PHYTOSOCIOLOGY AND LANDSAT TM DATA: A CASE STUDY FROM RIVER BEAS BED, PUNJAB, INDIA

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ABSTRACT

The present work was designed to study the phytosociology and its correlation with Landsat TM data from the catchment areas of river Beas, Punjab, India, for a stretch of 63 km between the towns of Beas and Harike for four seasons, i.e., summer, pre-monsoon, post-monsoon and winter seasons respectively. Various phytosociological parameters (density, abundance, frequency, relative density, evenness and relative abundance) and diversity indices (Simpson's, Shannon's, Margalef's, Brillouin's, Chao-I and Menhinick indices) were studied. During the pre-monsoon and winter seasons, Beas recorded maximum abundance and density. Maximum abundance was found for Harike during the post-monsoon season. Maximum Menhinick, Maragalef's, Chao-I, Simpson's and Shannon's indices were found for the Harike during the winter season. Significant positive correlation of band ratios (G/R) was found with Simpson's, Shannon's and Brillouin's indices, whereas negative correlation of band ratios (R/NIR) existed with Simpson's, Shannon's and Brillouin's indices. Various multivariate statistical techniques Principal component analysis (PCA), factor analysis (FA) and artificial neural networks analysis (ANN)) were applied for the analysis of results. ANN models were fitted to the data. Correlation between target and output values was found to be highly significant.

KEYWORDS: River Beas, vegetation, remote sensing, diversity indices and multivariate techniques

INTRODUCTION

Biological diversity is the prime ecological aspect of an ecosystem (Isbell et al. 2011). Phytosociology is the study of the vegetation of a particular area, which gives the existence of dominating species that control the community structure, and also the idea of rare species present in the area. Various workers reported that indices such as normalized difference vegetation index (NDVI), green chlorophyll index (GCI), spectral vegetation index (SVI) and simple ratio (SR) acquired from reflectance values are important measures of biomass, leaf area index and productivity in grassland and forests (Jakubauskas et al. 1996; Tieszen et al. 1997; Fassnacht 1997; Paruelo and Lauenroth 1998; Steininger 2000). Sharma and Pandey (2010) analyzed the phytosociology of Thar Desert, Rajasthan. Vidyasagaran et al. (2011) studied the phytosociology of mangroves, Kannur, Kerala. Vegetation mapping is necessary for the management of natural resources. Vegetation is the base for living beings and plays an important function in global climate change. Traditional techniques such as ancillary data analysis and field surveys for vegetation cover are time consuming and expensive. Remote sensing technique acquires the changes in vegetation cover over large areas (Langley et al., 2001; Nordberg and Evertson, 2003). Alhassan et al. (2015) in their studies on Sudan Savannah, Nigeria, analyzed the phytosociological parameters. Saurav and Das (2014) analyzed the community characteristics in cold temperate zone of Darjiling. Kumar et al. (2016 a, b, c) study the water and soil characteristics from river Beas. The present work was designed to study the correlation of satellite data such as green, red, NIR, and band rationing (G/R, R/NIR and NIR/R) with phytosociological parameters such as density, abundance, evenness, and diversity indices (Simpson's, Shannon's, Margalef's, Brillouin's, Chao-I and Menhinick indices) around the catchment areas of river Beas for a stretch of 63 km from Beas to Harike, Punjab.

MATERIALS AND METHODS

STUDY AREA

River Beas originates in the Himalayas in central Himachal Pradesh, India, at 31.51′ N lat., 77° 05′ E long., and flows for about 470 km to merge with river Sutlej, Punjab. The following three sites: Beas (31.510'N, 75.305'E and 211 m asl), Goindwal Sahib (31.376′ N, 75.162'E and 217 m asl) and Harike (31.150' N, 74.951'E and 210 m asl) were selected for phytosociological studies.

PHYTOSOCIOLOGICAL PARAMETERS

The quadrats were laid down for four different seasons at three sites. A total of 6 quadrats were laid down for each site for each season for the estimation of following parameters. The density, relative density, frequency, relative frequency, abundance and relative abundance were calculated as

$$\text{Density} = \frac{\text{Total number of individuals of a species in all the quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a single species}}{\text{Density of all the species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a single species}}{\text{Frequency of all the species}} \times 100$$

$$\text{Abundance} = \frac{\text{Number of individuals of a species in all the quadrats}}{\text{Number of quadrats in which species occurred}}$$

$$\text{Relative abundance (RA)} = \frac{\text{Abundance of a single species}}{\text{Abundance of all the species}} \times 100$$

The different diversity indices (Simpson's, Shannon's, Margalef's, Brillouin's, Menhinick, Berger-Parker and Chao-1) were calculated in the PAST software.

STATISTICAL ANALYSIS

The results were expressed as mean and standard error. The data was also analyzed by using Pearson's correlation, principal component analysis (PCA), factor analysis (FA) and artificial neural network analysis (ANN) (Kumar et al. 2017 a, b). The software's used were MS-excel, PAST, minitab-14, SPSS and Statistica-12.

