana*).

(d) *Carissa-Lantana-Rhus-Murraya* association: This association occurs on moderate slopes and the soil was usually dry and shallow with gravels. *Carissa* and *Rhus* contributed about 36% and 19%, respectively to the association. The shrub density varied from 1.2 (*Artemisia*) to 671.7 individuals 100 m-2 (*Lantana*).

(e) *Carissa-Lantana-Rhus-Artemisia* association: This community is frequent on moderate slopes with dry soil. *Rhus* and *Artemisia* contributed 9% and 15%, respectively to the association. The shrub density varied from 4.4 (*Mimosa*) to 566 individuals 100 m-2 (*Lantana*).

(f) *Lantana-Carissa-Artemisia-Zizyphus* association: This association prefers gentle slopes with deep and dry soil. *Artemisia* contributed 19% and *Zizyphus* 3% to the association. The Shrub density varied from 8 (*Adhatoda*) to 425 individuals 100 m-2 (*Lantana*).

Bhilangna Submergence zone:

(A) *Dalbergia-Ficusa-Grewia-Lantana-Carissa* community: This community is further divisible into five associations.

(a) *Mangifera-Grewia-Carissa-Lantana-Euphorbia* association: The dominant species of this association type were *Grewia oppositifolia, Mangifera indica, Ficusa (Ficus palmata), Pinus roxburghii* and *Cedrela toona* as the canopy species and the undercanopy layer was dominated by *Lantana, Carissa* and *Euphorbia*. Such association mainly occurs on the slopes near the agricultural fields. The soil was dry, deep and light brown in colour. The tree density ranged between 6 (*Emblica officinalis* and *Cedrela toona* each) and 18 trees ha-1 (*Mangifera*) and shrub density ranged from 12 (*Zanthoxylum*) to 1988 individuals 100 m-2 (*Lantana*).

(b) *Sapium-Bombax-Lantana-Carissa-Euphorbia* association: The canopy was dominated by Sapium insigne on steep slopes and on gentle slopes by *Bombax ceiba* and the undercanopy was dominated by *Lantana, Carissa* and *Euphorbia*. This association type generally occurs on gentle to steep slopes and near the agricultural fields. The soil was dry,

dark in colour and shallow on slopes, however, mesic, light brown and deep on gentle slopes. The tree density ranged from 1 (*Pinus roxburghii*) to 30 trees ha-1 (*Sapium*) and shrub density ranged from 62 (*Euphorbia*) to 2080 individuals 100 m-2 (*Lantana*).

(c) *Dalbergia-Lantana-Carissa* association: The associates of *Dalbergia* are *Grewia* and *Mangifera*, however, undercanopy strata was chiefly dominated by *Lantana* and *Carissa*. Most of the sites of this association occurs on gentler to steep slopes adjacent to agricultural fields and on open sites near riverine area. The soil was light to dark brown in colour and dry on slopes and near river side slightly mesic and coarse gravels were present in large proportion. The tree density ranged from 1 (*Albizzia*) to 19 trees ha-1 (*Grewia* and *Dalbergia* each) and shrub density ranged between 28 (*Euphorbia*) and 3903 individuals 100 m-2 (*Lantana*).

(d) *Dalbergia-Cedrela-Lantana-Carissa* association: Most of the sites of this association type occurs near the riverine areas, disturbed due to erosion and human interference and on abandoned agricultural land which have a good regeneration potential to grow *Dalbergia* and undercanopy strata was covered chiefly by Lantana. The soil was less deep on the riverine and eroded or disturbed sites, while deep, dry and dark in abandoned agricultural lands. The tree density ranged between 1 (*Acacia*) and 272 trees ha-1 (*Dalbergia*) and shrub density between 7 (*Euphorbia*) and 1852 individuals 100 m2 (*Lantana*).

(e) *Lantana-Carissa* association: The characteristic feature of the sites is there eroded nature, disturbed landscape and the proximity of sites to water channels. The soil was dark, deep and mesic near the water channels and light brown to brown, moderately deep and dry on eroded slopes. The tree density ranged between 4.0 (*Bauhinia*) and 12 trees ha-1 (*Dalbergia*) and shrub density ranged from 6 (*Rhus*) to 6452 individuals 100 m-2 (*Lantana*).

(B) *Ficusa-Dalbergia-Grewia-Lantana* community : This community is further divisible into associations.

