ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Patterns of Biodiversity in State Managed and Community Based Forest Management Categories of Terai Arc Landscape, Nepal

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ABSTRACT: This study was carried out in 147 forest units of seven sites of Terai Arc Landscape (TAL) in 2009 and 2012 to analyse and compare the structure of biodiversity within community based forest management (CBM) and state managed systems (SMS) and investigate the relationship among biodiversity indices. For each of these management modes, we simultaneously analysed 24 indices that are theoretically complementary and relate to number of species, evenness and diversity. Principal component analysis (PCA) with varimax rotation and multiple regression analysis (MLRA) were carried out to investigate empirical relationships between the selected indices. Under landscape level conservation, CBM has been found significantly better than SMS on diversity indices. The results confirmed that instead of using PCA and MLRA separately, use of factor score of PCA in MLRA can offer a good opportunity for developing and predicting model or equations on performance of biodiversity without multicollinearity problem.

KEYWORDS: Terai Arc Landscape, biodiversity indices, community based forest management, government managed forests, multiple regression analysis, principal component analyses.

I. INRODUCTION

Biodiversity is an important consideration in landscape level conservation particularly in areas under severe threats (Kharal and Oli, 2008). In case of Nepal, forests are brought under different management interventions under Terai Arc Landscape (TAL) program with increased number and area (International Forest Fire News, IFFN, 2006; National Planning Commission, NPC, 2012 and 2013; Ministry of Forests and Soil Conservation, MFSC, 2013), but there is limited information and monitoring on biodiversity conservation in terms of species richness, taxic diversity and crown coverage (Poudel, 2009). Though, there are some baseline information in community based forest operational plans about tree species, diameter class distribution and tree size (seedling, sapling, pole and tree), the basic usage of the information has been just to estimate timber volume (MFSC, 2009).

As biodiversity cannot be measured and monitored directly (Geburek, et al. 2010), a number of different measures on indicators have been proposed. The indicators must be measurable, scientifically valid and capable of providing information for management decision-making concerning different levels of biodiversity (Donnelly, et al. 2007; and Geburek, et al. 2010). Although there are some study reports about the biodiversity conservation focused on specific forest management regimes in particular forest areas of Nepal, however, these studies lack coverage of action focused approach or framework on forest biodiversity assessment.

This study a) assesses the performance of TAL program on biodiversity conservation by comparing plant species richness, evenness and diversity indices and b) examines the relationship between selected variables of biodiversity measurement with reference to the forest management modes and develop model for biodiversity indices making and prediction.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 3, Issue 12, December 2014

II. MATERIALS & METHODS

The study was carried out in 147 forest units (n) out of 240 forest units (N) of seven corridors and bottleneck areas namely Mohana-Laljhadi, Basanta, Khata, Barandavar, Mahadevpuri, Lamahi and Dovan and associated buffer zone areas in 2009 and 2012 with sampling error of 5% based on Cochran's sample size formula for categorical data collection. The sample units were divided into four groups (ACF) – After Community Forests, (n = 43); Group 2 (BCF) – Before Community Forests, (n= 43); Group 3 (BZC) –Nearby buffer-zone community forests, (n=18); and Group 4 (GMF)-nearby government managed forests (GMF), (n=43). Due to the proximity and topographical similarity within each modes, it is possible to observe large differences in the social and management factors of the different categories of the forest area studied. Field work was conducted by following the inventory protocols developed by the Government of Nepal (Department of Forests, DoF 2004; Aryal, *et al*. 2012) and attempted to incorporate ethno-botanical and biodiversity perspectives.

Table 1: Number of forests sampled

Sites	Community based management (CBM)		State managed system (SMS)		Total
	ACF	BZC	BCF	GMF	
Barandabar	9	9	9	9	36
Basanta	10	0	10	10	30
Dovan	3	0	3	3	9
Khata	4	4	4	4	16
Laljhadhi	5	5	5	5	20
Lamahi	8	0	8	8	34
Mahadevpuri	4	0	4	4	12
Total	43	18	43	43	147

(Source: Field survey, 2009 and 2012)

The species richness, evenness and unified indices were calculated for each site and each management modes. Beta-Diversity for each site was calculated on the basis of data from plots. The principal components were rotated via a varimax procedure to produce factors. Multiple Regression procedure was used to correlate species richness, evenness and biodiversity index.

