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Conserving the sacred medicine mountains: a vegetation analysis of Tibetan sacred sites in Northwest Yunnan

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Abstract. Mount *Kawa Karpo* of the *Menri* ('Medicine Mountains' in Tibetan), in the eastern Himalayas, is one of the most sacred mountains to Tibetan Buddhists. Numerous sacred sites are found between 1900 and 4000 m, and at higher elevations the area as a whole is considered a sacred landscape. Religious beliefs may affect the ecology of these sacred areas, resulting in unique ecological characteristics of importance to conservation; recent studies have demonstrated that sacred areas can often play a major role in conservation. The goal of this study is to preliminarily analyze the vegetation of sacred areas in the *Menri* region using existing vegetation maps and a Geographical Information System (GIS) for remote assessment. Sacred sites are compared to random points in the landscape, in terms of: elevation, vegetation, and nearness to villages; species composition, diversity, and richness; and frequency of useful and endemic plant species. Detrended correspondence analysis (DCA) ordination reveals that sacred sites differ significantly in both useful species composition ($p = 0.034$) and endemic species composition ($p = 0.045$). Sacred sites are located at lower elevations, and closer to villages, than randomly selected, non-sacred sites ($p < 0.0001$), and have higher overall species richness ($p = 0.033$) and diversity ($p = 0.042$). In addition, the high-elevation (> 4000 m) areas of the mountain – a sacred landscape – are found to have significantly more endemics than low-elevation areas ($p < 0.0001$). These findings represent an initial analysis of sacred sites and suggest that sacred sites in the *Menri* region may be ecologically and ethnobotanically unique.

Abbreviations: DCA – detrended correspondence analysis; DEM – digital elevation model; GIS – geographical information system; GPS – global positioning system; TAR – Tibetan Autonomous Region; TNC – The Nature Conservancy

Introduction

Sacred places have long and diverse histories in human cultures and demonstrate ancient links between peoples and their environments. Sacred places are a universal human phenomenon not associated with any specific religion or worldview (Engel 1985), but they have a strong religious context and are influenced by traditional local beliefs. In many regions of the world, sacred sites have been shown to have a major effect on conservation, ecology and environment due to the special precautions and restrictions associated with them. As a result of limited human activity due to taboos and prohibitions, sacred places frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility, and many ecologically and socially valuable plant species (Ramakrishnan 1996). Societies have long been responsible for conserving the environment of these sacred places through traditional land stewardship practices. As Ramakrishnan (1996, p. 11) points out, these traditional methods complement 'the more recent approaches to protected area management, based on Western scientific knowledge.' It is increasingly clear that social context plays a major role in the success of conservation ventures; therefore, consideration of traditional stewardship and indigenous belief systems is crucial.

In Tibet, sacred sites and sacred landscapes have played a major cultural role for millennia (Huber 1999). Sacred sites in Tibet can vary from an entire mountain range to a single rock believed to display the Buddha's footprint, from an ancient and venerated village tree to an entire sacred grove. Local laws and customs often limit human activity in these areas: hunting, grazing, and logging may be prohibited or restricted, and villagers take care not to damage the natural surroundings. These sites are cultural treasures that have been tended through traditional stewardship for many years, and their preservation is crucial to maintaining the Tibetan cultural system. The subject of this research is the equally crucial role that such sites may play in conserving the Tibetan ecosystem.

In recent years, conservation research on the role of sacred sites has demonstrated the sociological and ecological benefits of these places. Sacred sites have been studied, for example, among the Native Americans of the Western United States (Gonzales and Nelson 2000) and throughout Africa (Castro 1990; Dorm-Adzobu and Ampadu-Agyei 1991; Rodgers 1993; Lebbie and Guries 1995; Lebbie and Freudenberger 1996), and are known to exist in Nepal, Nigeria, Syria, and Turkey (Gadgil and Vartak 1975). In India the biodiversity and cultural value of sacred groves have been particularly well documented. Indian conservation studies (Gadgil and Vartak 1975, 1976; Vartak 1983; Vartak et al. 1987; Chandrakanth and Romm 1991; Ranjit Daniels et al. 1993; Kumbhojkar et al. 1996; Vartak 1996; Ramanujam and Cyril 2003; Upadhaya et al. 2003) have abundantly and quantitatively demonstrated the biological value of these sacred groves. Often, in populated areas, sacred sites conserve the only vegetation without radical human alteration (Ramakrishnan 1996).

Research on sacred sites in Southeast Asia and China is also prolific. Studies on indigenous conservation practices have focused on Vietnam (Chung 2000), Borneo (Salick et al. 1999), Thailand (Lakanavichian 2000; Ruttanakrajangsri 2000), and the Philippines (Bengwayan 2000), as well as China. Much research on sacred landscapes, particularly in recent years, is centered in Southwest China. Studies by Pei and Luo (2000), Xie et al. (2000), and Zhang (2000) examine indigenous beliefs and practices regarding sacred sites in Yunnan Province. In southern Yunnan, Liu et al. (2002) quantitatively document that restoration efforts in the holy hills of the Dai people have resulted in an increased species diversity that approaches that of the nearby national nature reserve. Clearly, sacred sites can provide vital ecological and conservation benefits; however, their role in Tibetan conservation is largely unexplored and deserves attention. This study examines the link between indigenous sacred sites and conservation in the ethnically Tibetan region of northwest Yunnan Province.

Northwest Yunnan lies within the Hengduan Mountains in Southwest China (Figure 1), part of the Eastern Himalayas and one of the most biologically diverse temperate ecosystems on Earth (Mittermeier et al. 1998). Four of Asia's greatest rivers – the Yangtze, Mekong, Salween, and Irrawaddy – flow in parallel within one hundred kilometers of each other through the area (Geatz 2002). The region, situated on the boundary between the temperate and tropical regions of Southeast Asia, is characterized by stunning mountains and spectacular river gorges. Combined with a monsoonal climate, this extreme topographic relief and broad gradient of biomes creates extraordinary biodiversity (Geatz 1999). As a result, the Hengduan Mountains are home to more than 7000 native plant species and dozens of rare and endangered animals. The peoples who inhabit this region are similarly diverse: 25 of China's 56 ethnic minorities reside in Yunnan (Geatz 1999), with Tibetans predominating in the northwest.

Conservation of the eastern Tibetan Plateau and Himalayas is of great concern both within and outside China. After torrential floods in 1998, a logging ban was instituted in the Hengduan Mountain region, causing a decline in the economy of northwest Yunnan (Zhang et al. 2000). In 1998 the Yunnan provincial government and The Nature Conservancy (TNC) established the Yunnan Great Rivers Project to conserve and sustainably develop the region while promoting ecotourism as a viable alternative to logging. As part of this project, TNC and the Deqin County government initiated the *Meilixueshan* (Meili Snow Mountain) Conservation Project. The goal of the project is to create a comprehensive plan for conservation and development of the mountain range on the border between the Tibetan Autonomous Region (TAR) and northwest Yunnan.

