

# TIBETAN LAND USE AND CHANGE NEAR KHAWA KARPO, EASTERN HIMALAYAS<sup>1</sup>

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*Jan Salick, Yang Yongping, and Anthony Amend* (Curator of Ethnobotany, Missouri Botanical Garden, PO Box 299, St. Louis, MO 63166-0299, e-mail addresses: jan.salick@mobot.org, yangyp@mail.kib.ac.cn, and amend@hawaii.edu). Collaborating Authors: Bee Gunn, Wayne Law, George Yatskievych, Wu Sugong, Fang Zhendong, Ma Jian, Wang Yuhua, Andrew Willson, Peng Shengjing, Zhang Chuanling, Sun Hongyan, Meng Zhengui, Liu Lin, Senam Dorji, Ana, Liqing Wangcuo, Sila Cili, Adu, Naji, Amu, Sila Cimu, Sila Lamu, Lurong Pingding, Zhima Yongzong, Loangbao, Bianma Cimu, Gerong Cili, Wang Kai, Sila Pingchu, Axima, and Benjamin Staver. TIBETAN LAND USE AND CHANGE NEAR KHAWA KARPO, EASTERN HIMALAYAS. *Economic Botany* 59(4):312–325, 2005. Tibetan land use near Khawa Karpo, Northwest Yunnan, China, incorporates indigenous forest management, gathering, pastoralism, and agriculture. With field-based GIS, repeat photography, and Participatory Rural Appraisal we quantitatively compare land use between higher and lower villages, and between villages with and without roads. Households in higher elevation (>3,000 meters) villages cultivate more farmland ( $z = -5.387$ ,  $P \leq 0.001$ ), a greater diversity of major crops ( $z = -5.760$ ,  $P < 0.001$ ), a higher percentage of traditional crops, and fewer cash crops ( $z = -2.430$ ,  $P = 0.015$ ) than those in lower elevation villages (<2,500 meters). Villages with roads grow significantly more cash crops ( $z = -6.794$ ,  $P \leq 0.001$ ). Both lower villages and villages with roads travel farther to access common property resources. Historical analyses indicate agricultural intensification in valleys, an increase in houses, new crop introduction, hillside afforestation, cessation of hunting, glacial retreat, and timberline advance within the past century. We suggest that Tibetan land use reveals trade-offs between high, remote villages and lower villages near roads. Higher villages offer abundant land and access to natural resources but short growing seasons and little market access; in contrast, lower villages have road and market access, an extended growing season, and modern technology, but limited access to land and many other natural resources.

**Key Words:** Northwest Yunnan; Tibet; land use; agriculture; non-timber forest products; geographic information systems; participatory rural appraisal; verticality.

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Studies of Tibetan land use are few and often concentrate on renowned patterns of nomad pastoralism on the high plateau (Ekvall 1983; Ning and Richard 1999). Less studied are Tibetan farming (but see Goldstein et al. 2003) and gathering (but see Xu and Wilkes 2004; Zhang, Wang, and Geng 2000). Nonetheless, in well-watered regions of the plateau and especially the monsoonal areas of the eastern Himalayas, agriculture, forestry, and gathering are important traditional activities central to Tibetan livelihoods. Tibetan resource management reflects a sustained human presence since 20,000 B.P. (Alderfer and Zhang 2004).

Land use patterns, and particularly the cata-

lysts fomenting their change, are complex and fit poorly with simple explanations (Lambin, Geist, and Lepers 2003; Lambin et al. 2001). Recent land use change is often attributed to globalization in many forms (Ausubel 1996; Grau et al. 2003; Lambin et al. 2001). Though many factors affect Tibetan subsistence activities, including rainfall (Winkler 1988), politics (Goldstein 1973; Goldstein and Beall 2002), and sanctity (Anderson et al. 2004; Guo 2000; Moseley 2003), this study examines two variables in particular: elevation and road access.

There is a vast literature on relations among road access, market accessibility, and economic growth (Chomitz and Gray 1996; Wilkie et al. 2000; Windle and Cramb 1997). Roads often cause agricultural change, deforestation, and habitat fragmentation (Cropper, Puri, and Griffiths 2001; Forman 1998; Hamlin and Salick 2003;

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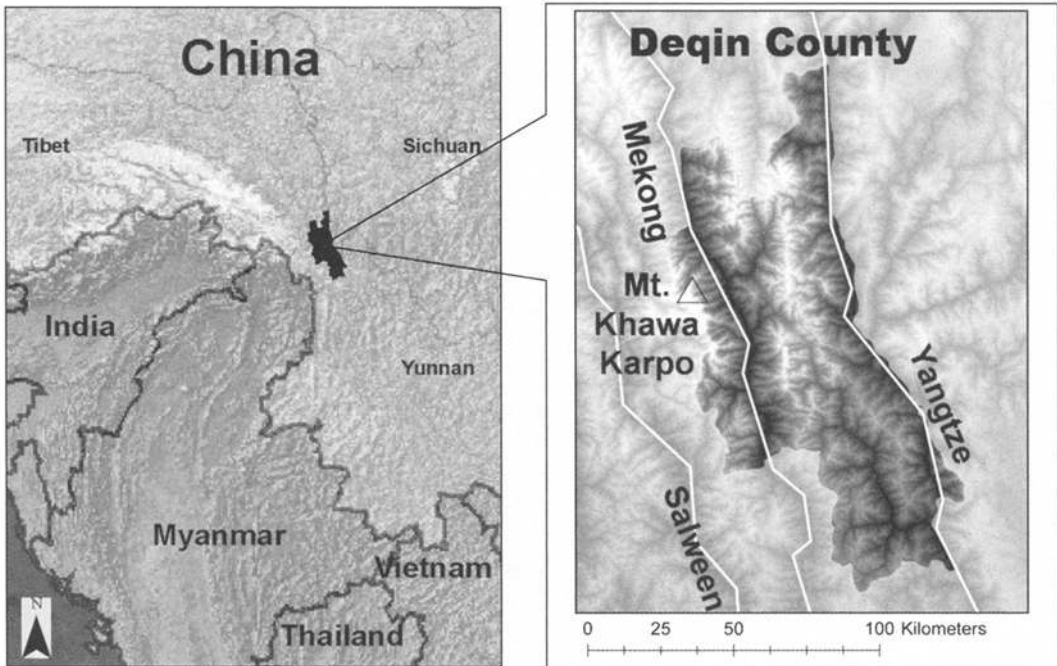


Fig. 1. Khawa Karpo located in Deqin County, Northwest Yunnan, China.

