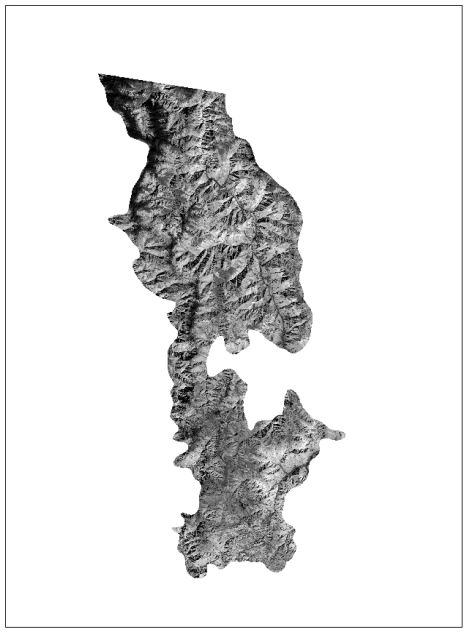
# HOME ON THE RANGE: CONSERVATION POLICY, TRADITIONAL LAND USE, AND YAK BUTTER TEA ON THE TIBETAN PLATEAU



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**ABSTRACT**

For integrated conservation and development policies to succeed, governing bodies must allow locals to practice traditional resource management regimes based on indigenous knowledge.

This concept is exemplified in Baimaxueshan Nature Reserve, located in an ethnographically Tibetan corner of Southwest China's Yunnan Province. Here, forest conservation strategies are resulting in degradation of alpine grasslands, traditionally grazed by yaks—whose butter is an important source of income and pride for local Tibetan villagers. Such rangeland degradation threatens the future of human development and environmental conservation in the Reserve.

I hypothesize that: (1) restrictions on logging, once the primary source of income in the region, have caused families to begin yak-rearing or increase their herd sizes to replace lost income; and, (2) increased overall grazing levels by growing yak herds is unsustainably pressuring alpine rangeland resources in Baimaxueshan.

Analysis of Landsat satellite remote sensing imagery and on-site field interviews with relevant stakeholders finds that these hypotheses are generally supported, but leave out other key factors. In particular: (1) restrictions on logging have indirectly led to larger herd sizes, and that this effect is intensified by increased market demand from the local tourism industry and cultural preferences for yak-rearing; (2) overgrazing by yaks has decreased the value of rangeland resources to Baimaxueshan's rangers, and this degradation has been exacerbated by prohibition of traditional land management practices, including forest clearing and periodic rangeland burning. Moreover, the effect from each of these drivers will only intensify under local projections for anthropogenic global climate change.

The findings suggest that both Baimaxueshan and national-level reserve policy should capitalize on indigenous knowledge of resource management and incorporate the right for communities to be involved in managing traditionally-used natural resources through networking strategies and comanagement with reserve staff.

## 简介

### 放牛吃草：西藏高原酥油茶，保育政策，以及传统土地利用

为了整合性保育及发展政策的成功，从中央到地方的领导组织必须使地方人士以当地智慧建立传统性资源管理系统.

此概念可见於位於云南省西北西藏地区的白马雪山自然保护区. 在此，森林保育措施造成以牧牦牛为传统的高山草原严重退化，而牦牛奶更是传统西藏村庄引以为傲的主要收入来源. 如此的草原破坏对未来人类发展以及环境保育将造成双方面的威胁.

经过笔者长期研究以及於云南进行的访问考察，提出以下两项论点:
第一: 伐木限制迫使家家户户将主要收入来源转移至牧牦牛或者增加牛群数量.
第二: 牦牛数量提高所造成的整体牧草程度的增加属於不永续经营的措施，将对於原已珍贵的高山牧草资源造成更进一步的压迫.

分析人造卫星 (Landsat)遥测图像以及笔者於当地与利益相关者进行的访问证明了以上论点的可信度，不过某些重要的因素仍被忽略. 尤其，(1) 伐木的限制间接性得造成牛群数量的递增，而市场需求以及旅游文化的转变更加强了这个此趋势. (2) 对於白马雪山的牧者来说，过度放牧牦牛已造成草地资源的减值. 而对於传统资源管理方式 (以定期性游垦及焚林为例) 的忽略，更进一步对草原造成不必要的破坏. 此外，更重要的是，由地方预测由人为因素所造成的全球气温上升将增强这些驱动草原破坏的因素.

以上发现建议白马雪山以及中央阶层的保护区政策尽速有效利用地方智慧进行草地资源管理. 此外，融入社区参与的权利，以关系网路的建立以及与保护区人员的共同管理将大力帮助草地资源的永续经营.

**OUTLINE**

**ILLUSTRATIONS**

*Figures*



*Tables*



*Maps*

**TERMS**

| | |
|---|---|
| 白马雪山自然保护区 | Baimaxueshan Nature Reserve |
| 茨卡桶村 | Cikatong Village |
| 霞若村 | Xiaruo Village |
| 各么茸村 | Gemerong Village |
| 德钦镇 | Deqin Township |
| 德钦县 | Deqin County |
| 维西镇 | Weixi Township |
| 维西傈僳族自治县 | Weixi Lisu Ethnicity Autonomous County |
| 中甸县 （香格里拉县） | Zhongdian (Xianggelila, Shangri-la) County |
| 中甸针 （建塘镇） | Zhongdian (Jiantang, Gyalthang) Township |
| 迪庆藏族自治州 | Diqing Tibetan Autonomous Prefecture |
| 贡山县 | Gongshan County |
| 云南省 | Yunnan Province |
| 四川省 | Sichuan Province |
| 西藏自治区 | Tibetan Autonomous Region (TAR) |
| | |
| 三江并流 | Three Parallel Rivers Region |
| 怒江 | Nu (Salween) River |
| 澜沧江 | Lancang (Mekong) River |
| 金沙江 （长江） | Jinsha (Yangtze) River |
| | |
| 少数民族 | Chinese Ethnic Minorities (Nationalities) |
| 藏族 | Zangzu (Tibetan Ethnicity) |
| 康 | Kham (region of cultural Tibet) |
| 松赞林寺 | Songzanlin Buddhist Monastery |
| 茶马古道 | Chama GuDao (Ancient Tea-Horse Road) |
| 并 | Bing (4kg brick of tea or butter) |
| 酥油茶 | Yak butter tea |
| | |
| 牦牛 | *Bos grunniens* (Yak) |
| 犏牛 | *Bos grunnien-taurus* (Yak hybrid) |
| 金丝猴 | *Rhinopithecus bieti* (Yun. Snub-nosed Monkey) |
| 松茸 | *Tricholoma matsutake* |
| 虫草 | *Cordyceps sinensis* (Worm grass) |
| 土大黄 | *Rumex nepalensis* |

## INTRODUCTION

*"Many of the people here live for their yaks first and themselves second."*

-Xiaruo Vice Village Head, Baimaxueshan Nature Reserve

Worldwide, the historical mission of nature reserve systems has been to protect the natural environment. Whether this meant preserving biodiversity, conserving natural resources, or ensuring the existence of a beautiful landscape, "protection" was generally something done to an environment to safeguard it from other human aims. As such, governments, scientists, and non-governmental organizations (NGOs) with conservation interests have implicitly or explicitly established dichotomies between the protection of nature reserves, which now cover 12% of the world's land area, and human development.

In the last twenty years, however, both conservation and development organizations have openly challenged this notion. Integrated conservation and development projects (ICDPs), in particular, have attempted to demonstrate that if properly managed, successful nature reserves allow, encourage, or even require local human socioeconomic development (Wells and McShane 2004). Implementations vary, but traditionally include designating zones of graduated permissible land use by local inhabitants, developing non resource-intensive economies, or building markets that leverage the sustainable use of a reserve's natural capital (Wells 1992). Typically, these projects also recommend education, capacity-building, and consensus dialogue among stakeholders in the reserve (Worah et al 1999). In developing countries like Asia, where high biodiversity is geographically correlated to human poverty (Peluso 1994) and top-priority nature reserves often include sizeable human populations, these "win-win" ICDPs have been broadly embraced and implemented (Sanjayan et al 1997).

Today, success of these projects is widely varied and hotly contested (Naughton-Treves et al 2005). Since Wells' introduction of the term in a 1992 international case study, ICDPs have "become all things to all people", as diverse interpretations, implementations, and objectives have muddled the concept (Sanjayan et al 1997). As witnessed by ongoing projects, however, both donors and implementing organizations remain generally convinced by the duel-role potential of ICDPs, and so continue to explore with new methods meant to successfully address both biodiversity and human development, and which will be self-sustaining beyond the life of the individual project (Colfer 2005).

The incorporation of local indigenous knowledge into nature reserve management and economic implementation is a promising focus for current and future ICDPs. In Southwest China, where government-run nature reserves are poorly funded and understaffed, but local indigenous inhabitants generally have a rich history of sustainably managing their environment, this concept has gained considerable traction in recent years. The 2003 the internationally-sponsored III Symposium on Montane Mainland Southeast Asia (MMSEA), held in Southwest China's Yunnan Province, was entitled "Indigenous Knowledge, Sustainable Livelihoods and Resource Governance". In it, Xu Jianchu, the head of the Center for Biodiversity and Indigenous Knowledge (CBIK), a local grass-roots NGO, remarked:

> These indigenous people who have lived in these mountain habitats for generations have developed ways of living, practices and belief systems which demonstrate their intimate relationship with the mountain environment and deep knowledge about the plants, wildlife, vegetation and ecosystems which surround them.

Support for these words is echoed in current project philosophies from not only CBIK and other NGOs with a local presence, including the International Rivers Network, Nature Conservancy, and World Wide Fund for Nature (WWF), but also increasingly from local government organs including the Yunnan Forestry

Department and nature reserve management offices. Local academics have joined in, too. Bai Zhihong, in a recent description of indigenous knowledge and development in Yunnan, brings the ICDP debate to the fore by arguing that "environmental conservation projects often cause human unsustainability" in modern Southwest Chinese nature reserves (Bai 2003), and offers that economic development should come second to the strong preservation of indigenous culture and, in turn, the natural environment.

The following thesis explores this intersection of conservation and development in an indigenous landscape through an empirical step-by-step case study of yak husbandry and rangeland management in a northwest Yunnan Province nature reserve.

