International Research Journal of Plant Science (ISSN: 2141-5447) Vol. 1(4) pp. 083-094, October, 2010
Available online http://www.interesjournals.org/IRJPS

Full Length Research Paper

Vegetation analysis and differences in local environment variables in indrawati hydropower project areas in Nepal

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Accepted 13 September, 2010

Vegetation covering an area has a definite structure and composition developed as a result of long term interaction with biotic and a biotic factors, and any change in the status of these factors disturbs the floristic composition of the environment. Five quadrates with sampling size of 20 X 20m^2 in 0.02 ha. area was selected for analysis of vegetation to quantify species diversity, composition, size class distribution and dominance of the species. A total of 387 tree individuals, representing 33 species, 32 genera and 23 families were recorded. Total stand density and basal area were, respectively, 638.55 trees ha−1 and 17.68 m2ha−1 in five plots. The highest IVI value was that of *Alnus nepalensis* (30.21) followed by *Castanopsis tribuloides* (21.22) and *Lyonia ovalifolia* (19.27) in plot 3 where the Dbh of tree was <10cm. Based on IVI values*, Alnus nepalensis, Castanopsis tribuloides,* and *Lyonia ovalifolia* were found to be the most dominant species in the study area. The three values as 0.09333, 0.9066 and 10.71 of Simpsons Diversity (D) of 33 species represent different biodiversity. The plot 3 of natural forest and plot 4 and 5 along the project area has found significantly deceasing number of species.

Key words: Vegetation Analysis, Indrawati III Project, Environmental Variables, Change and Impact, Species Diversity, Community forests

INTRODUCTION

Forest and vegetation of particular ecosystem generally influenced by the external factors especially the man made development activities. For along time it was believed by some ecologists like Clements (1916), Braun-Banquet (1932) and Odum (1971), that vegetation is composed of certain distinct and fairly discrete plant communities. This view regards communities as having a degree of internal organization which jointly modifies the environment with sharp delimitation from other communities (Odum, 1971).

The composition of plant structures is closely associated with the biotic and abiotic environmental factors which make sudden changes due to external factors of disturbances. The current vegetation reflects the site conditions and disturbances over time. Hence, hemeroby concept (Jalas, 1955; Sukopp, 1969; Kowarik, 1988, 1990) was developed for estimating environmental change at a given site using the difference of current vegetation in comparison with the pristine or potential natural vegetation. However, use of that method is flawed because one can not find a pristine ecosystem in this changed and changing world, because of the complex and nonlinear nature of ecosystems and unique ecological histories. Thus, vegetation that is completely “natural” and pristine, as well “potential natural” is hypothetical (Reif, 2000). Moreover, that method can not be used for a cross-scale evaluation because the species number found depends on the plot size studied (i.e. species-area relationship).

Composition and distribution pattern of vegetation and forest types and differences of local environmental variable in the Indrawati III Hydropower project area was studied with extensive literature (GoN/ Earth Science 1984, Science, G. E. 1984), Stainton, 1972)

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and collection/measurement of field data's.

The frequency of vegetation components, density and volume of trees in actual impact areas such as above intake-dam site (Haryali CF), Audit-C (Golma Raja Golma Rani CF), above Penstock (Golma Raja Golma Rani CF), Penstock and Powerhouse site were analyzed by quadrate sampling in representative transect stands at selected sampling sites.

Impacts produced by the implementation of power sector projects may degrade forest resources, including local ecology and ecosystems, and can eventually affect the sustainability of project benefit. Therefore, Environmental Impact Assessment (EIA) of Indrawati Hydropower project was conducted in 2002 as per Environmental Protection Regulation (EPR) 1997, Government of Nepal (GoN/MoLJPA 1996). Since the project operation in 2004 and implementation of EIA in order to make projects more environmentally sound, sustainable, and socially beneficial (GoN, MOE, NHC. 2002), this research illustrate the change in local environment with emphasis of quantitative analysis of forest and vegetation and change in environmental gradients through project operation.

MATERIAL AND METHODS

Study Area

The study area is located between 27º36'-28 º 13' north longitudes and 85º27'-86º16' east latitudes Sindhupalchowk district in Nepal. The district has an extent area of about 27km^2 (2710ha.) with elevation ranging from 1020m at the confluence of Harikhola and Indrawati known.

Physiographically, Indrawati river basin lies subtropical Tar besi region with elevation range from 850m asl to above. The catchments area of the Indrawati River is 437sq.km. The Indrawati watershed has good density of natural forests with crown cover of more than 70% occupy only 1.8% of the district mainly at the upper ridges of Indrawati watershed (Dobromez, 1974).

Out of total 25.3 m^3/s total discharges in the river the Indrawati III Hydropower Project is operating with its design discharge of 14.3m^3/sec for 7.5 MW power generations. The average annual rainfall of the project area is 2537.35mm and relative humidity ranges from 75 to 95% over the year. Maximum temperature recorded in the project area is 30º Celsius and minimum is 10º Celsius. The project area along with 5km long access road surrounded by river valley, community forest, cultivated land, barren land and settlements. The study was carried out in the forests of project influence area. **Figure.1**

Methods

Field study was carried out in April 2010 by measuring five plots an area of 200 sq.m size (0.02 hectare) in and around of Indrawati Hydropower project influence area. The five plots were measured in different disturbed and undisturbed forest patches like above dam site (Haryali CF), Above Audit C, above Penstock (Golma Raja Golma Rani CF), Penstock area and Powerhouse site. The quadrate size (20m x 20m^2) was randomly demarcated for study. The vegetation was analyzed by adopting releve analysis approach (Dombosis and Ellenberg, 1974). The Plant species of all growth forms within each quadrate were enumerated by using a simple matrix. The diameter at breast height and height of each trees including cut stumps, having more than 10cm circumference were measured.

Density, frequency, basal area and their relative values and importance value index (IVI) of tree species were calculated following Mueller-Dombosis and Ellenberg (1974). Botanical name and author citation was made following Government of Nepal, Department of Plant Resources (DPR) 2001 and Dictionary of Nepalese Plant Names (K. Shrestha 1998). In addition to quantitative data, interviews and group discussions was conducted to collect information relating to community forest management. In order to assess the general condition and vegetation pattern of the forest, a density-diameter histogram was developed. Girth of trees exceeding 10cm diameter at breast height was measured. The height of standing trees was measured by means of a hypsometer. The species area curve of each community forests was calculated by randomly adding up the number of tree species in each quadrate. The dominance diversity curve (D-D curve) was used in order to ascertain the resource apportionment among the various species at various sites.