Windle and Cramb 1997). Road building is a modern priority in China (Litzinger 2004; Wang et al. 2003) with a sprawling network extending to the most remote regions. So, we investigate the affects of roads on Tibetan land use.

Verticality in subsistence production has been well documented in mountain cultures of the Andes (Mayer 1985; Murra 1968; Zimmerer 1999) and the Himalayas (Maikhuri, Rao, and Semwal 2001; Sinclair and Ham 2000; Zimmerer 1999). On Khawa Karpo, its steep gradient enhances resource richness (Salick et al. 2004). So, we study elevation as a key environmental variable of Tibetan land use.

Thus, we address the neglected aspects of Tibetan land use—agriculture, forestry, and gathering—as well as pastoralism and change affected by two common agents, one environmental (elevation) and one socio-economic (roads).

### STUDY SITE

Khawa Karpo, the earthly image of the Tibetan warrior god, is one of the most sacred mountains to Tibetans. It lies on the border of Yunnan and Tibet in the easternmost Himalayas, between the upper Mekong and Salween Rivers, and within the region where the major temperate

and tropical floras of Asia merge (Fig. 1). Khawa Karpo has a steep elevational gradient from about 2,000 meters (m) at the Mekong River to its peak (6,740 m) over only 10 kilometers (km) with ecotypes ranging from subtropical scrub in the arid river valleys through oak, humid mixed, and coniferous forests, to alpine meadows, scree, and glaciers on a single mountain slope (Salick et al. 2004). The Hengduan Mountains, in which Khawa Karpo is among the highest peaks, are exceptionally diverse and considered a “hotspot” (Mittermeier et al. 1998). For all these reasons and because of major conservation efforts of The Nature Conservancy, we chose Khawa Karpo as our study site.

Six ethnic Tibetan villages were selected for this study based on elevation (two are higher than 3,000 m, four are lower than 2,500 m; see Table 1), access to roads (three are with roads, three are without), and their depictions in Joseph Rock’s photos from the early 1900s. While roads facilitate transportation to Deqin, the principle market town in the area, none are completely paved and frequent landslides block traffic. In the absence of roads, villagers rely on their backs, horses, mules, and yaks to transport goods by trail.

TABLE 1. TIBETAN VILLAGES NEAR KHAWA KARPO WERE SELECTED FOR ROAD ACCESS (1, 2, 3 WITH ROAD; 4, 5, 6 WITHOUT ROAD), FOR ELEVATION (1, 2, 3, 5 < 2,500 METERS; 4, 6 > 3,000 METERS), AND FOR THE HISTORICAL PICTURES TAKEN OF THEM BY JOSEPH ROCK IN THE EARLY 1900S.

Village	Distance to road (in meters)	Elevation (in meters)	Number of households	Total cultivated land (in square meters)
1	0	2,490	127	623,242
2	0	2,388	24	148,706
3	0	2,068	31	228,311
4	2,550	3,095	15	185,839
5	4,645	2,170	91	404,053
6	5,630	3,100	17	150,385

## METHODS

During May 2004, field research was conducted within each of six villages by a team consisting of a botanist, a GIS technician, a Participatory Rural Appraisal (PRA) facilitator, two Chinese graduate students, two Tibetan doctors, two village participants (one man and one woman), and one translator. Three such teams spent five days each in two villages.

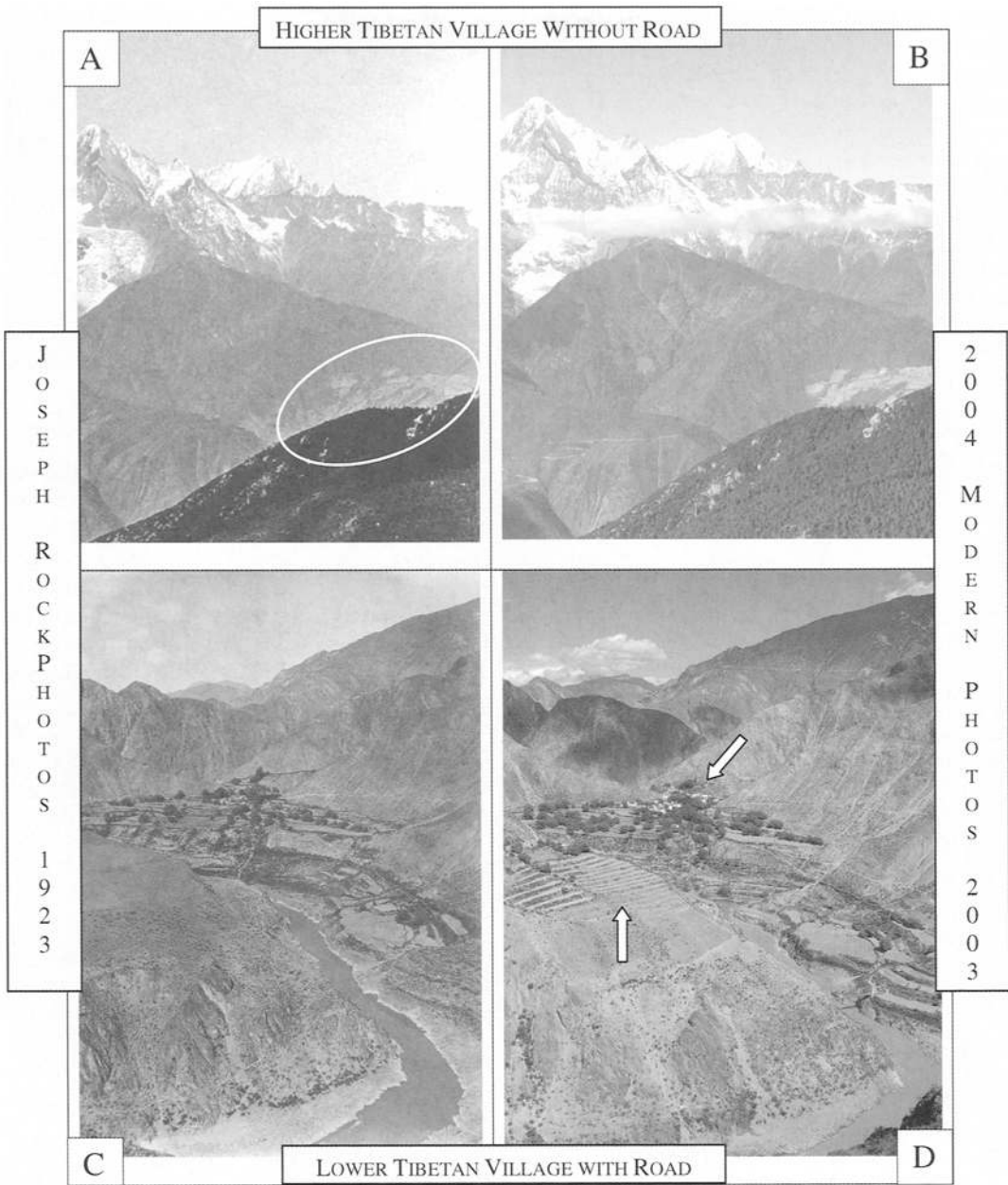
PRA mapping was popular among Tibetan villagers, who sketched their local surroundings on large sheets of paper, highlighting major landmarks (mountains, rivers, sacred sites, roads, trails, pastures, fields, buildings, etc.) and locations of key resources (forests, fuelwood, medicinal plants, mushrooms, etc.). These maps were then transferred to GIS maps in order to identify landmarks and measure distances to resources. Other PRA activities included semi-structured and informal interviews on land use (with GIS below) and historical change. Joseph Rock took photographs in most of the villages early in the twentieth century; these photos were shown and used to discuss historical change with village elders who could remember this earlier period (Fig. 2). In each village, between one and five elders were engaged in the semi-structured interviews based on the photos and their recollection of land use history, including number of households, amount of land farmed, crops grown, resources collected, pastures, animals, markets, roads, and overall living conditions.

