Millennium Ecosystem Assessment

Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multi-Scale Assessments

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TIBETAN ETHNOBOTANY AND GRADIENT ANALYSES: *MENRI* (MEDICINE MOUNTAINS), EASTERN HIMALAYAS

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ABSTRACT

Menri or Medicine Mountains of the Eastern Himalayas, including Kawa Karpo (6790m) the second most sacred mountain in Tibet, are the traditional source of many Tibetan medicinal plants. We established two transects from the upper Mekong River (2000m) to the upper vegetational reaches of these mountains (5000m); one transect had northern aspect and one southern. Every 200m of elevation along the transects, we sampled trees >10cm dbh in 5 random 100m^2 quadrats and all vegetation in 3 1m^2 quadrats within each larger quadrat. Results demonstrate that elevation is the predominant vegetational and ethnobotanical variable, with aspect and slope secondarily affecting plant species richness, diversity, and distributions. Notably, highest herb and shrub richness (S; southern aspect F=13.099, p=0.0001; northern aspect F=20.619, p=0.0001) and biodiversity (H'; southern aspect F=6.39, p=0.0001; northern aspect F=8.837, p=0.0001) are found in alpine meadows with secondary diversity in lower elevation dry scrub, while some mid-elevational areas with higher tree diversity have lowest overall species diversity (possibly due to shade). These results differ from many previous studies and from theories on the relationship between species richness and elevation. Useful plants follow overall patterns of biodiversity, although specific plants are associated with specific vegetation zones. Tibetan doctors co-authoring this paper stress the importance of all vegetation for Tibetan medicinal, cultural and economic stability. In bridging scales and epistemologies, we conclude that biodiversity conservation and cultural survival is crucially linked to conservation and sustainable use of natural resources by local Tibetans.

INTRODUCTION

Traditional peoples from all over the world adapt with a vast array of traditional knowledge and management practices to different type of environmental gradients: elevation, tempterature, moisture, nutrients, and so forth (Oviedo and Maffi 2000, Maafi 2001). Mountain peoples adapt to their vertical environment by varying their traditional use and management with elevation (). Today, these people must adapt not only to their extraordinarily variable environment but also to change of that variability with global change and with cultural change. Global change may affect alpine environments more immediately and more drastically than other habitats (Körner 1999). Loss of traditional culture and knowledge are other changes affecting Tibet. Although vigorous cultural revival is now in progress, still knowledge and traditions of plant use, central to Tibetan culture, are vulnerable. We study elevational vegetation gradients of the eastern Himalayas and Tibetan traditional knowledge of these gradients. These are mid-line studies, for comparison both with studies by earlier plant collectors and with further research on Tibetan adaptation to global alpine and cultural change.

Tibetan landuse and management is well adapted to alpine environments including high elevation agriculture, grazing, forestry and gathering; traditionally hunting was a livelihood component that is now outlawed. Here we concentrate on forestry and gathering in studying plants that Tibetan people use in the natural vegetation along an elevational gradient from 2000m to 4500m. The majority, but by no means all, of the plants sampled are used in traditional Tibetan medicine, an ancient, culturally rich, and well documented system. This study directly links cultural tradition, traditional knowledge and ecology, all direct causal factors linking biodiversity and indigenous cultures (Oviedo and Maffi 2000; Maffi 2001).

An important part of this study is to link not only scientific and traditional knowledge but also to link these perspectives in interpreting data and arriving at conclusions. Two traditional Tibetan doctors and a local Tibetan research assistant are co-authors on this paper for their contributions on plant use, management and preparation, for their review and interpretation of the data, and for their conclusions which aided us all in bridging epistomologies. It is their interpretations that put the results of this study in a larger context, meaningful to cultural survival, nature conservation and sustainable development.

Finally, this study generates data of theoretical significance to the scientific debate on relationships between elevation and species richness and diversity (reviewed in Rahbek 1997). Additionally, whereas other studies increasingly incorporate ecological factors such as environment, productivity, herbivory, and so forth, here we incorporate people as an integral part of nature, responding to and utilizing the vegetational gradient directly and coherently. We incorporate human ecology with vegetational gradient analyses.