In extreme northwestern Yunnan and southeastern Tibet lie the *Menri* ('Medicine Mountains' in Tibetan, transliterated to 'Meili' in Chinese) in an ethnically Tibetan region where a local dialect of Kham is spoken. Mount *Kawa Karpo* (Figure 2), the highest mountain in Yunnan and one of the most sacred mountains in Tibetan Buddhism, is the hub of the local culture and economy, rising to 6740 m between the Lancang (Upper Mekong) and Salween river gorges (Geatz 2002). Numerous pilgrimage routes and sacred sites exist here; the mountains are believed to be not only a transition point between this

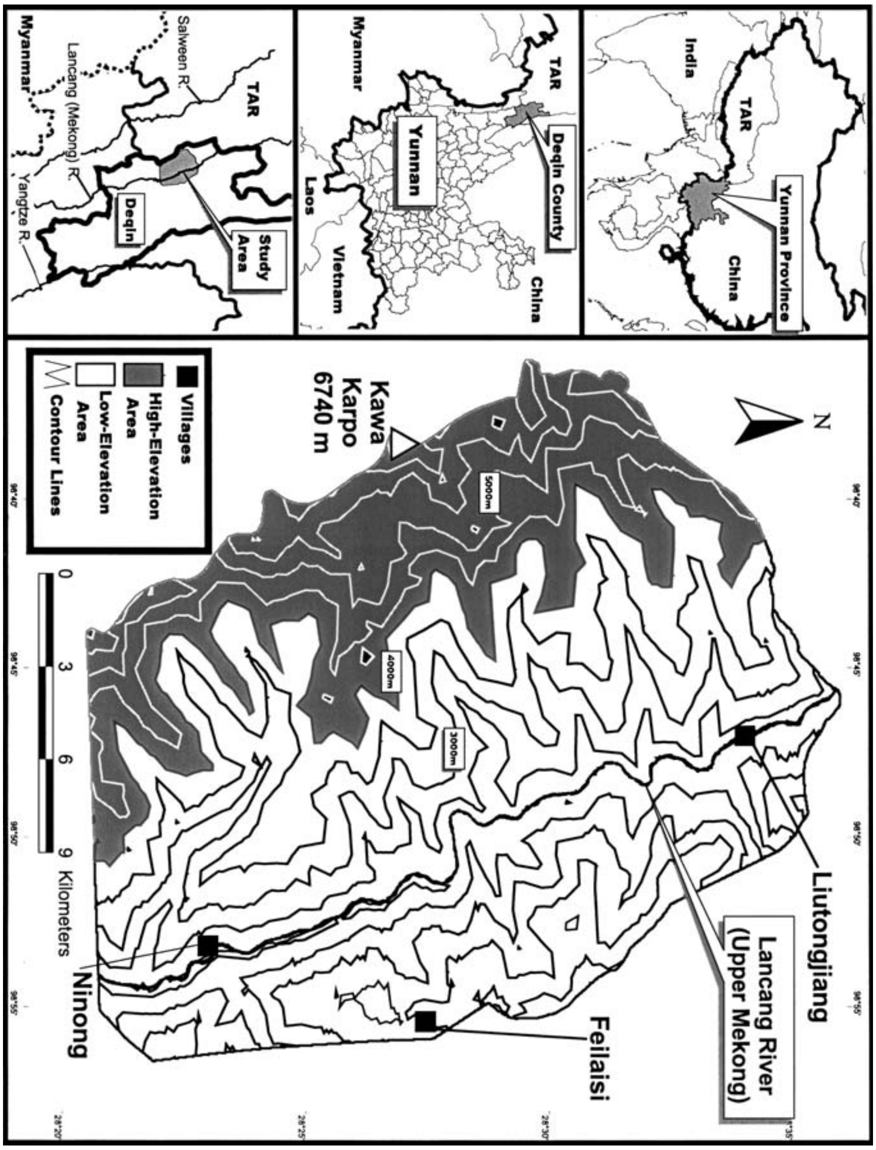

Figure 1. *Menri* study area, showing the location of the study area, Mount *Kawa Karpo*, the Lancang (Upper Mekong) river, and the boundary between 'low' (< 4000 m) and 'high' (> 4000 m) regions of study. Contour lines are marked at 500 m intervals; TAR = Tibetan Autonomous Region.

world and the next, but also the home of the god *Kawa Karpo* and a number of associated deities, including *Kawa Karpo*'s consort, son, dog, and guards (Guo 2000, Morell 2002). The high-elevation areas of the mountain are considered a

Figure 2. Mount *Kawa Karpo* lies on the border of Yunnan Province and the Tibetan Autonomous Region (TAR) in China. Rising to 6740 m, it is the highest mountain in Yunnan and one of the most sacred mountains in Tibetan Buddhism.

sacred landscape, demarcated by the *Ri Vgag* or 'sacred line'; today the *Ri Vgag* also marks the boundary between state-controlled, high-elevation lands and community-use lands at lower elevations. Over one hundred individual sacred sites have been documented thus far in the lower elevations of the *Menri* region (Figure 3), including both human-generated sites (such as temples, incense-burning sites, and *mani* stone piles) and natural sites such as caves, meadows, forests and lakes (Guo 2000).

A team from the Missouri Botanical Garden, in conjunction with TNC, the Kunming Institute of Botany, the Shangri-La Alpine Botanical Garden, Yunnan University, and other scientific groups, has undertaken a study on the ethnobotany and conservation of the *Menri* region. Plans to develop the area for tourism may threaten not only the plants themselves, but also the sacred landscapes and indigenous management systems that have protected the region's biodiversity for thousands of years. A major portion of the study focuses on identifying and describing the distribution of plant species in the region and the traditional methods employed in managing and utilizing these valuable resources.

The principal goal of this study of sacred sites in the *Menri* region is to preliminarily evaluate unique taxonomic, ecological and ethnobotanical characteristics of sacred sites using spatial analysis techniques. For example, local Tibetan doctors claim that many of the sacred sites in the *Menri* region serve to protect useful plant species, particularly medicinals. This statement of traditional knowledge is used as a basic hypothesis for this preliminary study, and for further ethnoecology field studies (Salick et al. in prep). Our analyses explore relationships between sacred sites and biodiversity, useful plants, and

Figure 3. Tibetan sacred sites in the *Menri* area take many forms. Clockwise from top left: (a) incense-burning site with small temple; (b) *mani* stone piles along a roadside; (c) sacred grove fed by a sacred spring in an otherwise dry area; (d) prayer wheel turned by the flow of the sacred river beneath it.

endemism. The goal of this project, and of future work, is to elucidate – pragmatically and quantitatively – relationships between Tibetan sacred sites and conservation objectives.