III. RESULTS

According to the analysis of α biodiversity indexes (Table 2), it was found that ACF environments are the most diverse (N=11995, S=32; d= 440/ha; Dmg=2.667; Dmn=0.433) while GMF are the least diverse (N=1999; S=17; d= 272/ha; Dmg= 0.944; Dmn=0. 289). All diversity indices, including Reciprocal Simpson Diversity Index ($1/\lambda$), Shannon Diversity Index (H'), Dominance Index (D) Inverted Berger-Parker Dominance Index (1/d) revealed that the ACF ($1/\lambda$=3.443; H'=3.152; D=0.629; 1/d=3.63) strongly dominate the rest modalities every regards. Similar result was found in the case of BZC ($1/\lambda$ = 2.793; H' = 2.845; D=0.563; 1/d=3.17). GMFs were found the least diverse ($1/\lambda$ = 1.642; H' = 1.874; D=0.249; 1/d=2.320) and greater evenness (J=0.846 and E=0.632).

These observations can be explained according to the characteristics of forest management category. The CBMs record a greater abundance as well as a higher variety of environments that are able to be develop by forests species than in other categories of forests. That means a greater amount of forest products available to be exploited by different communities of locals along the years. The buffer-zone, can be defined as transitional environments between CF and GMFs categories. The factor of legal rights of use in combination with duties of protections determines conducive environment for vegetation and diversity. GMF and BCF represent the most extreme type of environment on poor governance and high threats limiting diversity observed in these categories.

IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Table 2. Species number and alpha biodiversity estimator for each management category

Variables	Annotations	CBM		SMS	
		ACF	BZC	BCF	GMF
Abundance	N	11995	7294	2168	1999
Species richness	S	32	13	23	17
Density	^0D	440	551	294	272
Simpson Index	λ	0.362	0.479	0.691	0.750
Dominance Index	D	0.629	0.563	0.306	0.249
Reciprocal Simpson Index	1/λ	3.443	2.739	1.880	1.642
Shannon Index	H'	3.152	2.845	1.981	1.874
Menhinick Index	DMn	0.433	0.190	0.276	0.289
Buzas and Gibson's Index	E	0.456	0.522	0.586	0.632
Pielou's	J'	0.708	0.728	0.753	0.846
Simpson Index Approximation	A λ	0.181	0.227	0.344	0.375
Dominance Index Approximation	AD	0.810	0.786	0.645	0.623
Alternate Reciprocal Simpson Index	N2	6.834	5.112	3.740	3.234
Berger-Parker Dominance Index	d	0.307	0.355	0.471	0.695
Inverted Berger-Parker Dominance Index	1/d	3.630	3.170	2.588	2.320
Margalef Richness Index	DMg	2.677	1.519	0.931	0.944
Gini Coefficient	G	5.727	4.004	2.204	2.092

(Source: Field survey, 2009 and 2012)

As shown in Table 3, the absolute beta value, total amount of species turnover among the subunits of management, appeared to be highest in ACF (22.2) and lowest in BCF (12.5). Routledge's Beta index however shows that in terms of over lapping species pairs that beta diversity is greatest in ACF sites (7.73) followed by BZC sites (4.58), GMF sites (4.49) and then by BCF sites (2.5). Comparisons of Mountford's index in management modality showed the highest value to BCF (-0.6157) and lowest value to ACF (-0.1063). Community similarity in terms of comparing the number of common species showed the highest value of ACF (23) and lowest of BZC (12).

Table 3: Beta biodiversity estimators for each management category

Variables	Annotations	CBM		SMS	
		ACF	BZC	GMF	BCF
Absolute beta Value	Abv	22.2	13.4	15.9	12.5
Routledge beta-R Index	BR	7.73	4.58	4.49	2.50
Mountford Index	M	-.1063	-.2117	-.4467	-.6157
Number of Common Species	C	23	12	16	13

(Source: Field survey, 2009 and 2012)

Principal component analyses (PCA) and multiple regression analyses (MLRA)