I became interested in the Southwest Chinese intersection of traditional knowledge and ICDPs while working with Wu Yusong and Zhongtai at WWF China in Yunnan province over the course of two summers in 2004 and 2005. Over the past decade, these individuals worked to establish an ICDP in a local nature reserve— an endeavor which both inspired and enlightened my own investigation of this subject. I am indebted to them both, for offering their own extensive understanding of the context and forces at play in the northwest Yunnan mountains, and also for their (literal) guidance in my subsequent fieldwork in and research of the area. Much of the information that follows then, I attribute to our joint experience with the lands and people of Baimaxueshan.

Baimaxueshan Nature Reserve, located in a poor, ethnographically Tibetan corner of Southwest China's Yunnan Province, exemplifies the need for using indigenous knowledge and management techniques in the face pressing environmental and development concerns. Established in 1983 primarily for the protection of the endangered Yunnan Snub-Nosed Monkey, *Rhinopithecus bieti,* and the Red Panda, *Ailurus fulgens*, this reserve has since been upgraded to national-level jurisdiction

and today is home for over 12,000 human residents, the majority of whom fall below the Chinese domestic poverty line. Traditional livelihoods for reserve communities include scattered agriculture, the sale of timber and fuel wood, the gathering of edible fungi and other non-timber forest products (NTFPs), and the raising of yak herds for manure, meat and, most importantly, butter.

Current nature reserve policy and national environmental protection regulations, however, seriously restrict traditional land and resource use by reserve communities. Some of these restrictions, in turn, directly and indirectly undermine the dual mandates of Baimaxueshan Nature Reserve to both protect biodiversity and alleviate poverty among reserve communities. One nascent but pressing case example is the traditional and expanding practice of yak (*Bos grunniens*) herding on the reserve's limited alpine rangelands. Specifically, I hypothesize that:

(1) *Restrictions on logging, once the primary source of income in the region, have caused families to begin raising yaks or to increase their herd sizes to replace lost income*.

The temperate upland virgin forests in and around Baimaxueshan Nature Reserve have traditionally been a source of fuel wood and timber for the large, Tibetan-style homes preferred by local communities. Villages situated near particularly good forest resources could also sell some of this wood to neighboring communities for extra income. After the Chinese Communist Party took power in 1949, upland Yunnan forest resources were harvested by large state-owned logging firms. These firms provided the main source of employment in the area as well as over 85% of county tax revenue. Logging was not technically allowed within the nature reserve (as enforced by roadblock checkpoints), but ample employment opportunities for reserve inhabitants existed just outside reserve boundaries. WWF fieldwork in the late 1990's in the reserve indicates that the logging industry was an important, if not the primary source of income for most reserve families.

1n 1998, though, after a summer of devastating floods along the Yangtze river, Premier Zhu Rongji instituted the Natural Forest Protection Program (NFPP). This program included a logging ban for the entire upper Yangtze watershed which aimed to prevent erosion and runoff. Within one year, the Chinese central government had shut down all the logging firms with minimal financial support given to the already poverty-stricken former employees or local governments.

Removing this source of income has shifted pressure onto other livelihood activities. Agricultural lands in the reserve are generally poor in quality, limited in quantity, and unevenly distributed according to altitude and distance from the main Zhu Bao river. Previous researchers and organizations have investigated current market opportunities for NTFPs in the area, and found them to be important sources of income for communities who lack other capital (NTFP collection is particularly important in areas which foster the growth of matsutake mushrooms, *Tricholoma matsutake*, which are exported to Japan at a considerable profit to stakeholders throughout the supply chain both private and public; see Yeh 1998). Less attention though has been given to the possible expansion of yak husbandry in reserve communities as a result of the NFPP and other resource restrictions. However, informal accounts from both researchers and Baimaxueshan locals, considered alongside supporting economic, political, and social contextual landscapes, suggests that yak husbandry is in fact undergoing radical shifts in Baimaxueshan.

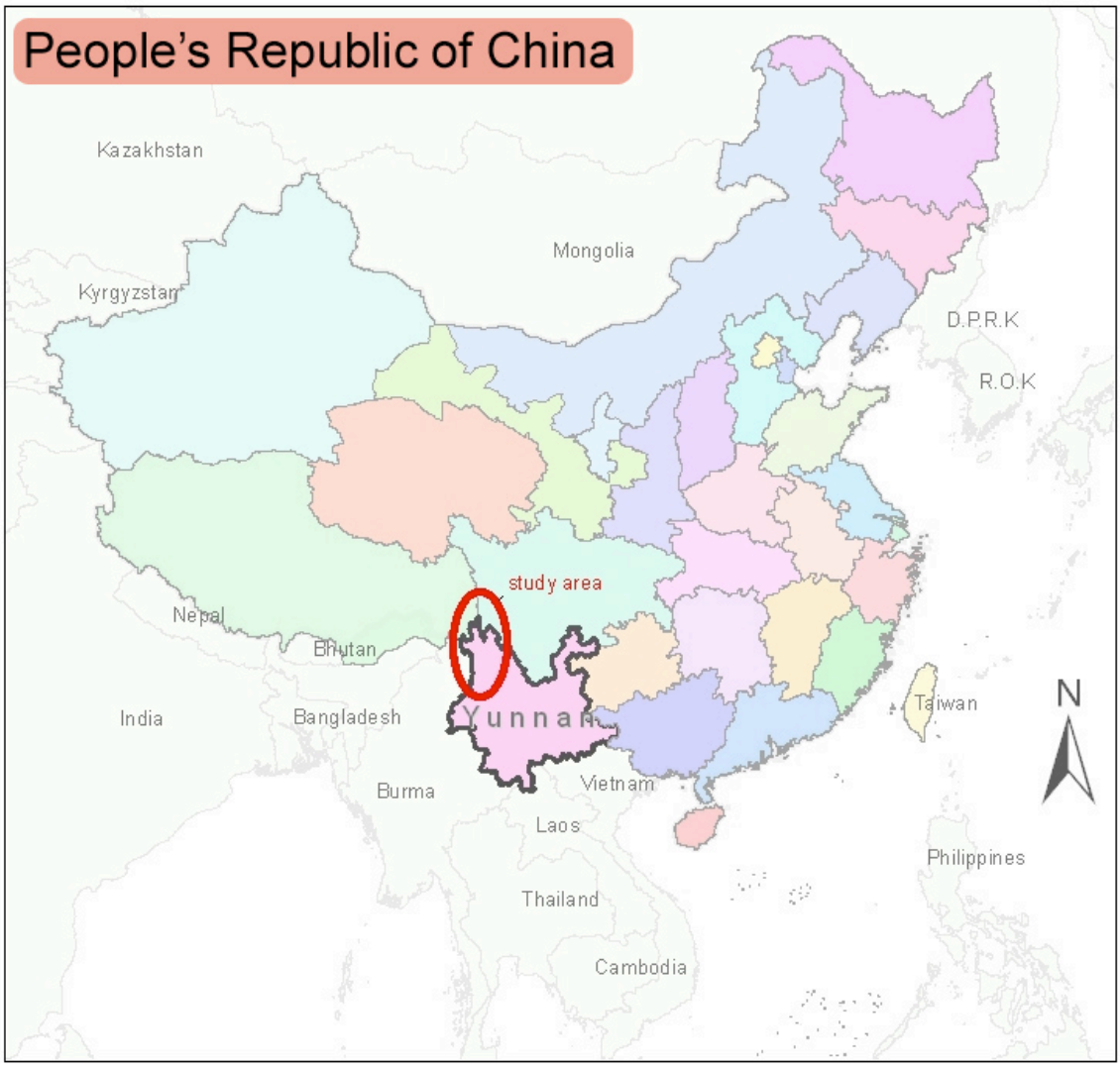
(2) *Increased overall grazing levels by growing yak herds is unsustainably pressuring alpine rangeland resources in Baimaxueshan.*

Given that conservation-oriented regulations in Baimaxueshan could be increasing local yak herd sizes at above background rates, and that alpine summer rangeland resources (located exclusively above altitudes of 4000m) are necessarily limited in

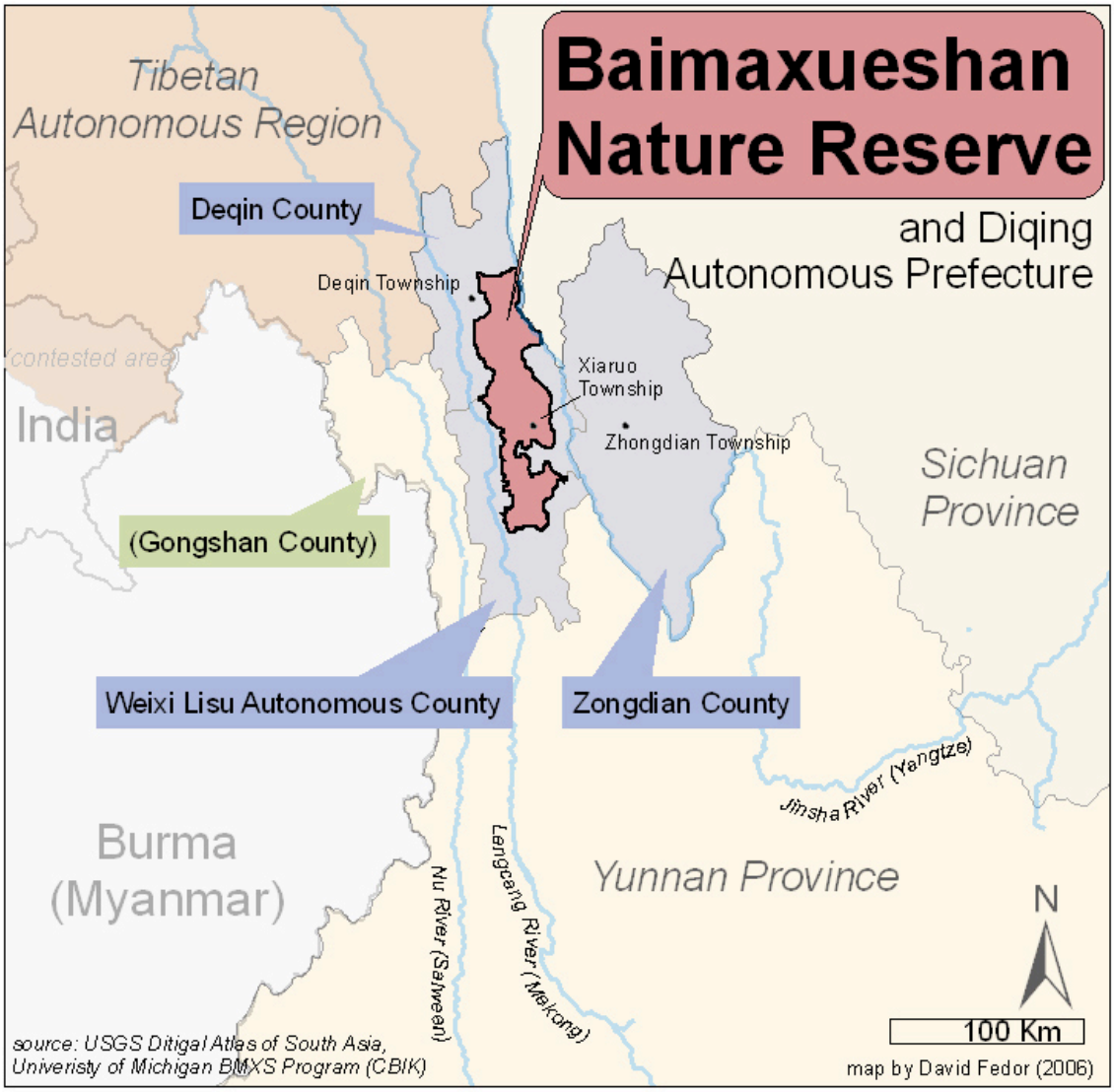
size due to spatial topography, there exists the possibility of overgrazing. This impact is especially possible in the absence of clearly defined tenure rights to (and therefore direct incentive to sustainably manage) grazing lands.