RESULTS AND DISCUSSIONS

Table (1) showed the phytosociological parameters for the summer season. From Beas, *Chenopodium ambrosoides* had highest RD, whereas the lowest RD was recorded for *Ranunculus sceleratus*. *A. conyzoides* had maximum relative abundance, whereas *C. ambrosoides* had the lowest relative abundance. Maximum A/F ratio was recorded from *A. conyzoides*, whereas lowest A/F ratio was observed for *C. ambrosoides.* In Goindwal Sahib, maximum relative density was recorded for *Sesbania bispinosa* and the lowest relative density was recorded for *Polygonium plebeium.* Relative abundance was maximum for *S. bispinosa* and minimum for *A. mexicana*. *S. bispinosa* had highest A/F ratio, whereas *Typha angustata* had lowest A/F ratio. In Harike, *C. album* had highest relative density and relative abundance, whereas *A. mexicana* had lowest relative density and relative abundance. *C. album* recorded maximum A/F ratio, whereas *P. hysterophorus* had lowest A/F ratio. Table (2) showed the phytosociological variables for the pre-monsoon season. In Beas, *P. hysterophorus* had maximum relative density, whereas *Saccharum bengalense* had lowest relative density. *Sida acuta* had maximum relative abundance and A/F ratio, whereas lowest relative abundance and A/F ratio were observed for *S. bengalense.* In Goindwal Sahib, *S. bispinosa* recorded maximum relative density and relative abundance, whereas *S. bengalense* had lowest relative density and relative abundance. *Cannabis sativa* had maximum A/F ratio, whereas lowest A/F ratio was recorded for *S. bengalense.* In Harike, *C. album* had maximum relative density and relative abundance, whereas *Ampelopteris prolifera* had the lowest relative density and relative abundance. Maximum A/F ratio recorded for *Lantana camara,* whereas the lowest A/F ratio was observed for *A. prolifera.* Table (3) showed the phytosociological parameters for the post-monsoon season. In Beas, *C. sativa* had maximum relative density, relative abundance, and A/F ratio, whereas *Tamarix dioica* had lowest relative density, relative abundance and A/F ratio. In Goindwal Sahib, *P. hysterophorus* had maximum relative density and relative abundance, whereas the lowest relative density and relative abundance found in *S. bengalense. S. acuta* had maximum A/F ratio, whereas the lowest A/F ratios were observed for *P. hysterophorus* and *S. bengalense.* In Harike, *A. prolifera* recorded the highest relative density and relative abundance, whereas the lowest relative density and relative abundance were recorded for *P. hysterophorus. A. prolifera* recorded maximum A/F ratio, whereas minimum A/F ratio was observed for *Achyranthes aspera* and *T. angustata.* Table (4) showed the phytosociological parameters for the winter season. In Beas, *T. angustata* had the highest relative density, whereas *T. dioica* and *A. conyzoides* had the lowest relative density. *A. aspera* had maximum relative abundance, whereas *P. hysterophorus* had the minimum. In Goindwal Sahib, *C. sativa* had maximum relative density, whereas lowest relative density was observed for *T. angustata. P. hysterophorus* had maximum relative abundance, whereas *T. angustata* had the lowest relative abundance. *A. conyzoides* had maximum A/F ratio, whereas *S. bangalense* had the lowest A/F ratio. In Harike, *A. conyzoides* had maximum relative density and relative abundance, whereas lowest relative density and relative abundance was recorded for *A. aspera* and *P. hysterophorus. A. aspera, A.conyzoides* and *P. hysterophorus* had maximum A/F ratio, whereas *S. bangalense* and *T. angustata* recorded the lowest A/F ratio.

Figs. (1-10) showed the density, abundance and evenness, and diversity indices of different seasons for different sites. During the summer season, Beas recorded maximum density, Simpson's, Shannon's, Brillouin, Menhinick, Margalef's and Chao-I indices. Maximum abundance, density, Simpson's, Shannon's, Brillouin's, Menhinick, Margalef's and Chao-I indices were found for Beas during the pre-monsoon season. Harike recorded maximum abundance during the post-monsoon season. During the winter season, maximum Simpson's, Shannon's, evenness, Menhinick, Margalef's and Chao-I indices were found for Harike. Pearson's correlation was applied to the different phytosociological parameters, reflectance values of bands (2, 3 and 4), and band ratioing (Table 5a and b). Correlation of density existed with evenness and Brillouin's index. Shannon's and Brillouin's indices are correlated with G/R, R/NIR, NIR/R and G/NIR. Diversity indices are highly correlated with each other. Band ratioing of reflectance data are also highly correlated among each other. PCA explained 99.86% of the total variance (72.14%, 25.82% and 1.90% respectively). Fig. 11 showed the loading plot of PCA for various phytosociological parameters.

FA explained two underlying factors for phytosociological parameters. Factor-1 had maximum loadings on Simpson's, Shannon's, Margalef's, Brillouin's, Menhinick, Berger-Parker and Chao-1 indices and accounted for 60.3% of the total variance. This factor influences the diversity indices of the study area. Factor-2 explained 27.4 of the total variance and had maximum loadings on abundance, density and evenness. This factor indicates the phytosociological parameters. Artificial neural network (ANN) models were fitted to the observed and the simulated data (Figs. 12.1-12.7). The correlations between target and output values from ANN for reflectance values for (green, red and NIR bands), and band ratioing (G/R, R/NIR, NIR/R and G/NIR) were highly significant.