The measured biodiversity characteristics were assessed by using scores derived from factor and PCA in MLRA for CBM and SMS. The summary results for MLRA in the CBM and SMS is presented in Table 4. The explained variation of CBM was nearly 61.5% R^2 and 47.5 % adjusted $R^2$with the significant regressors, viz. N, 0D, H', J' and G ($P<0.05$). R^2, adjusted R^2 and error of the estimate values for SMS were 56.1%, 31.4% and 0.975. 1/λ, 1/d and G provided important contributions in SMS ($P<0.05$). Variance Inflation Factor (VIF) estimates (3.41-51.56 for CBM and 1.41-66.93 for SMS) displayed that there was collinearity problem in regressor. Root of error variance of MLRA was 4.635 and 4.102 for CBM and SMS, respectively.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Table 4: Multiple regression analysis (MLRA)

Variables	CBM: ACF and BZC							SMS: BCF and GMF						
	B	SE	Beta	t	p	Tol*	VIF	B	SE	Beta	t	p	Tol*	VIF
(Constant)	-1.83	3.47		-0.53	0.60			2.72	3.04		0.90	0.37		
N	0.00	0.00	-2.29	-3.27	0.00	0.02	5.80	0.00	0.00	0.29	0.68	0.50	0.06	6.01
S								-0.49	2.22	-1.91	-0.22	0.83	0.00	66.93
0D	0.00	0.00	1.90	3.00	0.00	0.02	15.78	0.00	0.00	-0.28	-0.69	0.49	0.07	4.80
λ	1.80	2.54	0.48	0.71	0.48	0.02	13.47	0.58	2.17	0.19	0.27	0.79	0.02	7.51
D	-2.60	4.39	-0.68	-0.59	0.56	0.01	51.56	-0.40	2.24	-0.14	-0.18	0.86	0.02	13.40
1/λ	0.61	0.42	0.91	1.46	0.15	0.02	24.91	-2.29	0.88	-2.10	-2.60	0.01	0.02	18.31
H’	2.12	0.87	1.61	2.43	0.02	0.02	19.71	0.59	0.79	0.42	0.74	0.46	0.04	18.15
DMn	0.51	1.16	0.17	0.44	0.66	0.06	17.36	-0.93	1.24	-0.17	-0.75	0.46	0.22	4.53
E	1.30	1.79	0.24	0.73	0.47	0.08	11.91	-0.16	1.37	-0.03	-0.12	0.91	0.23	4.44
J'	-0.75	0.35	-0.60	-2.17	0.04	0.11	8.81	0.07	0.71	0.01	0.09	0.93	0.48	2.10
d	-3.10	3.17	-0.51	-0.98	0.33	0.03	10.84	0.30	0.27	0.18	1.10	0.28	0.42	2.36
1/d	-0.29	0.20	-0.42	-1.47	0.15	0.11	9.46	0.83	0.42	1.00	1.97	0.05	0.04	13.18
DMg	-0.86	0.83	-0.97	-1.04	0.31	0.01	10.65	0.51	0.81	0.25	0.63	0.53	0.07	14.26
G	-0.72	0.30	-1.88	-2.39	0.02	0.01	30.65	0.91	0.49	1.22	1.86	0.07	0.03	18.28
Abv								-0.02	1.74	-0.06	-0.01	0.99	0.00	40.40
BR	-0.27	0.45	-0.90	-0.60	0.55	0.00	25.37	0.50	0.41	0.69	1.22	0.23	0.04	18.65
M	-1.69	1.26	-0.23	-1.34	0.19	0.29	3.41	0.13	0.18	0.10	0.75	0.45	0.71	1.41
C	0.24	0.17	2.35	1.38	0.18	0.00	33.92	0.14	1.36	0.54	0.10	0.92	0.00	24.67
R^2: 61.5% R^2 adjusted: 47.5% RMSE: 0.823								R^2: 56.1% R^2 adjusted: 31.4% RMSE: 0.975						

(*Tol = Telerance)

Results of Using Factor Scores in Multiple Linear

Results of factor analysis are given in Table 5. Variation of 89.7% on dimension of CBM was explained by Factors 1-4 with 46.3%, 30.6%, 7.2% and 5.6%, respectively. Present communalities varied from 0.980 to 0.699 on CBM. S (0.980), Abv (0.979), C (0.979) and ^{0}D (0.970) made much higher contribution to Factor 1 compared with other regressors and 1/d (0.916), 1/λ (0.853), and H (0.713) were more significant contributors on the structuring of Factor 2. Furthermore, 0D (0.923) and N (0.904) made greater contribution to Factor 3. Similarly, J (0.855) was the highest contributor to Factor 4.