To investigate these hypotheses, this thesis leverages analysis of both on the ground semi-formal field interviews with private and public stakeholders in the Baimaxueshan Nature Reserve livestock system and quantitative interpretation of eight time-series Landsat satellite remote sensing images over a decade-long period of change. Used in concert, these interdisciplinary techniques allow for precise evaluations of land cover patterns, informed by an accurate context of land use regimes and their root motivators.

This thesis is organized into five sections. The first chapter has introduced the importance of incorporating indigenous knowledge into the evolving concept of ICDPs, and offered the issue of livestock management in Baimaxueshan Nature Reserve as a case study which illustrates the complexity of nature reserve management. The second chapter gives a brief background of Baimaxueshan, its environs, its people, and the macro-, meso-, and local management structures and regulations to which it is subject. Chapter three explains the methodology of field survey techniques and remote sensing image interpretation. Chapter four, which is based upon qualitative and quantitative data analyses and represents the bulk of this work, details plausible narratives of the workings of Baimaxueshan as they relate to the above hypothesis. Finally, chapter five draws recommendations for future ICDPs and reserve policies based upon the lessons distilled through the proceeding.




**Map 1.1**: People's Republic of China with Yunnan Province




**Map 1.2**: Diqing Autonomous Prefecture with Baimaxueshan Nature Reserve

Northwest Yunnan Province is an extremely diverse area, geologically, ecologically, and ethnically. Understanding this diversity is important, as it strongly influences the character of the region.

*Physical Geography*

Baimaxueshan Nature Reserve (literally, "White Horse Snow Mountain Nature Reserve") spans two counties in the Diqing Tibetan Autonomous Prefecture of northwest Yunnan Province: Deqin County in the north and Weixi County in the south. The reserve lies at 28 degrees north latitude, 99 degrees east longitude. It is bordered on the east by Sichuan Province and Zhongdian County, which was officially renamed as Shangri-la (Xianggelila) County in 2002 in an attempt to invoke *Lost Horizon*, James Hilton's 1933 novel about a mythical and hidden mountain paradise inhabited by immortals. The length of Yunnan Province extends to the south of the reserve, to the west lies Gongshan County and the border of Burma (Myanmar), and the Tibetan Autonomous Region (TAR) towers along the north.

Baimaxueshan Nature Reserve and the surrounding areas are also part of the United Nations Education, Scientific, and Cultural Organization's (UNESCO) "Three Parallel Rivers" World Heritage Site. This extremely rugged region is characterized by the soaring mountains and steep valleys of the Hengduan Mountain Range, and altitudes in the Reserve range over small distances from under 2000m to over 6500m above sea level. Here, the headwaters of the Yangtze (Jinsha), Mekong (Lancang), and Salween (Nu) Rivers all form and flow north to south through parallel gorges within 100km of each other along the edge of the Qinghai-Tibetan Plateau.

The Reserve itself, an IUCN category IV Protected Area, was established in 1983 and expanded in 1997 to its current size of 1,901 sq km. Nestled between the two ranges which form the western and eastern catchments for the Mekong and Yangtze Rivers, respectively, the Reserve extends over 200km north to south from the town of Deqin to the town of Weixi, but is never wider than 40km east to west. The southern half of the Reserve, on which this thesis focuses, is bisected by the Zhu Ba River (also known as the Zhu Ba Long River), which, after a series of many rapids, drains into the Yangtze River at Tuoding Township, just outside the border of the reserve.

*Ecology*

Northwest Yunnan Province is recognized both within China and internationally for its high levels of biodiversity and ecological endemism. Its upland temperate virgin forests and alpine grasslands are among the most biodiverse in the world, containing over 14,000 plant species and 7,000 vascular plant species, 13% of which are endemic to the region's 7 distinct micro-climate regimes and 10 vegetation types. Here, one can find over 200 species of rhododendron alone, in addition to numerous pine, oak, and exotic fungus species (CBIK 2006).

Moreover, local rare and endemic charismatic vertebrates, including the Yunnan golden snub-nosed monkey (*Rhinopithecus bieti)*, red panda (*Ailurus fulgens*), snow leopard (*Uncia uncia*), clouded leopard (*Neofelis nebulosa*), and black-necked crane (*Grus negricollis*), have been particularly effective in garnering conservation attention for the region. In addition to its UNESCO World Heritage designation, northwest Yunnan is also a Conservation International (CI) Critical Ecosystem Partnership Fund (CEPF) Hotspot, center to The Nature Conservancy's (TNC) Yunnan Great Rivers Project, home to two International Rivers Network focus areas, and two WWF Global-200 Ecoregions.

*Land Cover*

Whereas environmental geography is typically conceived of in terms of the cardinal directions, in mountainous areas it actually can be more useful to describe the range of ecosystems in terms of their altitudes. This is particularly true of Baimaxueshan Nature Reserve, where the wide range of altitudes in this landscape dictate the land cover patterns. In the southern half of Baimaxueshan, past WWF researchers (anonymous 2004 and Zhao et al 2004) have identified three primary altitude-based land cover categories, characterized by declining levels of primary production as altitude increases: (1) Riparian lowlands from 1950m-2200m; (2) Mixed forest, evergreen and deciduous, from 2200m-3400m, and; (3) Alpine meadow and bare rock, 3400m and above.

Riparian lowlands, from 1950m-2200m, along the Zhu Ba River, are well irrigated but see comparatively little precipitation throughout the year (~300mm annually). The peak of the rainy season is from July to August. This area is also the hottest in the Reserve, with annual average temperatures of approximately 16 degrees C and 250 frost-free days. This area represents 26% of land cover in the Reserve, much of which is cultivated for agriculture.

Mixed forested areas, from 2200m-3400m, are colder and wetter than the lowlands. Average annual temperatures range from 9-13 degrees C, with 200 frost-free days. Precipitation totals 400-500mm and reaches its peak from June-September. Snowfall typically begins in November. Land cover in this altitudinal band, which represents 15% of Reserve land area, includes *Sophora*, a type of mountain laurel, the clover *Lespedeza*, the flowering shrub *Indigofera*, and the grasses *Eragrostis* and *Pennisetum*, in addition to numerous *Rhododendron,* the deciduous oak *Quercus*, and the broadleaf *Pinus yunnanensis*. Often, this altitudinal band is split into two

sections, with the upper section containing more evergreen pine, and the lower section more deciduous oak and mixed dryland cultivation.

Alpine meadows begin above the tree line, approximately 3400m-3800m, and extend in fragments up through the glacial and rocky regions at 4200-4300m. These highly fragmented, island-like biogeographical areas above 3400m represent 59% of land cover in the Reserve. Climate at this high altitude is generally cold and wet. Average annual temperatures are roughly 5 degrees C, with high diurnal and seasonal variance. The frost-free period is only 130 days, roughly one-third of a year shorter than in the riparian lowlands. Precipitation averages over 700mm per year, more than twice that of the riparian lowlands, and snows generally begin in late October and last through April. The long period of snow cover in these alpine meadows controls to a large extent their vegetative composition. Shrubs, herbaceous, and small woody plants persist into the lower reaches of this section, but give way to a grassy understory above 3800m. In the past, botanists have characterized Baimaxueshan's alpine meadows as being covered primarily with *Salix* grasses, *Caragana* Siberian peashrub, *Arenaria* sandwort (Xu and Wilkes 2004), *Agrostis* bentgrass, and *Carex* sedges. However, Zhao et al, in a recent taxonomic inventory of Baimaxueshan alpine meadows(2004), have documented large shifts in the vegetative composition of these areas. This very phenomenon is a focus of this thesis.

*Culture*

Baimaxueshan is located along the southern edge of the Kham, one of the three traditional Tibetan cultural regions in what is now western China. Reserve management estimates that over 85% of the reserve's 12,000 human inhabitants are officially registered as belonging to the Tibetan "Nationality" (*Zang minzu*)—a term used by the Chinese Communist Party (CCP) and central government to refer to the 55 non-Han ethnic minority groups that nationwide constitute 8% of the

country's population (for more on the Chinese ethnic minority classification system, see Harrell 2001). The remaining 15% of Baimaxueshan's population belongs mostly to the Lisu ethnic minority, particularly along the extreme southern edge of the Reserve in Weixi County.

The Tibetan population in the Reserve and surrounding Diqing Autonomous Prefecture exhibit cultural traits that distinguish them from the Han ethnicity cultural majority of China, and even from other Tibetan groups. Two examples include local religion and language.