Methods

Our spatial analyses utilized maps of the central *Menri* region (28.62°S to 28.34°S, 98.59°E to 98.95°E) from Mount *Kawa Karpo* in the west to approximately the villages of Feilaisi in the east, Liutongjiang in the north, and Ninong in the south (Figure 1). This region was chosen because it is likely to experience the most impact from tourism development. The vegetation map used in our study was developed from a previous field survey (Ou et al. 2002). This survey used a Magellan 315 Global Positioning System (GPS) and generated 981 vegetation polygons of 22 distinct vegetation types (Figure 4). A 90 m-resolution digital elevation model (DEM) of the region (TNC, unpublished data) and locations of important features (villages and 104 known sacred sites) were obtained from TNC (Sangbo 2002). Sacred sites (104) were mapped as points at 'low' elevations (below 4000 m); high-elevation areas of the mountain (above 4000 m, only conservatively approximating the *Ri Vgag* which is unmapped and varies in elevation with site – usually below 4000 m) are considered a single sacred landscape with no distinct 'points' and

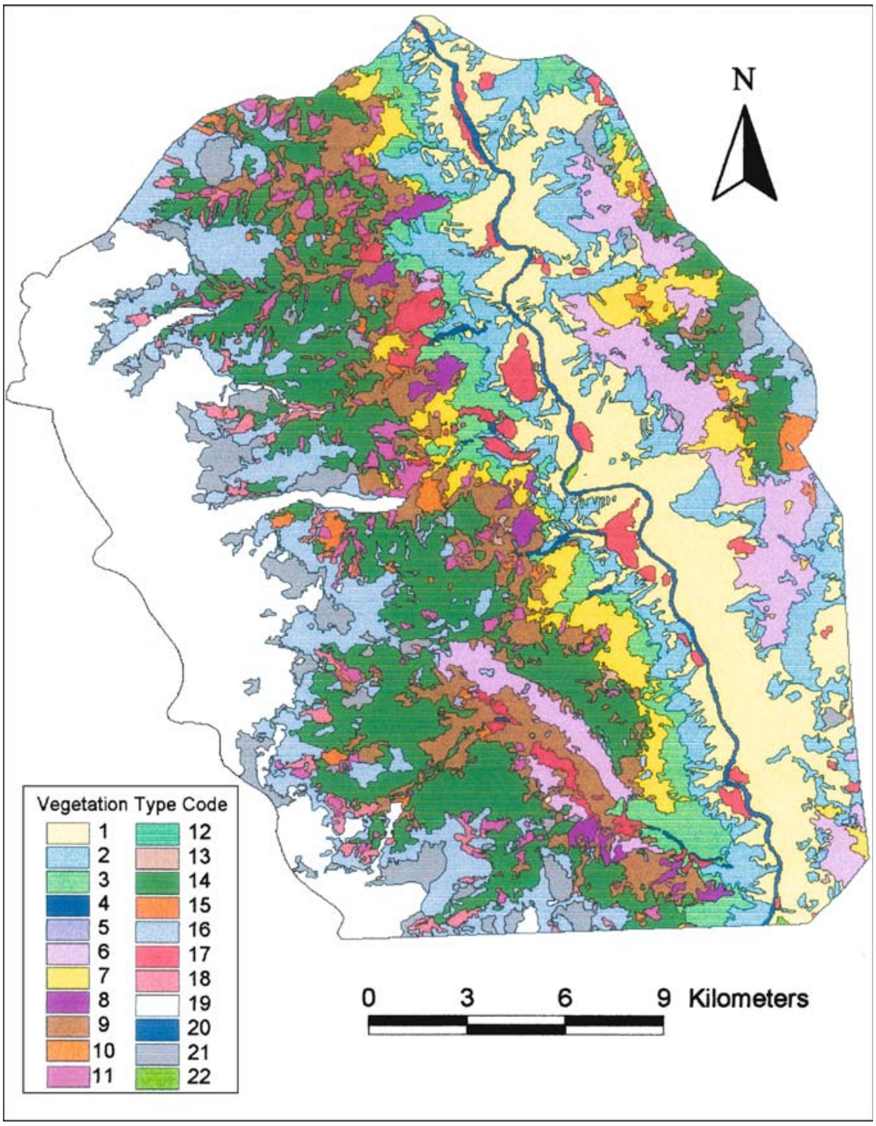

Figure 4. Vegetation types in the *Menri* study area. (1) Short shrubs; (2) *Platycladus* forest; (3) Tall shrubs; (4) Riparian forest; (5) *Hippophae* forest; (6) *Quercus* forest; (7) *Pinus densata* forest; (8) *Pinus armandii* forest*; (9) Mixed forest; (10) *Pseudotsuga* forest*; (11) Deciduous forest; (12) *Larix* forest; (13) *Picea* forest; (14) *Abies* forest; (15) Alpine and sub-alpine meadow; (16) Alpine and sub-alpine shrubs (including *Rhododendron);* (17) Crop land, villages, and gardens*; (18) Alpine *Salix* shrubs; (19) Snow and glacier*; (20) River*; (21) Rocks*; (22) *Cupressus* forest*. Asterisk (*) indicates non-vegetation and minor vegetation types excluded from analysis (1.2% of total area).

were evaluated independently (Figure 1). ArcView Version 3.2a (ESRI 2000) was used to overlay the three layers (vegetation layer, elevation layer, features layer) into a single map for each of the two study areas (high- and low-elevation).

In addition to maps of the region, our study utilized vegetation sampling data from Ou et al. (2002, see Appendix 1) including plot characteristics, vegetation type, and 206 species sampled with cover values. Non-vegetation types and vegetation types with no sampling plots (7 of 22; see Figure 4) were excluded from the analysis: snow, river, rocks, croplands, and three minor vegetation types (1.2% of total area). Consequently, 15 sacred sites falling within these seven excluded vegetation types were eliminated from the study. Thus, 89 sacred sites in the low-elevation study area fall within the fifteen sampled vegetation types, and these 89 points are used throughout the study. For statistical comparison, a random point generation program within ArcView (Lead 2002) was used to produce 89 randomly placed, non-sacred points within the low-elevation study area (Figure 5). Vegetation type, distance from the nearest village, and elevation of sacred and non-sacred points were recorded and compared.

Several sources were used to assign plant uses and endemism (Wu 1984; Yang and Chuchengjiangcuo 1987; Yang 1991; Wang 1993; Yunnan Provincial Medicinal Company 1993; Brach 1996; Fang in prep.). Use and endemism data were calculated for each site based on the vegetation samples (Ou et al. 2002) and this literature (see Appendix 1). Likewise, species composition, species richness, species diversity (Shannon-Wiener Index, Barbour et al. 1987), useful and endemic species with cover, and vegetation type with cover were calculated based on Ou et al. (2002) for each vegetation type and assigned to each site based on its mapped vegetation type.

Three detrended correspondence analyses (DCA; McCune and Mefford 1999) were run using cover values for 1) all 206 species, 2) only endemic species, and 3) only useful species in each vegetation type (again using the representative plot). These three ordination matrices were also used to calculate S (species richness) and H′ (diversity) values for each vegetation type and, consequently, assigned to each site.

The high-elevation (>4000 m) study area was analyzed in a different manner because the entire area is sacred, rather than individual sites. The ArcView random point generation program was again used, this time to produce 89 randomly placed points within the high-elevation sacred area (Figure 5); however, random points were not placed in areas of snow or rocks as little or no vegetation is found in these areas. These high-elevation points were statistically compared with the 89 randomly placed points in the low-elevation, non-sacred area for vegetation type, species composition, and frequency of useful and endemic plants.

Statistical comparisons use SPSS Version 11.0 (SPSS Inc. 2001); t-tests were used when normality and equal variance were achieved and Kruskal Wallis non-parametric tests when normality and equal variance could not be achieved.