(a) *Ficus-Grewia-Lantana-Euphorbia* association: This association type generally occurs on the sites comprising of agricultural fields and the marginal lands and was dominated by species like *Grewia* and *Ficus* and shrubs chiefly Lantana, Euphorbia, Artemisia and *Carissa*. The soil of the sites vary from light brown to dark brown and dry except at few sites, which was generally shallow and the percentage of coarse gravels was too high. The tree density ranges from 1.0 (*Ficus cunea*) to 37.0 trees ha-1 (*Grewia*) and shrub density from 1.2 (*Moringa*) to 1480.0 individuals 100 m-2.

(b) *Ficus-Dalbergia-Lantana-Eupatorium* association: This association type generally occurs on an undisturbed sites, as well as on disturbed sites and represented by *Ficus* and *Dalbergia* and chiefly dominated shrubs were *Lantana, Eupatorium, Carissa* and *Artemisia*. These sites vary in their edaphic characteristics from mesic to dry. The shrub layer on mesic site was dominated by Eupatorium, while on stony and dry sites Artemisia dominates in the abandoned agricultural fields. The tree density ranges from 3 (*Cedrela* and *Pyrus pashia* each) to 187 trees ha-1 (*Grewia*) and shrub density ranges from 0.8 (*Murraya* and *Parthenium* each) to 2409 individuals 100 m-2 (*Eupatorium*).

(c) *Dalbergia-Ficus-Grewia-Lantana* association: Most of the sites of this association type occurs generally on the marginal lands and on eroded lands. The soil colour varied from dark to light brown in old agricultural fields, light brown on the margins and very light in eroded lands. Soil was mainly dry and deep, except in few sites on eroded lands. The marginal lands provide a good habitat for fodder species, such as *Ficus* and *Grewia*. The tree density ranged from 1 (*Sapium*) to 47 trees ha-1 (*Dalbergia*) and shrub density ranged from 2 (*Zizyphus*) to 1736 individuals 100 m-2 (*Lantana*).

(d) *Ficus-Grewia-Dalbergia-Lantana-Adhatoda* association: The sites of this association are located in the township area of Tehri, along the paths. The soil was mainly dry, light in colour and shallow with coarse gravels in high proportion. Most of the sites were disturbed on slopes and covered by Lantana. The dominant tree species of this association were *Ficus, Grewia, Dalbergia, Cedrela* and *Melia*. The tree density ranged from 1 (*Syzygium*) to 22.0 trees ha-1 (*Dalbergia*) and shrub density ranged from 2 (*Euphorbia*) to 2052 individuals 100 m-2 (*Lantana*).

(C) *Melia-Dalbergia-Ficusb* community: This community type devoid of shrub species generally occurs on highly disturbed site. The soil was light in colour, shallow and dry. The other tree species were *Ficus* and *Dalbergia*. The tree density ranged from 22 (*Ficus benghalensis*) to 133 trees ha-1 (*Melia*).

(D) *Cedrela-Ficusb* community: This community type also occurs in the township area along the road side. The dominant tree species were *Ficus* and *Cedrela*. The tree density ranged between 1 (*Butea*) and 14 trees ha-1 (*Cedrela*).

Species Richness and Diversity Patterns

The species richness, diversity and evenness of each community/associations in both submergence zones is given in Table 4. From the conservation point of view it may be noted that sites with high species richness don't have advantage over species poor sites. The species distribution is mainly governed by topography and microclimatic condition of the sites.

Beta-diversity

The rate of species change is high (3.14-5.7) for *Lantana-Carissa-Agave-Euphorbia* and *Lantana-Carissa-Euphorbia* associations in Bhagirathi SZ (Table 5). However, it is high (3.13-4.18) for *Ficus-Dalbergia-Lantana-Eupatorium, Dalbergia-Ficus-Grewia-Lantana* and *Ficus-Grewia-Lantana-Euphorbia* associations in Bhilangna SZ. Beta-diversity of Bhilangna SZ (10.6) infers that the rate of change of species was high as compared to Bhagirathi SZ (7.5). However, the beta-diversity of the entire submergence zone is 14.3 which resembles with the beta-diversity of tree layer in west Himalayan region (Singh et al. 1994). In both Bhagirathi SZ and Bhilangna SZ for all communities/associations the dominance-diversity (d-d) curves approaches a geometric series over most of its length. This is mainly due to single species dominance which confirms the niche pre-emption hypothesis of Whittaker (1975). The low abundance of most of the species performed its distribution as general log-normal, which is a good fit for lower side of curves.

