academicJournals

Vol. 6(12), pp. 829-847, December 2014
DOI: 10.5897/IJBC2014.0745
Article Number: C9F477B49018
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Vegetation diversity and soil nutrient status of submergence zone of hydroelectric project in Srinagar of Garhwal Himalayas, India

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Received 14 July, 2014; Accepted 5 November, 2014

The aim of the present study was to assess vegetation diversity and soil nutrients status in submergence zone of hydroelectric project in Srinagar Garhwal Himalaya. The information on submergence zone was taken from hydroelectric project (HEP), the height of the dam is 93 m and subsequently submergence zone area will be developed. The submergence zone is presently under open condition and soon after completion of project work, the area will be submerged. The analysis of vegetation was done using quadrats method, and soil physico-chemical analysis was done using standard methods. The results indicate that average moisture percent of the study area was 7.78 %, water holding capacity 30.56% and bulk density 1.28 g m^{-3}. The soil pH was slightly basic (7.33). The soil organic carbon (SOC) was 0.23%. The amount of phosphorus (P) and potassium (K) were reported to be 12.25 and 103.07 kg ha^{-1}, respectively. The species diversity (H) ranged from H = 0.39-3.26 (trees) H = 1.84-3.01 (shrubs), H = 0.08-0.23 (herbs) and concentration of dominance (CD) ranged from CD=0.12-0.86 (trees), CD = 0.14 to 0.31 (shrubs), CD = 0.08-0.23 (herbs) however beta-diversity (β) ranged from β-2.72-4.0 (trees), β-3.10-4.0 (shrubs), β-4.93-9.77 (herbs). In the submergence zone, villagers are directly dependent on the resources traditionally for fuel, fodder, timber and many other things and have cultural and emotional attachment. Soon after submergence, the resources pressure of villager will be shifted to the adjacent forest (influenced zone). Therefore, special attention is needed through awareness of the villagers to restore the vegetation of adjacent forest from further degradation.

Key words: Submergence, plant and soil resources, hydroelectric project, Garhwal Himalaya.

INTRODUCTION

Biodiversity is essential for human survival, economic well-being and for the ecosystem function and stability (Singh, 2002). Biodiversity is essential to humankind, brings innumerable benefits, and has other importance values although humans have had strong negative impacts on biodiversity. Various ecosystem functions and

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services may be negatively affected by the loss of biodiversity (Schulze and Mooney, 1994). Habitat destruction, over exploitation, pollution and species introduction are the major causes of biodiversity loss (UNEP, 2001). Depletion of biodiversity is today's alarming problem all over the world. Extinction rate has been enhanced by human intervention resulting into habitat loss and climate change. Human have extensively altered the global environment, changing global bio-geological cycles, transforming land and enhancing the mobility of biota. Many species have been eliminated from areas dominated by human influences (Chapin III et al., 2000). The human influences on biodiversity and ecosystem are rapid and large, leading to frequent changes in land and resource use, increased frequency of biotic invasions, reduction in species number, creation of stresses and the potential for changes in the climate system (Kumar and Ram, 2005). The loss of biodiversity actually hampers and contrasts economic development (Kim and Weaver, 1994). The depletion of biodiversity is an alarming problem of the world. The rate of extinction has been enhanced by human-related habitat loss and climate change (Singh and Kushwaha, 2008).

Major causes of habitat destruction in the river valleys is construction of large hydroelectric projects, which have several benefits such as power, irrigation, tourism and industrial development, etc. But from biodiversity point of view, such projects are unethical as they impede the biological web of the environment, as a large hydro project leads to a complete alteration of a terrestrial habitat into an aquatic ecosystem (Gaur, 2007). Modifications in normal flow of river systems result in several complexities to people, forests, fauna, flora, microorganisms and land use pattern (Sharma, 2006). Gauthier et al. (2000) described that the vegetation dynamics of forest systems are controlled by numerous factors such as the available pool of species, the physical characteristics of the land, soil fertility, climate and disturbance regime characteristics.

Human and biological resources relations are closely linked. Human beings are taking several resources from the forests, but when the resources are exploited ruthlessly, it degrades the resources and hamper its further survival.

Keeping in view the importance of biodiversity and the consequent losses caused due to human activities, like road constructions, urbanization, dam constructions, etc., the present study was taken to assess the vegetation diversity and soil nutrient status in submergence zone of hydroelectric project in Srinagar valley, which may lost after submergence and affect the need of local inhabitants. Thus, the study was designed with the objectives: i) Assessment of vegetation diversity of proposed submergence zone of hydroelectric project on Alaknanda river, ii) soil nutrient status of the submergence zone, iii) Documentation of uses value of plants and iv) Possible recommendations for the conservation measures of vegetation diversity and soil nutrient status of the submergence zone.

METHODS

Study area

The study was conducted in the proposed submergence zone of hydroelectric project (HEP) of River Alkananda in Srinagar Garhwal Himalayas between the villages of Supana and Dhari Devi, covering a distance of 12 km approximately (Figure 1). A total of five sites, that is, site-I, II, III, IV and V were selected in the entire zone of 12 km. Each site was selected at 2 km interval to cover the complete zone with suitable representative samples of the study area. The River Alaknanda originates in the glacial region (Alkapuri glacier) of Himalaya in Chamoli district of Uttarakhand and enters district Pauri and Tehri Garhwal in Srinagar. The study was carried out in the right side of river flow from east to west direction which is proposed submergence zone of HEP, the area is located between 30° 14.472′ N latitude and 78° 49.953′ E longitude at an elevation ranging between 535-630 m from initial river flow. The identification marks of the study area for the soil and vegetation analysis in submergence zone was categorized with the help of GPS. The total height of dam is expected to be 93 m which is marked from the initial river flow at an elevation of 535 m above sea level marked in winter season.

Climate and vegetation

The climate of the study area is of monsoon type and has three different marked seasons in a year, viz., rainy, winter and summer. The mean annual temperature ranges between 17 to 23°C and the mean annual rainfall 960 mm. The forest was dominated by *Anogeissus latifolia* in tree layer and associated with *Acacia catechu* and *Lannea coromandelica* and in shrub species, *Carissa opaca* was observed dominant. The surrounding peaks are covered by *Pinus roxburghii* trees associated with *A. latifolia* in lower transitional boundaries.

Soil sampling and analysis

The soil sampling in submergence zone was done by categorizing total area into five sub-sites. The soil characteristic of each sub-site was done by collecting three samples randomly from two different depths, that is, 0-30, 30-60 cm. From each site, six samples were collected (two depths and 3 replicates each). Thus, from entire zone, 30 samples were collected for analysis. The collected soil samples were placed in a clean dried polythene bags with suitable description and identification marks. The collected soil samples were screened for coarse concentrations, stones, pieces of roots, leaves and other undecomposed or organic residues which were later removed. The samples were mixed well individually before use and were air dried at 20 to 25°C and 20 to 60% relative humidity (Jackson, 1958).

The moisture (%) was calculated by samples placed in oven at 100±2°C till their successive weights were constant. Water holding capacity (WHC) and texture of soil was determined as the methods described by Misra (1968). Soil bulk density (BD) was determined by the known volume of soil without disturbing the natural soil structure dried to remove moisture content. Soil pH was calculated with the help of dynamic digital pH meter by making (1:2.5, soil: water) solution. Soil organic carbon (SOC) was determined by Walkley and Black's rapid titration method (Walkley and Black, 1934). Exchangeable phosphorus (P) and available potassium