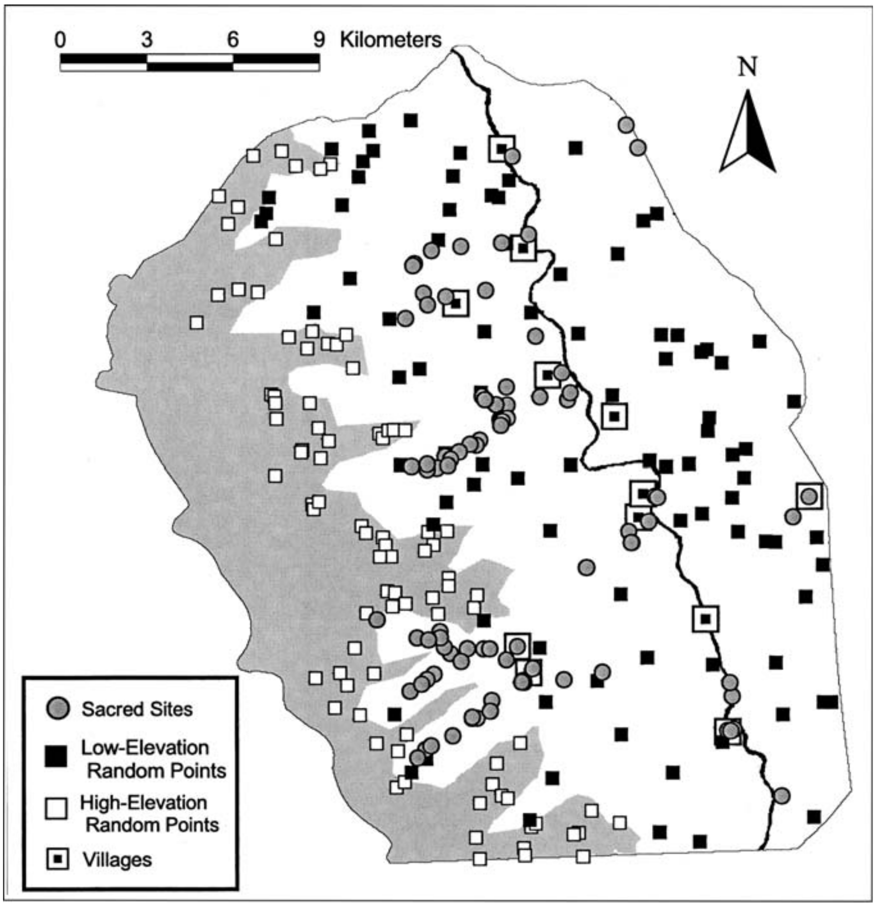

Figure 5. Statistically analyzed sites (267) within the *Menri* study area. The 89 analyzed sacred sites (all located below 4000 m) are compared with 89 points randomly generated across the landscape below 4000 m. Similarly, these 'low-elevation' randomly placed points are compared with 89 points randomly generated across the 'high-elevation' landscape above 4000 m. High-elevation random points were not placed in areas of rock or snow, causing the high-elevation random points to appear non-random on the map.

Results

DCA ordinations (Figure 6) using (a) all species, (b) only endemic species, and (c) only useful species explain a large amount of the variation among vegetation types, particularly with the first axes. In all three cases, the major environmental variable explaining the most variation is elevation; typically high-elevation vegetation types are closely clustered (i.e., having similar species compositions), while typically low-elevation types are more scattered (i.e., having very different species compositions). T-test comparison of axes scores

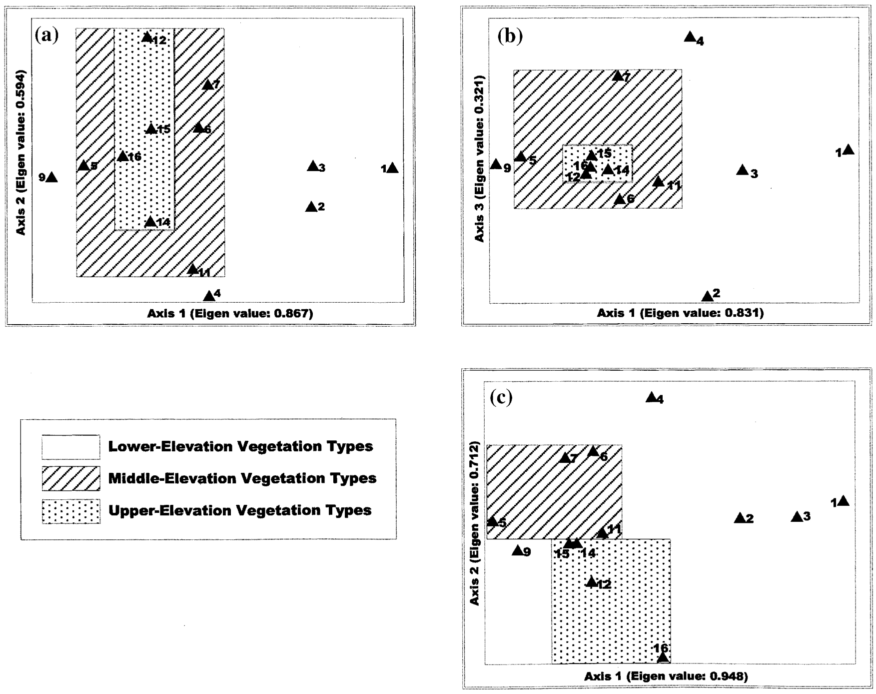

Figure 6. Elevation, the major environmental variable, affects vegetation of (a) all species, (b) endemic species and (c) useful species alike. With DCA ordinations of 13 vegetation types in the 'low elevation' (< 4000 m) study area, elevation consistently emerged as the major determinant of variation in species composition among vegetation types. Lower-elevation vegetation types include (1) Short shrubs, (2) *Platycladus* forest, (3) Tall shrubs, (4) Riparian forest, and (9) Mixed forest; typically middle-elevation vegetation types include (5) *Hippophae* forest, (6) *Quercus* forest, (7) *Pinus densata* forest, and (11) Deciduous forest; typically upper-elevation vegetation types include (12) *Larix* forest, (14) *Abies* forest, (15) Alpine and sub-alpine meadow, and (16) Alpine and sub-alpine shrubs (vegetation types: (13) *Picea* forest and (18) Alpine *Salix* shrubs, are omitted since no low-elevation points fall within these vegetation types). Eigen values are provided along each axis.

for sacred and non-sacred low-elevation sites using all species shows no significant differences, demonstrating that sacred sites do not differ from the surrounding landscape in terms of overall composition. In contrast, axes comparisons for useful species in sacred and non-sacred sites is significant along Axis 2 ($t = 2.132$, df = 176, $p = 0.034$) and for endemic species is significant along Axis 3 (Kruskal Wallis, $\chi^2 = 4.017$, df = 1, $p = 0.045$) although the latter explains little variation. Thus, although overall species composition is quite similar between sacred and non-sacred sites, useful and endemic species composition varies significantly.