METHODS

The Study Site

The Hengduan Mountains of the eastern Himalayas are one of the most biologically diverse temperate ecosystems on Earth (Mittermeier et al. 1998). Within the Hengduan (Figure 1), to the extreme northwest of Yunnan and southeast of Tibet, lie the *Menri* ("Medicine Mountains" in Tibetan, transliterated to *Meili* in Chinese). The highest peak, Mount *Khawa Karpo*, (6740m; 28°26'20"N latitude, 98°41'05"E longitude) is flanked by the river gorges of the Lancang River (upper Mekong) to the east and Nu River (upper Salween) to the west with elevations plummeting to 2000m and below in a distance of only 10 km. This extreme elevational gradient stretches from snowcapped summits and skree, through alpine meadows, rhododendron thickets, conifer forests, mixed and oak woodlands, to subtropical dessert scrub along the rivers. Along this gradient we sampled two transects extending from 2000m to 4500m, one with northern aspect and one southern.

Culturally, *Khawa Karpo* is the second most sacred mountain for Tibetan Buddhism and is circumambulated by thousands of pilgrims from all over Tibet each year. Locally, however, the area is predominantly Kham Tibetan with the people living in traditional villages based on agriculture, herding, forestry and gathering. The Medicine Mountains, as their name implies, are a traditional area for collecting Tibetan medicinal plants. This study is conducted with two traditional Tibetan doctors trained locally.

Sampling

Along both the northern and southern transects 2000-4500m, at approximately 200m elevational intervals we randomly established along the contour five $100m^2$ circular plots. Elevation, slope and aspect were measured for each plot. Species and diameter at breast height (dbh) were recorded for all trees > 10cm dbh. Three m^2 square plots were located within each larger plot (along opposite edges and in the center) within which all species of higher plants and estimated cover were recorded. Vouchers were collected of each species for identification, with duplicates deposited at the Kunming Institute of Botany, the Shangri-la Botanical Garden, Zhongdian, and the Missouri Botanical Garden. The two Tibetan doctors and Tibetan research assistant recorded Tibetan name, uses and preparation of each species and discussed use and management of the vegetation formations.

Analyses

Vegetation Gradient Analyses were performed with Canonical Correspondence Analysis (CCA; PC-ORD, Version 4.20; McCune and Mefford 1999) using basal area for trees species, average cover for herb and shrub species, and elevation, aspect[1] and slope as environmental variables. Separate ordinations were also run on useful plants but the patterns were virtually the same as the other ordinations, so only the statistical results of the useful plant ordinations are presented.

Species Richness and Diversity were calculated (Barbour et al. 1987) respectively as #species/$100m^2$ and Shannon-Weiner H'/$100m^2$ for each tree plot and #species/$3m^2$ and H'/$3m^2$ for each 3 herb and shrub plots. Using SPSS Version 11.0 (SPSS Inc. 2001) normality and equal variance were tested (using non-zero plots); non-parametric data sets were log transformed to achieve normality and equal variance. One-way ANOVAs were used to compare community attributes among elevations (using non-zero plots) with Bonferroni multiple comparisons. Species richness and

[1] Aspect is converted to a related variable "northness", where northness = cosine of aspect in radians. This is used because an aspect of 0 and an aspect of 359, for example, are only one degree apart but have vastly different values. In contrast, northness is close to 1 if the aspect is northern, close to -1 if the aspect is southern, and close to 0 for eastern and western aspects, which is appropriate since this study emphasizes N-S differences.

diversity of useful herbs and shrubs were tested separately; all tree species were useful so the statistics on trees sufficed for use as well.

Replacement Series (Whittaker 1975) were plotted along the elevational gradient using basal areas of individual tree species. Replacement series could not be determined for herbs, which were too speciose and were usually replaced over much shorter distances than trees (i.e., ~2-500m elevations).

RESULTS

Vegetation Gradient Analyses (Figure 2) confirm the predominance of elevation as the primary environmental variable for both trees and herbs-shrubs and for both northern and southern facing transects with aspect (northness) and slope secondary (Table 1). For Axes 1, the Eigen values were high (except trees of the south facing transect) and always significant although little of the enormous variation in vegetation was explained by any one axis. Elevation is always highly and significantly correlated with Axes 1; northness and/or slope are most often significantly (but less highly) correlation with Axes 2.