CONCLUSIONS

From the present study, it is revealed that maximum abundance and density were found during winter and pre-monsoon seasons in Beas. Harike recorded maximum abundance during post-monsoon season. Maximum Menhinick, Maragalef's, Chao-I, Simpson's and Shannon's indices were found for the Harike during the winter season. Positive correlation of band ratio (G/R) was existed with Simpson's, Shannon's and Brillouin's indices, whereas negative correlation of band ratio (R/NIR) was found with Simpson's, Shannon's and Brillouin's indices.

REFERENCES

Alhassan, J., Dadari, S.A., Shebayan, J.A.Y. and Babaji, B.A. 2015. Phytosociological attributes of weeds in lowland paddy at Talata Mafara, Sudan Savannah, Nigeria. International Journal of Agronomy and Agricultural Research 6, pp. 8-13.

Fassnacht, K.S., Gower, S.T., MacKenzie, M.D., Nordheim, E.V, and Lillesand, T.M. 1997. Estimating the leaf area index of North Central Wisconsin forests using the Landsat Thematic Mapper. Remote Sensing of Environment 61, pp. 229– 245

Isbell, F., Calcagno, V., Hector, A., Connolly, J., Harpole, W.S., Reich, P.B., Scherer-Lorenzen, M., Schmid, B., Tilman, D., Ruijven, J.V., Weigelt, A., Wilsey, B.J., Zavaleta, E.S. and Loreau, M. 2011. High plant diversity is needed to main-tain ecosystem services. Nature 477, pp. 199–202

Jakubauskas, M.E. 1996. Thematic Mapper characterization of lodge pole pine serals in Yellowstone National Park, USA. Remote Sensing of Environment 56, pp. 118–132

Kumar, V., Sharma, A., Bhardwaj, R. and Thukral, A. K. 2016a. Monitoring and characterization of soils from river bed of Beas, India, using multivariate and remote sensing techniques. British Journal of Applied Science & Technology 12, pp. 1-12

Kumar, V., Sharma, A., Chawla, A., Bhardwaj, R. and Thukral, A. K. 2016b. Water quality assessment of river Beas, India, using multivariate and remote sensing techniques. Environmental Monitoring and Assessment. DOI 10.1007/s10661-016-5141-6.

Kumar, V., Sharma, A., Dhunna, G., Chawla, A., Bhardwaj, R. and Thukral, A. K. 2017a. A tabulated review on distribution of heavy metals in various plants. Environmental Science and Pollution Research. 24, pp. 2210–2260.

Kumar, V., Sharma, A., Kaur, R., Thukral, A. K. Bhardwaj, R. and Ahmad, P. 2017b. Differential distribution of amino acids in plants. Amino acids. 49(5), pp. 821-869.

Kumar, V., Sharma, A., Thukral, A. K. Bhardwaj, R. 2016c. Assessment of soil enzyme activities based on soil samples from the Beas river bed, India using multivariate techniques. Malaysian Journal of Soil Science. 20, pp. 135-145.

Langley, S. K., Cheshire, H. M. and Humes, K. S. 2001. A comparison of single date and multitemporal satellite image classifications in a semi-arid grassland. Journal of Arid Environment 49, pp. 401–11.

Nordberg, M. L. and Evertson, J. 2003.Vegetation index differencing and linear regression for change detection in a Swedish mountain range using Landsat TM and ETM+ imagery. Land Degradation and Development 16, pp.139–149.

Paruelo, J.M., and Lauenroth, W.K. 1998. Inter annual variability of NDVI and its relationship to climate for North American shrub land and grasslands. Journal of Biogeography 25, pp. 721–733

Saurav, M. and Das A. P. 2014. Plant species richness and phytosociological attributes of the vegetation in the cold temperate zone of Darjiling Himalaya, India. International Research Journal of Environment Sciences 3, pp. 47-57.

Sharma, K. K. and Pandey, A. K. 2010. Phytosociological study of vegetation of some selected arid region of the Thar desert of Rajasthan, India. Current World Environment 5, pp. 51-58.

Steininger, M.K. 2000. Satellite estimation of tropical secondary forest above-ground biomass: data from Brazil and Bolivia. International Journal of Remote Sensing 21, pp. 1139–1157

Tieszen, L, Reed, B.C. and Dejong, D.D. 1997. NDVI, C3 and C4 production, and distributions in the Great Plains grassland cover classes. Ecological Applications 7, pp. 59–78.

Vidyasagaran, K., Ranjan, M. V., Maneeshkumar, M. and Praseeda, T. P. 2011. Phytosociological analysis of Mangroves at Kannur District, Kerala. International Journal of Environmental Sciences 2, pp. 671-677

