

SECTION 11: PRELIMINARY SYNTHESIS: SUMMARY OF PLANT-BASED INDICATORS OF BIODIVERSITY AND SOIL NUTRIENT AVAILABILITY

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11.1 Introduction

At the time of writing newly acquired insect taxonomic and beetle trophic data have just come to hand. These will be added to the present data pool and the whole re-analysed to seek new and informative relationships between plant and animal taxa, functional types, and site physical variables. All the data sets thus far have been subjected to correlative analysis to identify those plant-based variables with highest predictive values along the land use intensity gradient. Because biodiversity is made up of interacting complexes of taxa, functional types, individuals and populations, correlation analysis is an appropriate first point of entry in seeking efficient predictors. High correlations do not necessarily indicate causal relationships although in some cases this can be reasonably inferred, especially where correlates between different sets of variables vary consistently with soil nutrient availability.

11.2 Methods

Standard methods of regression (Pearson product-moment, using the MINITAB statistical package) were applied to help identify potentially useful plant-based surrogates of biodiversity. The sets of variables with highest linear correlates were also examined for non-linear pattern (second order polynomial regression as described in Part B, Annex II.) Because some of the highest correlates were associated with richness in plant species, *modi* and a ratio of species:*modi*, these variables were also examined for their potential value in predicting the occurrence of other taxa and functional groups as well as site physical variables. Table 11.1 below outlines the results.

11.3 Results

Plant species and PFTs or *modi* used alone and as a ratio tend to account for more variance in richness in animal taxa than animal taxa themselves. Overall there is a tendency for the species/*modi* ratio to greatly improve prediction for certain taxa and for above-ground carbon. This is evident in Table 11.1 a,b,c,d and is further illustrated in Annex II Figs 1a,b,c,d. for above-ground carbon, collembola, birds and termites. Table 11.2 lists correlations between plant-based variables and soil physico-chemical attributes.

11.4 Discussion

When the pattern of plant and animal taxonomic distribution along the LUTs is examined overall it is clear that the highest values tend to occur in certain pristine forest types and jungle rubber. This may be partly explained by the nature of the available niches in both intact forest and jungle rubber. Whereas the former has allowed the development of a series of cryptic terrestrial and arboreal habitats through a longer timespan, the relatively recent and more dynamic jungle rubber displays a much wider variety of niches due to the micro-fragmentary nature of the stand that is maintained by frequent disturbance by humans and animals. The cumulative graphs shown in Part B, Figure 1.1 show considerable similarity between the area curves for BS05, the richest intact rain forest, and those for jungle rubber (BS10). The nature

of the curves for the ratio values also reflects closely the general dynamic status of the LUT and whether it is degraded or not. The integration of the curves may provide a useful means for developing an index that reflects the overall indicator value of the species, *modi* and ratio combinations and this is the focus of a continuing study.

Of particular significance are the non-linear relationships of certain plant and vegetation structural variables with a sub-set of insect and bird taxa where the correlation is dramatically improved with ratios of species to PFT richness as distinct from correlations with either species or PFTs alone (Part B, Annex II, Fig. 1a,b,c,d) . There is no immediate explanation for this improvement although there is some suggestion of covariant patterns in soil nutrient availability. Table 11.2 outlines correlations between plant-based variables and a range of soil physico-chemical attributes. There are clear correlations between certain physical variables such as soil bulk density, soil pH, organic carbon and total N and Aluminium and species and PFT richness and increasing complexity in vegetation structure. The vegetation “V” index (ref: Part B) is also highly correlated with a range of soil variables. While diversity indices are rarely attributed much significance as biodiversity indicators, in the present study each of the Shannon-Wiener, Simpson’s and Fisher’s Alpha values are significantly correlated with a variety of key soil nutrients (Table 11.2).

11.5 Conclusions and recommendations

Before an appropriate synthesis can be made further investigation of more recently acquired data must be undertaken. However it is safe to say that the study so far clearly indicates that assessments of biodiversity should be designed to sample as much as possible of the spatial ranges of the taxa of concern to management. In general this translates to seeking out representative gradients of land use intensity and soil nutrient availability at landscape level and including climate at ecoregional level. Once these system boundaries have been located they offer a useful spatial and environmental context for identifying, calibrating and testing by spatial extrapolation, the best sets of biodiversity indicators. It is clear that there will be many situations where isolated samples taken for example from rain forest alone, are likely to give a misleading picture of regional patterns of biodiversity. The present study has revealed a new set of indicators that show promise for much wider application and testing. The study has shown that the plant-based attributes with taxonomic + functional complements possess potentially useful predictive value when coupled with certain taxa, soil nutrients and above-ground carbon. Taken together with readily measureable elements of vegetation structure such as mean canopy height and basal area, these offer an exciting prospect for examining the dynamics of biodiversity and associated land use at landscape scale.