Local religion in Baimaxueshan is influenced primarily by Tibetan Buddhism, or "Lamaism" as it is officially classified by the CCP, and related early traditional animistic religions including Bön and a local form of the Naxi ethnicity Dongba tradition. Religion plays a strong role in everyday life in Baimaxueshan. At its most visible, colorful strings of prayer flags run from roof to roof in every village, across rivers, and along remote mountainsides; vehicles go against traffic to circumnavigate giant whitewashed stupas set in the middle of highways and mountain roads; ancient Buddhist monasteries, such as Feilaizi Temple and the nearby Songzanlin Monastery— often supporting massive sutra libraries, a steady stream of religious pilgrims, and large populations of young monks from the countryside— dot the landscape with golden roofs and the smoky plumes of thousands of yak-butter candles; and the images of deities and high lamas rest alongside incense atop elaborately carved and hand-painted altars over the cooking fire of every home. Less obvious, but exceedingly important to local land use and land management practices, is the local religious-environmental landscape of a network of sacred mountain peaks, deity-guarded alpine lakes untouched by humans, and *rigua* spirit forests, sealed off by local high lamas to prevent logging and hunting in particularly revered but ecologically threatened natural areas (Guo 2003).

Baimaxueshan Tibetans speak a dialect of Kham Tibetan similar to the dialects found to the north in western Sichuan Province, but with local adaptations that make even these closely-related dialects mutually unintelligible. Within Baimaxueshan itself, individual villages will even adopt a unique dialect. It is common, then, for Tibetan villagers of some social rank in Baimaxueshan to speak many different languages in their daily interactions with traders or on shared rangelands. For example, a local forest ranger might speak 4 languages: his local village dialect of Kham Tibetan, a more standard form of Kham Tibetan used in speaking with other nearby villagers, a linguistically unique Lisu language dialect, and possibly even a local Yunnanese dialect of Mandarin Chinese. Access to formal education within the Reserve is extremely limited, however, and corresponding high rates of illiteracy (conservative estimates for woman in the reserve put the illiteracy rate— for any language— at over 50%) contribute towards limiting economic options for most of the Reserve's population.

And while the 12,000 human inhabitants of Baimaxueshan are culturally rich, they are economically destitute. WWF fieldwork in the Reserve indicates that in 2001, per capita annual incomes were only 550RMB (~67 USD at 8.2RMB to 1 USD). This figure is well below the Chinese CPI-weighted domestic poverty line for 2001 of 630 RMB per capita, which at the time included only 3.2% of China's population, putting villagers in Baimaxueshan among the poorest of the poor in China (National Statistics Bureau of China 2004). As in much of China, arable farmland resources in Baimaxueshan are also very limited at .11Ha per capita, much of which is of poor quality and unevenly distributed between reserve villages. As a result, households in Baimaxueshan report on average 3 months of food shortage each year, generally at the end of the long winter, and often rely on "resold grain" (grain that is resold by the state to the place of production to meet food demands in time of natural disaster or famine) in order to survive (WWF-MPO ECPE 2004).

With little economic capital, public infrastructure, or educational opportunities, inhabitants of Baimaxueshan have traditionally relied on the Reserve's natural resources to provide a livelihood. As outlined in the introduction of this thesis, the main sources of income in Baimaxueshan have traditionally been (in order of most income earned to least): (1) hourly wages from working in state-owned logging enterprises, which closed down in 1998 following the establishment of the NFPP; (2) collection of NTFPs for trade and eventual export to Japanese and domestic markets—important NTFPs include the edible matsutake mushroom, *Tricholoma matsutake*, which cannot be cultivated artificially and fetches hundreds of RMB per kilogram to the collector, and "worm-grass", *Cordyceps sinensis*, which sell for 10,000-20,000 RMB per kilogram in Guangdong Province Chinese medicine markets; (3) butter, meat, and fertilizer production from yaks and yak-cow hybrids, both for household consumption and for trade with Hui ethnicity Muslim meat merchants, Buddhist monks from the surrounding monasteries, and hospitality workers from Zhongdian Township, a nearby center for domestic tourism; and, (4) agricultural income from barley, wheat, maize, rice, beans, honey and walnut oil.

This thesis focuses on the investigation of yak husbandry for butter and meat production as an income source for the inhabitants of Baimaxueshan. Yak husbandry is particularly interesting in Baimaxueshan because of its financial, cultural, and environmental impact on the Reserve. Direct cash income from marketing yak products (mainly butter) in Baimaxueshan are estimated to represent approximately 20% of total income, behind average incomes from the gathering of NTFPs but ahead of agricultural income (Wu Yusong 2005, pers. comm.). Nearly every household holds at least one cow, so that the milk it produces can be made into bricks of butter which are used both daily throughout the year for consumption of traditional Tibetan yak-butter tea with every meal and also for the making of the butter candles used in religious worship. In fact, this Tibetan area of northwest Yunnan Province is so tied to the production and consumption of yak butter tea

that it is an important stop on the historical *Chama GuDao*, or "Ancient Tea Horse Road", a trading route stretching from Burma to Lhasa that dealt in tea, meat, and yak butter between Tibet, China, and Southeast Asia (similar to the famed Silk Road, to the north, which traded textiles and porcelains from the east coast of China into Central and Southwest Asia). What is more, traditional forms of yak husbandry-related land use have had widespread and lasting influences on land cover of the natural environment, particularly in alpine meadow ecosystems.

*Land Use*

Just as land cover in Baimaxueshan can be organized according to altitudinal stratification, so can human land use patterns. Moreover, because of the yearly grazing cycle traditionally used by Tibetan yak-rangers, each altitudinal land use zone is also intrinsically linked to a particular season (for more on traditional livestock-based land use in northwest Yunnan, see Yuan and Wilkes 2001, Chan 2002).

| -altitude (masl)- | **Classification** | **Yak Husbandry Land Use** | **Economic Activity** |
|---|---|---|---|
| *1950m-2200m* | riparian lowland | homes, winter fodder fields, fenced winter pens | agriculture, commerce |
| *2200m-3400m* | mixed forest | some homes, spring/autumn grazing | NTFP collection, some grazing |
| *3400m-4300m* | alpine meadow | butter shacks, summer grazing | yak butter production |

**Table 2.1:** Altitude-based land cover and land use zones in Baimaxueshan

The riparian lowlands, from 1950m-2200m, are highly modified by human use. Much of the Reserve population lives in this zone, and the landscape is primarily a mixture of irrigated terraced and sloped grain agriculture, large Tibetan-style single

family courtyard homes (mostly wooden, with only a few concrete structures), dirt and rock footpaths within each village, and a mostly unpaved public roadway which parallels the Zhu Bao River. Some of the steeper slopes in this zone, particularly alongside the river, are left covered with deciduous shrubs and fruit or nut trees, such as walnut. In the coldest parts of winter from January through as late as April, range livestock, including yaks and yak-hybrids, are brought down from the alpine meadows and put into pens or fields directly adjacent to villages, or even kept within a home's courtyard. During winter, yaks cannot graze through the snow cover, and instead are fed occasionally with fodder reserves which, following Tibetan tradition and reverence for livestock, are often heated into a warm gruel-like form before being fed to the animal. Fodder is limited however, and animals typically lose much of their weight during this period.

Mixed forested areas, from 2200m-3400m, have some of the tightest land use restrictions in the Reserve. Some scattered smaller villages with homes of entirely wood construction exist through the lower half of this zone, typically a few hours hike from the unpaved main road and the river. Villagers here keep some small agricultural fields around the village center for grain and fodder production, but they are much smaller than the lowland fields, unirrigated, and have rockier soil. At the height of the summer rainy season, this forested zone becomes a very important economic resource, however, as matsutake mushrooms begin to emerge from the soils of family gathering grounds, scattered unevenly in secret hillside locations. Yaks and yak-hybrids are grazed in "forest rangelands" in this zone in the autumn and spring transition months, typically October through December, and as early as January up through May, depending on each year's temperature and rain conditions. Traditionally, villagers have used this zone to cut wood or gather underbrush for fuel and home and fence construction, sometimes leaving grassy and herbaceous open spaces under the forest canopy that can used for yak grazing during this critical transition time when winter fodder reserves have run out but high altitude alpine rangelands are still ice-covered or too cold for the yak-hybrids.

Occasionally, these areas are even seeded with grasses to encourage rapid growth in thin years. Current Baimaxueshan forest-conservation policy, however, restricts cutting for local use in these forests, and discourages spring and autumn yak grazing in "forest rangelands".

Alpine meadows, from 3400m and above through 4300m, are critical rangeland resources for yaks during the comparatively warm summer rainy season. No agriculture or permanent human homes exist at these high altitudes. Instead, Tibetan and Lisu rangers build temporary wooden shacks along semi-protected ridgetops which they live in and use to process yak milk into butter from May through October, or until the first snowfall. During this season, livestock graze continuously to regain weight lost during the winter months, and the cows are milked daily. Pure yak breeds thrive in the oxygen-depleted cold climates higher on the mountain, and will often graze above the yak-cow hybrids in this zone. Often, the Tibetan ranger who lives alone on the mountaintop is a young male member of a family, and will make the multi-day trek on foot back to his village weekly to deliver bricks of butter and to retrieve food and water for his alpine camp. Alpine rangelands are not fenced, but instead grazing rights in one location are generally understood to belong to a certain village in perpetuity. The health of these alpine grasslands are so crucial to yak husbandry that it is common for individual villages in this area of northwest Yunnan to set a certain beginning and ending date each year specifying when the villagers are allowed to move their yaks to the highlands. Traditionally, these rangelands have been managed through a combination of pruning along the treeline to prevent encroachment by the forest or to nibble out extended rangeland resources, and by semi-controlled burning every few years to manage invasive and inedible grass species, as well as provide for nutrient cycling. Both of these practices are now prohibited under Reserve forest conservation policy.

*Local History and Tenure Arrangements*

As stops on the "Tea Horse Road", the Tibetan areas surrounding what is now Baimaxueshan Nature Reserve have been involved in yak husbandry since as early as the Tang Dynasty (618-907AD)— only shortly after the introduction of Buddhism into Tibetan society, and centuries before Tsongkhapa's establishment of the Gelug (Yellow Hat) sect in 1391. As such, the local landscape has a rich history of livestock-related management that continues through the present day.

Before the founding of the People's Republic of China in 1949, few formal land management or tenure institutions existed in Baimaxueshan. Government presence of any kind was weak, particularly following the 1911 fall of the Qing Dynasty and their northwest Yunnan outposts. Yuan and Wilkes (2002), in an investigation of animal husbandry practices in neighboring Gongshan County, describe livestock management during this time as a mixture of semi-nomadism and free ranging with seasonal grazing schedules similar to those still used today. Population density of livestock was relatively low and stable due to a lack of capital or infrastructure to expand herd sizes.