Table 1 Phytosociological parameters for the summer season

Name of site	Plant species	RD	Freq.	RF	RA	A/F
Beas	*Ageratum conyzoides* L.	19.05	83.33	13.16	40.26	0.038
	Argemone mexicana L.	4.76	50.00	7.89	9.44	0.015
	Cannabis sativa L.	5.95	66.67	10.53	10.07	0.012
	Chenopodium ambrosoides L.	25.00	83.34	15.79	3.59	0.003
	Erigeron bonariensis L.	7.14	66.67	10.53	8.39	0.010
	Parthenium hysterophorus L.	15.48	83.33	13.16	4.84	0.005
	Polygonium plebeium R.Br.	10.71	66.67	10.53	5.59	0.007
	Ranunculus sceleratus L.	4.76	50.00	7.89	9.44	0.015
	Rumex dentatus L.	7.14	66.67	10.53	8.39	0.010
Goindwal Sahib	*Argemone mexicana* L.	6.94	50.00	13.04	7.63	0.025
	Erigeron bonariensis L.	11.11	66.67	17.39	12.21	0.030
	Polygonium plebeium R.Br.	5.56	50.00	13.04	8.14	0.027
	Rumex dentatus L.	13.89	66.67	17.39	15.26	0.038
	Sesbania bispinosa (Jacq.)W.F.Wight.	54.17	83.33	21.74	47.61	0.094
	Typha angustata Chamb.	8.33	66.67	17.39	9.16	0.023
Harike	*Argemone mexicana* L.	8.69	50.00	12.00	10.26	0.027
	Chenopodium album L.	19.56	50.00	12.00	23.08	0.060

	Fumaria parviflora Lam.	15.21	66.67	16.00	13.46	0.026
	Oxalis corniculata L.	10.86	50.00	12.00	12.82	0.033
	Parthenium hysterophorus L.	13.04	67.00	16.00	11.54	0.022
	Polygonium barbatum L.	15.21	67.00	16.00	13.46	0.026
	Rumex dentatus L.	17.38	67.00	16.00	15.38	0.030

Table 2 Phytosociological variables for the pre-monsoon season

Name of site	Plant species	RD	Freq.	RF	RA	A/F
Beas	*Ageratum conyzoides* L.	14.697	67.00	12.90	15.69	0.037
	Canavis sativa L.	17.637	84.00	16.13	15.06	0.029
	Parthenium hysterophorus L.	20.576	84.00	19.35	14.64	0.028
	Polygonium barbatum L.	14.697	67.00	12.90	15.69	0.037
	Saccharum bengalense Retz.	8.8183	84.00	16.13	7.53	0.014
	Sida acuta Burm.f.	13.228	50.00	9.68	18.83	0.060
	Typha angustata Chamb.	11.758	67.00	12.90	12.55	0.030
Goindwal Sahib	*Cannabis sativa* L.	15.789	67.00	14.81	17.44	0.034
	Debregeasia longifolia (Burm.f.)Wedd	22.807	84.00	18.52	20.16	0.031
	Parthenium hysterophorus L.	14.035	84.00	18.51	15.50	0.024
	Saccharum bengalense Retz.	8.7719	67.00	14.81	9.69	0.019
	Sesbania bispinosa (Jacq.)W.F.Wight.	24.561	84.00	18.51	21.71	0.033
	Typha angustata Chamb.	14.035	67.00	14.81	15.50	0.030
Harike	*Ampelopteris prolifera*(Retz.)Copel	12.24	67.00	16.00	12.82	0.022
	Chenopodium album L.	24.48	84.00	20.00	20.51	0.029
	Lantana camara L.	12.24	50.00	16.00	17.09	0.040
	Parthenium hysterophorus L.	18.36	84.00	20.00	15.38	0.021
	Saccharum bengalense Retz.	16.32	67.00	16.00	17.09	0.030
	Typha angustata Chamb.	16.32	67.00	16.00	17.09	0.030

Table 3 Phytosociological variables for the post-monsoon season

Name of site	Plant species	RD	Freq.	RF	RA	A/F
Beas	*Achyranthes Aspera* L.	6.89	50.00	10.00	10.39	0.027
	Ageratum conyzoides L.	20.68	84.00	16.67	18.70	0.029
	Cannabis sativa L.	22.41	84.00	16.67	20.26	0.031
	Parthenium hysterophorus L.	18.96	84.00	16.67	17.14	0.026
	Saccharum bangalense Retz.	15.51	84.00	16.67	14.03	0.021
	Tamarix dioica Roxb. ex Roth	5.17	50.00	10.00	7.79	0.020
	Typha angustata Chamb.	10.34	67.00	13.33	11.69	0.022
Goindwal Sahib	*Ageratum conyzoides* L.	22.71	67.00	21.05	20.92	0.037
	Parthenium hysterophorus L.	24.98	84.00	26.32	18.41	0.026
	Saccharum bangalense Retz.	15.89	67.00	21.05	14.64	0.026
	Sida acuta Burm.f.	13.62	34.00	10.53	25.10	0.088

	Typha angustata Chamb.	22.71	67.00	21.05	20.92	0.037
Harike	*Achyranthes aspera* L.	14.54	67.00	17.39	14.04	0.030
	Ampelopteris prolifera (Retz.) Copel	23.63	67.00	17.39	22.81	0.049
	Chenopodium album L.	16.36	67.00	17.39	15.79	0.034
	Parthenium hysterophorus L.	10.91	50.00	13.04	14.04	0.040
	Sida acuta Burm.f.	19.99	67.00	17.39	19.30	0.041
	Typha angustata Chamb.	14.54	67.00	17.39	14.04	0.030