Coefficient (J) (Jaccard's P, 1912) was used to quantify the extent to which family and species composition overlapped between sample sites. It is defined as: $J = A /(A + B + C)$ where A is the number of family and species found in three sites, B is the families and species in site 3 but not in site 2, and C is the families and species in site 3 but not in 2.

'S,' or species richness, was determined following (Whittaker, 1976) by tabulating the number of woody species in each plot. Shannon-Weiner's diversity index 'H' (Shannon and Weiner 1963), concentration of dominance 'D' (Simpson, 1949) and Hill diversity numbers N_0, N_1 and N_2 (Hill 1973) were computed. Simpson's index 'D' was calculated using the formula 'D' = 1 - Σpi2, where pi is the relative density. Shannon-Weiner's diversity index 'H' was calculated using the formula 'H' = - Σpi Log pi, where pi represents the proportional abundance of the species in the community. Hill diversity indices were calculated using the following formulae:

Number 0: $N_0 = S$, where S is the total number of species;
Number 1: $N_1 = eH$, where 'H' is the Shannon's index;
Number 2: $N_2 = 1/D$, where 'D' is Simpson's index

RESULTS

Species area curve

The slope of the species area curve for each study site declined as sample area increased but did not approach an asymptote (Figure 2).

Vegetation composition

A total of 387 tree individuals, representing 33 species, 32 genera and 23 families, were identified within the 0.2 ha area of the study (**Table 1**). Eight species i.e. *Entada phaseolodies* (Leguminosae), *Fraxinus*

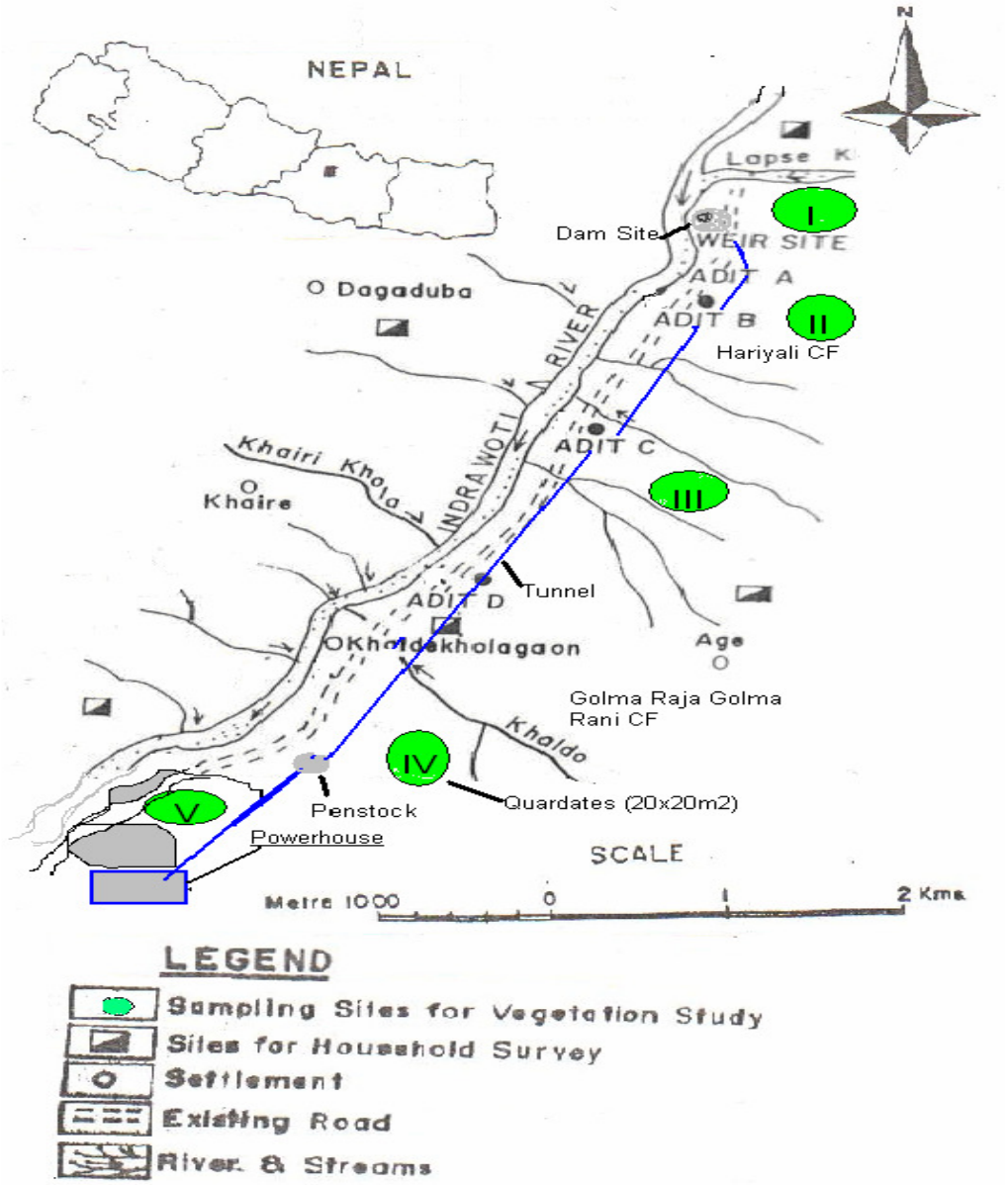

Figure 1. study area

flribunda (Oleaceae), Hedyotis scandens (Rubiaceae), *Indigolera pulchella* (Leguminosae), *Pegia nitida* (Anacardiaceae), *Pyrus pashia* (Rosaceae), *Rosa burnonii (*Rosaceae), *Smilax aspera* (Laliaceae) were found only above dam site (Haryali Community Forest) in plot 1. Two species, *Aesandra butyracea (*Spotaceae) and *Terminalia alata (*Combretaceae) were found above Audit C (Golma Raja Golma Rani CF) in plot 2. Three species, *Osyris wightiana* (Santalaceae), *Rubus ellipticus* (Rosaceae) and *Rhus javanica* (Anacardiaceae) were found only in above penstock (Golma Raja Golma Rani CF) in plot 3 (Plot 3 represents saplings of regenerated forest species less than 10cm dbh. This was the forest cleared area of Golma Raja Golma Rani CF during project construction.

), Single species of *Shorea robusta* (Dipterocarpaceae) was found in plot 4 (Plot 4 represents planted saplings of forest species and naturally regenerated saplings of *Alnus nepalensis* and *Lyonia ovalifolia less than 10cm dbh. In this area circular* Surge shaft (Tank) *with 30m height and 600m long penstock with 2.3 m diameter is located.*

) Penstock area and *three species, Dalbergia sissoo* (Leguminosae), *Mangifera indica* (Anacardiaceae) and *Zanthoxylum armatum* (Rutaceae) were found in plot 5 powerhouse sites respectively. (**Table 1**).