Mao Zedong's Great Leap Forward (1958-1962) and Great Proletarian Cultural Revolution (1966-1976) were times of rapid change for the land and people of Baimaxueshan. Xu (2004) describes how during the Great Leap Forward, deforestation accelerated rapidly as trees were cut to fuel backyard steel furnaces that burned around the clock, and as fields were cleared from forested areas in an attempt to achieve local self-sufficiency in grain production. Some of the rangeland areas that are used today, particularly in the mid-altitude mixed-used forest zone, were created during this period.

According to Reserve management, the first of the area's large rangeland collectives or communes was established in 1972. During this time, the county took ownership and management of all livestock and rangelands in the area

(technically property seizures began as early as 1958 in northwest Yunnan, however government presence was initially weak in many of the more remote areas surrounding Baimaxueshan). In this period of state control, county-level rangeland managers sought to increase herd sizes through seeding of grasses and winter fodder plants in alpine meadows, introduction of lowland cattle species, *Bos taurus*, to create hybrids more tolerant to warmer temperatures in lower altitudes, and through expansion of alpine rangeland into forest areas. During this time, the large state-owned logging companies were established and began intensive organized logging of forests in the region, causing great ecological damage but providing employment for tens of thousands of locals.

Rangeland communes began to dissolve in 1980 in Baimaxueshan with the introduction of Deng Xiaoping's Household Responsibility System. During this time, livestock were given to individual households roughly based on family size. Usage rights for state-owned alpine rangelands were generally reassigned to a neighboring village, based upon the human (and livestock) population of that village (Banks et al 2003). Ownership of most mixed-forest rangeland areas was retained by the state, and small winter grazing plots were generally assigned to the natural village. Debate exists over to which entity was granted ownership of the alpine rangelands, but it is generally believed to be held by the county government (e.g. Deqin or Weixi Counties), while natural and administrative villages are given temporary management rights (see Ho 2000). With *de jure* management and ownership rights unclear, however, *de facto* usage rights at the village level then tend to fall to the individual households with the most cattle, though this too varies from village to village (for more on local rangeland tenure arrangements, see Banks 2001, Xie et al 2002, and Banks et al 2003).

Because household tenure rights and long-term land leases were never formally assigned for alpine rangeland after the closure of state communes (as they were for

agricultural areas), *de facto* collective management—or lack of management— by cattle-holding households within a single natural village has become widespread.

In 1983, Baimaxueshan Nature Reserve was established in Deqin County primarily for the protection of the endangered Golden-Haired Yunnan Snub-Nosed Monkey. Borders for the Reserve were set based primarily upon ecological data concerning the habitat and range of this species (Long et al 1996). The Reserve was established first as a Provincial level reserve, and then upgraded to National (State) level owing to the importance of it biodiversity and levels of endemism. In 1999, the borders of Baimaxueshan Nature Reserve were expanded southward to include threatened primate habitat around Gemerong Administrative Village in northern Weixi County.

With the establishment of the Reserve, heavy restrictions were placed on land usage by the local people now living within the borders. All logging was forbidden within the Reserve, with exceptions made only on a household-level contractual basis for carpentry and collection of fuel wood. For fear of forest fire, traditional management of alpine rangeland through burning was prohibited as well. In part to address concerns about local access to natural resources in the Reserve, Baimaxueshan today is divided into three zones of land usage. A "core zone", where no human entrance is allowed; a secondary "buffer zone", where only very limited extractive uses are allowed, such as a gathering of NTFPs and some livestock grazing; and an "experimental zone", where tourism, agriculture, and livestock grazing are permitted. Such zones are required by Chinese national nature reserve law. In actuality, however, land use restrictions in these zones are routinely ignored (for example, all mid-altitude mixed-forest rangelands would be prohibited by these regulations), and Reserve management staff admit that the irregular boundaries of each zone are poorly understood by the staff themselves, let alone local villagers. For example, though no human land use of any kind is

officially permitted within Baimaxueshan's "core zone", in reality, many of the Reserve's alpine rangelands are actually wholly contained within these areas.

Other recent regional and national developments which have impacted the ecology and people of Baimaxueshan include the Natural Forest Protection Program (NFPP) and the Grain to Green Program. As mentioned above, the anti-logging and anti-erosion NFPP was enacted by Chinese Premier Zhu Rongji in October of 1998 in response to a summer of devastating floods along the lower Yangtze River that killed over 4000 people. This regional policy gave one year for the complete shutdown of the state-owned logging enterprises that had operated for decades along sloped hills of the upper Yangtze and Yellow River watersheds in western China. Even though this did not apply directly to Baimaxueshan, which, as a nature reserve, had already prohibited logging, it did affect families living within the Reserve, many of whom relied on the incomes of brothers and sons who worked in logging outside the reserve. The 2000 Grain to Green Project, a national "sister" project carried out in 174 counties throughout the same region as the NFPP, aimed to compensate farmers who retired farmland and planted trees on areas sloped more than 25 degrees. This project, now largely defunct due to lack of funding and national oversight, was carried out in Baimaxueshan to a limited extent on a trial basis with only minimal effects on land use or land cover patterns.

Most recently, Baimaxueshan has seen a host of domestic and international NGO-based projects carried out within its borders that aim to either strengthen conservation efforts, quicken human and infrastructure development within the Reserve, or achieve both simultaneously. One notable and early example is the WWF-China ICDP, which began in 2000 and has up to now focused on sustainable community-based management of NTFP resources and markets.

*Government Hierarchy and Legislative Framework*

In an arrangement common in China, responsibility for conservation and development activities in Baimaxueshan Nature Reserve falls under numerous government organs and historical pieces of legislation at the national, provincial, prefecture, county, and reserve levels. While this structure is important for understanding the formal legal context of the Reserve, its effect on the reality of on-the-ground management is often limited by staff capacity, fiscal obligations, or the individual priorities of a local official. As such, the following frameworks should be considered in light of realities of Chinese governance.

Though not universally applicable, one useful rule of thumb in interpreting the Chinese legal structure is to treat local regulations and officials as having at least temporary *de facto* power to trump possibly conflicting sets of regulations at higher levels. Higher-level legislation might take *legal* precedent in such situations, but, in practice, local regulations are more often enforced. Though this dictum is becoming less valid over time as the Chinese central government attempts to strengthen the national legal system, centralize authority structures, and root out "corruption" at lower bureaucratic levels, the general rule is nevertheless illuminating at all scales and particularly so in relatively remote and rural areas like Baimaxueshan. [For extended discussion of the parallel yet overlapping CCP and Chinese central government structures, including reform and political trends, see Edmonds 2000, Chu et al 2004, and Lieberthal 2004. This thesis avoids the complexities of the party-state interaction and, instead, focuses on what state-based *de jure* legal framework does exist and its *de facto* implementation at local levels.]

As a National Reserve, Baimaxueshan receives funding from the Chinese central government to pay for a network of ranger stations and 40 member reserve staff. Other welfare and development funding for the Reserve's human inhabitants is supposed to come from the government coffers of Deqin County and Diqing Autonomous Prefecture, though recent NGO investigation suggests that money that is earmarked for use in the Reserve is generally spent on projects elsewhere in the

county (pers. comm. 2004). Ownership of Baimaxueshan's actual land area is retained by the national government. Official control of the reserve, however, lies with the Yunnan Provincial Forestry Department, which handles the management a total of 96 out of the province's 111 nature reserves (only 6 of them national level—see Clarke GMS). Because of its managerial oversight, this provincial organ is indirectly responsible for the livelihoods of many of the 1 million Yunnanese who live in or around nature reserves, half of whom are in poverty (Li 2003).

Below the provincial level, the area surrounding Baimaxueshan in northwest Yunnan is controlled by government and party cadres of Diqing Tibetan Nationality Autonomous Prefecture, which is a somewhat abnormal Chinese administrative unit created in areas with particularly high concentrations of ethnic minority populations. In theory, the autonomous prefecture structure ensures that state-assigned local leaders will be of the same ethnicity of their constituents and therefore be able to better represent them. In practice however, such autonomous prefectures rarely have any autonomy outside of certain limited budgetary freedoms not granted to other areas (due to high rates of poverty, Diqing does receive annual budgetary supplements from the central government). Within Diqing Prefecture lies Deqin County, which, as described above, controls Baimaxueshan mainly through allocation of development funds received from prefectural authorities.

Within Baimaxueshan Nature Reserve, authority is split between two entities. Local implementation of political and many human development directives (national, provincial, prefectural, and county) comes primarily through township-level governments (for example, in Baimaxueshan, Xiaruo is both an administrative village and a township, which generally has wider geographic coverage). Township governments are led by mayors, include such entities as the Bureau of Agriculture and Animal Husbandry, and are the smallest official units of government in China. Meanwhile, Nature Reserve Management Stations, found in each administrative

village and in some large natural villages, are responsible for implementing and enforcing reserve-oriented conservation and, increasingly, human development projects and regulations that are passed from national and provincial (but not prefectural) organs through a central Nature Reserve Office in Deqin Town, capital of Diqing Prefecture.

Natural villages, or hamlets, exist with only informal structure. Often represented by a village elder or small committee of villagers, they are not recognized as a governmental administrative unit, and generally have no budget or coercive power. They have been shown, however, to be somewhat effective units for voluntary collective management, particularly for agriculture and NTFP collection but not for animal husbandry.