Vegetation types of sacred low-elevation sites, randomly placed low-elevation sites, and randomly placed high-elevation sites vary (Figure 7). Within the lower elevation area (non-sacred landscape), sacred sites are situated at significantly lower elevations than randomly selected, non-sacred sites (Figure 8;

$t = 3.575$, df = 176, $p < 0.0001$). Similarly, sacred sites are significantly closer to villages than random sites (Figure 8; $t = 4.633$, df = 176, $p < 0.0001$). Sacred sites have significantly higher overall species richness ($t = 2.045$, df = 176, $p = 0.042$) and diversity ($t = 2.155$, df = 176, $p = 0.033$) compared with non-sacred sites in the low-elevation study area, despite their similarity in overall species composition (i.e., overall vegetation is similar while number of species is higher in sacred sites). Similar tests using the reduced sample of only useful species and only endemic species show opposite results: there is no significant difference in the richness or diversity of useful or endemic species between sacred and non-sacred sites, even though sacred sites have different species of useful and endemic plants than non-sacred sites. However, comparison of high-elevation randomly placed sites – all located within the sacred mountain landscape – with low-elevation randomly placed sites reveals a significantly higher frequency of endemic plants in the high-elevation sacred landscape (Figure 9; $t = 14.372$, df = 156.8, $p < 0.0001$).

Discussion

The Tibetan sacred sites and landscapes of the *Menri* in the eastern Himalayas reveal a complex integration of biodiversity, conservation, sanctity, and human

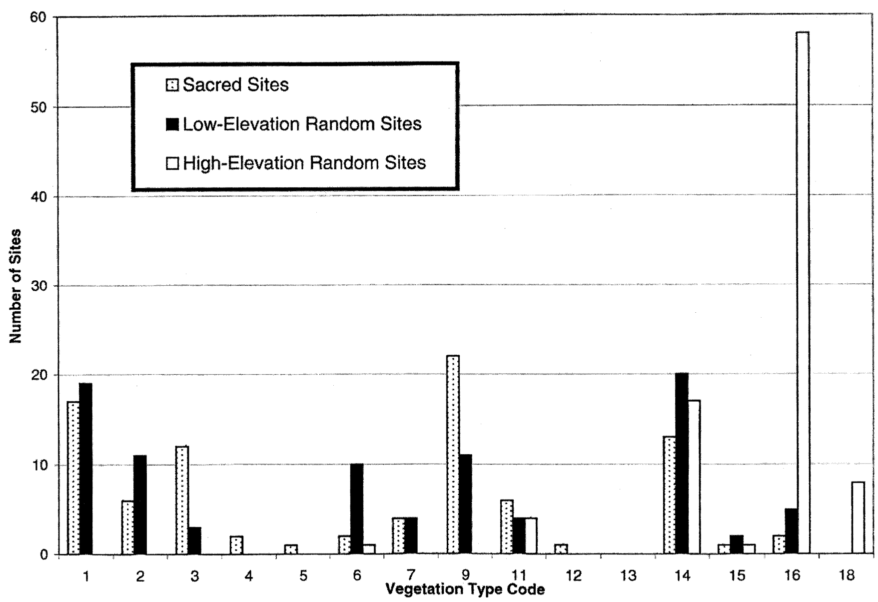

Figure 7. Vegetation types of statistically analyzed sites. Below 4000 m, sacred sites and randomly generated sites display fairly similar vegetation types. In contrast, randomly generated sites at higher elevations exhibit an extremely different distribution of vegetation types. Note that more than 65% of these high-elevation sites are located within a single vegetation type.

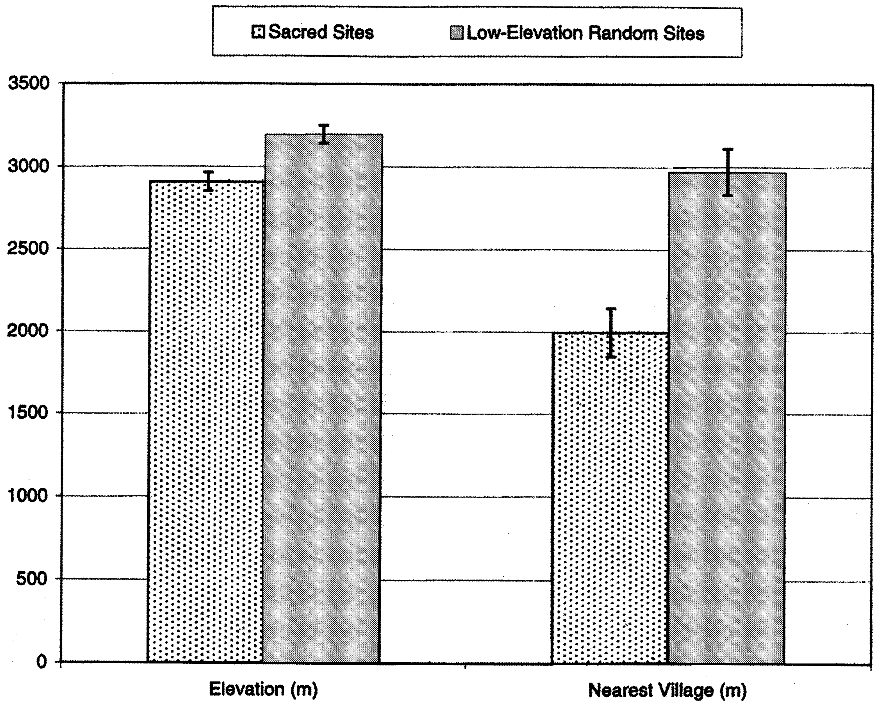

Figure 8. Analysis of elevation and nearness to villages of sacred sites and randomly generated sites (below 4000 m) reveals that sacred sites are located at significantly lower elevations ($t = 3.575$, $p < 0.0001$) and significantly closer to populated areas ($t = 4.633$, $p < 0.0001$) than randomly placed sites. Whiskers represent standard error.

plant use. This is not the only region of the world where traditional knowledge and beliefs unite with science to create natural resource management options and positive alternatives to biodiversity loss. Western conservationists increasingly consider the human dimensions of biodiversity (Alcorn 1995), yet the debate over the relative merits of traditional land stewardship practices is ongoing. A discussion of the specific results from the *Menri* project will provide a basis for considering these issues.

Not surprisingly, in the vertical landscape of the Eastern Himalayas, elevation is the single most important ecological determinant in the majority of analyses. In some analyses, elevation acts in correlation with human influence. Villages in the *Menri* region are typically situated at relatively low elevations (1900–3000 m) along the banks of the Lancang (Upper Mekong) River and its tributaries. The fact that sacred sites are much closer to these villages than would be expected by chance reflects the human choice inherent in sacred sites: it is both rational and practical for local people to identify areas as sacred that are close to inhabited areas.