Among the 33 species 28 species were calculated

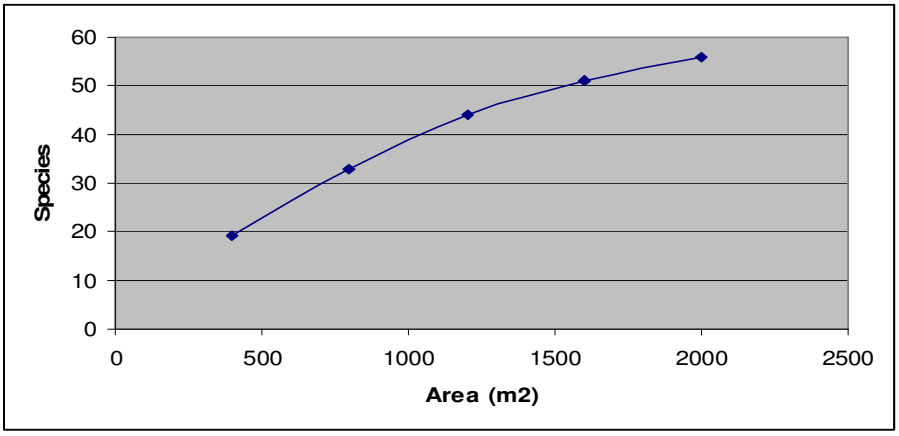

Figure 2. Species area curve

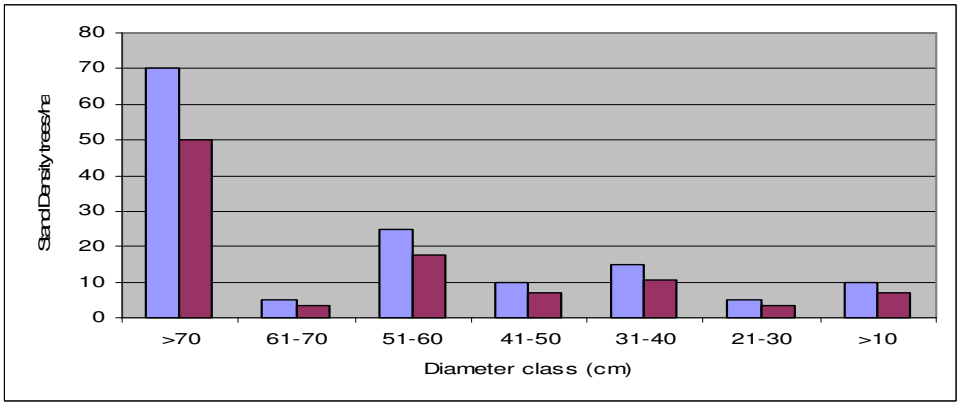

Figure 3: Distribution of tree in different size class

for density and basal area. Total stand density and basal area were, respectively, 638.55 trees ha−1 and 17.68 m2ha−1 in five plots (**Table 2 and 3**). Girth sizes of trees at breast height (gbh) ranged from 10 to 170 cm in five plots. The greatest gbh of *Bombex cebia* (170 cm) was found in plot 1 followed by *Schima wallichii* (160 cm). The greatest heights (>20 m) of tree species, *Engelhardia spicata, Schima wallichii, Bombax ceiba, Engelhardia spicata* and *Castanopsis tribuloides,* were observed only in plot 1.

The highest IVI value was that of *Alnus nepalensis* (30.21) followed by *Castanopsis tribuloides* (21.22) and *Lyonia ovalifolia* (19.27) in plot 3 where the dbh of tree are <10cm. The plot 3 was identified disturbed area of natural forest. There were regenerated saplings of tree species as forest was felled during construction period of the project. Based on IVI values, *Alnus nepalensis, Castanopsis tribuloides, and L. ovalifolia* were found to be the most dominant species in the study area (**Table 3)**. 6.6% of the total individuals of *Pyrus pashia* were observed cut stumps in plot 1 and 3.3% *Terminalia alata* were in plot 2 respectively.

Size class distribution

The distribution of Gbh classes conformed to an reverse 'J' shape curve, with 50% of individuals having Gbh between <70 cm: 17.86% individuals of 51-60 cm Gbh , 10.71% individuals of 31-40 cm, 7.14 of each 10-20cm and 41-50cm and rest 3.57% in each 21-30 cm and 61-70 respectively (**Figure 3**). The number of individuals with a diameter greater than 70 cm was 9 (64.28%) in plot 1, 3 (21.42%) in plot 2 and 2 (14.28%) in plot 4, totaling 50% of total species (**Figure 3)**.

Dominance diversity curve

Species dominance related to the availability of suitable niche and resource apportionment in a