Table 4 Phytosociological variables for the winter season

Name of site	Plant species	RD	Freq.	RF	RA	A/F
Beas	*Achyranthes aspera* L.	21.21	66.67	17.39	20.43	0.026
	Ageratum conyzoides L.	12.12	50.00	13.04	15.56	0.027
	Parthenium hysterophorus L.	15.15	67.00	17.39	14.59	0.019
	Sida acuta Burm.f.	18.18	67.00	17.39	17.51	0.022
	Tamarix dioica Roxb. ex Roth	12.12	50.00	13.04	15.56	0.027
	Typha angustata Chamb.	21.21	84.00	21.74	16.34	0.017
Goindwal Sahib	*Ageratum conyzoides* L.	15.61	50.00	14.29	21.74	0.033
	Canavis sativa L.	24.97	84.00	23.81	20.87	0.019
	Parthenium hysterophorus L.	21.85	67.00	19.05	22.83	0.026
	Saccharum bangalense	21.85	84.00	23.81	18.26	0.017
	Typha angustata Chamb.	15.61	67.00	19.05	16.30	0.019
Harike	*Achyranthes aspera* L.	16.67	67.00	17.39	19.23	0.019
	Ageratum conyzoides L.	26.67	84.00	21.74	24.62	0.019
	Parthenium hysterophorus L.	16.67	67.00	17.39	19.23	0.019
	Saccharum bangalense	20.00	84.00	21.74	18.46	0.014
	Typha angustata Chamb.	20.00	84.00	21.73	18.46	0.014

Table 5a Pearson's correlation analysis of phytosociological parameters with reflectance's values of different bands and band ratios

	Abundance	Density	Evenness	Simpson's index	Shannon's index	Brillouin's index	Menhinick index
Density	0.516						
Evenness	-0.434	-0.653*					
Simpson's index	-0.222	0.240	0.468				
Shannon's index	-0.126	0.503	0.178	0.950***			
Brillouin's index	0.123	0.730**	-0.046	0.832***	0.948***		
Menhinick index	-0.677	-0.124	0.482	0.802**	0.730***	0.481	
Margalef 's index	-0.498	0.193	0.275	0.878***	0.888***	0.716*	0.948***
Berger-Parker index	0.233	-0.039	-0.623	-0.966***	-0.849***	-0.697*	-0.784**
Chao-1 index	-0.273	0.491	-0.069	0.751**	0.868***	0.794**	0.756**
Green	0.133	-0.001	-0.427	-0.308	-0.239	-0.213	-0.173

Red	0.112	-0.065	-0.443	-0.402	-0.336	-0.310	-0.229
NIR	0.072	0.455	-0.302	0.264	0.379	0.412	0.205
G/R	0.129	0.413	0.229	0.592*	0.594*	0.605*	0.303
R/NIR	0.065	-0.407	-0.161	-0.586*	-0.617*	-0.613*	-0.393
NIR/R	0.038	0.472	0.072	0.518	0.568*	0.586*	0.312
G/NIR	0.082	-0.414	-0.086	-0.528	-0.577*	-0.577*	-0.373

Significant at *P <0.05 **P <0.01 ***P <0.001

Table 5b Pearson's correlation analysis of phytosociological parameters with reflectance's values of different bands and band ratios

	Margalef's index	Berger-Parker index	Chao-1 index	Green	Red	NIR	G/R	R/NIR	NIR/R
Berger-Parker index	-0.799**								
Chao-1 index	0.907***	-0.613*							
Green	-0.172	0.290	-0.163						
Red	-0.244	0.377	-0.221	0.989***					
NIR	0.319	-0.196	0.337	0.466	0.344				
G/R	0.408	-0.527	0.379	-0.577*	-0.689*	0.379			
R/NIR	-0.496	0.523	-0.489	0.500	0.609*	-0.526	-0.914***		
NIR/R	0.428	-0.434	0.442	-0.433	-0.550	0.586*	0.944***	-0.973***	
G/NIR	-0.477	0.465	-0.488	0.413	0.522	-0.601*	-0.861***	0.990***	-0.963***