New uncorrelated variables gave the best results for prediction of SMS. For instance, all the Factors 1-3 were responsible for 80.47% variability of the SMS. High percentage of variation for each original regressor was explained in Table 5. Communalities from SMS ranged between 0.967 and 0.181. S (0.966), C (0.966), Abv (0.965) and G (0.807) were of great importance in the settlement of Factor 1 ($P<0.01$). Similarly, 1/d (0.769),1/λ (0.753), and λ (-0.748) outstandingly contributed to the formation of Factor 2. The structuring of Factor 3 was with contribution of N (0.906).

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Table 5. Rotated Factor Loadings and Communalities

Variables	CBM					SMS			
	Factor 1	Factor 2	Factor 3	Factor 4	Comm	Factor 1	Factor 2	Factor 3	Comm
N	0.277	-0.231	0.904	-0.08	0.954	0.284	-0.015	0.906	0.902
S	0.98	0.104	0.089	-0.017	0.98	0.966	0.153	0.104	0.967
0D	0.089	-0.305	0.923	-0.133	0.97	-0.06	0.018	0.95	0.906
λ	-0.189	-0.73	0.586	-0.081	0.918	-0.518	-0.748	-0.271	0.901
D	0.178	0.734	-0.613	0.075	0.952	0.516	0.727	0.273	0.869
1/λ	0.332	0.853	-0.161	0.259	0.931	0.588	0.753	0.023	0.914
H’	0.467	0.713	-0.436	0.123	0.932	0.703	0.649	0.135	0.934
DMn	0.275	0.273	-0.293	0.68	0.699	0.079	-0.256	-0.855	0.802
E	-0.631	0.645	-0.214	0.206	0.902	-0.51	0.713	-0.165	0.795
J'	-0.133	0.174	-0.011	0.855	0.779	0.011	0.681	0.194	0.501
d	-0.107	-0.837	0.417	-0.107	0.897	-0.204	-0.235	-0.29	0.181
1/d	0.013	0.916	0.008	0.217	0.885	0.497	0.769	-0.006	0.838
DMg	0.906	0.23	-0.106	0.259	0.951	0.93	0.149	-0.214	0.932
G	0.665	0.599	-0.296	-0.103	0.899	0.807	0.538	0.07	0.945
Abv	0.98	0.103	0.09	-0.021	0.979	0.965	0.152	0.108	0.966
BR	0.972	0.099	0.098	-0.018	0.964	0.95	0.212	0.078	0.954
M	0.74	0.094	-0.079	0.049	0.564	0.402	0.1	0.192	0.209
C	0.98	0.103	0.09	-0.021	0.979	0.966	0.145	0.108	0.966
Eigen	8.332	5.505	1.2099	1.001		9.417	2.814	2.252	
% Var	46.3	30.6	7.2	5.6		52.32	15.64	12.51	

Results for using factor scores (FS) in MLRA are in Table 6 and 7. The new uncorrelated variables (FS1, FS2, FS3 and FS4) in MLRA for CBM positively influenced the dimensions. Factor scores (new derived regressors) were significant contributors (50.9 % R^2 and Adjusted % 49.9 R^2) for the CBM prediction. Room mean squared error (RMSE) was 0.35. Similarly, for SMSR^2, adjusted R^2 and RMSE were 48.2%, 46.7% and 0.361 respectively. Using factor scores in MLRA exhibited a good alternative to definitely eliminate multicollinearity problem. Factor scores (FS1, FS2, FS3 and FS4) were deduced to be considerable predictors.

Table 6: Results for Multiple Regression Analysis for Factor Scores on CBM

	B	SE	Beta	t	p	Tolerance	VIF
Constant	1.302	0.039		33.675	0		
FS1	-0.247	0.026	-0.629	-9.655	0	0.867	1.153
FS2	-0.083	0.026	-0.227	-3.23	0.002	0.747	1.338
FS3	-0.074	0.042	-0.115	-1.788	0.076	0.891	1.122
FS4	-0.022	0.041	-0.036	-0.539	0.591	0.803	1.245

(R =0.714; $R^2_=$ 0.509; Adjusted $R^{2=}$ 0.499; and RMSE of Estimate = 0.35)