Table 1. Composition and distribution of forest species in Five Sampling Plots

SN	Scientific Name	Local Name	Family	Sampling Plots 1	2	3	4	5	Total
1	*Aesandra butyracea*	Churi	Spotaceae	-	+	-	-	-	1
2	*Alnus nepalensis*	Utis	Betulaceae	-	+	+	+	+	4
3	*Bombax ceiba (L.)*	Simal	Bombacaceae	+	+	+	-	-	3
4	*Caesalpinia decapitala*	Arile kanda	Leguminosae	+	+	-	-	-	2
5	*Callicarpa macrophylla*	Guaili	Verbenaceae	-	+	-	-	-	1
6	*Castanopsis tribuloides*	Katus	Fagaceae	+	+	+	+	-	4
7	*Citrus maxima*	Bhogate	Rutaceae	+	-	-	-	-	1
8	*Cleistocalyx operculata*	Kyamuna	Myrtaceae	-	+	-	+	-	2
9	*Dalbergia sissoo*	*Sisau*	Leguminosae	-	-	-	-	+	1
10	*Engelhardia spicata*	Mawa	Juglandace	+	+	+	+	-	4
11	*Entada phaseolodies*	Pangra	Leguminosae	+	-	-	-	-	1
12	*Fraxinus flribunda*	Lakure	Oleaceae	+	-	-	-	-	1
13	*Gaultheria fragrantissima*	Dhasingare	Ericaceae	+	+	-	-	-	2
14	*Hedyotis scandens*	Dhudhe lahara	Rubiaceae	+	-	-	-	-	1
15	*Hedyotis scandens*	Bokrelahara	Rubiaceae	+	-	-	-	-	1
16	*Indigolera pulchella*	Phusareghans	Leguminosae	+	-	-	-	-	1
17	*Lyonia ovalifolia*	Aingire	Ericaceae	-	+	+	+	-	3
18	*Mangifera indica*	Anmp	Anacardiaceae	-	-	-	-	+	1
19	*Osyris wightiana*	Nundhiki	Santalaceae	-	-	+	-	-	1
20	*Pegia nitida*	Chutilahara	Anacardiaceae	+	-	-	-	-	1
21	*Pyrus pashia*	Mayal	Rosaceae	+	-	+	-	-	2
22	*Rhus javanica*	Bhakmilo	Anacardiaceae	-	-	+	-	-	1
23	*Ribes takare*	Dhursurlo	Gross	+	+	-	-	-	2
24	*Rosa burnonii*	Bhainsi kanda	Rosaceae	+	-	-	-	-	1
25	*Rubus ellipticus*	Ainselu	Rosaceae	-	-	+	-	-	1
26	*Sapium insigne*	Khirro	Euphorbiaceae	-	+	-	+	-	2
27	*Schima wallichii*	Chilaoone	Theaceae	+	-	+	-	+	3
28	*Seteria genniculata*	Kagune jhar	Gramineae	+	+	-	-	-	2
29	*Shorea robusta*	Sal	Dipterocarpaceae	-	-	-	+	-	1
30	*Smilax aspera*	Kukurdiano	Laliaceae	+	-	-	-	-	1
31	*Terminalia alata*	Saj	Combretaceae	-	+	-	-	-	1
32	*Toona cialita*	Tooni	Meliaceae	+	-	+	-	-	2
33	*Zanthoxylum armatum*	Timur	Rutaceae	-	-	-	-	+	1
Total				19	14	11	7	5	56

Note: + = Presence, - = Absence

community has often been interpreted from the dominance diversity curve (D-D curve). D-D curves for sampling plots 4 **(Figure 4)** were found consistent with the normal distribution model of Preston (FW, 1948), i.e., relatively few species had a high IVI. These curves illustrate resource partitioning among the various species (Verma et. al, 2001).

Species diversity

Table 4 depicts the plant species richness, Shannon-Weiner diversity index, Simpson's diversity index, Jaccard's coefficient and Hill's diversity index of five sampling plots in different forest patches of project area. Maximum species richness (19) was observed in plot 1 above dam site (Haryali CF) while the minimum (5) in plot 5 powerhouse site. This result proves that the disturbance of development activities in natural forest reduce the species diversity.

The adjusted Shannon-Wiener Index is the percent of the maximum possible diversity. The maximum is the in ("Total Number of Species"): 3.497. The Shannon-Weiner diversity index was 2.372 in sample plots, while the concentration of dominance Simpson diversity index for sampling was 78.14%. Jaccords, coefficient (J) was 0.37. Hill diversity numbers N0, N1 and N2 were 19, 17.92 and 1.071 respectively (Table 4).

The three different value of Simpsons Diversity (D) of 33 species were 0.09333, 0.9066 and 10.71 **(Table 4 and 5)** represents the different biodiversity.

DISCUSSION

While square plots are usually superior for correlating plant communities with local environmental variables (Ferreira and Merona, 1998), various shapes and sizes

Table 2: Basal Area and Volume of Trees species in each Sampling Plot

SN	Scientific Name	Nepali Name	Family	Girth (cm)	Height (m)	BA (m2)	Volume (m3)
Quadrate –I *(Above Dam Site-Haryali Community Forest)*							
1	*Engelhardia spicata*	Mawa	Juglandace	140	30	1.539	23.079
2	*Castanopsis tribuloides*	Katus	Fagaceae	40	5	0.1256	0.314
3	*Engelhardia spicata*	Mawa	Juglandace	90	20	0.636	6.36
4	*Schima wallichii*	Chilaoone	Theaceae	60	20	0.283	2.826
5	*Schima wallichii*	Chilaoone	Theaceae	116	45	0.950	21.372
6	*Toona cialita*	Tooni	Meliaceae	80	12	0.5024	3.0144
7	*Castanopsis tribuloides*	Katus	Fagaceae	50	10	0.196	0.98125
8	*Bombax ceibaL.*	Simal	Bombacaceae	170	70	2.269	79.403
9	*Castanopsis tribuloides*	Katus	Fagaceae	1.25	25	1.1304	14.13
10	*Schima wallichii*	Chilaoone	Theaceae	55	8	0.237	0.94985
11	*Schima wallichii*	Chilaoone	Theaceae	110	3	0.950	1.425
12	*Schima wallichii*	Chilaoone	Theaceae	48	18	0.181	1.6278
13	*Schima wallichii*	Chilaoone	Theaceae	160	85	2.01	85.408
14	*Schima wallichii*	Chilaoone	Theaceae	60	15	0.2826	2.1195
15	*Engelhardia spicata*	Mawa	Juglandace	110	25	0.950	11.873
Quadrate *II-Audit C (Golma Raja Golma Rani Community Forest)*							
1	*Terminalia alata*	Saj	Combretaceae	80	12	0.5024	3.0144
2	*Terminalia alata*	Saj	Combretaceae	70	15	0.38465	2.884875
3	Aesandra butyracea	Churi	Spotaceae	30	15	0.07065	0.529875
4	*Terminalia alata*	Saj	Combretaceae	100	10	0.785	3.925
5	*Terminalia alata*	Saj	Combretaceae	60	12	0.2826	1.6956
6	*Cleistocalyx operculata*	Kyamuna	Myrtaceae	20	5	0.0314	0.0785
7	*Terminalia alata*	Saj	Combretaceae	80	12	0.5024	3.0144
8	*Terminalia alata*	Saj	Combretaceae	60	11	0.2826	1.5543
9	*Terminalia alata*	Saj	Combretaceae	50	9	0.19625	0.883125
10	*Terminalia alata*	Saj	Combretaceae	40	7	0.1256	0.4396
Quadrate *V- Powerhouse Site*							
1	*Schima wallichii*	*Chiloone*	Theaceae	80	12	0.5024	3.0144
2	*Magnifera indica*	Anmp	Anacardiaceae	150	13	1.76625	11.48063
3	*Delbergia sisoo*	*Sisoo*	Leguminosae	10	11	0.007875	0.043313

Transect III and IV represents tree saplings and shrub species less than 10cm dbh.

of plots have been selected for other studies (**Table 6**). In Nepal, most studies designed for the study of diversity or family/species abundance (including the present) have employed square sample plots. Comparison of quantitative data from the present study to those collected at other forest sites has been shown in Table 6.