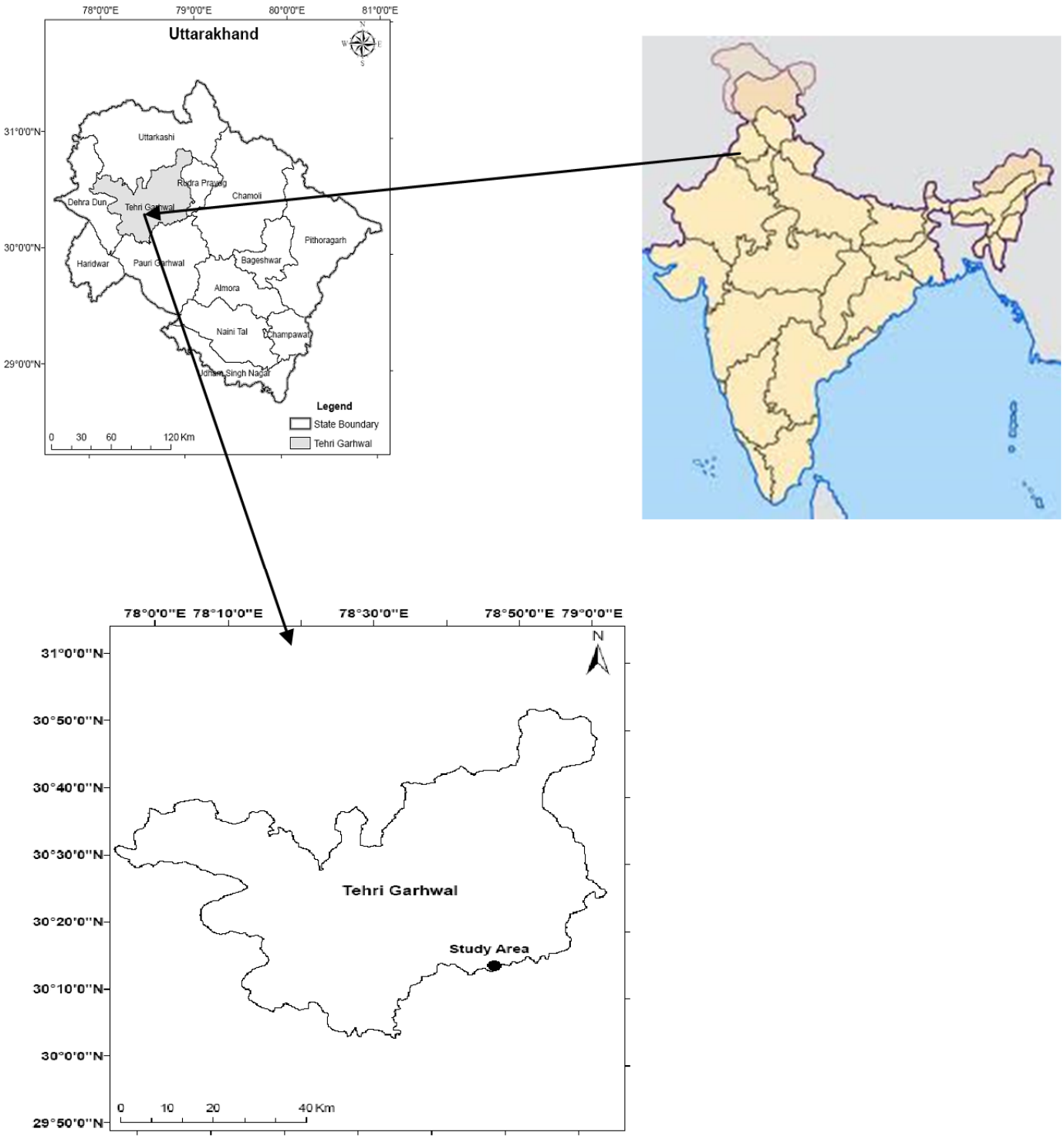

Figure 1. Location map of the study area.

(K) was determined as methods described by Jackson (1958).

Vegetation sampling and analysis

The vegetation sampling and analysis was carried out by placing 10 quadrats in each site and the total number of quadrats for entire submergence zone was fifty (50). The size of quadrate for trees was 100 m^2 and 10 quadrats which were randomly placed, 25 m^2 for shrubs and 1 m^2 for herbs was used in each site. The size and number of quadrats were determined based on species area curve (Misra, 1968) and the running means methods (Kershaw, 1973). In

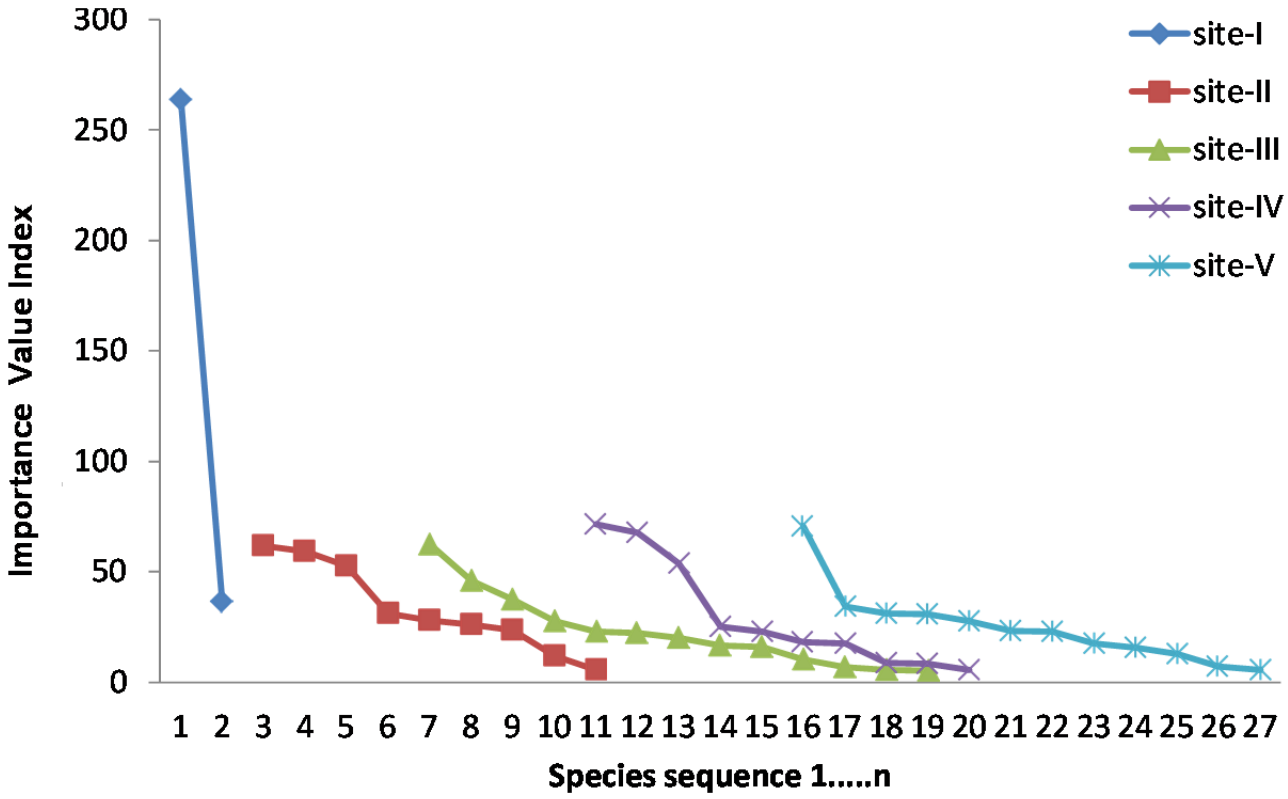

Figure 2. Dominance-diversity curve of trees on different sites.

each quadrate, the tree was considered having girth ≥30 cm (at 1.37 m from the ground). The quantitatively analysis of vegetation was done according to Curtis and McIntosh (1950). Importance value index (IVI) was calculated as sum of the relative frequency + relative density+ relative dominance (Curtis, 1959) for trees and shrubs while for herbs importance value (IV) was calculated as sum of relative frequency + relative density. Abundance to frequency ratio (A/F ratio) was determined for different species as regular (<0.025), random (0.025-0.05) and contagious (>0.05) following Curtis and Cottam (1956). Diversity index (H) was calculated using as the method described by Shannon and Wiener (1963), as: $H' = -\sum (Ni/N) \log_2 (Ni/N)$, where 'Ni' is total number of species 'i' and 'N' is the number of individuals of all species in that site. Concentration of dominance (CD) was also calculated as per Simpson (1949), as: $CD = \sum (Ni/N)^2$, where 'Ni' and N is the same as Shannon and Wiener information index. The beta-diversity (β-diversity) was calculated using following formula as: B-diversity = Sc/S, where Sc = α-diversity (species richness, S = total number of species that occurred in all sampling unit/total number of sampling unit. Dominance-diversity (D-D) curve was plotted between importance value index and species rank of trees (Figure 2) and shrubs (Figure 3). The curves indicate relationship among different species which shows the importance value of the site. The flora of Chamoli (Naithani, 1984) and Flora of western Himalayas (Gaur, 1999) were consulted for the identification of species. The details of species, their uses, parts used for different purposes by local inhabitant are based on secondary data (Table 6).