Similarity

In Bhagirathi SZ the similarity values between associations of *Lantana-Carissa-Rhus-Euphorbia* community were quite high (68.9-90.3%; Table 6), however, in Bhilangna SZ between associations of *Dalbergia-Ficus-Grewia-Lantana-Carissa* community were high (6.3-29.7%; Table 7).

Density and Biomass of major shrubs

The growth of *Lantana* in terms of diameter was maximum in its own associations in Bhagirathi SZ, while in Bhilangna SZ the diameter was almost same as *Lantana* was growing under the tree layer. The density of *Lantana* ranged from 2330-7200 plants ha-1 and 14840-64520 plants ha-1, respectively in Bhagirathi SZ and Bhilangna SZ. The density of *Lantana* was maximum in its own association with *Carissa* in both the submergence zones, however, the density was almost 9 times higher in Bhilangna SZ than that of Bhagirathi SZ (7200 plants ha-1). The biomass of *Lantana* ranged from 0.06-0.15 t ha-1 and 0.36-1.0 t ha-1 in Bhagirathi SZ and Bhilangna SZ, respectively. The biomass of *Lantana* was maximum in its own association as well as in other associations in Bhilangna SZ, while it was 3-4 times lower in other associations of Bhagirathi SZ.

The growth of *Carissa opaca* in terms of diameter was almost similar in all the communities/associations. The density of *Carissa* ranged from 1600-7980 plants ha-1 and 840-7140 plants ha-1 in Bhagirathi SZ and Bhilangna SZ, respectively. The biomass of *Carissa* ranged from 0.07-0.21 t ha-1 and 0.04-0.28 t ha-1, respectively in Bhagirathi SZ and Bhilangna SZ. The biomass was almost similar in *Lantana-Carissa-Rhus-Euphorbia* community in Bhagirathi SZ, as compared to other associations of Bhilangna SZ.

The average (community/associations) diameter, density and biomass of *Lantana* was 1.7 cm, 5190 plants ha-1 and 1.18 t ha-1 in Bhagirathi SZ and 1.9 cm, 25850 plants ha-1 and 5.94 t ha-1 in Bhilangna SZ, respectively. The average (community/associations) diameter, density and biomass of *Carissa* was 1.9 cm, 4300 plants ha-1 and 1.33 t ha-1 in Bhagirathi SZ and 2.0 cm, 3430 plants ha-1 and 1.11 t ha-1 in Bhilangna SZ, respectively. The linear equations between diameter and plant biomass were significant for both the species.

$$\textit{Lantana camara}: \quad Y = 11.48 + 133.2\,X \quad (r2 = 0.89, P<0.01)$$

$$\textit{Carissa opaca}: \quad Y = 65.4 + 141.77\,X \quad (r2 = 0.92, P<0.01)$$

The linear relationship between cover (%) and total biomass (gm) was significant for *Lantana camara* (Y = 38.9 + 1.7 X; r2 = 0.3, P<0.01) and *Carissa opaca* (Y = 33.7 + 2.5 X; r2 = 0.6, P<0.01) in Bhagirathi SZ. However, the linear relationship between cover (%) and total biomass (gm) was negatively correlated for Carissa (Y = -14.3 + 3.2 X; r2 = 0.7, P<0.01) and non-significant for *Lantana* (Y = -184.1 + 10.3 X; r2 = 0.2, NS) in Bhilangna SZ. It also

indicates that in this zone the distribution of *Lantana* was uneven. The biomass of *Lantana* was high in their own associations than that of other associations, which is directly related to the density of the associations, while some associations with high density have no advantage over others due to low diameter.