For all surveyed sites, the slope of the curve relating species and area declined as sample area increased. The species area curves for plots were more or less consistent with a gradual decrease in the number of species with area, initially down to 50 m^2, and then appears to be approaching an asymptote indicating that the sampled area of penstock and powerhouse area is inadequate for specific forest (**Figure 1**). It can be argued that, for sample plots at penstock and powerhouse site covering half hectares are inadequate. Thus, the project area near powerhouse and penstock area was not found forested activities and disturbed by the project and other anthropogenic activities.

The other three plots in Community forests one in Haryali CF and two in Golma Raja Golma Rani CF) have controlled forest management activities. The Haryali Community Forest located around intake and access road site covers an area of 95ha which was handed over as community forest in 2051/052 BS. The Golma Raja Golma Rani Community Forest covering an area of 48 ha was handed over in 2052/053 BS.

These community forest management runs under users' forest operational plan and forest Act which guides and regulates forest management. Despite the

Table 3: Frequency, Relative frequency, Relative Density, Relative Dominance and Importance Value

SN	Scientific Name	Local Name	F	RF	RD^1	RD^2	IVI	Remarks
1	*Aesandra butyracea*	Churi	20	1.28	0.26	5.11	6.65	
2	*Alnus nepalensis*	Utis	80	5.13	17.57	7.51	30.21	High
3	*Bombax ceiba (L.)*	Simal	60	3.85	1.03	0.20	5.08	
4	*Caesalpinia decapitala*	Arile kanda	40	2.56	0.52	0.10	3.18	
5	*Callicarpa macrophylla*	Guaili	20	1.28	1.55	0.31	3.14	
6	*Castanopsis tribuloides*	Katus	80	5.13	13.44	2.65	21.22	High
7	*Citrus maxima*	Bhogate	60	3.85	1.29	0.26	5.40	
8	*Cleistocalyx operculata*	Kyamuna	40	2.56	1.29	0.26	4.11	
9	*Dalbergia sissoo*	*Sisau*	20	1.28	2.07	0.41	3.76	
10	*Engelhardia spicata*	Mawa	20	1.28	8.79	1.47	11.54	Medium
11	*Entada phaseolodies*	Pangra	80	5.13	0.26	0.05	5.44	
12	*Fraxinus flribunda*	Lakure	60	3.85	0.26	0.05	4.16	
13	*Gaultheria fragrantissima*	Dhasingare	40	2.56	1.55	0.10	4.21	
14	*Hedyotis scandens*	Dhudhe lahara	20	1.28	1.03	0.20	2.51	
15	*Hedyotis scandens*	Bokrelahara	80	5.13	1.55	0.31	6.99	
16	*Indigolera pulchella*	Phusareghans	60	3.85	0.52	0.10	4.47	
17	*Lyonia ovalifolia*	Aingire	40	2.56	13.95	2.76	19.27	High
18	*Mangifera indica*	Anmp	20	1.28	0.26	0.05	1.59	Low
19	*Osyris wightiana*	Nundhiki	20	1.28	0.26	0.05	1.59	Low
20	*Pegia nitida*	Chutilahara	80	5.13	0.26	0.05	5.44	
21	*Pyrus pashia*	Mayal	60	3.85	0.52	0.10	4.47	
22	*Rhus javanica*	Bhakmilo	40	2.56	0.52	0.10	3.18	
23	*Ribes takare*	Dhursurlo	20	1.28	10.34	2.04	13.66	Medium
24	*Rosa burnonii*	Bhainsi kanda	80	5.13	1.03	0.20	6.36	
25	*Rubus ellipticus*	Ainselu	60	3.85	0.26	0.05	4.16	
26	*Sapium insigne*	Khirro	40	2.56	1.03	0.20	3.79	
27	*Schima wallichii*	Chilaoone	20	1.28	5.94	1.17	8.39	
28	*Seteria genniculata*	Kagune jhar	20	1.28	2.07	0.41	3.76	
29	*Shorea robusta*	Sal	80	5.13	1.55	0.31	6.99	
30	*Smilax aspera*	Kukurdiano	60	3.85	1.81	0.36	6.02	
31	*Terminalia alata*	Saj	40	2.56	2.33	0.46	5.35	
32	*Toona cialita*	Tooni	20	1.28	0.78	0.15	2.21	
33	*Zanthoxylum armatum*	Timur	80	5.13	4.13	0.82	10.08	Medium

F = frequency, RF = relative frequency, RD^1 = relative density, RD^2=relative dominance, IVI = importance value index

institution of community forest management, human disturbance continues in various forms, including development activities, grazing, tree felling, fuel wood collection, and encroachment on marginal land. The presence of mature trees (>70 cm Gbh) is the result of prolonged forest management, while the small poles and stumps in non CF areas signs of early succession and uncontrolled disturbance before project since 2001.

At the time of study, there were 15 (53.57%) trees/ha in Haryali CF, 7 mature trees (35.71%) in Golma raja Golma Rani CF as compared to 2 mature tree (7.14)/ha in powerhouse area and rest 3.52% immature trees were found in powerhouse and penstock area. The reduced diversity of vegetation can be attributed to the project impact noted above, which was particularly severe due to the loss and disturbance of project intervention and not implementation of mitigation measures mentioned in EIA report. The EIA report had already mentioned plantation of 0.6ha cleared forest lands and compensatory plantation in disturbed slopes. Disturbance has been considered an important factor structuring forest communities (Foster 1980) and different levels and types of disturbance have a differential impact on forest communities (Halpern and Spies 1995). High human and other biotic pressures with development activities are detrimental to the vegetation structure of forests.