Similarity index

The similarity index was calculated using method given by Sorenson (1948) as followed: IS = 2C/A+B, where A = total number of species in forest A, B = total number of species in forest B and C = number of species common in A and B forests.

Social status of the inhabitants

The living standards of the people close to HEP were of all categories but most of them are poor. Although through dam compensation, for various purposes the living standard of people is improved. The cropping pattern of the area is of both types, rain fed and irrigated but most of the agriculture land is rain fed and has been affected under dam developmental activities. Some of the lands become unproductive due to dam construction work. Now the land holding of surrounding villagers have changed into small land holding and the agriculture productivity also affected, therefore agriculture based dependency of animals is also affected and utilizing forest resources for generating their income.

RESULTS

Soil properties

In the entire study area, the moisture content of the soils was highest on site-I followed by sites of II, III, V and lowest on IV, however, the water holding capacity was highest on site-III and lowest on site-IV (Table 1). The bulk density was reported highest on site IV followed by site-II, V and lowest was on site-I. In texture (%), the

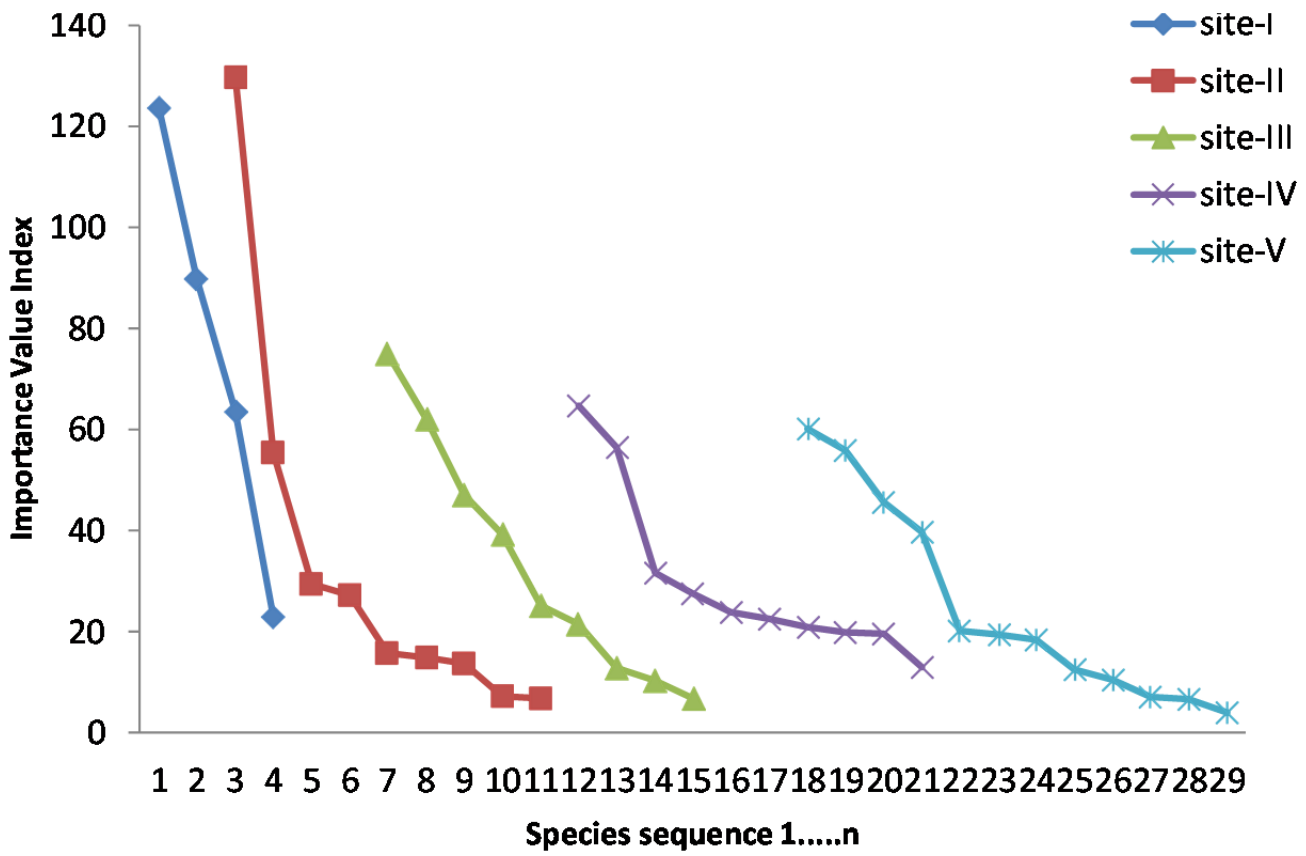

Figure 3. Dominance-diversity curve of shrubs on different sites.

maximum proportion of soil particles was contributed by sand particles on all the sites. The soil pH on all sites was slightly basic in nature. The minimum and maximum percentage of soil organic carbon was 0.16% and 0.28% on site-I and site-V. The soil organic carbon on each site reduced with increasing depth. Phosphorus (P) on each site reduced with depth except on site-II where, the amount of phosphorus was higher on lower depth. Among the site, the highest value of phosphorus was on site-II and lowest on site-I. Minimum and maximum amount of potassium was reported on site-I and site-III respectively (Table 1).

Dominance and species composition

Trees

On site-I, only two species, that is, *A. latifolia* and *Leucena leucocephala* were recorded of which the highest density and total basal cover was recorded for *A. latifolia* followed by *L. leucocephala* (Table 2). On site-II, a total of nine tree species were recorded where, *Holoptelia integrifolia* was the most dominant and *Cassia fistula* least dominant. The density was highest for *H. integrifolia* and lowest for *C. fistula*. While total basal cover was highest for *Mangifera indica* and lowest for *C. fistula.* Other associated species on the site were *A. latifolia*, *Adina cordifolia*, *Mallotus phillippensis*, *Aegle marmelos* and *Phoenix humilis.* On site-III, total thirteen species were recorded. The most and least dominant trees were *A. latifolia* and *Emblica officinalis* respectively. The density and total basal cover reported highest for *A. latifolia* and least total basal cover for *E. officinalis* and *Lannea coromandelica* however, least density for *H. integrifolia, Ficus bengalensis* and *E. officinalis*. Other associated species were *Acacia catechu, Mangifera indica, Aegle marmelos, Toona ciliata, Grewia oppositifolia, Ficus religiosa* and *Leucena leucocephala.* On site-IV, ten species were recorded. The highest values of importance value index, density and total basal cover were recorded for *A. latifolia*. The least total basal cover and importance value index was for *Toona ciliata*. The other species were *Acacia catechu, Mallotus philippensis, Aegle marmelos, Toona ciliata, Bauhinia variegata, F. religiosa, Lannea coromandelica* and *Leucena leucocephala*. On site-V, a total of twelve species were recorded where, the most and least dominant trees reported *A. latifolia* and *Bauhinia variegata*. The total basal cover, frequency and density

Table 1. Soil characteristics in different sites of submergence zone of hydroelectric project.