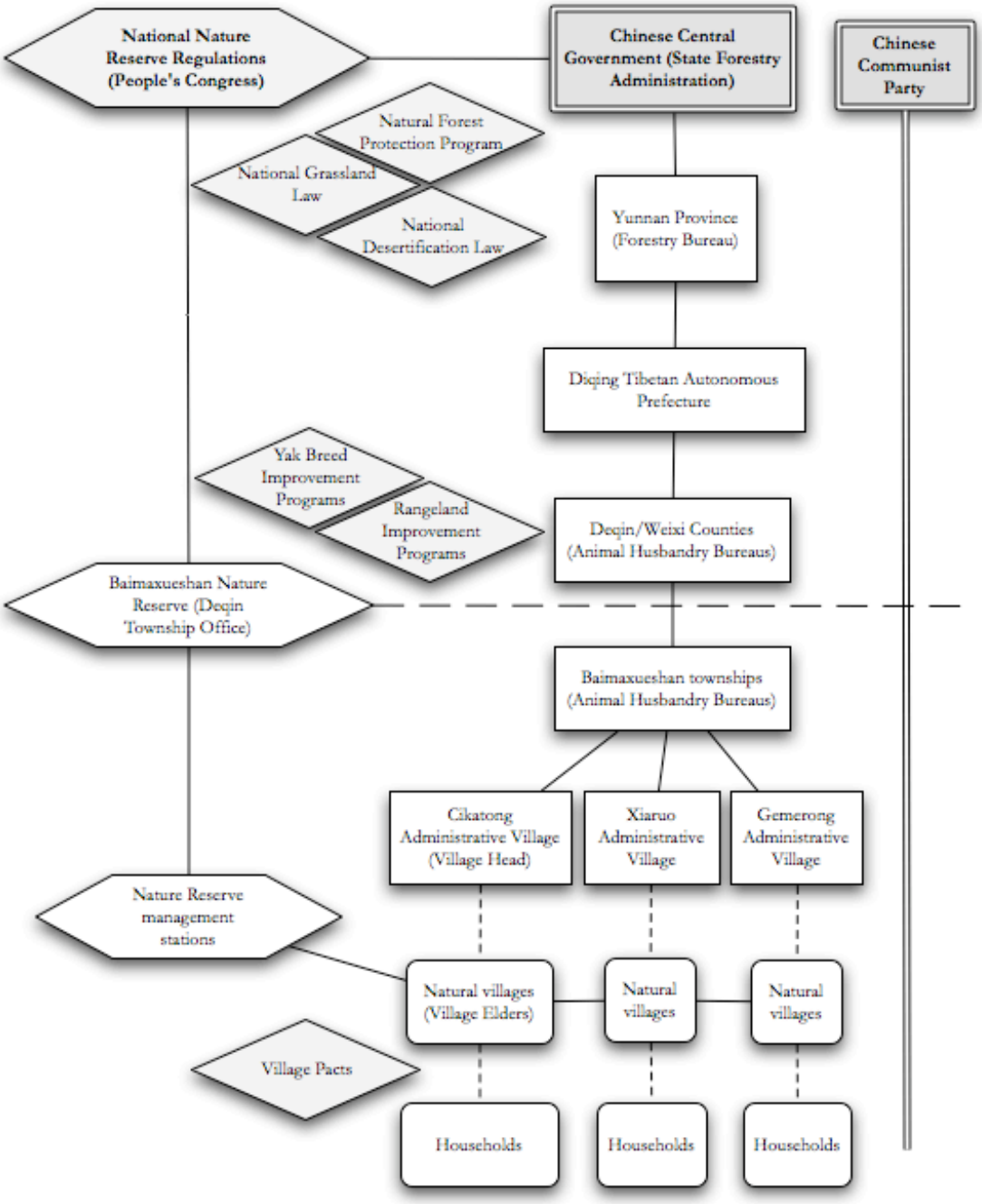



**Figure 2.1**: Overview of legislative and governmental hierarchy affecting Baimaxueshan herders

Existing legislation which applies to yak husbandry in Baimaxueshan includes:

*National Nature Reserve Regulations* These regulations, updated in 1994, take precedent over all other national and local-level environmental or land use

regulations for the 1000+ national nature reserves in China. Often interpreted alongside their Yunnan Provincial counterpart nature reserve regulations, this legislation outlines permissible and prohibited land use within nature reserves, associated fines and punishments for transgressions, and the goals of the nature reserve system—which include both ecological conservation and economic development. Many of the articles contained within, however, can be viewed more as ideal guidelines for nature reserve management rather than immutable law, as they often are simply irreconcilable with local social, economic, and budgetary contexts.

*National Grassland Law* Originally created in 1985 and updated by the 9th People's Congress in 2002, the rather terse Grassland Law provides general guidelines for, "improving the protection, management, and development of grasslands and ensuring their rational use." In doing so, it addresses the need to simultaneously protect the natural environment, modernize animal husbandry, enhance local economies (particularly in autonomous regions), and, "meet the needs of socialist construction and the people's life." Most articles are left quite vague, apparently open to interpretation as fit at more local levels.

*National Desert Prevention and Transformation Law* Adopted by the People's Congress alongside the updated Grassland Law in 2002, the Desertification Law highlights the need for grazing intensity to be carefully controlled so as to prevent loss of rangeland resources to permanent desiccation. It is similar in form to its companion Grassland Law.

Conservation and development plans which affect Baimaxueshan include:

*The Great Western Development Plan* Drafted in 2000, this state-level project targets 12 western provinces and is meant to close the development gap between China’s relatively poor, rural, inaccessible, and geo-ethnically diverse West with

the more prosperous eastern seaboard. Though this initiative does encourage environmental improvement as important to economic development in poor areas, it does not currently recognize the place of China's nature reserves as vehicles in implementing ecologically-integrated development.

*Wildlife Conservation and Nature Reserve Construction Project* This 50 year program, initiated in 2001 and administered by the Chinese State Forestry Administration, aims to expand the overall size and administrative capacity of the national nature reserve system by expanding coverage to 18% of total Chinese land area (up from 13.5% in 2001) and increasing overall funding (Li 2003).

*Yunnan Province Grassland Ecology Conservation Construction Plan* Covering the period from 2003-2010 and issued by the Yunnan Province Agricultural Ministry and the Yunnan Province Development and Planning Assembly Commission, this plan outlines the current state of degradation of Yunnan's grassland ecosystems, noting the impact on animal husbandry. To address this, it offers two frameworks: the "10 Great Constructions" and the "4 Great Systems", which are meant to improve rangelands through artificial planting, ongoing scientific surveys, and heightened levels of "enforcement".

*Yunnan Nature Reserve Development Plan* Announced in 1998 by the Yunnan Provincial Environmental Protection Bureau (EPB) under requirement from the Chinese State EPB and State Planning Commission, this provincial-level plan complements the "Nature Reserve Construction Project" (above). It aims to increase nature reserve coverage within Yunnan province to 8% by 2010 while increasing funding and staff capacity (Li 2003).

*Village Based Integrated Poverty Alleviation Plan for the Poorer Western Region* The national "Village Plan", started in 2001, aims to shift poverty alleviation from the township or county level to the administrative village allowing better targeting

and integration with other local development activities. In Yunnan Province, for instance, local governments have developed draft plans in over 4000 administrative villages. After each plan is fully developed, it must be presented to the county People's Congress for approval. Provincial and central government funds of 50,000 to 100,000 USD per village are then provided to support implementation of the plan. Since it takes place at a local level and is meant to be "integrated", village-based planning could potentially take into account environmental considerations, but anecdotal evidence suggests that village plans may be doing little to increase efficiency of conservation or development.

This thesis dwells in realms of both *land use* and *land cover*. To gain a deeper understanding of both of these, then, and at the human-environment interplay between, two distinct analytical perspectives are leveraged: (1) qualitative analysis of interview-based fieldwork with local stakeholders in Baimaxueshan that investigates the trends and driving forces behind yak-husbandry land use, and; (2) quantitative analysis of time series Landsat satellite remote sensing imagery that measures changes in alpine rangeland cover since 1992. Taken together, these two techniques illustrate narratives of the interface between humans and the environment in Baimaxueshan more completely than either method alone.

With the simultaneous increase in accessibility of satellite remote sensing imagery and GIS capability alongside growing interest in on-the-ground validation of remotely sensed land cover analyses, such interdisciplinary methodology is gaining popularity internationally. This is particularly true for investigations of indigenous peoples' resource use at the spatial scale employed by this thesis (in NW Yunnan, see Willson 2005 and University of Wisconsin-Madison Southwest China Project; in Asia see Zomer et al 2001, Müller and Zeller 2002, Rees et al 2002, Thomas et al 2003, Nagendra et al 2005, and East-West Center MMSEA Project; worldwide see Escamilla et al 2000, and Nyerges and Green 2000, among others).

*Investigation of Land Use*

Fieldwork in Yunnan Province was conducted in the summer of 2005, and was based upon scoping and background investigation of Baimaxueshan Nature Reserve with WWF in the summer of 2004. Primary fieldwork consisted of meeting with Kunming-based NGOs and Kunming Institute of Botany researchers with ongoing projects in northwest Yunnan, acquisition and translation of

Baimaxueshan-related grey literature, and semi-formal interviews with Baimaxueshan Reserve Management staff, cadres from local township and village-level governments, and villagers with livestock-holdings of various sizes across 3 administrative villages (out of 12 total) in the southern half of Baimaxueshan Nature Reserve: Cikatong Village, Xiaruo Village, and Gemerong Village.

Initially, 36 household interviews were conducted over the course of two weeks by the author with the help of local guides, usually reserve staff (with particular help from Zhongtai and Wu Jin), who were familiar with the area and, in general, with the families in each village. Interview discussion took place under informed consent as required by the Stanford University Internal Review Board's Human Subjects Protocol, and was conducted in the respondent's local language (usually a Tibetan dialect, though some respondents spoke a Lisu dialect instead), translated to Mandarin, and recorded by in a notebook in English during the interview. Because of the need to communicate through an intermediary language, accuracy of some responses was unsatisfactory, and so some interview results were discarded. Interviewees were not financially compensated for their responses, but each did receive a name card with tri-lingual contact information for the author in case of questions.

Based upon village size estimates from WWF and Nature Reserve Management, these 36 interviews across three administrative villages (comprising roughly 15 natural villages or hamlets) represent about 5% of the population in this part of Baimaxueshan when total family size of the interviewee is included. In each natural village in which interviews were conducted, two to three households were visited in semi formal interviews which lasted anywhere from 20 minutes to 3 hours depending on the interviewees' enthusiasm about animal husbandry in Baimaxueshan, proximity to meal times, and the availability of freshly brewed yak-butter tea. Most interviews were conducted with men, and an inquiry for an interview was never refused, though some interviewees were concerned that they

did not know enough about yak husbandry, or did own enough yaks, to be useful in answering any questions. Often, one interview would conclude with the interviewee leading the author and translator to another household in the village where someone might be at home.