Table 7: Results for Multiple Regression Analysis for Factor Scores on SMSs

	B	SE	Beta	t	p	Tolerance	VIF
Constant	1.795	0.034		52.971	0		
FS1	-0.167	0.014	-0.758	-11.696	0	0.824	1.214
FS2	-0.074	0.026	-0.261	-2.853	0.005	0.414	2.413

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

FS3	-0.026	0.014	-0.161	-1.863	0.065	0.464	2.157

(R =0.694; R^2 = 0.482; Adjusted R^2 = 0.467; and RMSE of Estimate = 0.361)

Multiple Regression Analysis for PCA Scores

With PCA, when original regressors were transformed into two new latent-regressors with eigenvalues of 8.332 and 5.505 and 56.9 % for variation explained for describing the chance of dimension of CBMs. PC1 and PC2 equations are:

CBM:

PC1= $- 0.730\ N – 0.806\ ^0D – 0.922\ \lambda + 939\ D + 0.811\ 1/\lambda + 0.26\ H' + 0.543\ DMn + 0.691\ E - 0.595\ G$

PC2= $0.990\ S - 0.574\ E + 0.906\ DMg + 0.694\ G + 0.989\ Abv + 0.982\ BR + 0.732\ DMn + 0.989\ C$

The PCA results for CBM and SMS are presented in Table 5. For SMS, two new-latent-regressors whose eigenvalues were 9.417 and 2.814 with 47.9% variation explained and their PCA equations were written below:

SMS:

PC1= PC1= $0.947\ S - 0.769\ \lambda + 0.758\ D + 0.838\ 1/\lambda + 0.901\ H' + 0.760\ 1/d + 0.915\ DMg + 0.953\ G + 0.946\ Abv + 0.956\ BR + 0.944\ C$

PC2= PC2 = $0.689\ N + 0.814\ ^0D - 0.860\ DMn + 0.506\ J$

Results from PCA scores in MLRA are described in Table 8 and displayed worthy predictors of two PC scores for CBM (86.5 % R^2 and Adjusted % 86.4 R^2). RMSE was observed 0.433. Using PCA scores in MLRA without multicollinearity problem was a good choice to achieve the greatest importance results. They yielded much high with 88.7 % R^2 and adjusted $R^2$88.5 % with RMSE 0.422 in SMS.

Table 8: Results of PCA Scores in Multiple Regression

	B	SE	Beta	t	p	Tolerance	VIF	R^2	R^2adjusted	RMSE
CBM								86.5%	86.4%	0.433
(Constant)	2.151	0.104		20.669	0					
PC1	-0.384	0.075	-0.432	-5.09	0	0.812	1.232			
PC2	0.092	0.106	0.073	0.863	0.39	0.812	1.232			
SMS								88.7%	88.5%	0.422
(Constant)	3.012	0.109		27.696	0					
PC1	-0.035	0.109	-0.035	-0.32	0.75	1	1			
PC2	-0.171	0.109	-0.17	-1.566	0.04	1	1			

IV. DISCUSSION AND CONCLUSION

The comparative design of this study allowed us to compare the performance between forests under different management modes. Due to the proximity and topographical similarity within each modes, differences in biodiversity indices are unlikely to be due to environmental factors; rather the impacts of management activities have resulted in differences in parameters. Differences in management activities are due forestry governance i.e. rules and management regimes. Under landscape level conservation, CBM has significantly better performance than SMS on diversity indices.

In literature, PCA and MLRA have been widely preferred with the goal to develop and predict index of biodiversity. (James, et al. 2006; Honnay, et al. 2009). However, use of factor scores of PCA in MLRA in order to remove

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

multicollinearity problem is very limited. Hence, the present results confirmed that multicollinearity problem can be removed in these two approaches with very smaller RMSE and VIF for each of new-uncorrelated-variables. As a result, the prediction models or equations obtained for using factor scores obtained in PCA scores could be employed reliably in MLRA by removing multicollinearity problem, influencing original variables and deriving useful new-uncorrelated variables. However, in order to generalize the present results, further studies must be carried out using more sample sites under much larger population.

ACKNOWLEDGEMENTS

We are grateful to the District Forest Offices for providing human resources and Dr. Achyut Aryal for technical support for this research. We are especially indebted to the local communities for taking part in this research during data collection. We are highly grateful to reviewers for providing critical comments to improve the manuscript.

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