Site	Depth (cm)	Moisture (%)	WHC (%)	BD (g cm^3)	Sand (%)	Silt (%)	Clay (%)	pH (1:2.5 ratio)	SOC (%)	Phosphorus (kg/ha)	Potassium (kg/ha)
Site-I	0-30	10.57±1.39	34.40±3.65	1.11 ±0.08	61.51 ±9.07	17.3 ±5.84	21.22±4.15	7.2±0.36	0.2±0.05	11.05±2.08	128.05±21.84
	30-60	9.24±2.06	34.24±4.32	1.09±0.13	63.73±11.01	16.75±6.70	19.62±4.89	7.5±0.2	0.12±0.04	5.52±0.62	60.89±17.56
Site-II	0-30	9.76±2.15	34.16±1.03	1.28±0.25	59.88±16.93	23.02±12.12	17.1±4.98	7.1±0.06	0.3±0.02	13.62±1.94	145.97±19.15
	30-60	6.86±1.30	34.15±1.80	1.31±0.07	56.80±17.70	23.72±13.34	19.47±4.52	7.6±0.17	0.15±0.04	21.90±0.74	65.57±10.64
Site-III	0-30	9.76±4.13	28.78±1.84	1.08±0.02	65.69±6.13	14.47±2.19	19.84±3.98	7.2±0.17	0.30±0.04	15.29±2.48	158.29±23.23
	30-60	6.53±2.05	26.34±0.96	1.34±0.05	62.97±5.40	14.45±2.58	22.59±2.81	7.6±0.12	0.13±0.03	5.92±1.78	75.04±7.84
Site-IV	0-30	4.47±1.41	23.11±1.03	1.64±0.08	49.85±6.92	25.15±7.90	25.01±1.86	7.1±0.2	0.34±0.04	15.89±4.28	141.87±5.17
	30-60	5.94±0.84	26.44±1.12	1.51±0.06	50.53±6.89	25.60±8.27	23.87±4.13	7.7±0.17	0.15±0.03	6.71±4.20	60.48±2.96
Site-V	0-30	6.27±1.05	30.66±2.44	1.24±0.22	67.37±12.82	16.45±4.28	16.18±8.57	6.8±0.21	0.4±0.06	18.75±0.90	142.24±13.44
	30-60	8.41±4.83	33.34±1.88	1.24±0.19	62.78±12.87	17.72±8.68	19.50±4.36	7.5±0.25	0.16±0.06	7.89±3.33	52.27±9.53

values were also highest for *A. latifolia*. The associated species on the site were *Acacia catechu, Mallotus philippensis, Aegle marmelos, Toona ciliata, F. religiosa, F. bengalensis, Cassia fistula, Ficus carica, Lannea coromandelica* and *L. leucocephala* (Table 2).

Shrubs

On site-I, four species of shrub were reported of which *Mimosa himalayana* was the most dominant and *Eupatorium adenophorum* least dominant. The highest total basal cover was for *M. himalayana* and least for *E. adenophorum*. The highest density was for *Carissa opaca.*

On site-II, a total of 9 species were reported. The highest total basal cover, density and importance value index was for *Adhatoda vasica*, however lowest total basal cover of *Lantana camara* and density and importance value index for *Randia tetrasperma*. Other associated species were *Mimosa himalayana, Murraya koenigii, Carissa opaca, Abrus precatorius, Sida cordifolia, Euphorbia royleana* (Table 3).

On site-III, dominant shrub was *Adhatoda vasica* while highest total basal cover and density were reported for *E. royleana* and *Adhatoda vasica* respectively. The other associated species reported on this site were *Woodfordia fruiticosa, Ricinus communis, Plumbago zeylanica, Carissa opaca, Mimosa himalayana* and *Abrus precatorius*.

On site-IV, a total 10 species were reported where the most dominant and the least dominant species were *A. vasica* and *E. adenophorum* respectively. The highest total basal cover and density on the site was for *A. vasica*. The associated species were *W. fruiticosa, R. communis, C. opaca, M. himalayana, Euphorbia royleana, Murraya koenigii, Lantana camara.*

On site-V, Twelve species were reported with dominant species *Euphorbia royleana* and least dominant *R. communis*. The highest total basal cover and density was of *E. royleana* and *A. vasica* respectively. However, least total basal cover and density was for *R. communis*. The highest frequency was recorded for *C. opaca* and *M. koenigii*. The associated species on the site were *Ziziphus mauritiana, Rhus parviflora, Lantana camara, Colebrookia oppositifolia* and *Sida cordifolia* (Table 3).

Herbs

On site-I, ten species were reported with the highest importance value of *Peristrophe bicalyculata and lowest for Achyranthes aspera. The highest and lowest values of density were*

Table 2. Density (Ind. ha^{-1}), total basal cover (m^2 ha^{-1}), A/F ratio of trees on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	TBC	A/F ratio	Density	TBC	A/F Ratio	Density	TBC	A/F ratio	Density	TBC	A/F Ratio	Density	TBC	A/F ratio
Anogeissus latifolia	120	1.7	0.075	50	2.65	0.056	210	4.25	0.058	150	2.96	0.031	130	5.17	0.052
Leucena lecocephla	10	0.2	1.250	-	-	-	20	0.55	0.050	30	0.44	0.033	30	0.25	0.033
Acacia catechu	-	-	-	180	4.69	0.037	120	1.54	0.033	50	0.91	0.056	70	1.12	0.044
Mengifera indica	-	-	-	60	11.73	0.067	30	2.34	0.017	-	-	-	-	-	
Adina cordifolia	-	-	-	80	1.76	0.050	160	2.24	0.044	130	2.58	0.020	60	1.42	0.038
Mallotus philippensis	-	-	-	90	1.71	0.100	-	-	-	40	0.88	0.044	110	1.20	0.123
Holoptelia integrifolia	-	-	-	190	6.08	0.053	10	0.36	0.100	-	-	-	-	-	-
Aegle marmelos	-	-	-	80	2.83	0.050	50	0.97	0.125	20	0.24	0.200	30	0.31	0.075
Phonex humilis	-	-		20	1.02	0.050	-	-	-	-	-	-	-	-	-
Cassia fistula	-	-	-	10	0.45	0.100	-	-	-	-	-	-	60	0.64	0.067
T oona ciliata	-	-	-	-	-	-	40	2.44	0.100	10	0.11	0.100			
Ficus bengalensis	-	-	-	-	-	-	10	0.64	0.100				10	0.37	0.100
Grewia oppositifolia	-	-	-	-	-	-	90	1.84	0.100	-	-	-	-	-	-
Ficus religiosa	-	-	-	-	-	-	20	1.84	0.050	10	0.51	0.100	20	2.07	0.050
Emblica officinalis	-	-	-	-	-	-	10	0.32	0.100	-	-	-	-	-	-
Lannea comandelica	-	-	-	-	--	-	50	0.32	0.020	100	2.93	0.063	60	1.82	0.150
Bauhinia variegata	-	-	-	-	-	-	-	-	-	20	0.38	0.050	10	0.13	0.100
Ficus carica	-	-	-	-	-	-	-	-	-	-	-		60	0.32	0.150

reported for Solanum nigrum and Oxalis corniculata. The other associated species on the site were *Parthenium hysterophorus, Tridax procumbens, Euphorbia hirta, Bidens pilosa, Gnaphalium luteo-album* and *Leptadenia reticulata.*

On site-II, a total of 22 species were recorded. The highest importance value was for *Poa annua* and lowest for *Sida acuta*. The associated species on the site observed were *Achyranthes aspera, Barleria strigosa, Nepeta hindostana, Sida cordifolia, Borreria articularis, Abrus precatoricus, Debregeasia longifolia, Solanum nigrum, Bidens pilosa, Blepharis maderaspatensis, Lamium amplexicaule, Chenopodium album, Gnaphalium lueto-album, Adiantum incisum, Cynodon dactylon, Euphorbia hirta, Brassica rugosa, Parthenium hysterophorus, Cymbopogon martinii* and *Thysanolaena maxima.*

On site-III, sixteen species were reported. The highest and lowest values of importance value and density were reported for *Andropogon munroi* and *Asparagus racemosus* (Table 4). The associated species were *Phymbeyo zeylanica, Cryptolapis buchananii, Parthenium hysterophorus, Cissampelos pareira, Chenopodium album, Cynodon dactylon, Solanum nigrum, Poa annua, Gnaphalium luteo-album, Achyranthes aspera, Peristrophe bicalyculata, Barleria cristata* and *Lamium amplexicaule.*

On site IV, Out of eighteen species, the highest importance value was reported for *Parthenium hysterophorus* and lowest for *Asclepias curassavicca*. The highest density was of *Andropogon munroi* and lowest for *Asclepias curassavica*. The other associated species were *Adiantum incisum, Reinwardtia indica, Coccinia grandis, Ipomoea nil, Peristophe bicalyculata, Barleria cristata, Cynodon dactylon, Asclepias curassavica, Boehraria diffusia, Achyranthes aspera, Evolvulus alsinoides, Oxalis corniculata, Debregeasia longifolia, Poa corniculata, Euphor-*