The density and biomass of *Lantana* and *Carissa* (in which they present) in both the submergence zone in different communities/associations is shown in

[IMAGE]

Figure 3. Density (individuals 100m-2) and biomass (kg 100 m-2) of *Lantana* and *Carissa* in different communities/associations in Bhagirathi and Bhilangna submergence zones

. As it is evident from the r2 values, the relationships of diameter with plant biomass (*Lantana* and *Carissa* in which they present) were generally satisfactory

[IMAGE]

Figure 4. The relationship between density and biomass of *Lantana* and *Carissa* in Bhagirathi and Bhilangna submergence zones

. Comparisons among zone suggests that biomass of *Carissa* and *Lantana* was high in Bhagirathi SZ and Bhilangna SZ, respectively. This is largely due to growth (diameter) and suggests that *Carissa* will attain more girth on flat regions and *Lantana* on slopes. In present study sites the biomass of different communities/associations of *Lantana* was very low (0.01-0.03 times) than that reported for the *Lantana* shrubland in Kumaun Himalaya at 1500m (Bhatt et al. 1994). This may be due to the collection of *Lantana* as fuel wood, as they do not have any other species in the area and also due to heavy browsing by sheep and goats during the migration from lower to higher regions.

The extrapolation of data indicates that for entire submergence zone the biomass is 862484 tonnes, of which *Lantana* accounted for 74.5% and *Carissa* 25.4%. The total consumption of fuel (based on average consumption in the submergence zone; Awasthi et al. 1999) as per the demand is 7713 t yr-1 for *Lantana* and 4787 t yr-1 for *Carissa*. Of the total available biomass, the requirement of fuelwood is high (2.2%) for *Carissa* than that of *Lantana* (1.2%). However, in terms of energy *Carissa* provide good amount of energy fuelwood.

[[Conclusion]] In a nutshell, Bhagirathi SZ has more or less uniform topography and geomorphology, while Bhilangna SZ has diverse, which leads to the distribution of plant communities. Although, both the submergence zone had 4 major communities, while their associations within and between submergence zones varied much. The Bhilangna SZ contributed high species diversity and as well as rate of species change (ß-diversity) along the gradient due to mesicness of large area, which was also reflected by xeric species (Bhagirathi SZ has high and Bhilangna SZ has low). The diversity values were high on those sites, where the dominance of canopy species was more and low in the sites, which were near the agricultural fields or on disturbed sites. Though, the animals are in low density, the loss of their habitat after impound of water is likely to cause the impact on surrounding areas. The scrub vegetation forms a typical habitat for Partridges, which will be lost permanently after the impoundment. After the impoundment of water the moisture regime will support luxuriant vegetation and its growth, while the dam could provide a potential wintering habitat to the waterfowls of the country as well as from abroad in future.

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Table 1: Characteristic features of Bhagirathi SZ and Bhilangna SZ.

Bhagirathi SZ	Bhilangna SZ
The land: **· primarily an agricultural land on both the sides of the river** ***The vegetation:*** **· mostly xerophytic consisting mainly of shrubs · tree cover is very low and mainly comprises of sisham** ***(Dalbergia sissoo)*** **which appears to have been air sown to add greenery to the valley (Uniyal** ***et al.*** **1995).** ***Geology:*** **· represent a thick succession of quartzite, slate and limestone. Quartzite is mainly medium grained, pink, grey to buff and dark violet quartzite are characterized by sizeable interaction of purple and green slates. Slate is fine grained greyish green or brown, violet, bluish black slate and limestone are medium to fine grained overlying the slates and quartzite. The terrain is undulating, slightly rocky with moderate slope (Saklani 1993)** ***The soil:*** **· usually dry with gravels throughout the Bhagirathi SZ**	**· less agricultural fields and habitation as compared to Bhagirathi SZ** **· by and large well developed vegetation composition as compared to Bhagirathi SZ, while within the submergence zone vegetation composition is relatively poor on the right side · most of the sites provide a good habitat for bird communities and lower plants, such as bryophytes and ferns, however, few places are the source of spring water for the locals.** **· mainly comprises of low to medium grade metamorphics like gneiss, quartzite, kind of schists, phyllite, marble's lenticular bands, epidiorite and amphibolites. Owing to its typical rock types, the Bhilangna river section designated as Bhilangna formation (Saklani 1972). In between Panwali thrust and Thayeli thrust there exist a Bhilangna formation, generally formed by streaky porphyroblastic gneiss quartzite, schist, marble, amphibolite, crystalline limestone and carbonaceous phyllite.** **· except few places the soil is more or less same as compared with Bhagirathi SZ**

Table 2: Vegetation characteristics of Bhagirathi SZ and Bhilangna SZ.