GIS mapping used Ikonos 1 m/pixel resolution, orthorectified satellite images of villages. The images were converted to MrSID format and viewed through ARCPad (ESRI 2002) on Compaq iPAQ PDAs. Polygons of field and pas-

ture boundaries and points of gardens, buildings, and other structures were mapped onto the images using a Garmin etrex GPS unit attached to the PDA. Alternatively, these polygons and points were traced by hand over the satellite images. Information about the polygons and points also were entered into the PDA. Field and pasture polygons attribute information included the following: associated household or common property status, crops, crop variety, seed source, chemical and organic inputs, and crop rotation data; for gardens only household and crops were recorded; for houses information included the household name, the number of occupants, and the date of construction; for other buildings and structures the information was identity, household or common property, date of construction. Since Chinese law regulates the use of cartographic equipment, Chinese citizens conducted GIS fieldwork. Polygon area was calculated using a script (Zhou 2001) in ArcView GIS 3.2 (ESRI 1992–1999). Resource distance was calculated using ARCMAP 9.0 (ESRI 2004).

Before and since collectivization of lands (1960s–1980s), a Tibetan household—all inhabitants of a given house sharing economic and natural resources and considered a single entity by the village's governing body—is the basic unit of agricultural production. The household is used as the basis of most of our analyses unless otherwise stated. Crops in fields and gardens were identified by villagers and vouchered if identification was in question. All fertile non-timber products and trees were vouchered and located by GPS. Vouchers are deposited at the Kunming Institute of Botany and the Missouri Botanical Garden.

Statistics calculated include the richness or



**Fig. 2.** Examples of historic photos of study sites taken by Joseph Rock in 1923 (A and C) and modern repeats (B taken in 2004 and D taken in 2003), which show subtle differences in land use. A comparison of Rock's historic photo A with modern photo B shows a bit more modern forest cover and less modern hillside agriculture (right). A comparison of Rock's historic photo C with modern photo D reveals some new terracing, irrigation, and cultivation of land (left) as well as more houses and walnut trees (center).

number of species (S) and Shannon's diversity  $H' = -\sum_i (n_i/N) \log (n_i/N)$  (Shannon and Weaver 1949). Normality was tested using the Shapiro-Wilk test, and since all data were distrib-

uted non-parametrically or were percentages, Mann Whitney rank sum statistics (Z) and Kruskal-Wallis for K independent samples ( $\chi^2$ ) were computed using SPSS (2003).

TABLE 2. FIELD CROP AREAS IN SQUARE METERS (M<sup>2</sup>) CULTIVATED PER HOUSEHOLD IN LOWER AND HIGHER VILLAGES. THESE NON-PARAMETRIC STATISTICS (THUS NO STANDARD DEVIATION REPORTED) DEMONSTRATE THE DIFFERENCES IN ELEVATIONAL CROPPING PATTERS AND AREAS CULTIVATED (SEE FIGURE 3 AND TEXT FOR STATISTICAL RESULTS). COMMERCIAL GRAPES DO NOT THRIVE AT HIGH ELEVATIONS, WHILE BARLEY, BUCKWHEAT, POTATOES, AND TURNIPS DO. MORE LAND IS CULTIVAED PER HOUSEHOLD IN THE HIGHLANDS DUE TO ABUNDANT AVAILABLE LAND AND TO THE SHORT GROWING SEASON WITH SINGLE YEARLY ROTATIONS AND REDUCED YIELDS.

Major crops	Lower villages: mean area cultivated in square meters (m <sup>2</sup> ) per household	Higher villages: mean area cultivated in square meters (m <sup>2</sup> ) per household
Barley	600	2,600
Buckwheat	70	800
Cabbage	1	30
Maize	600	1,400
Potato	50	300
Turnip	0	80
Walnut	50	200
Wheat	2,000	3,000
Grape	300	0
Households (N)	270	32

## RESULTS

### CULTIVATED AREA

The area of land cultivated per household (Fig. 3) is significantly greater in higher villages (Mann-Whitney:  $z = -5.387$ ,  $P < 0.001$ ). Cultivated land area in higher villages is  $10,507 \pm 1,171$  square meters per household (m<sup>2</sup>/household), while lower villages cultivate only  $5,144 \pm 890$  m<sup>2</sup>/household. The area of cultivated land per household is not significantly different between villages with and without road access (Mann-Whitney:  $z = -1.19$ ,  $P = 0.230$ ).