Table 3. Density (ind. 25m^2), total basal cover (cm^2 25 m^{-2}) of shrubs on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio	Density	TBC	A/F ratio
Adhatoda vasica	1.9	0.06	0.211	9	0.115	0.090	5.4	0.016	0.084	2.9	0.04	0.080	4.1	0.036	0.164
Mimosa himalayana	1.3	0.94	0.325	1.5	0.031	0.375	2.1	0.010	0.084	2.6	0.03	0.067	0.3	0.009	0.300
Murraya koenigii	-	-	-	3.3	0.040	0.092	4.2	0.013	0.086	1.4	0.02	0.157	4.0	0.070	0.112
Carissa opaca	2.8	0.09	0.175	0.9	0.006	0.225	1.2	0.012	0.300	1.1	0.01	0.123	2.9	0.025	0.081
Abrus precatorius	-	-	-	0.9	0.009	0.225	0.4	0.005	0.400	-	-	-	-	-	-
Lantana camara	-	-	-	0.4	0.003	0.400	-	-	-	1.9	0.01	0.475	0.5	0.021	0.500
Sida cordifolia	-	-	-	0.8	0.005	0.200	-	-	-	-	-	-	-	-	-
Randia tetrasperma	-	-	-	0.3	0.004	0.300	-	-	-	-	-	-	-	-	-
Euphorbia royleana	-	-	-	0.8	0.057	0.800	1.0	0.039	0.250	0.4	0.02	0.100	1.8	0.170	0.113
Eupatorium adenophorum	0.7	0.03	0.700							0.4	0.01	0.400	-	-	-
Woodfordia fruiticosa	-	-	-	-	-	-	0.4	0.008	0.400	0.4	0.03	0.400	-	-	-
Ricinus communis	-	-	-	-	-	-	0.6	0.009	0.067	0.9	0.01	0.058	0.1	0.002	0.100
Plumbago zeylanica	-	-	-	-	-	-	0.2	0.003	0.200	-	-	-	-	-	-
Rhus parviflora	-	-	-	-	-	-	-	-	-	0.6	0.01	0.150	0.3	0.069	0.300
Ziziphus mauritiana	-	-	-	-	-	-	-	-	-	-	-	-	0.4	0.008	0.400
Colebrookia oppositifolia	-	-	-	-	-	-	-	-	-	-	-	-	1.8	0.016	0.450
Sida cordifolia	-	-	-	-	-	-	-	-	-	-	-	-	1.1	0.015	0.123
Aerva sanguinolenta	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0.007	0.225

Bia hirta and *Tridax procumbens.*

On site-V, a total of 17 species were reported, where the highest importance value among species was for *Andropogon munroi* and lowest of *A. racemosus*. The highest density again was reported for *Andropogon munroi* and lowest for *A. racemosus*. The other associated species were *Ipomoea nil, Chenopodium album, Adiantum incisum, Barleria strigosa, Boehraria diffusia, Parthenium hysterophorus, Cynodon dactylon, Cissampelos pareira, Achyranthes aspera, Poa annua, Oxalis corniculata, Euphorbia hirta, Rubia manjitha, Anisochilus carnosus* and *Tridax procumbens* (Table 4).

Species richness

In tree layer, among the sites, the maximum species richness (13 species) was on site-III and minimum richness (2 species) on site-I. Among the shrub, the richness was highest on site-V and lowest on site-I. In herb layer, the maximum species were on site-II (22 species) and minimum (10 species) on site-I (Table 5).

Distribution pattern (%)

In tree layer (Table 2), on site-I, the distribution pattern of both species was contagious. On site-II, the distribution pattern of all species was contagious, and some of the species were distributed randomly and none of the species were reported regularly in distribution. On site-III, maximum species were distributed contagiously. *M. indica* and *L. coromandelica* were distributed regular and rests of the species were distributed randomly. On site-IV, the distribution pattern of most species was contagious except of *Mallotus philippensis, Anogeissus latifolia* and *L. leucocephala* which were distributed random and *Adina cordifolia* regularly (site-IV). On site V, among the species, majority of species were distributed contagiously, few random and none of

Table 4. Density (ind. m^2), IV (importance Value) and A/F ratio of herbs on different sites in submergence zone of hydroelectric project.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio
Solanum nigrum	1.85	43.6	0.074	0.35	11.0	0.152	0.25	5.3	0.250	-	-	-	-	-	-
Achyranthes aspera	0.2	4.5	0.8	0.25	5.1	0.250	0.15	2.8	0.600	0.15	3.4	0.150	0.35	8.0	0.088
Parthenium hysterophorus	0.8	20.5	0.128	1.4	16.1	0.363	2.4	30.3	0.150	4.25	36.2	0.118	2	24.5	0.099
Tridax procumbens	1.9	39.1	0.119	-	-	-	-	-	-	0.5	5.1	0.500	0.7	9.9	0.175
Euphorbia hirta	0.25	7.5	0.25	0.25	3.4	0.200	-	-	-	0.35	4.3	0.350	1.55	20.6	0.097
Oxalis corniculata	0.15	6.5	0.15	-	-	-	-	-	-	1.6	15.6	1.177	0.25	4.4	0.250
Bidens pilosa	0.65	11.5	0.65	0.25	3.4	1.000	-	-	-	-	-	-	-	-	-
Gnaphalium luteo-album	0.25	7.5	0.25	0.35	7.5	0.133	0.35	5.9	0.350	-	-	-	-	-	-
Peristrophe bicalyculata	3.55	50.7	0.393	-	-	-	0.55	10.9	0.138	0.6	8.2	0.150	-	-	-
Leptadenia reticulata	0.35	8.5	0.35	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon munroi	-	-	-	1.5	16.1	0.350	6.5	59.0	0.289	4.5	30.6	0.367	8.1	57.8	0.400
Barleria strigosa	-	-	-	0.35	4.0	1.400	-	-	-	-	-	-	0.15	2.3	0.600
Nepeta hindostana	-	-	-	1.4	10.8	1.600	-	-	-	-	-	-	-	-	-
Cannabis sativa	-	-	-	0.25	10.4	0.104	-	-	-	-	-	-	-	-	-
Borreria articularis	-	-	-	0.35	4.0	0.800	-	-	-	-	-	-	-	-	-
Abrus precatorius	-	-	-	1.4	16.1	0.200	0.2	4.9	0.200	-	-	-	-	-	-
Debregeasia longifolia	-	-	-	0.25	6.9	0.933	-	-	-	0.250	3.9	0.250	-	-	-
Blepharis maderaspatensis	-	-	-	0.35	9.3	0.125	-	-	-	-	-	-	-	-	-
Lamium amplexicaule	-	-	-	1.4	10.8	0.200	0.2	3.1	0.800	-	-	-	-	-	-
Adiantum incisum	-	-	-	1.4	12.6	0.350	-	-	-	2.45	19.6	0.233	0.8	10.4	0.200
Brassica rugosa	-	-	-	0.35	4.0	2.200	-	-	-	-	-	-	-	-	-
Sida acuta	-	-	-	0.25	3.3	0.600	-	-	-	-	-	-	-	-	-
Cymbopogon martinii	-	-	-	0.35	5.8	0.350	-	-	-	-	-	-	-	-	-
Thysanolaena maxima	-	-	-	1.4	12.6	0.400	-	-	-	-	-	-	-	-	-
Phymbeyo zeylanica	-	-	-	-	-	-	0.25	5.3	0.250	-	-	-	-	-	-
Cryptolepis buchananii	-	-	-	-	-	-	0.35	5.9	0.350	-	-	-	-	-	-
Asparagus racemosus	-	-	-	-	-	-	0.1	2.5	0.400	-	-	-	0.1	2.1	0.400
Cynodon dactylon	-	-	-	-	-	-	0.7	11.9	0.175	0.15	3.4	0.150	0.7	9.9	0.175
Chenopodium album	-	-	-	0.25	5.1	0.150	1.35	19.8	0.150	3.9	35.9	0.092	2	20.0	0.222
Barleria cristata	-	-	-	-	-	-	0.2	4.9	0.200	0.5	7.8	0.125	-	-	-
Reinwardtia indica	-	-	-	-	-	-	-	-	-	0.3	5.5	0.133	-	-	-
Coccinia grandis	-	-	-	-	-	-	-	-	-	0.25	3.9	0.250	-	-	-
Ipomoea nil	-	-	-	-	-	-	-	-	-	1	8.8	0.444	0.15	3.8	0.150
Asclepias curassavica	-	-	-	-	-	-	-	-	-	0.1	1.8	0.400	-	-	-

Table 4. Contd.