That these sites are found at lower elevations does not, however, imply that sacred areas only exist at these low elevations. On the contrary, the entire

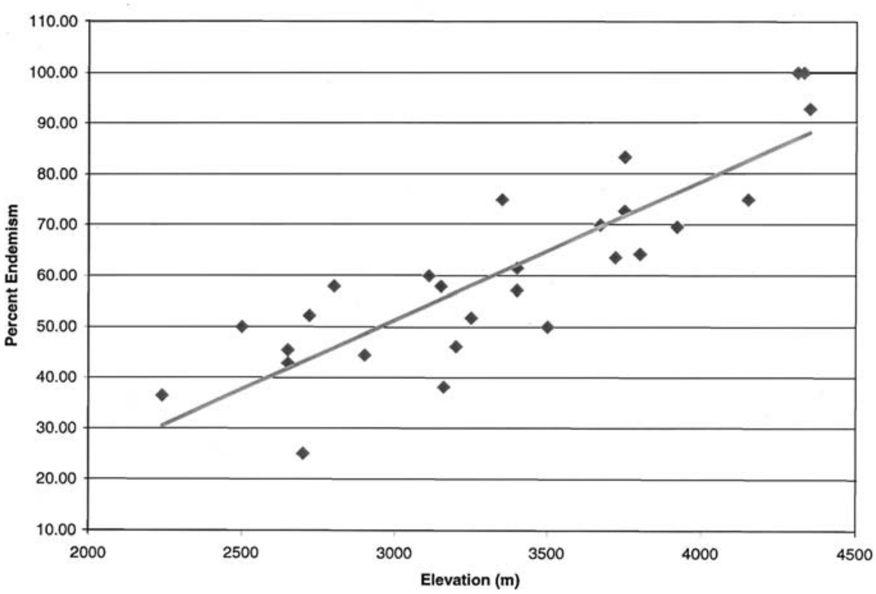

Figure 9. Percent endemism correlates directly with elevation in the *Menri* study area ($y = 0.0273x - 30.625$; $R^2 = 0.7355$).

high-elevation region of the *Menri* peaks is considered a sacred landscape, held in extreme reverence by the local inhabitants. In effect, then, the most sacred regions of the *Menri* landscape are found in both unusually low and unusually high elevations; this bimodal distribution of sacred sites is an atypical and highly non-random result of human influence in the determination of 'sacredness.'

DCA ordinations also reveal elevation-related variation in species composition among sites (β-diversity), with greater variation at lower elevations. These observations point to a major concern in the conservation of this region, namely that preserving the natural vegetation at low elevations – and the sacred sites therein – will require conservation strategies for a wide range of vegetation types. Fortunately, this broad-scale process is a conservation approach for which TNC, one of the main actors in the region, is well known (TNC 2001; Moseley et al. 2004). The role of elevation is also seen in the increased frequency of endemic plants at higher elevations; increased endemism is frequently associated with more isolated areas such as those found on high mountain slopes and peaks. This is a trend found in many areas of the world (Major 1988; Kessler 2000) that has important implications for conservation. Conservation projects often focus on protecting and maintaining endemic species because they are seen as a hallmark of local biodiversity (Kessler 2000). However, as the results from *Menri* demonstrate, culturally valuable species are not always found in high-endemism areas. To incorporate human dimensions with conservation priorities, species of local importance and species of value to Western conservationists must receive balanced consideration.

The lack of significant differences in overall vegetation composition between sacred and non-sacred sites shows that sacred sites represent the vegetation of the region as a whole, in spite of their non-random elevational placement and higher biodiversity. As a result, cultural conservation of these sites is linked to conservation of overall vegetative biodiversity in the *Menri* region, as well as the holistic cultural and biological context in which these sacred areas exist. In contrast, the composition of useful and endemic species does differ in sacred and non-sacred sites, supporting the claim of indigenous doctors that sacred sites act as a repository for particular useful and unique species. Conservationists have observed such situations in India (Gadgil and Vartak 1975; Vartak et al. 1987; Ranjit Daniels et al. 1993; Kumbhojkar et al 1996; Vartak 1996) and the presence of a similar connection in *Menri* between useful plants and sacred sites is exceptionally promising.

The concept of 'sacred space' which is so vital in Tibetan culture provides the opportunity for conservation projects in the *Menri* region to undertake not only the preservation of ecologically valuable regions – such as high-endemism areas – but also the preservation of culturally valuable regions – as exemplified by sacred sites and other areas where useful plants are found. This preliminary vegetation analysis of the *Menri* region suggests that sacred sites may well play a vital role in preserving biodiversity, endemic plants, and culturally valuable useful plants in the *Menri* region. Thus these sacred sites play a vital role in the preservation of both biodiversity and cultural diversity in the *Menri* region.

The results of vegetation analysis in the *Menri* region demonstrate that Tibetan sacred sites and landscapes may indeed play a significant role in the ecological makeup of Mount *Kawa Karpo* and the surrounding areas. However, remote assessment, despite its considerable analytical power, cannot provide details that can be obtained through field sampling. Similarly, literature-based 'useful' plant lists are easy to compile, since textual resources are abundant. Yet these lists cannot possibly describe in any detail the local pharmacopoeia of Tibetan doctors in a particular region, who often rely on locally available species that may be completely unknown in other areas of Tibet. Ongoing field research in the *Menri* area (Salick et al. in prep), incorporating vegetative sampling in sacred sites and interviews with local doctors, will hopefully serve to test the results obtained in this preliminary study, and may potentially reveal new patterns beyond the scope of this study.

The presence of TNC and other research and conservation groups in the *Menri* region ensures that this 'biodiversity hotspot' will receive a great deal of attention from Western and Chinese conservationists alike in coming years. It is vital that the participation of the local inhabitants be integrated into these projects. Conservation programs deeply affect the daily life of local people and demand efforts and sacrifices from them. As Ramakrishnan (1996, p. 12) aptly puts it, consideration and application of traditional practices ensures that 'rural people perceive their participation as an integral part of the functioning of an ecosystem, rather than as a form of outside manipulation.' Ultimately, we must keep in mind that in areas of religious and cultural importance such as the *Menri*, conservation affects not only the physical ecosystem as we see it, but also the invisible – and inestimably precious – sacred landscape.

Acknowledgements

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Appendix 1. Sampling plots and observed species of the Menri *region* (from Ou et al. 2002) used as the sample set for species richness, diversity, and useful and endemic plant distribution in this study.

Sample plot:	1	3	4	5	7	6	8	9	11	12	13	14	15	16	18	17	19	20	22	23	21	24	25	26	27	28	29		
Vegetation type:	1	2	3	4	9	4	4	6	14	7	15	5	3	11	13	6	6	18	12	14	14	14	15	16	16	16	16		
Elevation (m):	2240	2500	2650	2650	2700	2720	2800	2900	3110	3150	3160	3200	3250	3350	3400	3400	3500	3670	3720	3750	3750	3800	3920	4150	4310	4330	4350	End[a]	Use[b]
Species																													
Abies georgei						1.0			4.0							3.0		0.5	4.0	5.0	3.0	4.0	2.0	0.5		1.0		E	8
Acer caesium						2.0		2.0								3.0													8
Acer cappadocicum					2.0																								2
Acer pectinatum									0.5																			E	2
Adiantum davidii								0.5																					3
Adiantum fimbriatum									1.0					0.5															0
Agrostis hookeriana																							2.0	0.5		0.5	0.5	E	0
Agrostis perlaxa											2.0																	E	0
Ainsliaea fulvipes										1.0		0.5																E	0
Ainsliaea latifolia						0.5		1.0	2.0		0.5																		3
Ainsliaea latifolia var.																		0.5	0.5		1.0							E	3
Ainsliaea xanthiifolia																								0.5				E	0
Allantodia crenata						0.5																							0
Amygdalus mira				5.0			2.0																					E	3
Anaphalis nepalensis															0.5													E	3
Anemone demissa							1.0		0.5				0.5										3.0					E	0
Anemone vitifolia							1.0												1.0									E	3
Arabis paniculata																							0.5						0
Aralia chinensis											1.0																		1,3
Arenaria rotundifolia									0.5		1.0																		0
Arisaema erubescens												0.5																E	3
Arisaema lobatum						1.0																						E	3
Artemisia mattfeldii	2.0	0.5	2.0																										0