A total of 19 plant families were reported in sample plots of Haryali CF, 14 in Audit C and 11 above penstock in Golma Raja Golma Rani CF, 7 in Penstock area and 5 in powerhouse area respectively. Among them, three families (Rosaceae, Leguminosae and Anacardiaceae) were identified as more abundant. Leguminosae was the most diversified family with 4

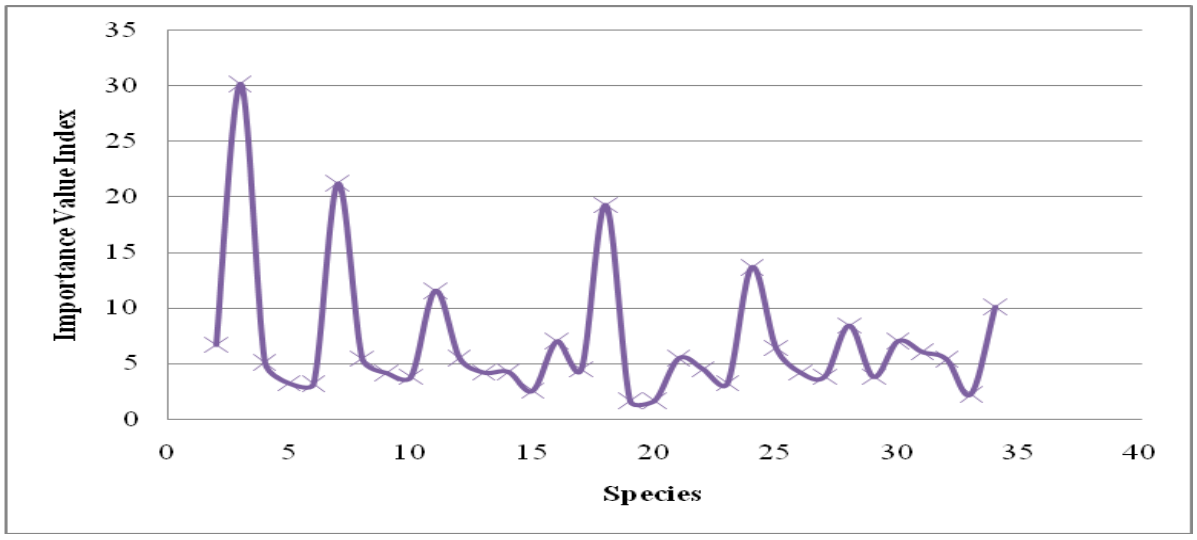

Figure 4. Dominance diversity curve for the tree species given in Table 3

Table 4. Diversity indices of sampling plots

Total Number of trees and Shrubs	387	Total Number of Species:	33
Simpson Index (Evenness):	0.09336	Whittaker's Index S/alpha):	1
Dominance Index (D = 1 - Simpson):	0.9066	Alternate Whittaker's Index (S/alpha-1):	0
Simpsons Reciprocal Index =1/D	10.71		
Berger-Parker Dominance Index:	0.1757	Number of Common Species:	33
Inverted Berger-Parker Dominance Index:	5.691	Sørensen's similarity index:	1
Shannon-Wiener Index:	2.732	Sørensen's similarity index (%):	100%
Hills diversity number (H)			
No (Species richness)	19		
N1	17.92		
N2	1.071		
Jaccards coefficient (J)	0.37		

individuals, 3 species and 3 genera, followed by Rosaceae, with three individuals, Anacardiaceae two species and two genera. Alnus nepalensis in Golma Raja Golma Rani CF above Penstock contributed the maximum sapling density (340 trees /ha), or about 53.24% of the total stand Density and *Lyonia ovalifolia* (270 tree /ha), or about 42.28% of the total stand. *The maximum density in that area is due to protection of naturally regenerated species through non access for livestock and local people.*

Stand density differed slightly among study sites, although there was a broad similarity in major species composition. Density is influenced by various factors, including elevation, soil type, dominant and associated species and human activities (cf. Shrestha et al. 1998). Climatic factors, environmental stability, land use and area and habitat heterogeneity are the factors often discussed as determinants of variability in species richness (Spies and Turner 1999).

In three sampling sites of these study areas, the values for total basal area and density were higher than the values (15-60 m2/ha and 320-2080 trees /ha) reported by Bhandari et al. (1997) in temperate forests of the Garhwal Himalaya. As vegetation matures, total stand density tends to decrease and the stand increases in height, basal area and volume. Density and dispersion are quite sensitive to size and intensity of disturbance. The remarkable differences in stand density between the managed and disturbed forest areas were due to development intervention and its proper management history.

The total basal area also differed significantly i.e. 12.24m^2 in quadrate 1, 3.16m^2 in quadrate 2 and 2.27 m^2 in plot 4, respectively. The higher total basal area in plot 1 was the result of the high proportion of tree

Table 5. Percentage Diversity Indices of sampling plots

SN	*Scientific Name*	Numbers	Percentage	$(n_i(n_i - 1))/(N(N - 1))$	$(n_i)\ln(n_i/N)$
1	*Aesandra butyracea*	1	0.26%	0	-0.0154
2	*Alnus nepalensis*	68	17.57%	0.0305	-0.3055
3	*Bombax ceiba (L.)*	4	1.03%	8.03E-05	-0.04726
4	*Caesalpinia decapitala*	2	0.52%	1.34E-05	-0.02721
5	*Callicarpa macrophylla*	6	1.55%	0.0002008	-0.0646
6	*Castanopsis tribuloides*	52	13.44%	0.01775	-0.2697
7	*Citrus maxima*	5	1.29%	0.0001339	-0.05619
8	*Cleistocalyx operculata*	5	1.29%	0.0001339	-0.05619
9	*Dalbergia sissoo*	8	2.07%	0.0003749	-0.08019
10	*Engelhardia spicata*	34	8.79%	0.007511	-0.2137
11	*Entada phaseolodies*	1	0.26%	0	-0.0154
12	*Fraxinus flribunda*	1	0.26%	0	-0.0154
13	*Gaultheria fragrantissima*	6	1.55%	0.0002008	-0.0646
14	*Hedyotis scandens*	4	1.03%	8.03E-05	-0.04726
15	*Hedyotis scandens*	6	1.55%	0.0002008	-0.0646
16	*Indigolera pulchella*	2	0.52%	1.34E-05	-0.02721
17	*Lyonia ovalifolia*	54	13.95%	0.01916	-0.2748
18	*Mangifera indica*	1	0.26%	0	-0.0154
19	*Osyris wightiana*	1	0.26%	0	-0.0154
20	*Pegia nitida*	1	0.26%	0	-0.0154
21	*Pyrus pashia*	2	0.52%	1.34E-05	-0.02721
22	*Rhus javanica*	2	0.52%	1.34E-05	-0.02721
23	*Ribes takare*	40	10.34%	0.01044	-0.2346
24	*Rosa burnonii*	4	1.03%	8.03E-05	-0.04726
25	*Rubus ellipticus*	1	0.26%	0	-0.0154
26	*Sapium insigne*	4	1.03%	8.03E-05	-0.04726
27	*Schima wallichii*	23	5.94%	0.003387	-0.1678
28	*Seteria genniculata*	8	2.07%	0.0003749	-0.08019
29	*Shorea robusta*	6	1.55%	0.0002008	-0.0646
30	*Smilax aspera*	7	1.81%	0.0002812	-0.07258
31	*Terminalia alata*	9	2.33%	0.000482	-0.08747
32	*Toona cialita*	3	0.78%	4.02E-05	-0.03767
33	*Zanthoxylum armatum*	16	4.13%	0.001607	-0.1317
Total		387	100.00%	0.09335405	-2.73236

circumference greater than 70 cm (**Figure 2**).