Species	Site-I			Site-II			Site-III			Site-IV			Site-V		
	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio	Density	IV	A/F ratio
Evolvulus alsinoides	-	-	-	-	-	-	-	-	-	0.25	3.9	0.250			
Cissampelos pareira	-	-	-	-	-	-	1.2	20.6	0.098	-	-	-	0.15	3.8	0.150
Boehraria diffusia	-	-	-	-	-	-	-	-	-	-	-	-	0.25	4.4	0.250
Poa annua	-	-	-	1.4	21.4	0.118	0.5	6.9	0.500	0.15	2.1	0.600	0.3	4.7	0.300
Rubia manjitha	-	-	-	-	-	-	-	-	-	-	-	-	0.65	9.6	0.163
Anisochilus carnosus	-	-	-	-	-	-	-	-	-	-	-	-	0.15	3.8	0.150

the species show regular distribution. In shrub layer (Table 3) and herb layer (Table 4), all the species were distributed contagiously.

Diversity indices

In tree layer (Table 5) among the sites, maximum diversity of tree was on site-V (H=3.26) and the minimum diversity on site-I (H=0.39). In shrub layer (Table 5), the maximum diversity was on site-V (H=3.01) and minimum on site-I (H=1.84). In herb layer (Table 5), the highest diversity was on site-II and lowest diversity on site-I. The concentration of dominance ranged from CD=0.12-0.86 (trees), CD=0.15-0.31 (shrubs) and CD=0.08 to 0.23 (herbs) (Table 5). In tree layer, the β-diversity ranged from β-2.72 (site-II) to β-4.0 (site-I), in shrub layer β-3.10 (site-III) to β-4.0 (site-I), in herb layer β-diversity from β-4.93 (site-IV) to β-9.77 (site (II).

Similarity index

The similarity index of species was calculated between the zones of similar layers of vegetation. In the tree layer, the index of similarity was 88% between the submergence and influenced zone. However, the similarity in shrubs layer was 91% and in herb layer was 58%.

DISCUSSION

Soil properties

In the physical properties of soil, moisture was 7.78%, WHC was 30.56, bulk density 1.28 g cm^3. The low amount of moisture and WHC in sub-mergence zone could be because of regular construction work where most of the trees were affected. The canopy cover was too low which enhanced evaporation in the soil. Lower canopy cover reduced organic matter input in soil which also reduced WHC. Among the soil particles, higher proportion was reported for sand. Silt and clay proportion was reported comparatively similar (Table 1).

In the chemical properties of soil, the average values of soil pH, SOC, P and K were reported to be 7.33, 0.23, 14.92 kg ha^{-1} and 103.07 kg ha^{-1} respectively (Table 1). A study carried out by Kumar et al. (2010a) on the *Anogessius latifolia* forest of this same region, reported that SOC ranged from 0.47 to 0.68%, phosphorus 9.67 to 10.56 kg ha^{-1} and potassium 141.87 to 172.48 kg ha^{-1}. The values of SOC and P of the present study were lower than the study carried out by Kumar et al. (2010a).

The reducing level of SOC and P in the present study might be due to high biotic pressure on the site and disturbances created on vegetation for dam construction and other activities.

Dominance and species composition

Among the sites, the average tree density and total basal cover was 584 plants ha^{-1} and 16.24 m^2 ha^{-1}, respectively. However, in shrub layer, the average density and total basal cover values were 14.18 plant 25 m^2 and 0.424 cm^2 25 m^2, respectively. A study carried out by Kumar et al. (2004), in sub-tropical forests of the Garhwal Himalaya, shows values of total density and total basal cover ranging from 832 to 884 trees ha^{-1} and 14.30 to 24.83 m^2 ha^{-1}, respectively. These values of density were quite higher than the present study, because of high biotic pressure on the forest by villagers for various requirement including dam development activities. Kumar et al.

Table 5. Species richness, species diversity (H), concentration of dominance (CD) and beta diversity of trees, shrubs and herbs on different sites in submergence zone of hydroelectric project.

Site	Species richness			Species diversity (H')			Concentration of dominance (CD)			beta diversity (β)		
	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs
Site-I	2	4	10	0.39	1.84	2.63	0.86	0.31	0.21	4.0	4.0	6.66
Site-II	9	9	22	2.81	2.30	4.06	0.17	0.30	0.08	2.72	3.33	9.77
Site-III	13	9	16	3.09	2.51	2.88	0.15	0.23	0.22	3.22	3.10	5.81
Site-IV	10	10	18	2.80	2.98	3.23	0.16	0.14	0.14	3.22	3.33	4.93
Site-V	12	12	21	3.26	3.01	2.89	0.12	0.15	0.23	3.75	3.75	5.23

Table 6. Plant species and their ethno medicinal uses by surrounding inhabitants.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
Acacia catechu (L.f.) Willd.	Mimosaceae	Fairly Common	T	Medicinal, timber	Bark	Diarrhoea, Dysentery, Bronchitis, Menstrual disorders
Adina cordifolia (Roxb.) Hook.f. ex Brandis	Rubiaceae	Common	T	Medicinal, Construction Furniture, Agricultural implements	Bark Roots	Diabetes Dysentery
Abrus precatorius L.	Fabaceae	Common	S	Medicinal	Roots Seed Powder and Paste	Bone fracture Cough, Oboritifacient, Fever, Rheumatic Arthritis , Dysentery
Achyranthes aspera L.	Amaranthaceae	Fairly common	H	Medicinal Beverage	Roots Leaf	Malarial fever Dropsy Bronchitis
Adhatoda vasica Nees	Acanthaceae	Fairly Common	S	Medicinal Vegetable	Roots Leaves Flowers	Cough, Cold Pulmonary infections Bronchitis & Fever
Adiantum incisum Forsk	Adiantaceae		H	-	-	-
Aegle marmelos (L.) Corr.	Rutaceae	-	T	Medicinal	Fruit Pulp	Digestive disorders
Aerva sanguinolenta (L.) Blume	Amaranthaceae	Common	S	Medicinal	-	Diuretic & Demulcent
Andropogon munroi C.B Clarke	Poaceae	Not common	H	Fodder	-	-
Anisochilus carnosus (L.f.) Wall. ex Benth	Lamiaceae	Fairly common	H	Medicinal	Plant extract	Cough Cold

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
Anogeissus latifolia (Roxb. ex DC.)	Combretaceae	Common	T	Construction Agricultural implements Tannin Black dye	-	-
Asclepias curassavica L.	Asclepiadaceae	Common	H	Medicinal	Roots , Latex	Causes Vomiting Cuts and wounds
Asparagus racemosus Willd.	Liliaceae	-	H	Medicinal	Roots	Antiseptic and Refrigerant
Barleria cristata L.	Acanthaceae	Fairly common	H	Medicinal, Beverage	Roots Leaves	Bronchitis Pneumonia Wound Swelling
Barleria strigosa Willd.	Acanthaceae	Common	H	Medicinal, Apiculture	Roots	Cough
Bauhinia variegata L.	Caesalpiniaceae	Common	T	Medicinal, Construction Agricultural implements	Dried Leaves	Cough
Bidens pilosa L.	Asteraceae	Common	H	Medicinal, Fodder	Plant extract	Cough Bronchitis Leucoderma
Blepharis maderaspatensis (L.) Roth	Acanthaceae	Uncommon	H	-	-	-
Boerhavia diffusa L.	Nyctaginaceae	Common	H	Medicinal	Leaf	Eye complaints
Borreria articularis (L,f.) F.N Williams	Rubiaceae	Common	H	Medicinal	Seeds Leaves	Diarrhoea, Dysentery Haemorrhoids
Brassica rugosa Prain	Brassicaceae	-	H	Medicinal, Vegetable	Seed oil	Body ache, Skin diseases , Cold
Carissa opaca Stapf ex Haines	Apocyanaceae	Frequent	S	Edible	-	-
Cassia fistula L.	Caesalpiniaceae	Common	T	Medicinal	Bark Fruit pulp	Antiseptic, Asthama, Bronchitis, Skin Diseases
Chenopodium album L.	Chenopodiaceae	Common	H	Vegetable	-	-
Cissampelos pareira L.	Menispermaceae	Common	H	Medicinal	Leaves Roots	Constipation Gastric troubles, Psychotherapy Cough, Urinary troubles
Coccinia grandis (L.) Voigt	Cucurbitaceae	Common	H	Medicinal	Leaves, Roots Fruit, juice	Diabetes, Antiseptic and Gonorrhoea
Colebrookia oppositifolia J.E. Smith	Lamiaceae	Common	S	Medicinal	Leaf	Wounds
Cryptolepis buchananii Roem. and Schult.	Asclepiadaceae	Frequent	H	-	-	-
Cymbopogon martinii (Roxb.) Wat.	Poaceae	Common	H	-	-	-
Cynodon dactylon (L.) Pers.	Poaceae	Common	H	Medicinal	Roots	Fever and Internal injury