Significant at *P <0.05 **P <0.01 ***P <0.001

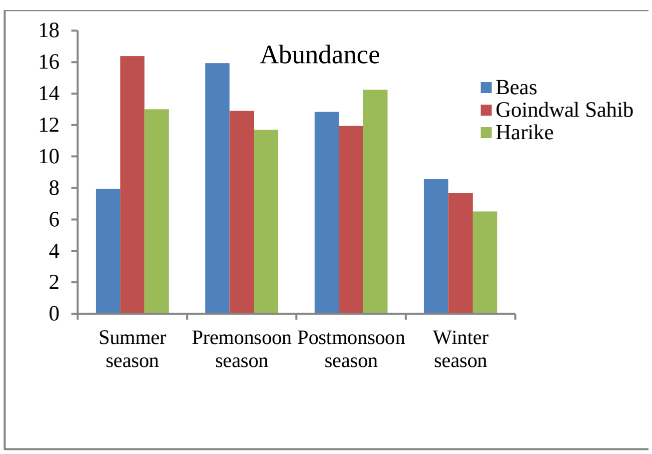

Fig. 1 Abundance of different sites for different seasons

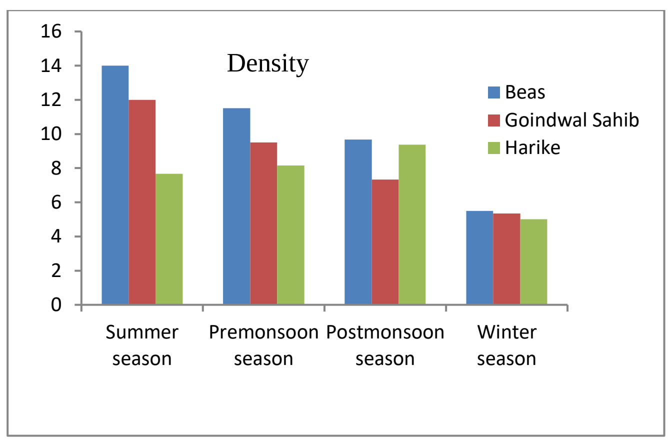

Fig. 2 Density of different sites for different seasons

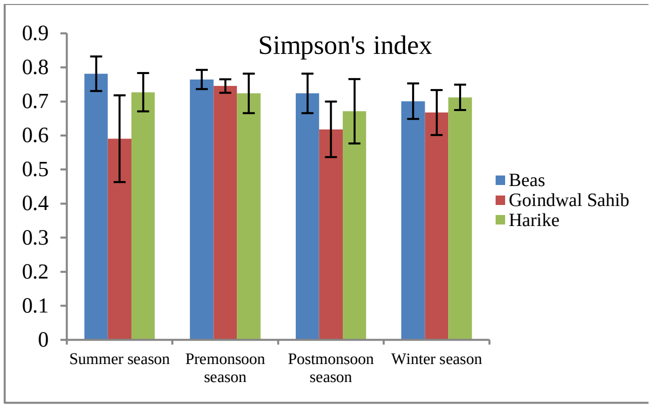

Fig. 3 Simpson's index of different sites for different seasons

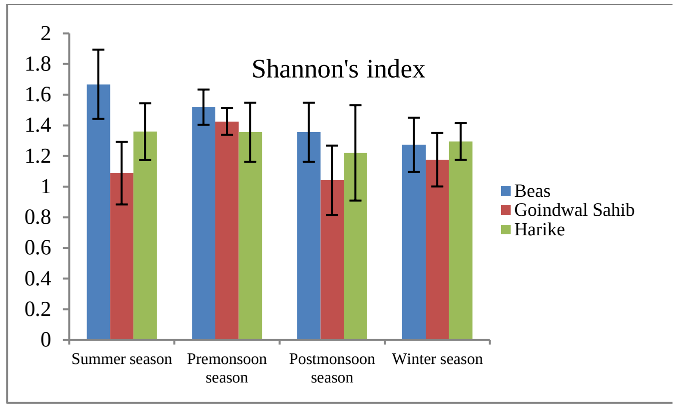

Fig. 4 Shannon's index of different sites for different seasons

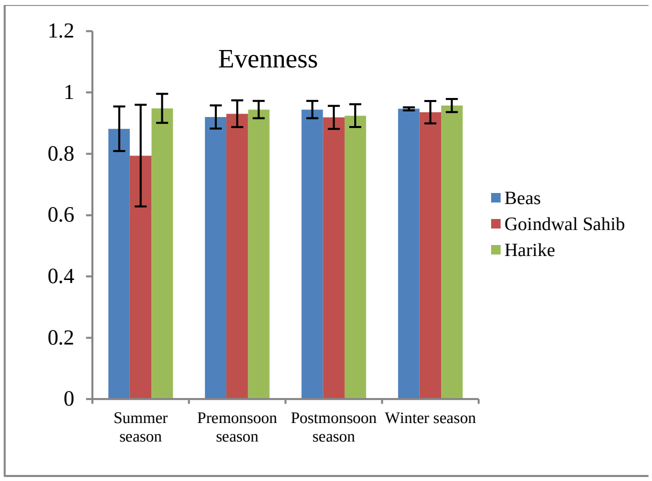

Fig. 5 Evenness of different sites for different seasons

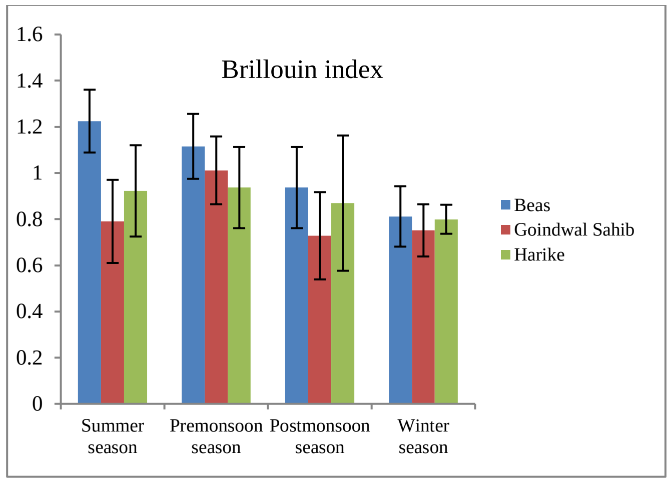

Fig. 6 Brillouin index of different sites for different seasons