Species Richness and Diversity differed significantly with elevation along both transects and for all three vegetation types: trees (all useful), herbs and shrubs, and useful herbs and shrubs (Figure 3; Table 2). For herbs and shrubs, highest species richness and diversity were recorded in high alpine meadows and secondarily in mixed scrub at lower elevations; lowest herb-shrub species richness and diversity were found in mid-elevations where trees and bamboo dominated. Herbs and shrubs tended to be more diverse and richer along the transect with southern aspect. Higher tree richness and diversity had a much broader range with more vegetation types along the northern aspect transect (~2200m-4200m; scrub, oak, pine, bamboo, fir, spruce, rhododendron, alpine meadow) than the southern aspect transect (~3000m-4000m; scrub, oak, pine, alpine meadow). Useful plant richness and diversity closely mirrored overall plant richness and diversity.

Replacement Series (Figure 4) for trees are very different for the southern and northern facing transects: oaks are common throughout the southern aspect with spruce-fir forests only at 4000m elevation, while along the northern aspect transect oaks were only present at low elevations with spruce-fir forests at 3000-4000m with many large spruce trees. Species patterns are more individualistic than community based but are also variable.

Useful species and vegetation types were diverse, including plants used for medicine, food, fodder, fiber, dyes, timber, construction, firewood, religion, etc. However, the Tibetans stressed the fact that overall diversity does not directly mirror the usefulness of vegetation for people. Although highly diverse alpine meadows are very important to the Tibetan doctors for collecting their medicinal plants, important medicinal plants are found at other elevations. Some of the most economically valuable useful species (e.g., matsutake mushrooms) are collected from less diverse oak woodlands. Our Tibetan co-authors emphasize that all vegetation provides plants for their use and that all vegetation types are important for Tibetan subsistence and culture. Loss of any vegetation type would seriously hinder Tibetan life and culture.

DISCUSSION

Relationships among Elevation and Plant Richness, Diversity, and Composition in our study compare both positively and negatively with other studies in the simmering scientific debate (reviewed in Rahbek 1997). Various models exist which purport to explain these relationships due to productivity (e.g., Terborgh 1977), Rapoport's rule (Rapoport 1982, Stevens 1989, 1992), and a null model (Colwell and Hurtt 1994, Colwell and Lees 2000). A fourth empirical model that lacks mechanistic explanation, shows species richness and diversity peaking at lower but intermediate elevations (e.g., Rosenweig 1995).

In comparison to these models, our data on tree species richness and diversity (ignoring a few dips and dives) generally conform to Colwell's null model with an intermediate elevational "hump". In stark contrast, our data on herbs and shrubs does not fit any of these models with only limited similar data in the literature. Highest species richness is found in alpine meadows (see Körner and Spehn 2002) and secondarily at lower elevations with dry scrub vegetation (like Vazquez and Givnish 1998). Both of these humps have previously been explained by the absence of a competing overstory, which also might partially explain the dip in herb-shrub species richness and diversity that we record in the midst of the tree species hump. This negative relationship between trees and herbs highlights the need to include herbs (most often neglected in favor of trees > 10cm dbh) in species richness and diversity studies of vegetation.

The gradient analyses by ordinations fit well with preconceived ideas of plant distributions (e.g., Whittaker 1960, 1975), correlating with elevation and secondarily with aspect and slope. Likewise, comparisons of the north and south facing transects with spruce-fir forests on northern aspects and drought tolerant species concentrated on southern aspects are similar to these and other studies. Individualistic responses of tree species to elevation, again, is as published, however we do not see any evidence of even distributions among species (e.g., Gauch and Whittaker 1972).

As in previously reported (Salick et al. 1999), useful plant species richness and diversity closely track overall species richness and diversity, both in herbs-shrubs and obviously in trees (since all tree species are useful in this study). This direct relationship between plant diversity and useful plant species makes the whole concept of biodiversity meaningful to our Tibetan co-authors; conversely Tibetan concepts of sustainable natural resource use and management make biodiversity conservation feasible, as we will next discuss.