Trees with larger diameter have wider canopy cover and as canopy becomes close plant competition intensifies and slow growing trees become stunt and die. The wide range in basal area in plot 1 shows its heterogeneity. The presence of a large number of trees in the 10-30 cm diameter class indicates that the study area is in mid-level succession. However, there were few trees in the small size classes (<10 cm): only in plot 3 and plot 4. The paucity of small trees indicates that the forest is not sustaining itself. This may be due to the recurrent human disturbance. The extent of disturbance can be attributed to easy access, grazing, inefficient management of planted species, and lack of alternative sources of forest products.

Local people involved in community forestry programmes, on the other hand, generally protect their forests and access to government managed forests out of self-interest (Shrestha and Paudel 1996, Kunwar 2002). Strengthening local control, strongly implementation of EIA mitigation measures in project influence area and policy oversight is urgently needed to assure long-term sustainability of the project and maintaining integrity of the local environment (Bhatt R. et al. 2009).

The top niches were occupied by *Alnus nepalensis, Castanopsis tribuloides, Engelhardia spicata* in three plots in all sites; the remaining species shared the intermediate and lower niches more or less equally. However, the powerhouse area was occupied planted species with low numbers and naturally regenerated *Alnus nepalensis* was degrading. The gentle slope of D-D curve (Figure 3) observed in indicates steady growth of trees in Haryali and Golma Raja Golma Rani CF, while sharp depression of the curve representing the small size classes trees in powerhouse and penstock area is the result of human disturbance or project intervention. The distribution pattern of tree species was similar, with the notable exceptions of Schima wallichii *in plot 1 and Terminalia alata* in site 2.

Table 6. Vegetation characteristics of various forest types

Forest type	Location	Study area (ha) /Plot size (m2)	Girth size (cm)	T. stand density (trees ha_1)	T. basal area	Source
Shorea robusta forests	RBNP, Nepal	2.81 / (25x25)	>30	333-385	32-35	Giri et al. (1999)
Castanopsis hystrix forests	MBNP, Nepal	0.60 / (10x10)	> 30	1921-3075	23-36	(Shrestha et al., 2002
Shorea-Castanopsis forests	MBNP, Nepal	3.84 / (20x20)	≥ 10	1425	59	Chaudhary and Kunwar (2002)
Castanopsis hystrix forests	MBNP, Nepal	0.60 / (10x10)	≥ 30	1921-3075	23-36	Shrestha et al. (2002)
Riverine forests	KTWR, Nepal	1.84 / (20x20)	≥ 30	472-652	20-31	Karki et al. (2001)
Temperate forests	Kavre, Nepal	0.37 / (10 m radius)	-	5-132	8-19	Shrestha et al. (1998)
Himalayan forests	Nainital, India	0.10 / (10x10)	≥ 30	620	16.8	Khera et al.(2001)
Dry evergreen forests	Southern India	0.50 / (50x20)	≥ 20	280-1130	11-36	Visalakshi (1995)
Dry evergreen forests	Southern India	2.00 / (100x50)	≥ 10	453-819	11-20	Parthasarathy and Sethi (2001)
Himalayan forests	Garhwal, India	0.20 / (10x10)	≥ 10	792-1111	56-126	Pande (2001)
Semi evergreen forests	Eastern ghat, India	4.00 / (10x10)	≥□30	367-667	26-42	Kadavul and Parthasarathy 1999)
Upland forests	Jau NP, Amazonia	4.00 / (40x10)	≥□30	160-178	32-40	Ferreira and Prance (1998)

Such pattern of distribution is a general characteristic of nature (Odum 1971)

Under severely disturbed conditions, the age class distribution of colonizers may be narrow, while individuals of diverse ages are found where disturbance is less severe (Figure 2). A total of seven size-classes of tree species with an interval of 10 cm Gbh were recognized for each forest site; such a large number of size-classes are the result of better protection due to community forest management. The proportion of different age-classes of plant species across a landscape and over time is one of the fundamental characteristics of the vegetation mosaic (Spies and Turner 1999). The reverse 'J' shaped size-class distribution curve was obtained which is typical of all types of forests (Ferreira and Merona 1997).

If one compares the Shannon diversity values observed in the present study with the values reported (between 1.16-3.4) for temperate forests by Saxena and Singh (1982), the present study falls within the earlier reported range. Biodiversity was relatively low in project intervened area. The impact of human activities such as firewood/fodder collection, tree felling and cattle grazing as well as project activities browsing accounts for the reduced diversity of vegetation in direct impact zone of the project. The representation of species number in natural forest areas in plot 1-3 was found high species richness and decreasing number in project disturbed area in plot 4 and 5. The hill diversity number and Jaccards coefficient (J) was also found in decreasing pattern in disturbed area. The similarity index of the studied sites reveals a remarkable degree of overlap in vegetation composition and structure.

CONCLUSION

Differences in number of individual trees, species, families, total basal area, and vegetation composition may be due to differences in local environmental variables (disturbance gradients and vegetation characteristics). The dominance of *Schima wallichii, Terminalia alata, Alnus nepalensis, Lyonia ovalifolia, Castanopsis tribuloides,* with their major contribution to total basal area, frequency, stand density and IVI, indicates that these are frequent in the studied forests. The contribution of seven species to total species diversity and of three species to dominant species list indicated that the study area vegetation is Schima *wallichii* dominant in plot 1, *Terminalia alata in plot 2, Engelhardia spicata and Castanopsis tribuloides* in plot 1 and 2, and *Alnus Nepalensis* in plot 3, 4 and 5 respectively. Although the forest existed in several girth classes, there was a reduced number of small

tree individuals (<10 cm) in plot 3,4 and 5 which may be attributed to recurrent disturbances (marginal land encroachment, grazing and firewood collection); this dearth of immature individuals indicates impaired sustainability of the surveyed forests. Better management for CF and protection of regenerated species and additional plantation in disturbed areas surrounding in the project as per recommendation of EIA and local control over the forests is therefore urgently needed. The present study conclude that the project impact on forests of project influence area cannot recover the natural condition of the local environment but the effective implementation of EIA mitigation measures could reduce the impacts. To meet the natural condition in project impact area, intensive control on human disturbance in forest and afforested areas as well as protection of natural regeneration of species may preserve integrity of local ecosystem.