Bhagirathi SZ	Bhilangna SZ
· Secondary scrub accounts for most of the vegetation	**· Same as in Bhagirathi SZ**
· In general, of the total land - vegetation cover ***ca.*** **40%; - agricultural lands (including agricultural fields left by the locals in the past) cover** ***ca.*** **50%; - open area cover 10%**	**· In general, of the total land - vegetation cover** ***ca.*** **55% - agricultural lands (including agricultural fields left by the locals in the past) cover** ***ca.*** **30% - open area cover 15%**
· Of the total vegetation cover - 80% shrubs - 15% mixed vegetation (trees and shrubs) and - 5% trees	**· Of the total vegetation cover - 70% shrubs - 25% mixed vegetation (trees and shrubs) and - 5% trees**

Table 3: Frequency (%) distribution of dominant woody species in Bhagirathi SZ (# 105) and Bhilangna SZ (# 72).

Species	Bhagirathi SZ	Bhilangna SZ		
Frequency	Total frequency	Frequency	Total frequency	
Adhatoda vasica	15.7 ± 4.3	8.6	52.9 ± 4.6	19.4
Artemisia indica	30.0 ± 5.5	16.2	56.0 ± 6.5	13.9
Bombax ceiba	22.7 ± 3.0	9.5	20.8 ± 2.9	16.7
Carissa opaca	62.8 ± 3.3	82.0	52.9 ± 2.6	48.6
Dalbergia sissoo	27.5 ± 10.7	5.7	45.6 ± 3.3	54.2
Euphorbia royleana	45.0 ± 4.7	40.0	44.0 ± 3.7	44.4
Grewia oppositifolia	30.0 ± 8.6	10.5	51.7 ± 4.4	33.3
Lantana camara	82.7 ± 3.1	68.6	81.7 ± 1.9	90.3
Melia azedarach	22.5 ± 3.7	2.9	33.0 ± 5.6	13.9

Table 4: Species richness, diversity and evenness of different communities/ associations in Bhagirathi SZ and Bhilangna SZ.

Community/Association	Richness	Diversity	Evenness
Bhagirathi Submergence zone			
*Melia-Ficus*a	3.0	0.719	0.654
Carissa-Euphorbia-Bombax-Pinus			
Euphorbia-Carissa-Agave	3.3 ± 0.3	0.912 ± 0.21	0.766 ± 0.11
Carissa-Agave	3.7 ± 0.3	0.480 ± 0.25	0.346 ± 0.20
Carissa-Euphorbia-Bombax	5.0 ± 1.0	0.957 ± 0.16	0.590 ± 0.10
Carissa-Euphorbia-Pinus	3.0 ± 0.2	0.617 ± 0.04	0.598 ± 0.06
Carissa-Euphorbia-Mimosa	3.5 ± 1.0	0.946 ± 0.01	0.771 ± 0.08
Lantana-Carissa	5.0 ± 0.8	1.013 ± 0.37	0.629 ± 0.23
Lantana-Carissa-Rhus-Euphorbia			
Lantana-Carissa-Agave-Euphorbia	3.9 ± 0.2	0.934 ± 0.07	0.703 ± 0.05
Lantana-Carissa-Pyrus-Grewia	4.3 ± 0.5	1.008 ± 0.14	0.740 ± 0.09
Lantana-Carissa-Euphorbia	3.7 ± 0.2	0.775 ± 0.05	0.594 ± 0.04
Carissa-Lantana-Rhus-Murraya	5.2 ± 0.3	1.082 ± 0.06	0.669 ± 0.03