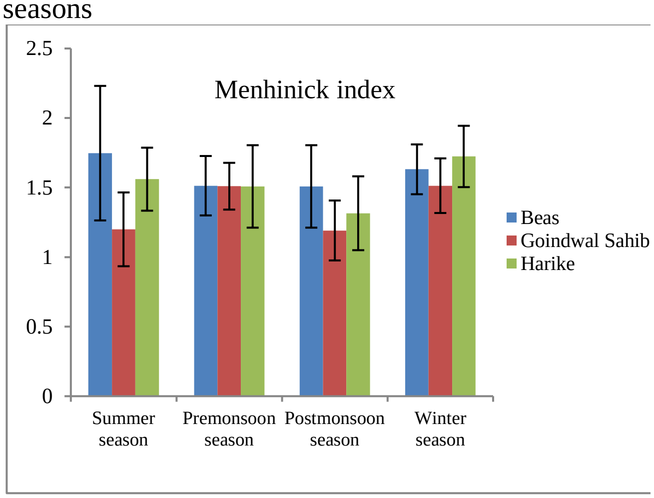

Fig. 7 Menhinick index of different sites for different seasons

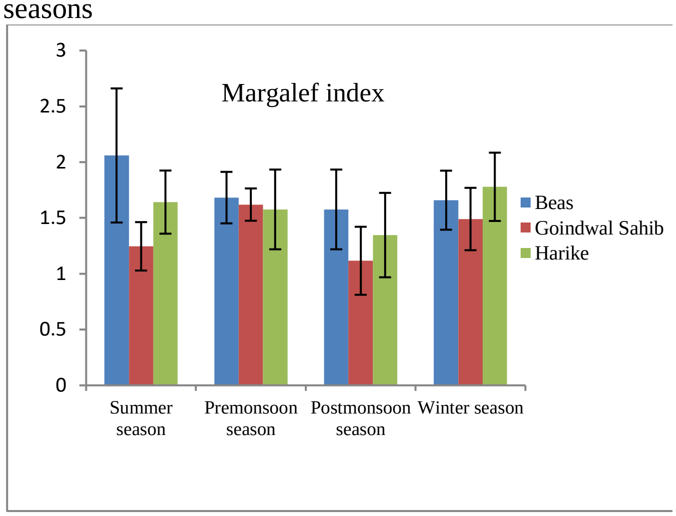

Fig. 8 Margalef's index of different sites for different seasons

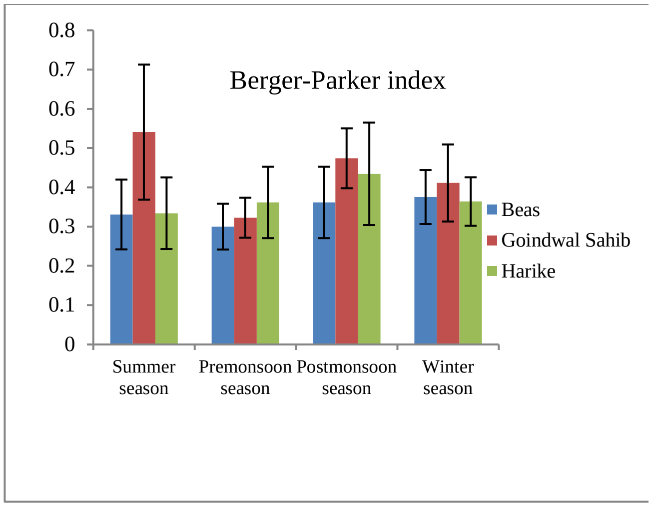

Fig. 9 Berger-Parker index of different sites for different seasons

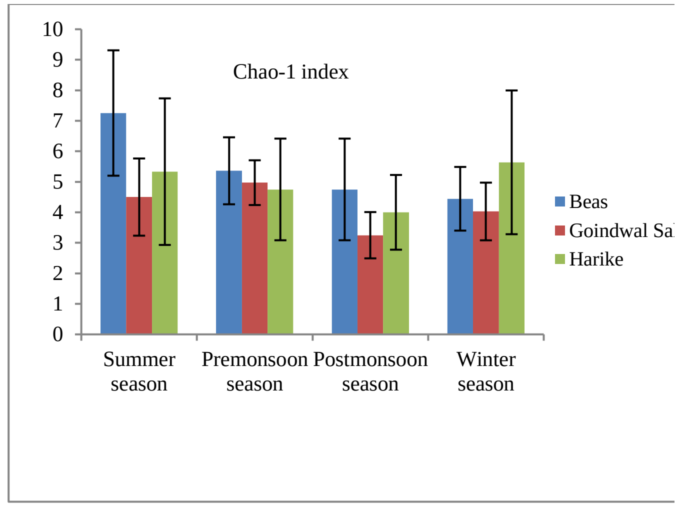

Fig. 10 Chao-1 index of different sites for different seasons

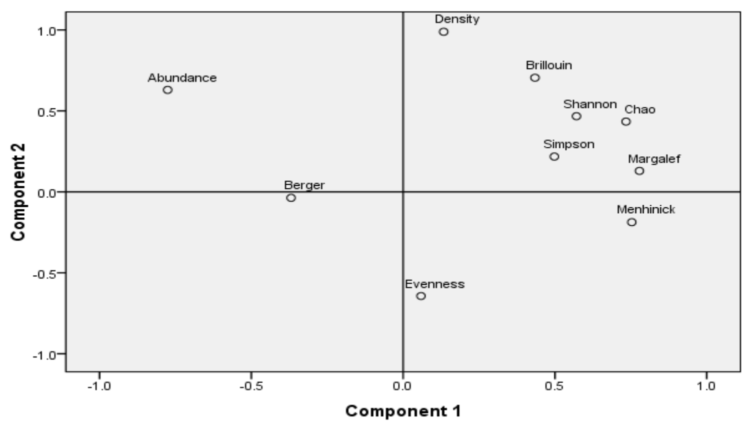

Fig. 11 Loadings of principal component analysis

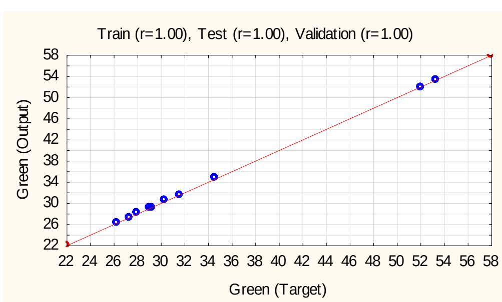

Fig. 12.1 Correlation between target and output green band using ANN model

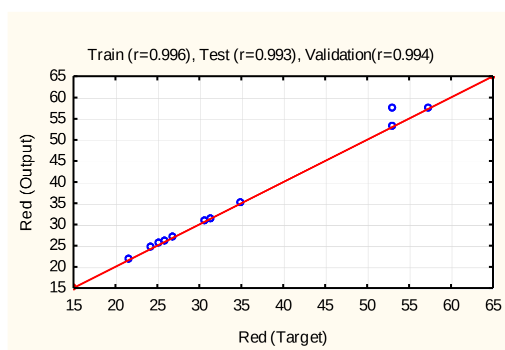