Based on present findings, the message for managers of forested and agroforested lands is to maintain a mosaic of land cover types to maximise the availability of ecological niches. Not only is this likely to enhance biodiversity, recent experience suggests this may have a beneficial effect by facilitating biological pest management as well as providing increased flexibility for varying management options under conditions of environmental and socioeconomic change.

Table 11.1a Linear correlations between beetle trophic groups[#], plant species and PFTs*

Troph.Grp	PFT	Species	Spp/PFT
Pchew1sp	0.498	0.663	0.564
Pchew2sp	0.581	0.585	0.369
Pchewspt	0.539	0.650	0.508
Pchew1fm	0.349	0.663	0.713
Pchew2fm	0.764	0.590	0.190
Pchewfmt	0.431	0.713	0.711
Pred1sp	0.336	0.438	0.366
Pred2sp	0.322	0.491	0.443
Predsptt	0.354	0.467	0.394
Pred1fm	0.608	0.449	0.115
Pred2fm	0.044	0.324	0.448
Predfmtt	0.542	0.521	0.286
Scav1sp	0.411	0.404	0.245
Scav2sp	0.407	0.755	0.781
Scavsptt	0.437	0.503	0.372
Scav1fm	0.165	0.362	0.395
Scav2fm	0.338	0.794	0.928
Scavfmtt	0.210	0.471	0.525
Tot1sp	0.447	0.527	0.400
Tot2sp	0.583	0.744	0.608
Utotalsp	0.482	0.580	0.451
Totalsp	0.401	0.337	0.156
Tot1fm	0.335	0.577	0.572
Tot2fm	0.450	0.854	0.899
Totfam	0.339	0.573	0.562

Pchew1sp = Phytophagous chewers – primary species;
Pchew2sp= secondary species;
Pchewt = total; -fm = family;
Pred = predators;
Scav = scavenger;
Utotalsp = total unique species.

*PFTs = Plant Functional Types;
Shaded areas with $r = >0.500$.
Bold type = high indicator value.

Table 11.1b Linear correlations between beetle trophic groups and vegetation structure*

Troph.Grp#	Can. Ht	Cr. Cov%	W. Plts	Ba. Area
Pchew1sp	0.313	0.172	0.734	0.388
Pchew2sp	0.248	0.232	0.529	0.329
Pchewspt	0.298	0.197	0.679	0.376
Pchew1fm	0.343	0.330	0.748	0.552
Pchew2fm	0.600	0.572	0.222	0.530
Pchewfmt	0.405	0.390	0.749	0.599
Pred1sp	0.104	0.126	0.631	0.248
Pred2sp	0.061	0.074	0.559	0.352
Predspt	0.106	0.128	0.661	0.272
Pred1fm	0.203	0.041	0.516	0.182
Pred2fm	-0.090	-0.069	0.520	0.281
Predfmt	0.138	0.007	0.660	0.273
Scav1sp	-0.005	0.142	0.461	0.203
Scav2sp	0.440	0.564	0.742	0.687
Scavspt	0.088	0.239	0.550	0.317
Scav1fm	-0.044	0.117	0.538	0.281
Scav2fm	0.537	0.490	0.731	0.784
Scavfmt	0.063	0.196	0.614	0.397
Tot1sp	0.143	0.167	0.609	0.299
Tot2sp	0.359	0.402	0.705	0.536
Utotalsp	0.192	0.221	0.636	0.355
Totalsp	-0.065	-0.008	0.478	0.103
Total1fm	0.232	0.276	0.680	0.473
Total2fm	0.572	0.549	0.712	0.846
Totalfm	0.223	0.264	0.682	0.465

* Can.Ht = Mean canopy height (m)
 Cr.Cov.% = Crown cover percent of dominant stratum
 W.Plts = Domin cover-abundance estimate of woody plants <2m tall
 B.Area = Basal area of all woody plants m²ha⁻¹ (Bitterlich)
 Shaded areas with r = >0.500.
 Bold type = high indicator value.

Table 11.1c Linear correlations between richness of plant species, plant functional types and their ratios, and various animal taxa and above-ground plant carbon #

Attribute	Species	Modi	Spp/Modi
Ground-dwelling			
Termite abundance	0.872	0.766	0.946
Termite species	0.849	0.698	0.976
Lep/ground	0.834	0.790	0.920
Canopy:			
Unident. insects	0.771	0.418	0.839
Collembola	0.643	0.089	0.882
Ant-total	0.633	0.729	0.393
Total insects	0.593	0.487	0.526
Orthoptera	0.545	0.378	0.528
Thysanoptera	0.470	0.756	0.138
Isoptera (canopy)	0.417	0.140	0.496
Psocoptera	0.398	0.148	0.457
Coleoptera	0.312	0.458	0.127
Hymenoptera	0.302	0.446	0.129
Formicidae	0.274	0.370	0.142
Acari	0.190	-0.232	0.443
Spiders	0.186	0.307	0.050
Blattodea	0.124	-0.014	0.204
Hemiptera	0.098	0.229	-0.026
Diptera	0.038	0.404	-0.197
Bird total spp.	0.599	0.347	0.704
Above-ground carbon	0.796	0.558	0.909

Shaded areas with $r = >0.500$. Bold type = high indicator value.