Scales and Epistemologies are extremely important in interpreting the significance of biodiversity in the eastern Himalayas. From the botanical epistemology, we have found that tree diversity and use are highest at mid-elevations, whereas herb-shrub diversity and use are highest in high elevation alpine meadows and in low elevation dry scrub. As the scale of vegetation changes, so change the relationships among plant diversity, plant use and elevation.

From the Tibetan epistemology, our co-authors stress that all vegetation is important for their use. Although local (α) diversity is very high in alpine meadows, supplying many important Tibetan medicinal plants, oak forests with lower diversity provide matsutake mushrooms, the major commercial product of the region. This is only one example, however, in general, regional (γ) diversity is of more concern to Tibetan epistemology.

Thus, changing scales and epistemologies highlight different but interrelated trends in plant biodiversity and use. Of relevance to the Millenium Ecosystem Assessment we conclude that plant biodiversity and its use must be conserved simultaneously at different scales to incorporate our different, though interrelated epistemologies. In the eastern Himalayas, Alpine meadows and dry scrub must be conserved along with less diverse but culturally and economically important conifer and oak forests. Above all, our epistemologies must be joined for biodiversity conservation and cultural survival to be effective; biodiversity conservation must be linked to sustainable natural resource use by locals. Cultural survival and traditional livelihoods depend on biodiversity conservation. Surely, these conclusions – from a scaled ethnobotanical study in the eastern Himilayas, joining Tibetan and botanical epistemologies – bridges scales and epistemologies worldwide.

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Table 1. Gradient Analyses Statistics (CCA; PC-ORD, Version 4.20; McCune and Mefford 1999). Transect aspect is the general orientation of the whole transect. Vegetation refers to the trees sampled in $100 m^2$ plots (all of which were useful so no useful trees appear separately), herbs and shrubs sampled in $3 m^2$ plots, and useful herbs which are ordinations of only those herbs used by the Tibetan doctors co-authoring this study. Correlations are Pearson's species-environment correlations. Variation is percent of variation explained. Elevation, northness and slope are the correlations between the axes and each of these environmental variables. Significance (p=) are determined by Monte Carlo test results.

Transect aspect	Vegetation	Axis	Eigenvalue	Correlation	p =	Variation	Elevation	Northness	Slope	p =
Southern	herb/shrub	1	0.973	0.996	0.001	6.5	-0.989	0.297	-0.009	0.001
		2	0.647	0.933	0.001	4.3	0.109	-0.656	0.842	0.001
	trees	1	0.553	0.828	0.001	22.5	0.679	-0.268	0.353	0.001
		2	0.043	0.304	0.417	1.7	0.173	0.053	-0.243	0.249
	useful herb	1	0.973	0.996	0.001	6.8	-0.993	0.277	0.003	0.001
		2	0.638	0.929	0.001	4.4	0.117	-0.721	0.89	0.001
Northern	herb/shrub	1	0.971	0.993	0.001	4.9	0.998	0.183	-0.248	0.001
		2	0.688	0.92	0.001	3.5	0.047	0.88	0.754	0.001
	trees	1	0.936	0.976	0.001	7.7	-0.965	-0.171	0.26	0.001
		2	0.612	0.834	0.001	5.1	0.258	0.879	0.855	0.001
	useful herb	1	0.966	0.991	0.001	5	0.996	0.314	-0.145	0.001
		2	0.681	0.923	0.001	3.5	0.057	0.872	0.76	0.001

Table 2. Species Richness and Diversity Statistics (SPSS Version 11.0, SPSS Inc. 2001). Significance determined by ANOVAs.

Transect aspect	Vegetation	Species	Richness	Species	Diversity
		F value	p =	F value	p =
Southern	herb/shrub	13.099	0.0001	6.39	0.0001
	trees	12.178	0.0001	6.875	0.01
	useful herb	13.988	0.0001	7.011	0.0001
Northern	herb/shrub	20.619	0.0001	8.837	0.0001
	trees	6.124	0.0001	7.207	0.0001
	useful herb	8.941	0.0001	6.938	0.0001