Carissa-Lantana-Rhus-Artemisia	**6.1 ± 0.4**	**1.266 ± 0.07**	**0.715 ± 0.04**
Lantana-Carissa-Artemisia-Zizyphus	**4.7 ± 0.7**	**1.153 ± 0.05**	**0.798 ± 0.05**
Dalbergia-Carissa-Murraya-Adhatoda	**2.3 ± 0.9**	**0.598 ± 0.35**	**0.569 ± 0.02**
Bhilangna submergence zone			
Dalbergia-Ficus*a*-Grewia-Lantana-Carissa			
Mangifera-Grewia-Carissa-Lantana-Euphorbia	**8.5 ± 4.5**	**0.744 ± 0.36**	**0.353 ± 0.08**
Sapium-Bombax-Lantana-Carissa-Euphorbia	**4.4 ± 0.3**	**0.574 ± 0.08**	**0.390 ± 0.05**
Dalbergia-Lantana-Carissa	**3.7 ± 0.4**	**0.455 ± 0.07**	**0.391 ± 0.08**
Dalbergia-Cedrela-Lantana-Carissa	**4.6 ± 0.3**	**0.701 ± 0.11**	**0.495 ± 0.08**
Lantana-Carissa	**7.0 ± 3.0**	**0.534 ± 0.11**	**0.293 ± 0.01**
Ficus*a*-Dalbergia-Grewia-Lantana			
Ficus-Grewia-Lantana-Euphorbia	**7.2 ± 1.2**	**0.827 ± 0.13**	**0.431 ± 0.04**
Ficus-Dalbergia-Lantana-Eupatorium	**6.9 ± 2.5**	**1.118 ± 0.14**	**0.606 ± 0.07**
Dalbergia-Ficus-Grewia-Lantana	**7.5 ± 1.0**	**0.575 ± 0.15**	**0.290 ± 0.06**
Ficus-Grewia-Dalbergia-Lantana-Adhatoda	**9.5 ± 2.8**	**1.027 ± 0.19**	**0.460 ± 0.07**
***Melia-Dalbergia-Ficus*b**	**5.0**	**1.480**	**0.920**
***Cedrela-Ficus*b**	**5.0 ± 0.7**	**1.443 ± 0.15**	**0.920 ± 0.02**

Ficus*a *Ficus palmata*; *Ficus*b *Ficus religiosa/Ficus benghalensis

Table 5: Beta-diversity (bD) of different communities/associations in Bhagirathi SZ and Bhilangna SZ.

Community/association	b-diversity
Bhagirathi submergence zone	
***Melia-Ficus*a (1)**	***1.0***
***Carissa-Euphorbia-Bombax-Pinus Euphorbia-Carissa-Agave* (2) *Carissa-Agave* (3) *Carissa-Euphorbia-Bombax* (4) *Carissa-Euphorbia-Pinus* (5) *Carissa-Euphorbia-Mimosa* (6) *Lantana-Carissa* (7)**	***1.8 1.4 1.4 3.0 1.1 1.4***
***Lantana-Carissa-Rhus-Euphorbia Lantana-Carissa-Agave-Euphorbia* (8) *Lantana-Carissa-Pyrus-Grewia* (9) *Lantana-Carissa-Euphorbia* (10) *Carissa-Lantana-Rhus-Murraya* (11) *Carissa-Lantana-Rhus-Artemisia* (12) *Lantana-Carissa-Artemisia-Zizyphus* (13)**	***3.6 2.0 5.7 3.1 1.8 1.3***
***Dalbergia-Carrisa-Murraya-Adhatoda* (14)**	***2.1***
bD of entire area	***7.5***
Bhilangna submergence zone	
***Dalbergia-Ficus*a-Grewia-Lantana-Carissa *Mangifera-Grewia-Carissa-Lantana-Euphorbia* (1) *Sapium-Bombax-Lantana-Carissa-Euphorbia* (2) *Dalbergia-Lantana-Carissa* (3) *Dalbergia-Cedrela-Lantana-Carissa* (4) *Lantana-Carissa* (5)**	***1.5 1.8 2.2 2.8 1.6***
***Ficus*a-*Dalbergia-Grewia-Lantana Ficusa-Grewia-Lantana-Euphorbia* (6) *Ficusa-Dalbergia-Lantana-Eupatorium* (7) *Dalbergia-Ficusa-Grewia-Lantana* (8) *Ficusa-Grewia-Dalbergia-Lantana-Adhatoda* (9)**	***4.2 3.1 3.3 2.4***
***Melia-Dalbergia-Ficus*b (10)**	***1.0***
***Cedrela-Ficus*b (11)**	***2.6***
bD of entire area	***10.6***

a *Ficus palmata;* b *Ficus benghalensis*/*F. religiosa*
Values in parenthesis are for communities/associations.

Table 6 : Similarity (%) between communities/associations in the Bhagirathi SZ.

	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
1*	100													
2*	0	100												
3*	15	0	100											
4*	26	0	24	100										
5*	26	0	35	87	100									
6*	26	0	41	74	87	100								
7*	26	0	59	45	58	75	100							
8*	21	0	24	21	30	30	38	100						
9*	27	0	31	39	37	37	37	69	100					
10*	27	0	16	39	39	39	39	69	69	100				
11*	26	0	20	37	39	38	38	72	74	90	100			
12*	27	0	16	35	36	36	37	65	79	76	78	100		
13*	27	0	16	30	30	31	31	63	80	69	72	81	100	
14*	28	0	15	33	33	33	33	64	71	76	79	75	86	100

*** see Table 5 for communities/associations.**

Table 7: Similarity (%) between communities/associations in Bhilangna SZ.