Arthraxon micans	1.0												1.0																0
Asparagus myriacanthus															0.5													E	3
Bauhinia brachycarpa			1.0																										3
Berberis jamesiana		0.5							1.0																			E	3,4
Berberis stiebritziana														0.5						0.5							2.0	E	0
Berberis wilsonii																		1.0						1.0					0
Berberis yunnanensis																							3.0					E	0
Berchemia yunnanensis								0.5																					0
Bergenia purpurascens													0.5								1.0			0.5		1.0		E	3,4
Betula utilis													2.0	4.0		2.0		0.5	3.0									E	0
Boehmeria platyphylla						2.0																							0
Boenninghausenia albiflora													0.5																3
Brachypodium sylvaticum																			0.5										0
Buddleja myriantha	0.5		0.5																										0
Campanula modesta																							2.0					E	0
Campylotropis hirtella							1.0																						0
Campylotropis polyantha		1.0	0.5																										3
Campylotropis reticulata			0.5																										3
Caragana bicolor																	1.0											E	0
Carex rubrobrunnea											0.5			0.5															0
Carex setosa																							0.5	2.0	1.0	2.0	1.0	E	0
Carpesium cernuum								0.5																					0
Cassiope pectinata																									4.0			E	0
Chenopodium album												1.0																	2,3
Chloris virgata																							0.5						0
Clematis gracilifolia				0.5			1.0		0.5	0.5			1.0	1.0		0.5			1.0									E	0
Corydalis petrophila								0.5			2.0		0.5															E	0
Corylus chinensis		1.0																											1

Appendix 1. (Continued)

Sample plot	1	3	4	5	7	6	8	9	11	12	13	14	15	16	18	17	19	20	22	23	21	24	25	26	27	28	29		
Vegetation type	1	2	3	4	9	4	4	6	14	7	15	5	3	11	13	6	6	18	12	14	14	14	15	16	16	16	16		
Elevation (m)	2240	2500	2650	2650	2700	2720	2800	2900	3110	3150	3160	3200	3250	3350	3400	3400	3500	3670	3720	3750	3750	3800	3920	4150	4310	4330	4350	End[a]	Use[b]
Species																													
Corylus yunnanensis							1.0																						1
Cotoneaster franchetii	2.0														1.0														0
Cotoneaster microphyllus	1.0												1.0															E	3
Cremanthodium rhodocephalum						0.5	1.0									0.5						0.5						E	3
Cystopteris fragilis													2.0			2.0													0
Daphne longilobata		1.0	1.0																									E	0
Daphne tangutica																		2.0											3
Deyeuxia scabrescens		1.0						0.5						1.0		1.0	0.5					0.5						E	0
Dryopteris fibrillosissima						1.0								1.0														E	0
Dryopteris lachoongensis								0.5	2.0							1.0				1.0								E	0
Elsholtzia feddei								1.0			1.0																		3
Elsholtzia fruticosa							2.0																						3
Excoecaria acerifolia	2.0		4.0	1.0									2.0															E	3
Fragaria orientalis								0.5	0.1	1.0	2.0	0.5		0.5		0.5				1.0		0.5		0.5					0
Fritillaria cirrhosa																							0.5					E	3
Galium aparine				0.5		0.5					2.0	0.5	0.5			0.5													0
Gentiana arethusae																										1.0	1.0	E	3
Gentiana atuntsiensis																								1.0				E	0
Gentiana crassicaulis							0.5																						0
Gentiana panthaica										0.5	0.5											0.5	1.0		0.5			E	3
Geranium nepalense				0.5				0.5	0.5		1.0	1.0															0.5	E	0
Hedera nepalensis								1.0																					3,9

Helwingia himalaica															1.0													E	3
Hemiphragma heterophyllum					0.5					0.5											2.0								3
Hippophae rhamnoides											0.5																		1,3,7
Ilex dipyrena					0.5																							E	0
Indigofera lenticellata		1.0		0.5			2.0	1.0		1.0			1.0			0.5				0.5								E	0
Indigofera pseudotinctoria			0.5															1.0											0
Inula pterocaula														0.5														E	0
Jasminum humile		0.5																										E	0
Kobresia pygmaea																							2.0	3.0	1.0		1.0	E	0
Kobresia setschwanensis								1.0	0.5				1.0				0.5	2.0			1.0							E	0
Larix speciosa																		1.0			4.0							E	0
Leontopodium artemisiifolium															0.5		0.5	0.5		0.5			1.0				1.0	E	0
Leontopodium sinense										0.5			0.5																0
Lepisorus morrisonensis						2.0						0.5				0.5												E	3
Leptodermis potanini						0.5													1.0										0
Ligularia stenocephala																							1.0						0
Ligusticum delavayi				0.5																								E	3
Ligustrum lucidum			2.0																										3
Lilium duchartrei								0.5		0.5																		E	0
Litsea chunii										1.0																		E	4
Lonicera ferdinandii				2.0				1.0																					0
Lonicera lanceolata		1.0											0.5	1.0	0.5													E	0
Lonicera myrtillus		0.5															1.0						1.0					E	3
Lysimachia chenopodioides				0.5					0.5		2.0		0.5	0.5	0.5	0.5	0.5						1.0	0.5			0.5		0
Mahonia lomariifolia								3.0																					3
Medicago sativa				0.5																									0
Morina nepalensis															0.5													E	0
Onosma multiramosum	0.5																											E	3
Ophiopogon bodinieri									1.0					2.0	0.5		0.5												3

Appendix 1. *(Continued)*

Sample plot	1	3	4	5	7	6	8	9	11	12	13	14	15	16	18	17	19	20	22	23	21	24	25	26	27	28	29		
Vegetation type	1	2	3	4	9	4	4	6	14	7	15	5	3	11	13	6	6	18	12	14	14	14	15	16	16	16	16		
Elevation (m)	2240	2500	2650	2650	2700	2720	2800	2900	3110	3150	3160	3200	3250	3350	3400	3400	3500	3670	3720	3750	3750	3800	3920	4150	4310	4330	4350	End[a]	Use[b]
Species																													
Osteomeles schwerinae	1.0	1.0											1.0																3
Oxalis acetosella	0.5		0.5																										3
Oxalis griffithii						0.5																							0
Paeonia delavayi																0.5												E	3,9
Paris polyphylla							2.0																						3
Pedicularis macrosiphon															0.5													E	0
Pedicularis roylei																								0.5				E	0
Pentapanax leschenaultii																2.0												E	3
Photinia serrulata						3.0																							3,9
Phtheirospermum tenuisectum							0.5																						3
Phytolacca acinosa												1.0																	3
Picea likiangensis						1.0			3.0					0.5		5.0					2.0							E	8,9
Pinus armandii								2.0		0.5							1.0												1,4
Pinus densata										3.0					2.0													E	3,4
Plagiogyria glaucescens															1.0													E	0
Platycladus orientalis		5.0																											3,8
Poa annua										1.0	1.0	2.0										1.0							0
Polygonatum cirrhifolium														0.5														E	3
Polygonum aviculare									1.0	0.5												0.5							0
Polygonum forrestii								1.0														1.0						E	3
Polygonum macrophyllum																								2.0		0.5	1.0	E	3
Polygonum nepalense													1.0																0