Table 11.2 Plant-based linear correlates with soil physico-chemical attributes

	pH_H ₂ O	pH_KCl	C_org, %	N_tot,%	K	Na	Mg	Al	ECEC	Al_sat	Bulk D.
Mean Ht	-0.719	-0.828	0.486	0.386	0.005	-0.205	-0.370	0.632	0.441	0.558	-0.770
	0.002	0.000	0.056	0.140	0.984	0.446	0.159	0.009	0.087	0.025	0.000
Basal A.	-0.684	-0.780	0.503	0.395	0.048	-0.198	-0.347	0.684	0.491	0.595	-0.784
	0.004	0.000	0.047	0.130	0.859	0.462	0.188	0.003	0.053	0.015	0.000
CC%	0.215	0.125	0.092	0.095	-0.063	0.076	0.278	-0.057	-0.107	-0.089	-0.120
	0.424	0.644	0.737	0.728	0.818	0.779	0.298	0.833	0.694	0.743	0.659
Wplts	-0.285	-0.206	0.502	0.376	0.475	0.381	0.300	0.296	0.512	0.137	-0.627
	0.284	0.445	0.048	0.151	0.063	0.146	0.259	0.265	0.043	0.614	0.009
Bryo	-0.593	-0.777	0.459	0.526	0.097	-0.164	-0.300	0.697	0.584	0.527	-0.743
	0.016	0.000	0.074	0.037	0.720	0.545	0.260	0.003	0.018	0.036	0.001
Mean FI	0.172	0.293	-0.144	-0.026	0.093	0.175	0.180	-0.123	-0.094	-0.074	0.291
	0.525	0.270	0.594	0.925	0.732	0.516	0.504	0.651	0.728	0.786	0.274
Modi	-0.402	-0.471	0.878	0.742	0.609	0.393	0.097	0.643	0.880	0.279	-0.890
	0.123	0.066	0.000	0.001	0.012	0.132	0.720	0.007	0.000	0.295	0.000
Species	-0.550	-0.653	0.716	0.550	0.329	0.104	-0.225	0.687	0.650	0.484	-0.868
	0.027	0.006	0.002	0.027	0.214	0.700	0.403	0.003	0.006	0.058	0.000
Spp/modi	-0.683	-0.745	0.405	0.278	-0.012	-0.196	-0.463	0.616	0.353	0.602	-0.742
	0.004	0.001	0.120	0.298	0.966	0.466	0.071	0.011	0.180	0.014	0.001
Vindex	0.664	0.755	-0.611	-0.477	-0.174	0.056	0.291	-0.688	-0.575	-0.544	0.852
	0.005	0.001	0.012	0.061	0.520	0.838	0.274	0.003	0.020	0.029	0.000
Shannon	0.352	0.231	-0.507	-0.496	-0.545	-0.327	-0.348	-0.366	-0.732	-0.049	0.615
	0.181	0.390	0.045	0.051	0.029	0.217	0.186	0.163	0.001	0.858	0.011
Simpson	-0.367	-0.309	0.722	0.661	0.647	0.445	0.327	0.479	0.866	0.100	-0.767
	0.162	0.244	0.002	0.005	0.007	0.084	0.216	0.060	0.000	0.712	0.001
F_Alpha	0.488	0.542	0.240	0.174	0.585	0.633	0.876	-0.348	0.290	-0.651	-0.018
	0.055	0.030	0.370	0.519	0.017	0.009	0.000	0.187	0.276	0.006	0.946

Refer Section 10 and Annex III Table 2 for soil symbols; Mean Ht = mean canopy height, Basal A = basal area m² ha⁻¹, CC% = crown cover percent, Wplts = Cover abundance of woody plants <1.5m tall, Bryo = cover abundance of bryophytes, Mean FI = Mean Furcation Index canopy trees, *Modi* = total functional *modi* or Plant Functional Types, Species = total plant species, Vindex = Vegetation Index, Shannon = Shannon-Wiener Diversity Index for PFTs, Simpson = Simpson's diversity index for PFTs, F_Alpha = Fisher's Alpha diversity index for PFTs. Correlation 'r' value on each first line, probability value on each second line; shaded cells with p < 0.020. Clay not listed due to poor correlation.