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
Debregeasia longifolia (Burm.f.) Wedd.	Urticaceae	Common	H	Fodder and Fibre	-	-
Emblica officinalis Gaert.	Euphorbiaceae	-	T	Medicinal Tannin	Fruit	Source of Vitamin C
Eupatorium adenophorum Spreng.	Asteraceae	Common	S	Medicinal	Leaves	Wounds
Euphorbia hirta L.	Euphorbiaceae	Common	H	Medicinal	Plant extract	Bronchial infection Asthama
Euphorbia royleana Boiss.	Euphorbiaceae	Fairly Common	S	Medicinal	Latex	Antiseptic and Germicidal
Ficus benghalensis L.	Moraceae	Fairly Common	T	Medicinal, Tent Poles Cart Yokes, Boats	Latex	Antidiabetic
Ficus carica L.	Moraceae	Common	T	Good fodder, fruit	Leaves, fruit	Fruits used as digestive purposes
Ficus religiosa L.	Moraceae	Common	T	Medicinal, Charcoal and Packing Cases	Bark	Bronchitis and Skin ailments
Gnaphalium luteo-album L.	Asteraceae	Common	H	-	-	-
Grewia opositifolia Buch.-Ham. ex D. Don	Tiliaceae	Common	T	Medicinal and Edible Ropes, Nets, Sacs Brushes and brooms	Fruit	-
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	Abundant	T	Medicinal, Charcoal Construction and Fuel	Bark	Rheumatic Pain
Ipomoea nil (L.) Roth	Convolvulaceae	Common	H	Medicinal	Decoction of seeds	Fever Constipation
Lamium amplexicaule L.	Lamiaceae	Fairly common	H	-	-	-
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	-	T	Medicinal, Tannin Fuel, Fodder and Agricultural Implements	Bark	Diarrhoea
Lantana camara L.	Verbenaceae	Common	S	Medicinal and Fuel	Leaves	Insecticidal, Germicidal and Skin Ailments
Leptadenia reticulata (Retz.) Wight and Arn.	Asclepiadaceae	Rare	H	Medicinal	Leaves Roots and Plant extract	Skin ailments Antiseptic and Useful to control abortion
Leucaena leucocephala (Lam.) De Wit.	Mimosaceae	Not uncommon	T	Planted for soil conservation	-	-
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	-	T	Dye, Anthelmintic, Purgative, Fuel and Match Boxes	-	-

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
Mangifera indica L.	Anacardiaceae	Abundant	T	Medicinal Edible and Construction	Bark, Seeds and Resin	Haemorrhage and Diarrhoea
Mimosa himalayana Gamble	Mimosaceae	Common	S	Medicinal and Fodder	Leaves	Cough, Cold Bronchitis and Urinary Complaints
Murraya koenigii (L.) Spreng.	Rutaceae	Common	S	Medicinal Flavouring	Bark, Leaves Roots	Insecticide and Pisicide
Nepeta hindostana (Roth.) Haines	Lamiaceae	Common	H	Medicinal	Plant extract	Cardiac tonic Fever and Gonorrhoea
Oxalis corniculata L.	Oxalidaceae	Common	H	Vegetable	-	-
Parthenium hysterophorus L.	Asteraceae	Common	H	-	-	-
Peristrophe bicalyculata (Retz.) Nees	Acanthaceae	Common	H	Medicinal	Plant paste	Wounds
Phoenix humilis Royle ex Becc. and Hook.f.	Arecaceae	Common	T	Edible, Fibre Brooms and Hats	-	-
Plumbago zeylanica L.	Plumbaginaceae	-	H	Medicinal	Roots	Skin diseases, Wounds
Poa annua L.	Poaceae	Common	H	-	-	-
Randia tetrasperma (Roxb.) Poir.	Rubiaceae		S	-	-	-
Reinwardtia indica Dumort.	Linaceae	Common	H	Apiculture and Mouth wash	Petals	Mouth wash
Rhus parviflora Roxb.	Anacardiaceae	Abundant	S	Medicinal Edible and Fuel	Leaves	Cholera
Ricinus communis L.	Euphorbiaceae	-	S	Castor oil	Seeds	Purgative and Laxative
Rubia manjith Roxb. ex Fleming	Rubiaceae	Common	H	Medicinal and Dye	Roots, Stem Flowers	Tonic, Astringent and Bacillary dysentery

T: Tree, S: shrub, H: herb.

Table 6. Contd.

Tree species	Family	Status	Life form	Biodiversity value	Part used	Ailment
Sida acuta Burm.f.	Malvaceae	Common	H	Medicinal and Fibre	Leaves Roots Stem	Demulcent Diuretic and Leucorrhoea
Sida cordifolia L.	Malvaceae	Common	H	Medicinal and Fibre	Roots Seed powder	Astringent, Diuretic, Tonic and Dyspepsia
Solanum nigrum L.	Solanaceae	Common	H	Medicinal and Edible	Fruit Plant extract	Liver, Piles Dysentery Diarrhoea, Fever Eye ailments
Thysanolaena maxima (Roxb.) O. Kuntze	Poaceae	Common	H	Fodder and Brooms	-	-
Toona ciliata M. Roem.	Meliaceae	Common	T	Construction Furniture and Dye	-	-
Tridax procumbens L.	Asteraceae	Common	H	Medicinal and Vegetable	Plant paste	Wounds and Cuts
Woodfordia fruticosa (L.) Kurz	Lythraceae	Common	S	Medicinal and Dye	Leaves Bark and Dried flowers	Febrifuge, Tonic and Haemorrhoids
Ziziphus mauritiana Lam.	Rhamnaceae	Fairly Common	S	Edible, Construction, Agricultural implements ,Apiculture	-	-

T: Tree, S: shrub, H: herb.

(2010a) also conducted a study on different aspects of *A. latifolia* forest, the density for trees ranged from 260 to 380 trees ha^{-1} and for shrub ranged from 970 to 1790 shrubs ha^{-1}. In this study, the values of density were quite lower because of higher pressure especially by the villagers for their daily needs.

In the tree layer, the common species reported were *A. latifolia, Acacia catechu, Adina cordifolia, Cassia fistula, E. officinalis Holoptelia integrifolia, Lannea coromandelica, Mallotus philippensis*. The forest was dominated by *A. latifolia*. *Carissa opaca* was dominant in shrub layer with associated shrubs of *Abrus precatorius, Adhatoda vasica, Colebrookia oppositifolia, Lantana camara, Mimosa himalayana, Murraya koenigii, Rhus parviflora, Woodfordia fruiticosa and* Ziziphus mauritiana. In herb layer, the common species noticed were *Solanum nigrum, Achyranthes aspera, Tridax procumbens, Euphorbia hirta, Oxalis corniculata, Barleria strigosa, Nepeta hindostana, Sida cordifolia*, *Solanum nigrum, Poa annua, Bidens pilosa, Blepharis maderaspatensis, Chenopodium album, Adiantum incisum, Sida acuta*, *Asparagus racemosus, Cynodon dactylon.*

Among the sites, the trees density was highest in site-III however; the TBC was reported higher on site-II, while the lowest values of density and TBC of trees were reported on site-I (Table 2). In shrub layer, the highest density was on site-II and TBC on site-V (Table 3). Herb layer density was highest on site-V and lowest on site-I (Table 4).