ACKNOWLEDGEMENT

The authors acknowledge express their gratitude and thanks to the support and encouragement extended from School of Science. Kathmandu University, Nepal. The help and cooperation of Indrawati III Hydropower Project is acknowledged. The financial support extended by the Nepal Academy of Science and Technology to the first author for Ph.D. fellowship is gratefully acknowledged.

REFERENCES

Bhandari BS, JP Mehta, BP Nautiyal, SC Tiwari (1997). Structure of a chir pine *(Pinus roxburghii Sarg.)* community along in altitudinal gradient in Garwal Himalaya. Int. J. Ecol. Environ. Sci. 1:67-74.

Bhatt R, Khanal S (2009). Environmental Impact Assessment System in Nepal - An overview of Policy, Legal Instruments and Process. Kathmandu University Journal of Science, Engineering and Techenology. VOl. 5, No. II: 160-170p.

Braun-Blanquet J (1932). Plant Sociology: The study of plant communities: New York, McGraw-Hill, 439 p.

Clements FE (1920). Plant Succession: An Analysis of the Development of Vegetation: Washington, D.C., Carnegie Institute, 388 p.; Publication No. 290.

Dobromez F J (1974). Divisions Phytogeographiques du Nepal et de l'Himalaya (The Major Phytogeographical Regions of Nepal and the Himalayas). Bull. Soc. Bot. France,119 (1/2): 111-120.

Ferreira, L.V. and Rankin-de Merona, J.M. 1998. Floristic composition and structure of a one-hectare forest in central Amazonia . Pp. 649-662 in Dallmeier, F. and Comiskey, J.A. (eds). Forest biodiversity in North, Central and South America, and the Caribbean . Research and Monitoring. MAB Series Vol. 21. UNESCO, Paris.

Foster RB (1980). Heterogeneity and disturbance in tropical vegetation. In: Soule' ME and BA Wilox (eds), *Conservation biology: An evolutionary ecological perspective*. Sunderland (MS): Sinauer Associates. p 75-92

FW P (1948). *The commonness and rarity of species.* Ecology 29: 254-83.

GoN. (1996). *Topographic maps.(1:50.000).* Nepal Survey Department in Cooperation with the Government of Finland.

GoN, MoLJPA (1997). Environmental Protection Act 1997 and Environmental Protection Regulation 1997. Ministry of Law, Justice, and Parliamentary Affairs). Law Books Management Board. Kathmandu. Nepal.

GoN/Earth Science (1984) . Department and Kenning Earth Science Ltd. Canada: Land Resource Mapping Project.

GoN, MOE, NHC (2002). Environmental Impact Assessment of Indrawati Hydroelectric Project. National Hydropower Company Ltd. Kathmandu. Nepal.

Halpern CB, Spies TA (1995). Plant species diversity in natural and managed forests of the Pacific Northwest. Ecol. Appl **5**: 913-34.

Hill MO (1973). Diversity and evenness: A unifying notation and its consequences. *Ecology* **54**: 427-32

Jaccard, P. (1912). *The distribution of flora in alpine zone. New Phytol 11: 37-50.* New Phytol 11: 37-50.

Jalas J (1955). Hemerobe and hemerochore Pflanzenarten - ein terminologischer Reformversuch. Acta Soc. Fauna Flora Fenn. 72(11), 1-15.

Kunwar RM (2002). Participation and benefits to local people in community forestry*: A case from Makawanpur district, Nepal* [thesis]. Bhopal (India): Indian Institute of Forest Management. 93 p

Kowarik I (1990). Some responses of flora and vegetation to urbanization in Central Europe. In: H. Sukopp, S. Hejný and I. Kowarik (Editors), Urban Ecology: Plants and Plant Communities in Urban Environments. SPB Academic Publishing bv, The Hague, The Netherlands, pp. 45-74.

Kowarik I (1988). Zum menschlichen Einfluss auf Flora und Vegetation – Theoretische Konzepte und ein Quantifizierungsansatz am Beispiel von Berlin (West). Landschaftsentwicklung und Umweltforschung, Schriftenreihe des Fachbereichs Landschaftsentwicklung der TU Berlin 56, 1-280.

Mueller-Dombois D, Ellenberg H (1974). *Aims and methods of vegetation ecology*. New York: John Wiley and Sons. 547 p

Odum EP (1971). Fundamentals of ecology, 3rd ed. Philadelphia: Saunders. 574 p

Parthasarathy N and P Sethi. 2001. Tree diversity in a dry evergreen forest. *Trop Ecol* **42**(1): 20-9.

Reif A (2000). Das naturschutzfachliche Kriterium der Naturnaehe und seine Bedeutung fuer die Waldwirtschaft. Z. Ökol. Nat.schutz 8: 239-250.

Shannon CE, Weiner (1963). The mathematical theory of communication. Urbana (USA): University of Illinois Press. 117 p.

Sukopp H (1969). Der Einfluss des Menschen auf die Vegetation. Vegetatio 17, 360-371.

Saxena AK, Singh JS (1982). A phyto-sociological analysis of forest communities of a part of Kumaun Himalaya. Vegetation **50**: 3-22

Saxena AK, Singh JS (1984). Tree population structure of certain Himalayan Forest association and implications concerning their future composition. Vegetation **58**: 61-9

Science GE (1984). Land Utilization, Land Capability, Land System Map (1:50,000). GoN, Topographical Survey

Shrestha S, PK Jha and KK Shrestha 1998. Vegetation of degraded, regenerating and natural forests in Riyale, Kavre, Nepal. Pak J. Pl. Sci. **4**(1): 13-28

Shrestha RK, Paudel KC (1996). Oak forest under threat: an urgent concern for the mountain environment. In: Jha PK, GPS Ghimire, and SB

Shrestha K (1998). Dictionary of Nepalese Plant Names. Mandala Book Point. Kathmandu Simpson EM. 1949. Measurement of diversity. Nature **163**: 688

Spies TA, Turner MG (1999). Dynamics forest mosaics. In: Hunter ML Jr. (ed.). *Maintaining biodiversity in forest ecosystems*. Cambridge: Cambridge University Press. p 95-160

Stainton (1972). *Forest of Nepal.* Jhon Murray: London, 181 p.

Verma RK, Singh D(2001). *Analysis of biodiversity and improvement in soil quality under plantations on degraded land.* For 24(1): 21-8: IndJ.

Visalakshi N (1995). Vegetation analysis of two tropical dry evergreen forests in Southern India. *Trop Ecol* **36**(1): 117-27.

Whittaker R H (1953). A consideration of climax theory: the climax as

a population and pattern. Ecol. Monogr. 23: 41-78.
Whittaker RH(1976). *Evolution and measurement of species diversity.* Taxon 21: 231-51.