The following question list, created from an initial series of scoping interviews to identify important issues for investigation, formed the outline for each interview, though interviewees often elaborated on related points or issues not directly addressed by these questions, and these responses were recorded to the best of the author's understanding and ability:

> 1. 10 years ago, what were your household's three main sources of income, from highest to lowest? What are they now?
> 2. Of these three current income-generating activities, which one do you think is most important personally and culturally?
> 3. How many head of cattle did your household have 10 years ago. How many does it have now? Why the change in numbers? How many are female, and how many are male?
> 4. In general, has your total household income and quality of life increased, decreased, or remained the same over the past 10 years? [usually, I was offered a reason for the change]
> 5. Is the average amount of milk produced by each cow each year less, more, or the same as 10 years ago?
> 6. Over the past 10 years, have you noticed any changes in summer alpine rangeland quality? How has it changed?
> 7. Do you think the rangeland you are currently using is enough for your household's herd? Do you plan to increase or decrease herd size in the future? Why?
> 8. What do you see as the main problems your household faces in animal husbandry?

Later, 20 more interviews were conducted by a local schoolboy at the direction of the author to investigate the value that more wealthy households in Xiaruo Administrative Village place on yak husbandry, and their willingness to explicitly pay for it. These interviews, conducted across six different natural villages, were slightly more simple than the core interview above:

> 1. How many head of cattle does your household have today?
> 2. Do you plan to increase or decrease herd size in the future?
> 3. Is the average amount of milk produced by each cow each year less, more, or the same as 10 years ago?
> 4. Over the past 10 years, have you noticed any changes in summer alpine rangeland quality? How has it changed?
> 5. Would you be willing to pay a yearly per-yak rangeland use fee to your natural village, in a fund to be shared across the natural village for rangeland upkeep costs or fertilizer purchase for households without cattle holdings?
> 6. [if yes to above] How much would you be willing to pay, annually, per head of cattle?
> 7. What is your yearly household income?

Though all household interviews were conducted anonymously, usually with the head of a herding family, in his home, each interview was organized by location of the natural village (hamlet) of the interviewee, and included basic demographic information including ethnicity, family size, and the author's estimate of interviewee age. Efforts were made to achieve a statistically random sample in interviews, but this proved logistically impossible for three reasons: there exists no central list of Baimaxueshan households from which to randomly draw interview subjects; interviews were conducted in July and August during the first weeks of strong rains in Baimaxueshan, when valuable *matsutake* mushrooms begin to

emerge, and so most villages were nearly empty of people as entire families hunted fungus in the forest: and, at the time of interviews, many yak-herders had already decamped to alpine summer rangelands with their herds, and heavy rains and landslides made travel to those areas difficult.

To increase the representative value of the household interview sample, then, the author attempted to stratify respondents based upon geographic village location, village altitude and proximity to the public road, family income level and primary livelihood activities, cattle herd size, gender, age, and ethnicity. This was done with the help of locals and Nature Reserve rangers who were often familiar with the natural villages visited, and sometimes even individual households.

Because the author was led by Reserve staff for approximately half of the household interviews, it is possible that some bias might have been introduced through interviewee selection or even translation. However, the author lacked any impression of sampling bias on this account, as the guides typically suggested a natural village to visit, but actual interviewees were chosen based mostly on chance of who actually happened to be in a village upon arrival. Additionally, staff guides did not seem to be pursuing a particular agenda, and in fact seemed very interested in themselves listening to what interviewees had to say about yak husbandry in the Reserve. Moreover, without these staff guides to lead me to villages, translate interviews, and provide introductions, no interviews at all would have been possible.

In part to address this concern of bias, though, additional interviews were conducted in a more independent fashion in easily accessible lowland villages in Xiaruo with the aid of only a local schoolboy to act as translator. Here, houses were more or less randomly selected upon walking past a village, without suggestions from any figures of authority.

Another concern for interview accuracy or bias was that some villagers might have been reluctant to provide certain information to an unknown (and somewhat suspicious-looking?) foreigner who asked not immediately intuitive questions about resource use. So even though no audio equipment was used to record interviews, no names were asked or recorded, and no questions pertaining to illegal activities were asked in a measure to minimize interviewee anxiety, it is possible that interviewees in some circumstances might have been wary of providing information about resource use that they might have *perceived* to be illegal, even if it was not. This topic is addressed later in the analysis of shifts in livelihood patterns due to reserve regulations.

During this time, both Baimaxueshan Nature Reserve Management staff and local government officials at the natural village, administrative village, and township levels and were also interviewed concerning animal husbandry practices, rangeland degradation, social development, and future management plans for the reserve. These interviews were typically longer, more open ended and informal discussions. Official interviewees agreed to be interviewed by name, but no notes were taken during the interview. Instead, the author recorded summary notes for the interview immediately following conclusion of the discussion.

*Investigation of Land Cover*

Geographic analyses of land cover change in Baimaxueshan in this thesis center around time series Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper (ETM+) Earth-sensing satellite imagery. Such data is particularly useful for analyzing land cover vegetative change—such as alpine rangelands in Baimaxueshan— because of its compatible spatial, temporal, and radiometric scales.

Spatially, Landsat data has an irreducible pixel size of 28.5 meters, and data is distributed in scenes ~185km (2 degrees) on a side, which means it has both a spatial resolution fine enough to characterize alpine rangelands which range from 100-2000m across while having a wide enough swath to cover much of the 200km-long Baimaxueshan Nature Reserve.

Temporally, Landsat collects data of the same location on the Earth approximately every 15 days, and the combined database of images acquired from the Landsat TM and ETM+ sensors extends from the mid 1980s through present day. This time scale made it possible to analyze imagery from near-anniversary dates over a decade-long time series from 1994-2002, a time period of rapid change in Baimaxueshan's animal husbandry land use.

Radiometrically, Landsat records reflectance data about Earth land cover in a series of 7 bands across the electromagnetic spectrum. These bands are narrow enough and positioned so as to provide both "true-color" panchromatic imagery of land cover and also useful information about vegetation cover and biomass, leaf-area index, and plant stress when manipulated mathematically using a ratio known as the Normalized Difference Vegetation Index (NDVI).

The effectiveness of using Landsat TM and ETM+ imagery to monitor alpine rangeland at this scale has been demonstrated (Shi et al 1999, Willson 2005) and the NDVI calculation has been found most useful and accurate in describing rangeland health/degradation as a result of domestic overgrazing in NW China (Liu, et al 2004). Similarly, this analysis uses a time series of eight Landsat satellite images of southern Baimaxueshan Nature Reserve to discern changes in alpine rangeland patch composition, extent, and vegetation cover relative to nearby forested patches. This is meant to quantitatively illustrate the changes in land cover that both resulted from and drove land use change among Baimaxueshan yak herders over the 1990s.

To achieve this, eight satellite images were acquired from Chinese and American data clearinghouses of WRS path 132, row 41, showing the southern portion of the Reserve area (measuring roughly 20x70km). Image acquisition dates were chosen in the late-fall months of 1994, 1995, 1996, 1997, 1999, 2000, 2001, and 2002. Phenologically, this image acquisition date approaches the winter "leaf-off" season, but is before the first winter snow in most images, and follows the long summer grazing period of alpine rangelands. Such seasonality of images is acceptable, then, but imperfect. However, these image dates are also chosen out of necessity—cloud cover in these alpine regions is so heavy in other years and at other seasons that satellite imagery is unusable.

Standard preprocessing, georeferencing, and coregistration was performed for this image set using RSI ENVI, IDRISI Kilimanjaro, and ESRI ArcMAP GIS and image analysis computer software packages. Following image identification and purchase, each image was reprojected to a WGS-1984 UTM 47N standard with 30m pixel width. While all purchased imagery was formatted with georeferenced positions upon delivery, the quality of the georeferencing was quite poor (greater than 15pixel = 450m difference among images), making these numbers unusable for analysis. Fortunately, the author was able to make field measurements with a Garmin 12XL handheld GPS unit, which indicated that the 2001 Landsat ETM+ image was well georeferenced with real world geographic coordinates. Therefore, this image was assigned as a master reference for the other seven image dates. After subsetting all images around the southern portion of the reserve, each image was georeferenced to the 2001 master using twelve user-selected ground control points. RMS error ranged from .3-.8, and overlaying the images showed pixel offsets of about one pixel. These errors are not excellent, but are satisfactory given the scale of analysis and the difficulty of georeferencing in such a dynamic vegetation-covered environment.

A mask was created from the Baimaxueshan Reserve border based upon a hand-digitized, projected, and georeferenced map image. Additionally, each image was registered to a Digital Elevation Model (DEM) of 90m (3 arc second) surface spatial resolution as provided by the June 2005 free release of USGS Shuttle Radar Topography Mission (SRTM) data. This DEM assigns an altitude to each pixel in the Landsat image scene, which is particularly useful for spatial analysis of land cover in mountainous regions such as Baimaxueshan with extreme vertical relief. Due to the nature of the NDVI-based time series analysis of vegetation trends in the Reserve, however, neither topographic nor atmospheric corrections were performed to preserve precision of sensor data (see Song et al 2001).

Field measurements were also taken the summer of 2005 in Baimaxueshan to collect "ground truth" data to train user-identification of rangeland cover in the Landsat imagery. Thirty points were taken throughout the study area of the reserve and particularly around villages where household interviews were conducted, pictures were taken, and notes were recorded to describe both land cover and land use. However, because of harsh weather and terrain, and a lack of local villagers willing to make the multi-day trek from the valley floor to the alpine rangelands, the author could only visit in person a handful of rangelands to note land cover to compare with the satellite imagery. A formal and statistically-rigorous accuracy assessment of image analysis, then, is impossible. To address this, additional estimates were taken describing the distance and compass bearing of alpine rangelands that were visible from lower parts of the valley as identified by local rangeland users during household interviews. These data, then, alongside observations made about actual land use for particular rangelands during household interviews throughout the reserve (in terms of seasonal use patterns, grassland quality, and grazing pressure), help to inform accurate image analysis.

The actual methodology used for analysis of temporal changes in rangeland vegetation is quite simple and easily repeatable for similar investigations. Using the

Reserve mask mentioned above along with geographic coordinates of villages taken during fieldwork, the southern reserve area was roughly divided into three sections, each one representing the "sphere of influence" of an administrative village as outlined above in by fieldwork: Cikatong Village in the far north, Xiaruo south of that, and Gemerong farthest to the south. Based upon field observations and image interpretation in the lab, 6 patches each of alpine rangeland and forests (within 1 km of chosen rangeland patch) were chosen along the southern face of mountain ridges (to avoid topographic sun shading) in each of 3 villages. Altitudes of the chosen 36 patches were primarily between 3700m and 4100m above sea-level, squarely in the "alpine rangeland" land cover/land use band of reserve topography identified above.