### FIELD CROPS

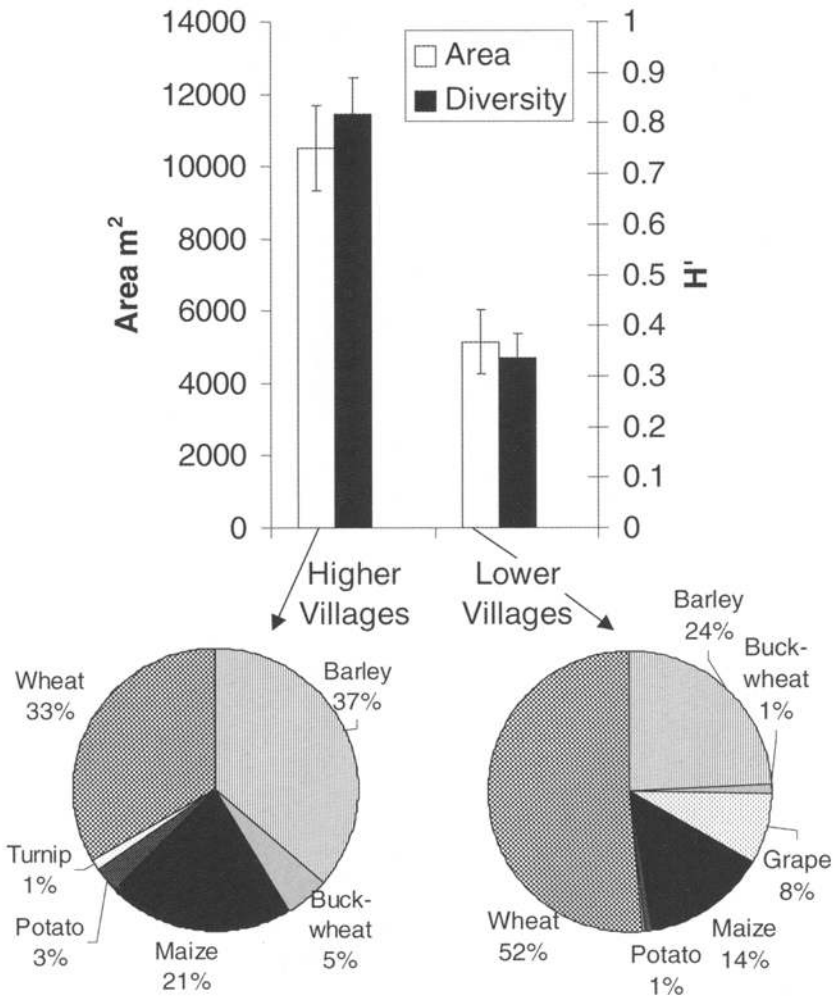
Field crop areas (m<sup>2</sup>) cultivated per household in lower and higher villages (Table 2) describe some differences in elevational cropping patterns and areas cultivated. Commercial grapes do not thrive at high elevations, while barley, buckwheat, potatoes, and turnips do. More land is cultivated per household in the highlands due to abundant available land and to the short growing season with single yearly rotations and re-

duced yields. However, to avoid biasing land use comparisons by area cultivated and to concentrate on crops, the percentage of cultivated areas is compared among villages. Households in high villages grow a significantly greater percentage of traditional Tibetan crops (Fig. 3) including barley ( $\chi^2 = 29.135$ ,  $P < 0.001$ ), buckwheat ( $\chi^2 = 14.962$ ,  $P < 0.001$ ), cabbage ( $\chi^2 = 20.068$ ,  $P < 0.001$ ), and turnips ( $\chi^2 = 51.661$ ,  $P < 0.001$ ). They also grow greater percentages of American crops including potatoes ( $\chi^2 = 50.718$ ,  $P < 0.001$ ) and maize ( $\chi^2 = 25.566$ ,  $P < 0.001$ ), although the latter is grown in special lower-elevation fields. Households in lower villages grow a significantly greater percentage of commercial grapes ( $\chi^2 = 6.972$ ,  $P = 0.008$ ).

In higher villages the extreme elevational gradient is used to cultivate a variety of crops (Fig. 4). Maize and walnuts are grown only at lower elevations while barley is grown mostly higher. Higher villages have scarce, smaller cropping areas lying approximately 200–300 m below the village for cultivating these lower elevation crops. Of the agricultural households surveyed in the higher villages, 88% cultivate land in both high and lower areas. In these lower areas, corn is the most common crop, comprising 84% of the total. Other crops (e.g., buckwheat and yellow beans) also are planted in the lower zone, but in the season of this study (spring), these minor crops are infrequent.

Households in higher villages have significantly greater field crop diversity (Mann-Whitney:  $z = -5.760$ ,  $P < 0.001$ , Fig. 3). Road access does not significantly affect field crop diversity. Households nearer to roads, however, cultivate significantly larger areas of cash crops (Mann-Whitney:  $z = -6.794$ ,  $P < 0.001$ , Fig. 5). Elevation has a similar though less significant affect: households in lower villages have more cash crops (Mann-Whitney:  $z = -2.430$ ,  $P = 0.015$ ) than those in higher villages (Fig. 5).

These significant differences are mirrored in the fact that roadless villages grow greater percentages of barley ( $\chi^2 = 26.933$ ,  $P < 0.001$ ), buckwheat ( $\chi^2 = 8.211$ ,  $P = 0.004$ ), turnips ( $\chi^2 = 9.05$ ,  $P = 0.003$ ), and maize ( $\chi^2 = 28.551$ ,  $P < 0.001$ ); whereas households in villages with roads grow significantly more commercial grapes ( $\chi^2 = 39.796$ ,  $P < 0.001$ ) and wheat ( $\chi^2 = 53.397$ ,  $P < 0.001$ ).