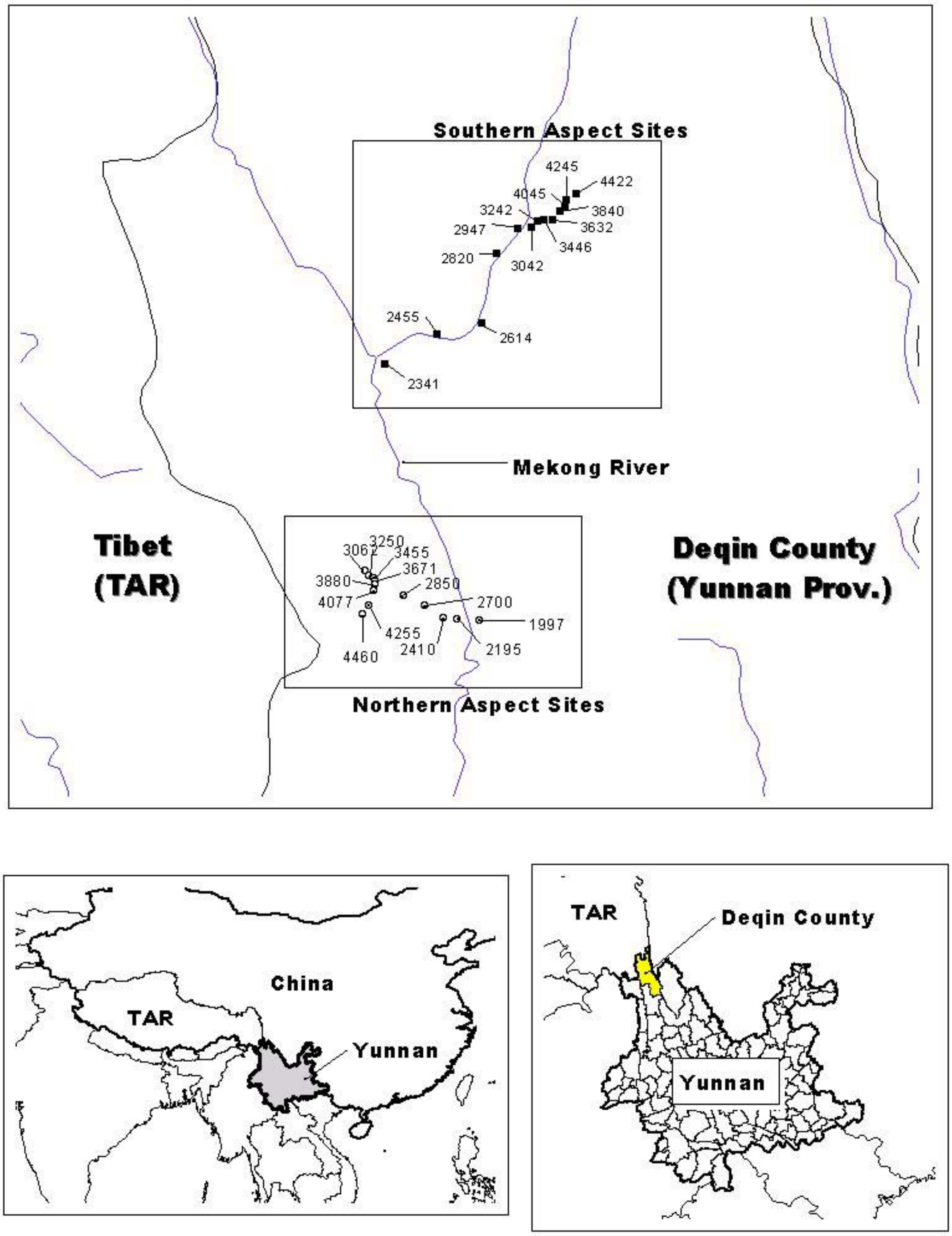

Figure 1. Study Site in *Menri* (Medicine Mountains) of the Eastern Himalayas on the border of Tibet in northwest Yunnan (Deqin County) China. From the upper Mekong River, sampling sites (5 random samples each) along the northern and southern aspect transects are labeled with elevations from ~2000m to ~4500m.