Fig. 12.2 Correlation between target and output red band using ANN model

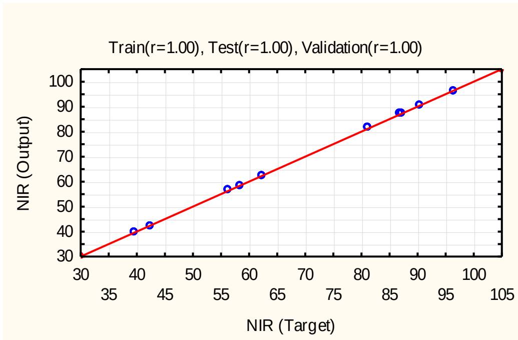

Fig. 12.3 Correlation between target and output NIR band using ANN model

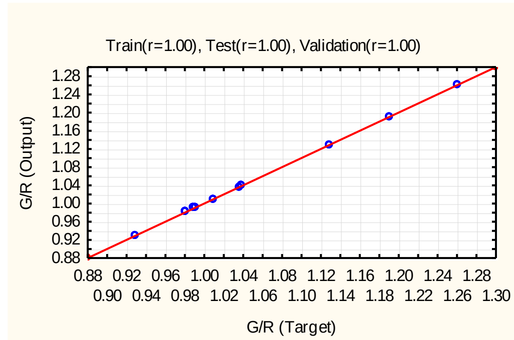

Fig. 12.4 Correlation between target and output G/R band ratioing using ANN model

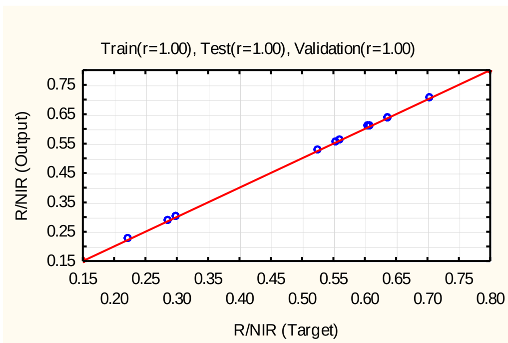

Fig. 12.5 Correlation between target and output R/NIR band ratioing using ANN model

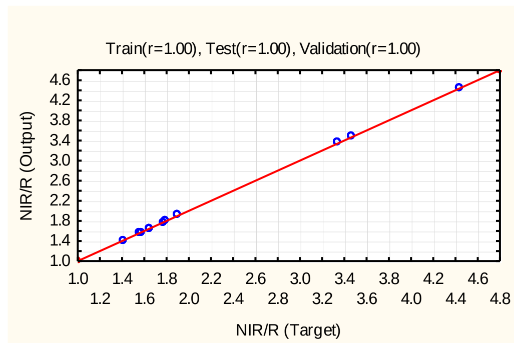

Fig. 12.6 Correlation between target and output NIR/R band ratioing using ANN model

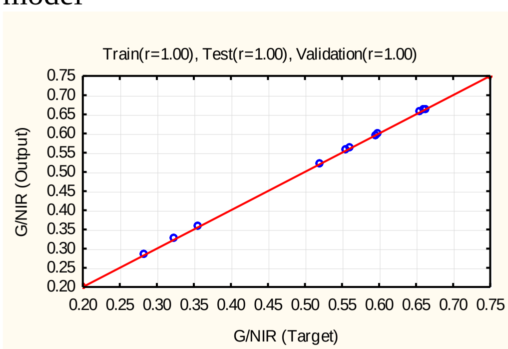

Fig. 12.7 Correlation between target and output G/NIR band ratioing using ANN model