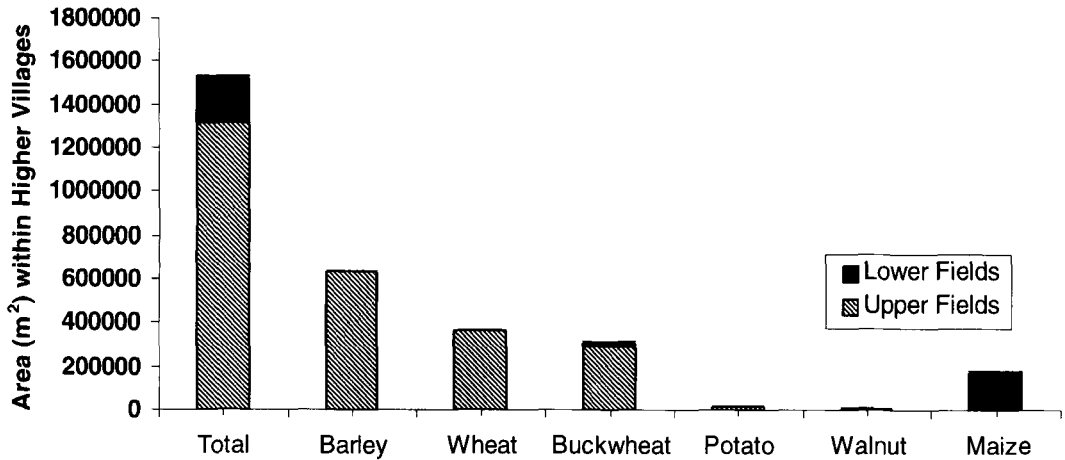
**Fig. 3.** Field crop diversity and total cultivated area are significantly greater in villages at higher elevations. Also households in high villages grow significantly greater percentages of barley, buckwheat, turnips, potatoes, and maize. Households in lower villages grow a significantly greater percentage of commercial grapes. Error bars denote standard error.

**GARDENS AND TREES**

In addition to fields, most households maintain a small garden plot that often is adjacent to the house. Garden plots may contain a variety of vegetables, herbs, and medicines not found in fields (see the Appendix). Fruit and nut trees are sometimes incorporated into these gardens, but more commonly are found around the perimeter of fields, particularly in the lower villages. The most common tree crop is walnuts, which are eaten, used for oil, or sold. Orchards are uncommon, although villagers anticipate planting more fruit and nut trees on abandoned sloping fields and poorly irrigated areas.

**ANIMAL HUSBANDRY**

Pastoralism and animal husbandry are crucial aspects of Tibetan livelihoods. Aside from providing the majority of protein and fat to the diet in the form of dairy and meat, yaks are symbolic of Tibetan tradition. Yaks are pastured near home or given fodder in the byre over winter. Small common property pastures near the villages or crop fields with grain stubble are used for this purpose. Fodder is either grain stalks or forest leaves. In the summer, herds are taken to more distant pastures and alpine meadows where herders live in stone cabins. Pastures are more distant from lower villages (Fig. 6) since most



**Fig. 4.** Higher villages partition crops between upper fields (left: barley, wheat, buckwheat, potatoes) and lower fields (right: maize and walnuts). The high area is dominated by barley (48%), wheat (27%), and buckwheat (22%). It is also where all of the home garden plots are located. The limited lower fields, which are approximately 200–300 meters below the village, are dominated by maize (84%).

summer pastures are in the mountains. Road access does not affect distance to pastures. Yaks also cycle nutrients from pastures, fodder, and bedding into compost and onto crop fields. Other common livestock include goats, sheep, pigs, chickens, ducks, and guinea fowl that scavenge and are fed with grain and cooked fodder.

**NON-TIMBER FOREST PRODUCTS (NTFPs)**

Commercial collection of NTFPs is a regular and lucrative activity. Most villagers cite NTFP collection—principally *Tricholoma* spp. (matsutake) and *Cordyceps sinensis* (caterpillar fungus)—as their principle sources of income (Table

3). Getting NTFPs to market is difficult in villages without access to roads; however, villagers at lower elevations with road access must travel farther to collect NTFPs (Fig. 6; although sample sizes were not large enough to run statistics).

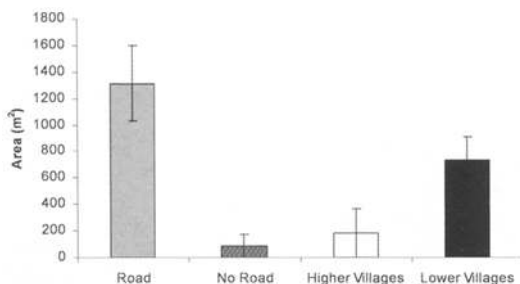
Tibetan medicine depends on the collection of medicinal plants that takes place in all habitats, although alpine meadows often were identified on PRA maps as particularly important. The Tibetan doctors (collaborating authors) particularly stress the importance of this often-cryptic land use for traditional Tibetan livelihoods.

Fuelwood is used for heat and for cooking food and animal feed. Traditional stoves are inefficient and villagers seldom have adopted solar or biogas cookers—their reasons include culture concepts of pollution, use of dung in compost, technical malfunction, time, labor, smell, etc.