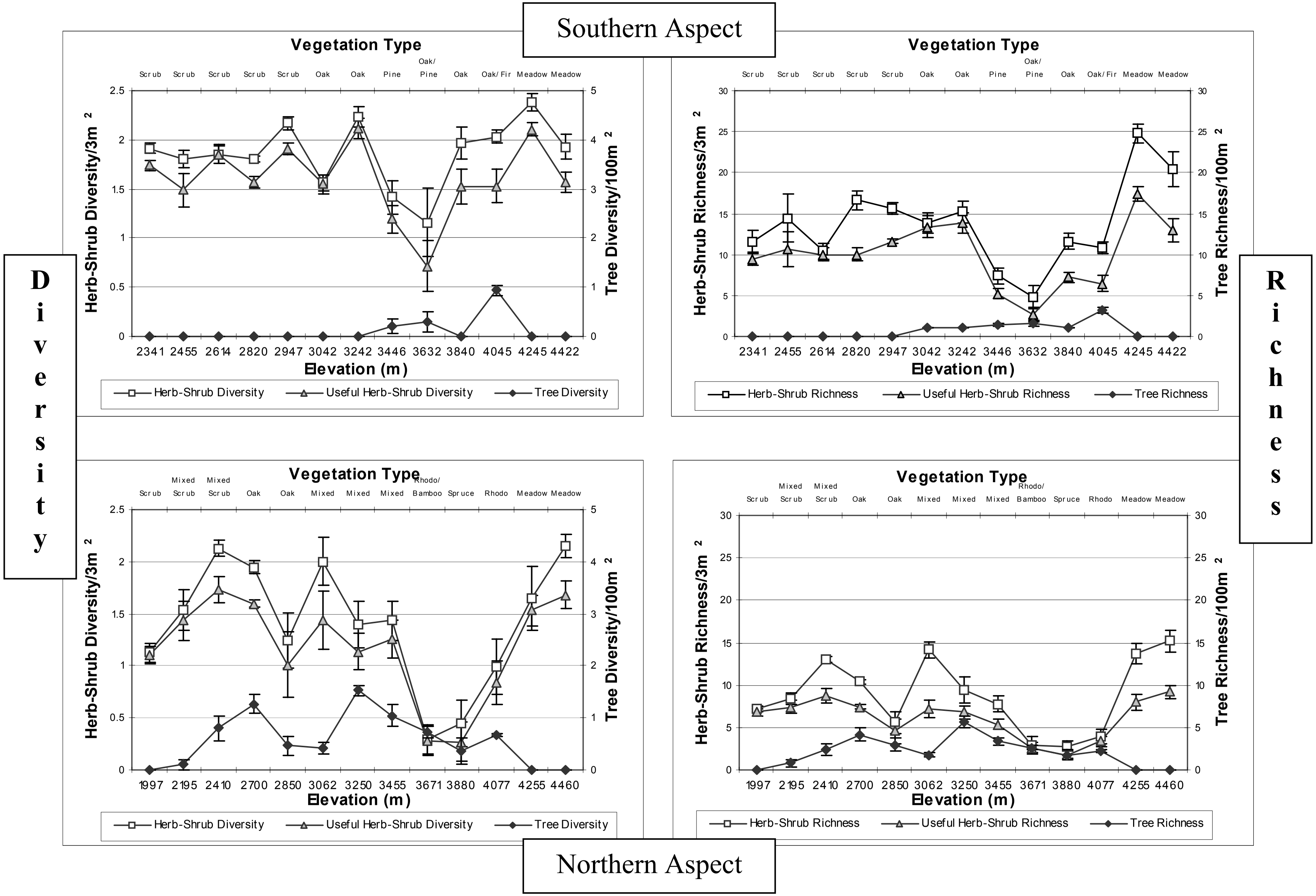

Figure 3. Richness and Diversity (H') of Herb-Shrubs and Trees. Top: Southern aspect diversity (left) and richness (right). Bottom: Northern aspect diversity (left) and richness (right). Elevation and vegetation type at each site are given on the horizontal axes. Note that herb-shrub statistics are per $3m^2$ while tree statistics are per $100m^2$. Whiskers denote standard error (SE).