Species richness

The maximum richness of species in tree layer was on site-III, because the site was located far from the inhabitant's area thus pressure on the forest was mild which favoured species richness. The minimum number of species was observed on site-I, because site-I was close to dam development site. Therefore, most of the species have been damaged by heavy machinery work and dust pollution created by machine as well as human activities such as movement of labour, rolling of stone, damping materials, etc. A study carried out by Yadav and Gupta (2005) in Rajasthan suggested that anthropogenic disturbances have adverse impact on the woody vegetation. They also suggested that species richness was higher in undisturbed forest as compared to partially disturbed forest. Kumar et al. (2010b) conduct a study in the same site of the dam project for conservation strategies of *A. latifolia* showing that various disturbance agents such as grazing, browsing, over-exploitation and major dam construction work in this valley affect the growth of *A. latifolia*. The dominant forest cover of this valley area is covered by *A. latifolia* which is main source of fuel, fodder and minor timber and highly disturbing by developing activities, that is, dam and road construction work. Boring et al. (1981) emphasized the positive role of mild disturbances in improving the regeneration of tree. Levin (1976) also indicated sever disturbance has deleterious effect on regeneration. Khan et al. (1986) reported that erosion action of torrential rains on slopes can also cause a decrease in the number of seedling during the rainy season. The long history of human interaction with plants, animals and environmental factors in the mountain region has a significant impact on the biological diversity at different levels. The topography, soil, climate and geographical location also influenced the vegetation diversity of the forest. In modern time, Himalayan forest ecosystems have witnessed great natural and biotic disturbances. Yadav and Gupta (2005) reported that the number of shrubs reduced with increasing level of anthropogenic disturbance on the forest sites.

Distribution pattern (%)

Among the vegetation layers, the distribution pattern of trees was contagious, random and regular. Although contagious distribution pattern of the species was common and in shrub layer, most of the species were distributed contagiously. However in herbs layer all the species on all sites were distributed contagiously. Odum (1971) stated that contagious distribution is the commonest pattern in nature and random distribution found only in very uniform environment and the regular distribution occurs where sever competition between the individuals exist (Panchal and Pandey, 2004; Kumar et al., 2010a). Regular and random distribution pattern of the species reflect the high biotic pressure through grazing and lopping.

Species diversity (H') and concentration of dominance (CD)

The diversity values were 0.39-3.26 for tree layer, 1.84-3.01 for shrub layer. Kumar et al. (2004) also reported diversity value 2.76 for the sub-tropical forest of *A. latifolia* of this region in Garhwal Himalaya. Kumar et al. (2010a) carried a study on *A. latifolia* forest and reported diversity values 0.846 to 1.710 for trees and 1.943 to 2.847 for shrubs which are within the range values of the present study.

The concentration of dominance ranged from 0.12 to 0.86 (trees), 0.14 to 0.31 (shrubs). The values of CD reported by Riser and Rice (1971) and Knight (1975) ranged from 0.326 to 0.693 for trees and 0.185 to 0.719 for shrubs. These reported values of CD for trees are within the range of present study but shrub values were higher for the present study.

Similarity index

Similarity index is a comparison of the current vegetation on site. A similarity index determines how closely the plant community resembles. Similarity index is expressed as percentage of the reference community that is currently on an ecological site. The results suggest that the similarity between the sites for shrubs layer was higher followed by trees and shrubs. Thus it is indication that where the similarity index is low the species are diverse. Therefore diverse vegetation has diverse resources which are used by the local inhabitant for their need. In this comparison, the diverse species reported from submergence zone were *Phonex humilis, F. carica* (tree layer), *Sida acuta* (shrub layer) and *Achranthes aspera, Brassica rugosa, Cymbopogon maritinii, Phymbeyo zeylanica, Asparagus racemosus, Barleria cristat, Coccinia grandis, Asclepias curassavica,* Boehravia diffusa (herb layer) were only reported from the submergence zone, although the species are providing several needs to the local inhabitants. Resource consumption by local inhabitant from submergence zone. The resource consumption by local people from submergence zone is given in Table 6. A total of 71 species were recorded from the submergence zone having 65 genera and 37 families in the study area in which 18 species of trees having 17 genera and 12 families were recorded in the tree layer, and 15 species with 15 genera in 14 families were observed for shrub layer while in herb layer 38 species having 36 genera in 22 families were recorded (Table 7).

People use these resources, that is, fuelwood, fodder, timber, edible wild fruits, medicinal plants daily for human and animal uses and several other purposes from submergence. It is evident from the studies carried out by

Table 7. Total species, genera and families of plants in submergence zone of HEP.

Parameter	Trees	Shrubs	Herbs	Total
Species	18	15	38	71
Genera	17	15	36	65
Families	12	14	22	37

Table 8. Resource consumption by local inhabitant from submergence and influenced zones of HEP.

Zone	Forest resource use									
	Major						Minor			
	Fuel	Fodder	Timber	Grazing	Browsing	Agricultural implements	Medicinal value	Edible fruit	Religious purpose	Fiber
Submergence	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low
Influenced	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low

other workers (Ballabha, 2013; Tiwari, 2010) that the species are used by the villager for several purposes. Bahuguna et al. (2011) also carried out a study in this region and also suggested local villagers used different plant species for various purposes such as food, religious uses, perfume, medicinal, fodder, dye, household articles, agricultural implements, beverage, fuel, ornamental, narcotic, insecticide, etc. Although people are still utilizing forest resources from the adjacent influence zone (Table 8). Just after submergence of the present study area, the demand of the villagers/inhabitant will be directly shifted to the influenced zone, which will be comparatively double. This shifted pressure of inhabitant on influenced zone will rapidly degrade the resources and there will be rapid loss of biodiversity from the influenced zone.

Although the hydroelectric project stimulate economic growth, building of roads, schools, hospitals cultural and recreation facilities under their plans but it has some negative impacts on biodiversity of the area.

Recommendations for conservation of biodiversity

The study on collected data revealed that the submergence zone is rich particularly in plant diversity as they are the source of different villagers need, but the developmental activities, the constructions of hydroelectric power projects are causing a great loss of plant diversity under the functioning of hydro project work and the most loss will occur after submergence of the area. The earlier studies are evident that hydroelectric power projects create environmental issues originating from submergence of large area including forest (Samant et al., 2007; Tiwari, 2010). The degradation of biodiversity in the Himalayan region has reached dangerously alarming state (Gupta, 1960; Gaur, 1999). The catchment area of rivers supports a large number of plant species of human use and scientific interest, including highly potential medicinal herbs; these require special attention for conservation (Uniyal, 1968; Gaur et al., 1993; Tiwari, 2010).

The sustainability and efficiency of forest ecosystems being influenced by the hydroelectric power projects in river valleys can be restored by strengthening the knowledge on sustainable plant utilization (Tiwari, 2010). These evidences indicate that the submergence of hydroelectric project areas have been losing both plant and animals' biodiversity in alarming rate. The construction of HEP in the Himalayan and other regions of India are major threats to the biodiversity and are also losing habitat especially for those species under threatened categories.

Thus, the following suggestions should be adopted to conserve the valuable resources in the surrounding of the dam construction areas.

1. The area for dam construction should be selected where biological diversity is low.
2. Dam construction should be done where minimum area can be used.
3. Dam construction should be avoided where species are under threatened categories
4. Dam height should be reduced to minimize the loss of plant and animal diversity in submergence zone.
5. The heavy machinery work should be minimized to conserve species diversity.
6. The heavy vehicle moment in dam construction areas should be restricted except using few roads to minimize disturbances to the biodiversity.
7. The dumping of construction material should not be stored at plant diversity rich areas.
8. Blasting of dam construction work should be done where there is minimum disturbance of animals and birds.
9. Conservation techniques of plants through cultivation should be used for further sustainable use of the species.

Conclusion

The soil pH was slightly basic in nature. The soil organic carbon and potassium was lower, because of disturbance. Moisture (%) and WHC was also reported to be lower, because of various disturbances and developmental activities, where most of the trees were affected.

The people living close to the study area are dependent on the forest which is importance for their livelihood sustainability. The loss of vegetation diversity in submergence zone will affect the biodiversity of submergence zone as well as diverted pressure of inhabitant on influenced zone will also rapidly degrade the resources for the influenced/surrounding areas. Therefore, proper awareness program need to be carried out in the inhabitant area to restore vegetation through plantation and self-sustaining of vegetation by the co-operation of local inhabitant from further degradation of forest. Thus, the future sustainability of the forest can be maintained with the saving of traditional culture of the local inhabitants.

Conflict of Interests

The author(s) have declared that there is no conflict of interests.

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