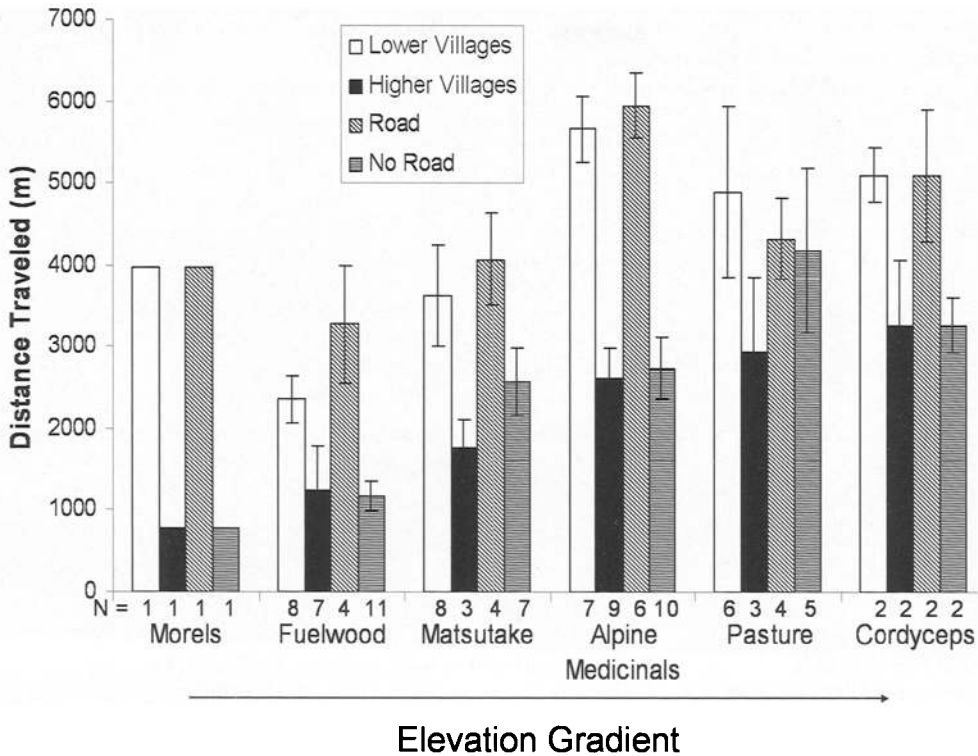
Leaves, twigs, and small branches are used for animal bedding, and are mixed with animal dung to make compost in the early spring. Frequent trips for fuelwood, fodder, and bedding make the distance to forests important to villagers (Fig. 6, see fuelwood).

**SACRED SITES**

A combination of Buddhism and Bön, the Tibetan religion near Khawa Karpo attributes legends and resident entities to many topographic and natural features—including Khawa Karpo himself. It is the duty of local Tibetans to maintain the precarious balance between beneficent



**Fig. 5.** Cash crops are more important in Tibetan villages with roads and at lower elevations. Households in lower villages have devoted significantly more area to cash crops than those in the higher villages. The same is true of households with roads compared to households without roads. Cash crops are apples, grapes, oranges, peaches, pears, pomegranates, and walnuts. Error bars denote standard error.



**Fig. 6.** Distances to common property resources are greater for both lower villages and those with road access (except for pastures with the latter). Common property resources include pastures, fuelwood, and non-timber forest products like fungi and Tibetan medicinal plants. Mean distances (bars with standard error whiskers) from villages to their respective common properties are calculated from GIS maps with reference to the PRA village maps. Numbers of common property samples (N) vary with commonness of the resource (e.g., lands with morels and cordyceps are uncommon, whereas forests with fuelwood are essential and ubiquitous) and are limited because villages have little if any access to these valuable resources, so we use only descriptive statistics.

and malevolent forces. To this end, Tibetans maintain the sanctity of the supernatural realm by observing an elevational boundary (*ri-vgag*) above which lies the sacred realm while the secular lies below it. Although villagers use many resources from above the *ri-vgag*, generally logging is tolerated only below the boundary.

In addition, traditional Tibetan worldviews hold that features as disparate in scale as an entire mountain or a single stone contain a ritual significance. Habitats surrounding these features are variously protected. On a hillside in one village, for example, fodder collection is prohibited, although gathering medicinal plants and mushrooms is tolerated. Beside the sacred alpine lake of the same village, however, not even the local Tibetan doctor may collect plants.

All villagers, regardless of village elevation or road access, identify numerous sacred sites on their PRA maps and during PDA mapping.

These sites include monasteries, stupas, shrines, retreats, mani piles, mountains, valleys, caves, rocks, lakes, rivers, waterfalls, forests, trees, pastures, and even vistas. To these Tibetans devote pilgrimage, pay homage, perambulate, and incessantly pray. The sacred is a genuine land use for Tibetans.

### CHANGES IN LAND USE

Present land use reflects Tibetan tradition, adaptation, and change, which are hard to distinguish. Change includes global change and political change. Some aspects of land use change—although such is surprisingly subtle compared to drastic changes in other parts of China and the world—are seen by comparing old photographs with the situation today, and some of these aspects emerge in discussion with village elders shown these photos (Fig. 2). The photographs show there have been infrastructural changes,



TABLE 3. SOME NTFPS COLLECTED BY VILLAGERS NEAR KHAWA KARPO. THIS TABLE IS AN EXTREMELY SMALL BUT REPRESENTATIVE SUBSET OF THE TOTAL SPECIES ACTUALLY COLLECTED.

Taxon	Resource type	Market price
<b>Fungi</b>		
<i>Tricholoma</i> spp. (Fries) Staude	Matsutake, mycorrhizal mushroom exported to Japan	200–1,200 yuan/kg <sup>1</sup> (price is extremely volatile)
<i>Cordyceps sinensis</i> (Berk.) Sacc.	Caterpillar fungus, alpine fungus used in traditional Chinese and Tibetan medicines	10 yuan/stroma pair
<i>Morchela</i> spp. Dill. ex Pers.	Morels, forest, forest mushroom exported abroad and used in traditional Chinese medicine	600–110 yuan/kg dry weight 6 yuan/kg fresh (Zhang et al. 2000)
<b>Alpine Medicinal Plants</b>		
<i>Fritillaria</i> spp. L.	Alpine plants used in traditional Chinese and Tibetan medicines	<i>F. cirrhosa</i> D. Don 6 yuan/kg (Zhang et al. 2000)
<i>Saussurea</i> spp. DC.		<i>S. laniceps</i> Hand.-Maxx. 2 yuan/kg
<i>Picrorhiza</i> sp. Royle ex Benth.		<i>S. medusa</i> Maxim. 1 yuan/kg <i>Picrorhiza</i> sp. 2 yuan/kg (Zhang et al. 2000)
<b>Edible Plants and Lichen</b>		
<i>Pinus armandii</i> Franch.	Pinenut (seed) sold in local markets	6–12 yuan/kg
<i>Pteridium</i> spp. Gled. ex Scop.	Edible fern	.5 yuan/kg
<i>Permelia</i> sp.	Edible lichen	15 yuan/plate (restaurant)
<i>Aralia chinensis</i> sp. L.	Edible leaves and shoots	15 yuan/plate (restaurant)
<i>Toona sinensis</i> M. Roem.	Edible leaves and shoots	15 yuan/plate (restaurant)
Orchids		
<i>Cymbidium</i> spp. Sw.	Epiphytic orchid	250–1,000 yuan/plant
Various other orchids		5–50 yuan/plant

<sup>1</sup> 8.26 yuan = 1 U.S. dollar

such as construction of roads, irrigation ditches, and houses. There also have been environmental changes, such as glacial retreat, tree line advance, and afforestation, especially of hillsides.