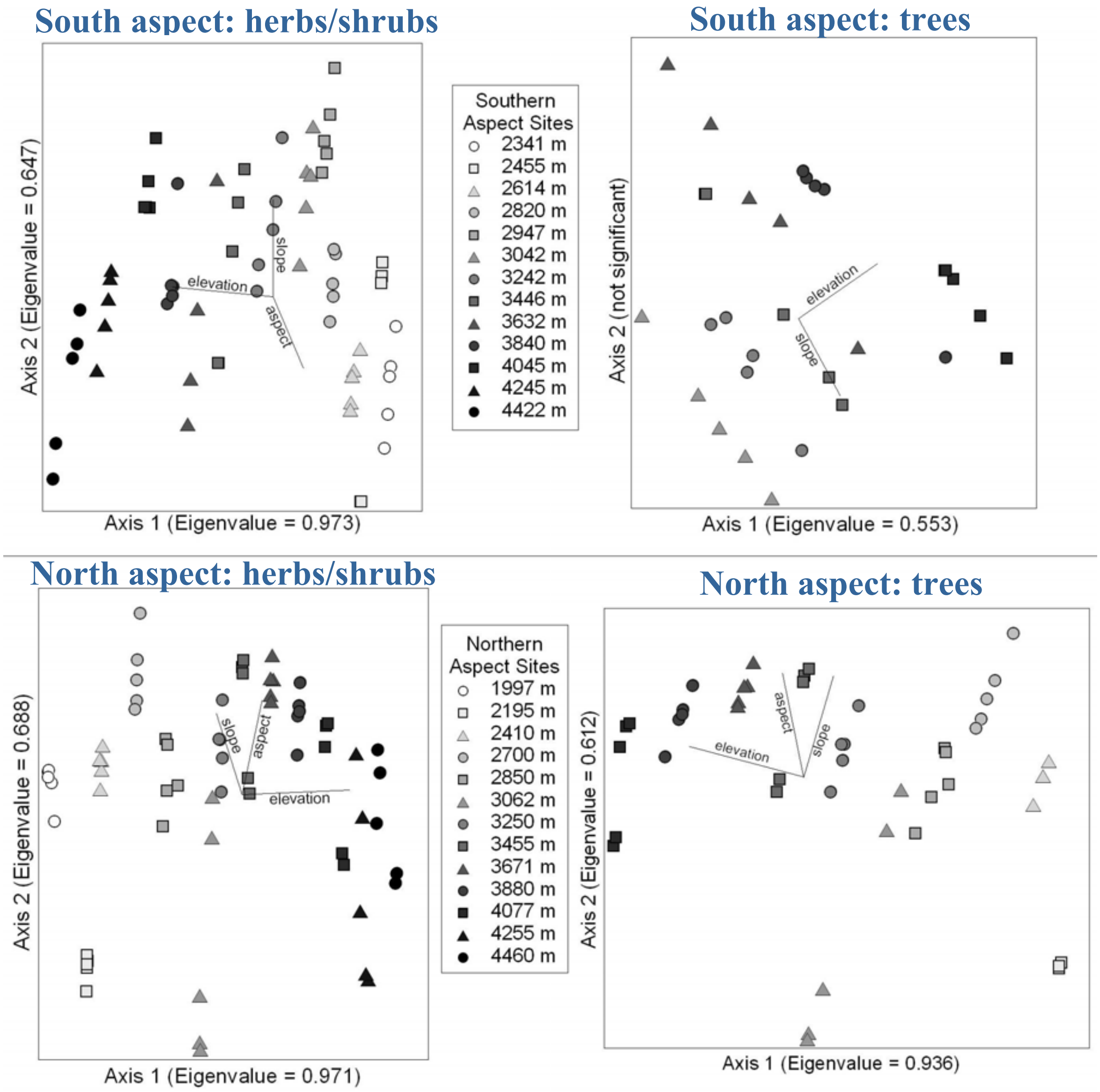

Figure 2. **Vegetation Gradient Analyses** performed with Canonical Correspondence Analysis (CCA; PC-ORD, Version 4.20; McCune and Mefford 1999) confirm the predominance of elevation as the primary environmental variable for both trees and herbs-shrubs and for both northern and southern facing transects with aspect (northness) and slope secondary. Lower elevations are in progressively lighter shades and higher elevations in darker shades from ~2000m (white circles) to ~4500m (black circles).

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