Polygonum viviparum															1.0			1.0		1.0						0
Populus haoana			4.0									3.0														E	0
Populus rotundifolia								2.0																			0
Populus yunnanensis																2.0			2.0								0
Potentilla cuneata								1.0								1.0				0.5	3.0	2.0	1.0			E	0
Potentilla polyphylla																1.0		1.0								E	0
Potentilla stenophylla																						0.5		3.0	1.0	E	3
Primula amethystine																					0.5					E	0
Primula capitata																				0.5	1.0					E	0
Primula polyneura																		1.0								E	0
Prunella hispida									1.0																	E	3
Prunus serrula											0.5									2.0						E	0
Pseudotsuga forrestii						3.0																				E	8
Pteridium aquilinum		2.0											2.0														1,3
Quercus aquifolioides						4.0		3.0																		E	0
Quercus pannosa															5.0											E	0
Rabdosia loxothyrsa	0.5																									E	0
Rabdosia tenuifolia	0.5																									E	0
Rabdosia wikstroemioides									1.0																	E	0
Rhododendron anthosphaerum								2.0			1.0				1.0												0
Rhododendron balfourianum																							1.0			E	0
Rhododendron beesianum															5.0									4.0	0.5	E	0
Rhododendron campylogynum																2.0			1.0							E	0
Rhododendron decorum													3.0		0.5												0
Rhododendron mekongense																3.0										E	0
Rhododendron oreotrephes																					1.0						0
Rhododendron phaeochrysum																									3.0	E	0

Appendix 1. *(Continued)*

Sample plot	1	3	4	5	7	6	8	9	11	12	13	14	15	16	18	17	19	20	22	23	21	24	25	26	27	28	29		
Vegetation type	1	2	3	4	9	4	4	6	14	7	15	5	3	11	13	6	6	18	12	14	14	14	15	16	16	16	16		
Elevation (m)	2240	2500	2650	2650	2700	2720	2800	2900	3110	3150	3160	3200	3250	3350	3400	3400	3500	3670	3720	3750	3750	3800	3920	4150	4310	4330	4350	End[a]	Use[b]
Species																													
Rhododendron primuliflorum																		2.0										E	3
Rhododendron rupicola																		3.0										E	0
Rhododendron saluenense																										4.0		E	0
Rhododendron sanguineum																		1.0			2.0							E	0
Rhododendron wardii																					3.0							E	0
Rhododendron yunnanense														2.0														E	0
Ribes glaciale									2.0																			E	0
Ribes himalense												0.5	1.0			1.0			1.0	1.0		0.5							0
Ribes moupinense														1.0															0
Rodgersia aesculifolia													3.0																0
Rosa dequenensis	1.0																											E	0
Rosa grossa-bracteata							1.0																					E	0
Rosa omeiensis																			0.5										0
Rosa sweginzowii				1.0													1.0												0
Rubia oncotricha						0.5																							0
Rubus cockburnianus								1.0																					3
Rubus fockeanus																						0.5						E	0
Rubus fragarioides																1.0												E	0
Rubus stans						1.0	1.0	1.0	1.0																			E	0
Rumex hastatus								0.5	0.5		3.0												1.0						0
Sabina saltuaria																											1.0	E	8
Sabina squamata																								4.0					0

Sageretia horrida		0.5																										E	1
Salix luctuosa							4.0																						0
Salix myrtillacea																		3.0			2.0							E	0
Salvia mairei													0.5																3
Sambucus adnata						1.0					4.0	3.0																E	3
Sambucus williamsii									1.0																				0
Sarcococca ruscifolia						1.0																							0
Saxifraga hispidula																							0.5					E	0
Securinega suffruticosa													0.5																0
Senecio scandens																	0.5												3
Silene esquamata			0.5																									E	3
Sinopodophyllum hexandrum																				0.5			0.5					E	3
Smilacina purpurea													0.5															E	3
Smilax mairei										0.5																		E	0
Smilax menispermoidea									1.0				0.5	0.5														E	0
Smilax stans										1.0																			0
Sophora viciifolia	4.0	1.0											4.0																0
Sorbus rehderiana																			2.0									E	0
Sorbus rufopilosa									2.0					1.0														E	0
Spiraea veitchii		0.5																											0
Stellera chamaejasme		0.5																											3
Taraxacum eriopodum			0.5				1.0				0.5		0.5											1.0			0.5	E	0
Taxus yunnanensis						5.0																						E	3,8
Thalictrum delavayi						0.5	1.0	0.5	1.0			0.5	0.5	1.0					0.5									E	3
Tilia chinensis					3.0			2.0																					2,6,9
Toxicodendron verniciffuum					1.0		1.0	1.0	0.5																				1,3,4
Tsuga demosa									3.0																			E	8
Urtica dentata																1.0													3
Veronica persica											0.5							0.5		1.0									3
Viburnum betulifolium										0.5																			3
Viola urophylla										0.5																		E	0

Appendix 1. *(Continued)*

Sample plot	1	3	4	5	7	6	8	9	11	12	13	14	15	16	18	17	19	20	22	23	21	24	25	26	27	28	29		
Vegetation type	1	2	3	4	9	4	4	6	14	7	15	5	3	11	13	6	6	18	12	14	14	14	15	16	16	16	16		
Elevation (m)	2240	2500	2650	2650	2700	2720	2800	2900	3110	3150	3160	3200	3250	3350	3400	3400	3500	3670	3720	3750	3750	3800	3920	4150	4310	4330	4350	End[a]	Use[b]
Species																													
Vittaria mediosora																0.5													0
Zanthoxylum simulans							2.0																						0
Coverage	15.5	16.5	14.5	14.0	10.0	26.5	26.0	31.5	31.5	21.0	27.5	16.5	29.5	22.5	13.0	27.5	18.5	28.5	15.0	13.0	23.0	14.5	29.5	20.0	8.5	17.0	14.5		
No of species	11	16	14	11	4	23	19	27	25	19	21	13	29	20	13	21	14	20	11	11	12	14	23	16	6	9	14		
No of useful species	5	8	7	4	3	12	9	13	9	5	8	7	8	4	5	9	4	5	4	3	4	5	5	4	1	5	4		
No of endemic species	4	8	6	5	1	12	11	12	15	11	8	6	15	15	8	12	7	14	7	8	10	9	16	12	6	9	13		

Information for sample plots include plot number (row 1), vegetation type (row 2, see Figure 4 for key), elevation (row 3), and cover values (Braun-Blanquet) for the observed species. Information for each species includes endemism[a] and uses[b] (far right columns), and cover.

[a]Species endemic to the Hengduan Mountains or the Himalayas are indicated by (E).

[b]Use categories include human food (1), animal food (2), medicinal (3), chemical (4), fiber (6), cultural use (7), construction (8), environmental/ornamental use (9), and no known use (0).

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