Less obvious from the photographs, but consistently and adamantly discussed by elders, are changes in policy and tenure. Individual and monastic ownership prevalent in the early 1900s and before gave way to nationalization in the 1950s, collectivization in the 1960s, the cultural revolution in the 1970s, decollectivization in the 1980s, and cultural and religious renaissance in the 1990s. Some changes that were begun in the 1950s continue now, such as production of roads, hydroelectrics, irrigation, and crops (particularly commercial crops).

Afforestation is discussed by many village elders as being a result of government policies outlawing both steep hillside agriculture and pasture burning. Nearly all of the early photographs show agriculture on steep hillsides above

villages, which are now abandoned (Fig. 2). Older villagers recall buckwheat, hemp, beans, opium, and other crops that are seldom seen today. Villagers offered several reasons for these changes in cultivation. Some cite the "Law of the People's Republic of China on Water and Soil Conservation." Passed in the 1991, this law prohibits cultivation of crops on hillsides with a slope of over 25°. Other people point out that hillside agriculture yields less than irrigated valleys. Afforestation was bolstered by the Chinese government's "Grain-to-Green" plan, which provides economic incentives to replace hillside agriculture with trees and grasslands. Suppression of pasture burning has caused the tree line to shift upward into alpine meadows and has reduced pasture quantity and quality with an influx of fire intolerant plant species that are also unpalatable, indigestible, and/or poisonous.

Trees apparent in photos, however, do not indicate natural forests. Indeed, monoculture plan-

tations, often of non-native *Pinus* spp. trees, are prevalent in areas where the government has paid villagers to convert cropland to forest. Older villagers in four out of six study sites report having to travel farther now than in their childhoods to gather forest resources.

Government programs to increase irrigation have had a large impact on cropping and agricultural productivity (Fig. 2). All but one of the villages surveyed used irrigation. Landslides, disputes, and road construction all have disrupted irrigation and caused field abandonment in the recent past. In one village, a burgeoning commerce in rice cultivation was abandoned after the construction of a new road, which limited its water supply; today rice is not found in the area. The government has actively promoted particular crops at various times; today these are grapes in the irrigated valleys and reforestation on the hillsides.

Change in agricultural technology has particularly affected villages near roads. Pesticides are used and chemical fertilizers now compliment traditional oak/manure composts. Plastic sheeting to suppress weeds was introduced in the early 1980s to increase yields and reduce fallow time for corn and potatoes.

Changes in the collection of non-timber forest products have had a notable impact on the land use patterns near Khawa Karpo. Local residents note that *Fritillaria cirrhosa* and other medicinal plants, which are still collected but are worth less, were once the most sought after resources. Mushroom collection for commercial markets, by far the most lucrative wild-gathered resource, was unknown at the beginning of the century. Some villages are limiting use of oak forests, which once provided mainly compost, fodder, and fuelwood, in order to manage a more productive habitat for matsutake mushrooms. Matsutake commoditization has changed land use in other ways too. Villages with high matsutake productivity now charge outsiders collection fees for harvest rights.

All villagers surveyed report an increase in household ownership of livestock during the past century. Informants, however, cite diminishing pasture quality due to over-grazing, and increasing dependence on fodder.

One of the less subtle differences between the images in Joseph Rock's historic photos and the present is the number of houses. Concluding that an increase in household numbers signifies an increase in village populations may be an unwarranted assumption, however. In remote vil-

lages, healthcare is still largely traditional, with high mortality, so that the Chinese government allows minority peoples to have two children rather than only one as elsewhere in China. And, as elsewhere in China, a great majority of children are male. Much of the male population leaves the villages for cash income, most commonly on road crews and in military service. Thus, very large, traditional, Tibetan houses are seldom at capacity. House construction is also indicative of nascent tourism, another recent government initiative. Three study villages located on the major Tibetan pilgrimage route have embraced the potential influx of capital that tourists and pilgrims provide by constructing better trails, bridges, guesthouses, home additions, and small shops. Indeed, tourism portends even greater change for the future.

## DISCUSSION

Traditional Tibetan land use often is associated with the harsh upper-elevation climates of the expansive Tibetan plateau, supporting little more than barley, buckwheat, and pastoralism. In contrast, Tibetans on the eastern slopes of the Himalayas have for millennia adapted to monsoonal rains and a steep elevational gradient (Salick et al. 2004). Khawa Karpo has one foot inside and one foot outside of Tibet: linguistically and culturally it is Tibetan, and yet politically, the eastern half has been under Chinese sovereignty since the early eighteenth century (Aris 1992). Traditional Tibetan land use near Khawa Karpo—agriculture, forestry, gathering, and pastoralism—is complex, with many trade-offs and much change over millennia. Specifically, Tibetan land use is affected significantly by both elevation and by roads; moreover, *change* is effected by these two variables.

Verticality and the concept of zonal complementarity of resources (Mayer 1985; Murra 1968; Zimmerer 1999) is a much-discussed concept that, socio-political ramifications notwithstanding, explains much of Tibetan land use. Road access affects land use and impels change because of both markets (Jacoby 2000; Van De Walle 2002) and the spread of Han Chinese culture and government (Lai 2002; PRC 2001). The relationships between roads and deforestation, which are important in many other studies (e.g., Chomitz and Gray 1996; Wilkie et al. 2000), are less of an issue in this area partially because many roads follow the dry river valleys that nev-

er have been forested. Livelihood trade-offs dominate, depending on where Tibetans live—near or far from roads and at higher or lower elevations—like elsewhere in the world (Banik et al. 2004; Takasaki, Barham, and Coomes 2001). In the process of detailing these results, we establish other significant environmental, socio-economic, and policy determinants, many of which also have been discussed in the literature. Examples of these determinants are outside labor and household economics (Goldstein et al. 2003), irrigation, and non-bovine livestock holdings (Wilkes 2003); while others remain unconfirmed, such as household and village populations (Xu and Wilkes 2004).