	*1**	*2**	*3**	*4**	*5**	*6**	*7**	*8**	*9**	*10**	*11**
*1**	100										
*2**	11.6	100									
*3**	20.1	29.7	100								
*4**	7.7	9.0	8.7	100							
*5**	9.8	11.3	13.0	6.3	100						
*6**	6.0	7.1	10.6	6.2	5.3	100					
*7**	7.3	0.7	6.3	3.7	7.4	12.7	100				
*8**	14.3	11.4	10.5	13.8	18.6	9.2	7.2	100			
*9**	5.9	2.4	2.3	5.3	5.6	10.8	7.0	11.5	100		
*10**	0	1.5	3.0	5.3	0.6	1.0	4.4	4.8	3.4	100	
*11**	3.9	3.1	1.3	5.5	0	8.8	2.0	9.0	18.4	3.7	100

*** see Table 5 for communities/associations.**

Appendix I: List of plant species present on the sites in Tehri Dam submergence zone.

(BGSZ-Bhagirathi submergence zone; BLSZ- Bhilangna submergence zone)

Species	Family	Status	BGSZ	BLSZ
Acacia catechu **Willd.**	**Mimosaceae**	**Tree**	**-**	**+**
Aegle marmelos **(L) Correa**	**Rutaceae**	**Tree**	**-**	**+**
Albizzia lebbeck **(L) Willd.**	**Minosaceae**	**Tree**	**-**	**+**
Bauhinia vahlii **Wight. & Arn.**	**Caesalpiniaceae**	**Tree**	**-**	**+**
Bombax ceiba **Linn.**	**Bombacaceae**	**Tree**	**+**	**+**
Butea monosperma **(Lam.) Taub.**	**Fabaceae**	**Tree**	**-**	**+**
Cedrela toona **Roxb. ex Rottl.**	**Meliaceae**	**Tree**	**-**	**+**
Celt is austral is **Linn.**	**Ulmaceae**	**Tree**	**-**	**+**
Dalbergia sissoo **Roxb.**	**Fabaceae**	**Tree**	**+**	**+**
Emblica officinalis **Gaertn**	**Euphorbiaceae**	**Tree**	**+**	**+**
Eucalyptus globulus **Labitl**	**Myrtaceae**	**Tree**	**+**	**+**
Ficus benghalensis **Linn.**	**Moraceae**	**Tree**	**-**	**+**
Ficus cunea **Buch.-Ham. ex Roxb.**	**Moraceae**	**Tree**	**-**	**+**
Ficus palmata **Forsskal**	**Moraceae**	**Tree**	**-**	**+**
Ficus religiosa **Linn.**	**Moraceae**	**Tree**	**+**	**+**
Grevillea robusta **A. Cunn. ex R. br**	**Proteaceae**	**Tree**	**-**	**+**
Grewia opositifolia **Roxb. ex Masters**	**Tiliaceae**	**Tree**	**+**	**+**
Lannea coromandelica **(Houtt.) Merr.**	**Meliaceae**	**Tree**	**-**	**+**
Litchi chinensis **Sonnerata**	**Sapindaceae**	**Tree**	**+**	**-**
Mallotus philippensis **Muell.-Arg.**	**Euphorbiaceae**	**Tree**	**+**	**-**
Mangifera indica **Linn.**	**Anacardiaceae**	**Tree**	**+**	**+**
Melia azedarach **Linn.**	**Meliaceae**	**Tree**	**+**	**+**
Morus alba **L.**	**Moraceae**	**Tree**	**-**	**+**
Pinus roxburghii **Sargent**	**Pinaceae**	**Tree**	**+**	**+**
Prunus cerasoides **D.Don**	**Rosaceae**	**Tree**	**-**	**+**
Psidium guajava **Linn.**	**Myrtaceae**	**Tree**	**+**	**-**
Punica granatum **Linn.**	**Punicaceae**	**Tree**	**+**	**+**
Pyrus pashia **Buch.-Ham ex D.Don**	**Rosaceae**	**Tree**	**+**	**+**

Salix wallichiana **Anderss.**	**Salicaceae**	**Tree**	**-**	**+**
Sapium insigne **(Royle) Benth. ex Hook.**	**Euphorbiaceae**	**Tree**	**+**	**+**
Syzygium cumini **(L.) Skeels**	**Myrtaceae**	**Tree**	**+**	**+**
Abutilon bidentatum **Hochst.**	**Malvaceae**	**Shrub**	**-**	**+**
Adhatoda zeylanica **Medikus**	**Acanthaceae**	**Shrub**	**+**	**+**
Agave cantula **Roxb.**	**Agavaceae**	**Shrub**	**+**	**+**
Artemisia indica **Willd.**	**Asteraceae**	**Shrub**	**+**	**+**
Berberis lycium **Royle**	**Berberidaceae**	**Shrub**	**+**	**+**
Caesalpinia decapetala **(Roth) Alston**	**Caesalpiniaceae**	**Shrub**	**-**	**+**
Calqtropis procera **(Willd.) Dryand**	**Asclepiadaceae**	**Shrub**	**-**	**+**
Carissa opaca **Stapf ex Haines**	**Apocynaceae**	**Shrub**	**+**	**+**
Celastrus paniculatus **Willd.**	**Celastraceae**	**Shrub**	**-**	**+**
Citrus medica **L.**	**Rutaceae**	**Shrub**	**-**	**+**
Colebrookea oppositifolia **Smith**	**Lamiaceae**	**Shrub**	**+**	**+**
Debraegasia oppositaefolia	**Urticaceae**	**Shrub**	**-**	**+**
Dodonea viscosa **(L.) Jacq.**	**Sapindaceae**	**Shrub**	**-**	**+**
Euphorbia royleana **Boiss.**	**Euphorbiaceae**	**Shrub**	**+**	**+**
Hypericum oblongifolium **Choisy**	**Hypericaceae**	**Shrub**	**-**	**+**
Lantana camara **Linn.**	**Verbenaceae**	**Shrub**	**+**	**+**
Lindera pulcherrima **(Nees) Benth. ex Hook.**	**Lauraceae**	**Shrub**	**-**	**+**
Mimosa himalayana **Gamble**	**Mimosaceae**	**Shrub**	**+**	**-**
Moringa oleifera **Lam.**	**Moringaceae**	**Shrub**	**-**	**+**
Murraya koenigii **(L.) Sprengel**	**Rutaceae**	**Shrub**	**+**	**+**
Opuncia dillenn **Haw.**	**Cactaceae**	**Shrub**	**-**	**+**
Rhamnus triqueter **(Wallich) Lawson**	**Rhamnaceae**	**Shrub**	**-**	**+**
Rhamnus virgatus **Roxb.**	**Rhamnaceae**	**Shrub**	**-**	**+**
Rhus cotinus **Linn.**	**Anacardiaceae**	**Shrub**	**+**	**-**
Rhus parviflora **Roxb.**	**Anacardiaceae**	**Shrub**	**+**	**+**
Ricinus communis **Linn.**	**Euphorbiaceae**	**Shrub**	**+**	**+**
Rubus ellipticus **Benth.**	**Rosaceae**	**Shrub**	**+**	**+**

***Woodfordia fruticosa* (L.) Kurz**	**Lythraceae**	**Shrub**	**-**	**+**
***Xylosma longifolium* Clos.**	**Bixaceae**	**Shrub**	**-**	**+**
***Zanthoxylum alatum* DC**	**Rutaceae**	**Shrub**	**+**	**+**
***Zizyphus mauritiana* Lam.**	**Rhamnaceae**	**Shrub**	**+**	**+**
***Abutilon hirtum* (Lam.) Sweet**	**Malvaceae**	**Herb**	**-**	**+**
***Eupatorium adenophorum* Sprengel**	**Asteraceae**	**Herb**	**-**	**+**
***Musa paradisiaca* Linn.**	**Musaceae**	**Herb**	**+**	**-**
***Parthenium hysterophorum* Linn.**	**Asteraceae**	**Herb**	**-**	**+**
***Sauromatum venosum* Kunth**	**Araceae**	**Herb**	**-**	**+**
***Solanum erianthum* D.Don**	**Solanaceae**	**Herb**	**-**	**+**
***Urtica parvifolia* Roxb.**	**Urticaceae**	**Herb**	**-**	**+**
***Verbascum thepsus* Linn.**	**Scrophulariaceae**	**Herb**	**-**	**+**