Non-timber forest products (NTFPs) are and have always been essential in Tibetan livelihoods (Cooper 1871; Ward 1990), particularly so in the “Menri” or Medicine Mountains in which Khawa Karpo is the highest (Salick et al. submitted). Data from other studies within the prefecture (Xu and Wilkes 2004; Zhang, Wang, and Geng 2000) put the percentage of income earned from NTFPs at between 25% and 80% of total household incomes, the most lucrative being Matsutake (He 2003; Yeh 2000; Yun 1997).

Change in Tibetan land use can be attributed to changes in environment, economics, and policies as found in this study and elsewhere. Glacial retreat is tracked from repeat photographs of the area (Baker and Moseley submitted) as monitored elsewhere in the world (Hall and Fagre 2003; Luckman and Kavanagh 2000). In China, burgeoning markets (Chow 2004; Dreyer 2003; Qian and Wong 2000), tourism (Dreyer 2003; Weaver 2002), globalization (e.g., mushrooms, FAO 2004; Yun, Hall, and Evans 1997), and medicines (Janes 2002) affect Tibetan regions as noted in this study. Chinese government policy, well documented elsewhere, is an obvious factor driving change. Deforestation does not appear to be an issue near Khawa Karpo, unlike other studies from China (Albers, Rozelle, and Li 1998; Li et al. 1988; Richardson 1990; Shapiro 2001; Smil 1983; Winkler 1988). On the contrary, afforestation or increasing forest cover (Baker and Moseley submitted) is a result of less commercial timber extraction, little road access, traditional Tibetan sacred designations (Anderson et al. 2005; Salick et al. in press), and recent government bans on steep hillside cultivation, forest extraction, and setting fires in nat-

ural forests (Luo, Xu, and Pei 2001; Zhang et al. 2000).

Looking forward at large government programs designed to increase tourism and development in the Khawa Karpo region, we appeal for the integration of traditional Tibetan knowledge, culture, and land use in planning and implementation. While change is inevitable, enlightened change is not. Tibetans have acted as environmental stewards of Khawa Karpo for millennia, and the future should hold a sustained, empowered, and influential role for them and their traditions.

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## APPENDIX. SOME CULTIVATED PLANTS FOUND NEAR KHAWA KARPO.

Latin Binomial <sup>1</sup>	Family	Common Name	Higher	Lower	Road	No Road
<i>Allium cepa</i> L.	Liliaceae	Onion	X	X	X	X
<i>Allium cepa</i> L. var. <i>schallot</i> Seregin	Liliaceae	Shallot		X	X	
<i>Allium schoenoprasum</i> L.	Liliaceae	Chives		X	X	
<i>Amaranthus</i> spp. L.	Amaranthaceae	Amaranth		X	X	
<i>Aralia chinensis</i> L.	Araliaceae	Angelica Tree	X	X	X	X
<i>Brassica oleracea</i> L.	Brassicaceae	Cabbage	X	X	X	X
<i>Brassica rapa</i> L.	Brassicaceae	Turnip	X	X	X	X
<i>Brassica chinensis</i>	Brassicaceae	Bok Choi	X	X	X	X
<i>Brassica</i> spp. L.	Brassicaceae	Mustards		X	X	
<i>Cannabis sativa</i> L.	Cannabaceae	Hemp		X	X	
<i>Chaenomeles speciosa</i> (Sweet) Nakai	Rosaceae	Chinese Quince	X	X	X	X
<i>Citrus</i> spp. L.	Rutaceae	Citrus		X	X	
<i>Coriandrum sativum</i> L.	Apiaceae	Coriander		X	X	
<i>Cucurbita</i> spp. L.	Cucurbitaceae	Squash		X	X	
<i>Daucus carota</i> L.	Apiaceae	Carrot		X	X	
<i>Fagopyrum esculentum</i> Moench	Polygonaceae	Buckwheat	X	X	X	X
<i>Fagopyrum tataricum</i> (L.) Gaertn.	Polygonaceae	Tartary buckwheat	X	X	X	X
<i>Glycine max</i> (L.) Merr.	Fabaceae	Soy Bean		X	X	
<i>Helianthus annuus</i> L.	Asteraceae	Sunflower		X	X	
<i>Hordeum vulgare</i> L.	Poaceae	Barley	X	X	X	X
Indetermined		"Mane"		X	X	
<i>Juglans regia</i> L.	Juglandaceae	Walnut	X	X	X	X
<i>Juglans sigillata</i> Dode	Juglandaceae	Iron Walnut	X	X	X	X
<i>Lactuca sativa</i> L.	Asteraceae	Lettuce		X	X	
<i>Lycopersicon esculentum</i> Mill.	Solanaceae	Tomato	X	X	X	X
<i>Malus</i> sp. Mill.	Rosaceae	Apple	X	X	X	X
<i>Medicago sativa</i> L.	Fabaceae	Alfalfa	X	X	X	X
<i>Pisum sativum</i> L.	Fabaceae	Pea	X	X	X	X
<i>Punica granatum</i> L.	Lythraceae	Pomegranate		X	X	
<i>Pyrus communis</i> L.	Rosaceae	Pear		X	X	
<i>Raphanus sativus</i> L.	Brassicaceae	Radish	X	X	X	X
<i>Rosa</i> spp. L.	Rosaceae	Rose		X	X	
<i>Rubus</i> sp. L.	Rosaceae	Raspberry		X	X	
<i>Solanum tuberosum</i> L.	Solanaceae	Potato	X	X	X	X
<i>Thlaspi arvense</i> L.	Brassicaceae	Penny Cress	X	X	X	X
<i>Triticum</i> sp. L.	Poaceae	Wheat		X	X	
<i>Vicia</i> sp. L.	Fabaceae	Vetch	X	X	X	X
<i>Vitis vinifera</i> L.	Vitaceae	Grape		X	X	
<i>Zea mays</i> L.	Poaceae	Maize	X	X	X	X

<sup>1</sup> Authors and families from Wierssema, J. and B. León. 1999. World economic plants: A standard reference. CRC Press, Boca Raton, FL.