Each of these 36 patches were relatively small, 9 pixel squares (~90m on each side), and consistently applied to the same geographic area in each of the 8 satellite images over the decade-long time series. Next, an NDVI calculation was performed for each pixel of the 8 time series images to identify variations in vegetation cover and health (a Soil-Adjusted Vegetation Index (SAVI) calculation was also performed with varying coefficients of aridity for the images to test for the usefulness of applying this related vegetation index, but overall correlation with NDVI was very high, so further SAVI calculations were deemed redundant). Using the NDVI values from each of the 9 pixels in the 36 patches across the Reserve, minimum, maximum, mean and standard deviation values were calculated for each patch in each year, and plotted to identify trends and anomalies between both rangeland and forest sites across varying altitudes and villages locations.

Further geographic land cover analyses and visualizations, including the graphing of total vegetation densities across altitudinal bands in the Reserve to identify natural breaks in land cover, were performed to complement the methodology outlined above.

The purpose of all these spatial land cover analyses is to be able to quantify changes in alpine rangeland vegetation composition, density, and extent relative to nearby forested areas. During field interviews, local land users from around the reserve reported changes in all of these variables. Additionally, other researchers in the area have predicted or observed related changes in alpine rangelands over the past decade. This use of satellite imagery, then, provides a comprehensive and objective illustration of actual on-the-ground trends to either support or refute the qualitative assessments gained through fieldwork. At the same time, field interviews provide direction for image analysis and act as check against "runaway" lab-based image interpretations which seem to be supported by the numbers but in actuality do not fit in with the realities of land use in the Reserve. Field interviews and image analysis are both powerful tools. And taken together, they tell convincing narratives of the human-environment interplay of yak husbandry in Baimaxueshan.

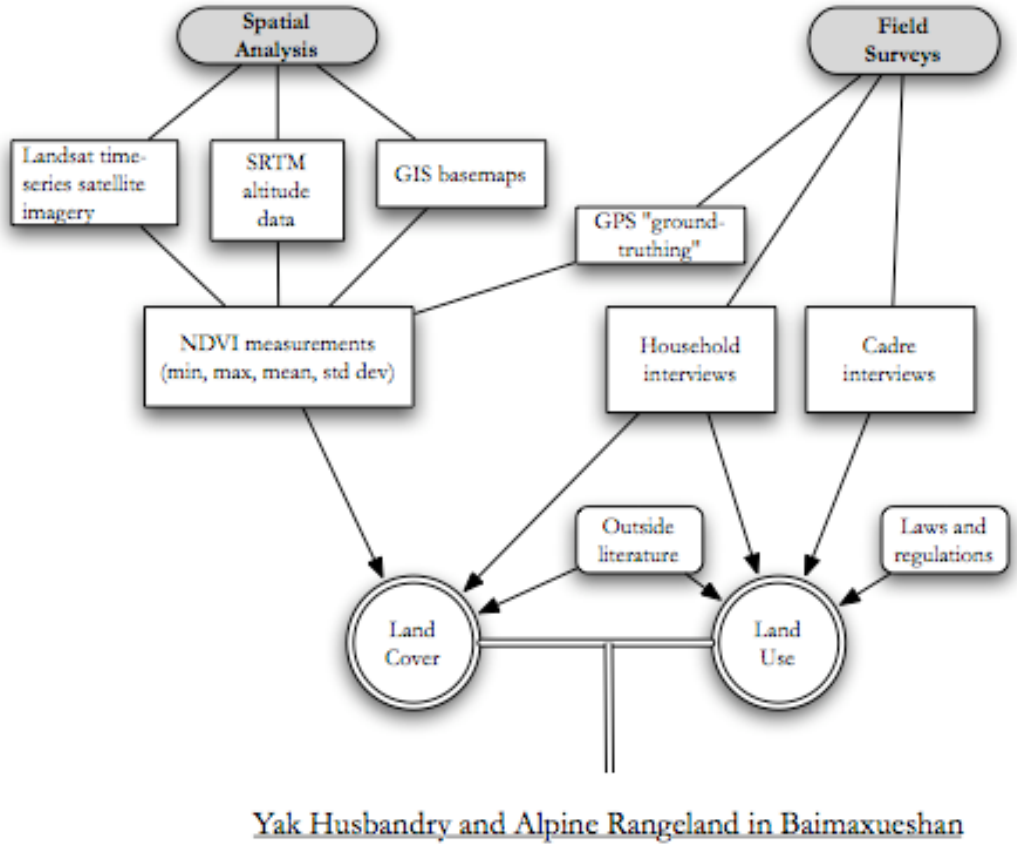
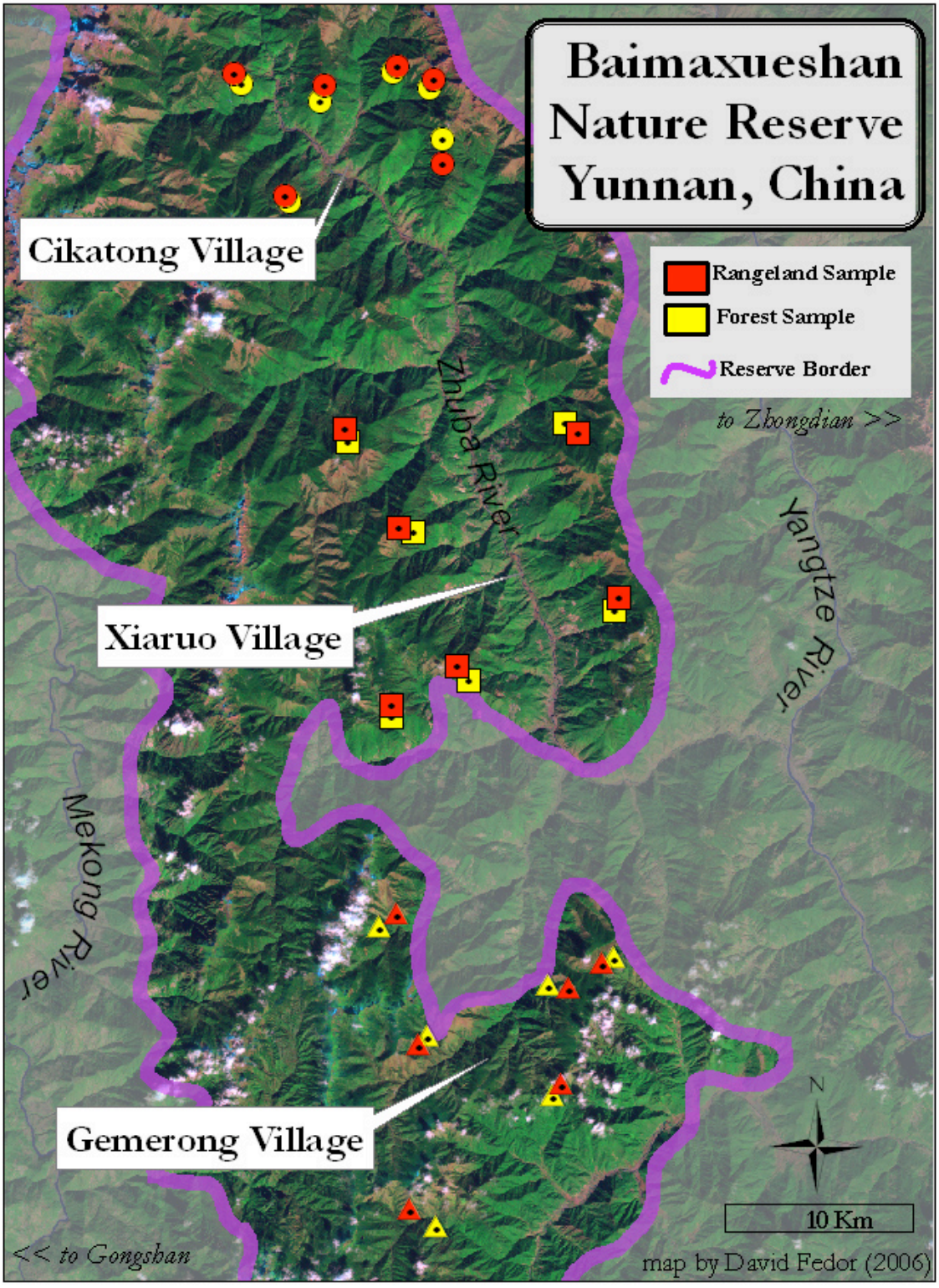



**Figure 3.1**: Integration of spatial analyses with field surveys




**Map 3.1**: Baimaxueshan Nature Reserve with NDVI sample sites

Conservation and development are continuous processes in Baimaxueshan as elsewhere. As such, the following section, though it results from analysis and consideration of diverse data, does not offer conclusions. Instead, it attempts to illustrate two plausible (and ongoing) narratives of yak husbandry in Baimaxueshan Nature Reserve over the past decade: (1) yak husbandry expansion; and (2) alpine rangeland degradation. These broad interpretations of the forces that drive human and environmental welfare in Baimaxueshan are intended to provide a comprehensive and useful foundation for researchers, managers, and community members.

Yak Husbandry Expansion:

> Restrictions on logging, once the primary source of income in the region, have caused families to begin raising yaks or to increase their herd sizes to replace lost income.

This hypothesis was tested primarily through field surveys and a review of literature pertaining both to Baimaxueshan and similar neighboring regions. Though drivers varied across different administrative villages in the Reserve according to special circumstances, the effect was generally consistent:

> Restrictions on logging have *indirectly* led to larger herd sizes, and that this effect is *intensified* by increased market demand from the local tourism industry and cultural preferences for yak-rearing.

*-Phenomena-*

Average herd sizes in Baimaxueshan have increased through the past decade, and will continue to increase. Out of 36 current yak holders interviewed in Baimaxueshan, 24 have increased the size of their yak herds over the past decade, 10 have decreased, and 2 have not changed. This phenomenon is more pronounced in the poorer households of Gemerong and Cikatong Administrative Villages, which are higher in altitude and farther from the Reserve's main river and road. Here, among 22 households interviewed, 18 have increased their herd sizes over the past decade while only 4 have decreased. In richer Xiaruo Administrative Village, however, where agricultural landholdings are relatively large, productive, and widespread, the ratio was even: 6 households having increased, 6 decreased, and 2 without change.

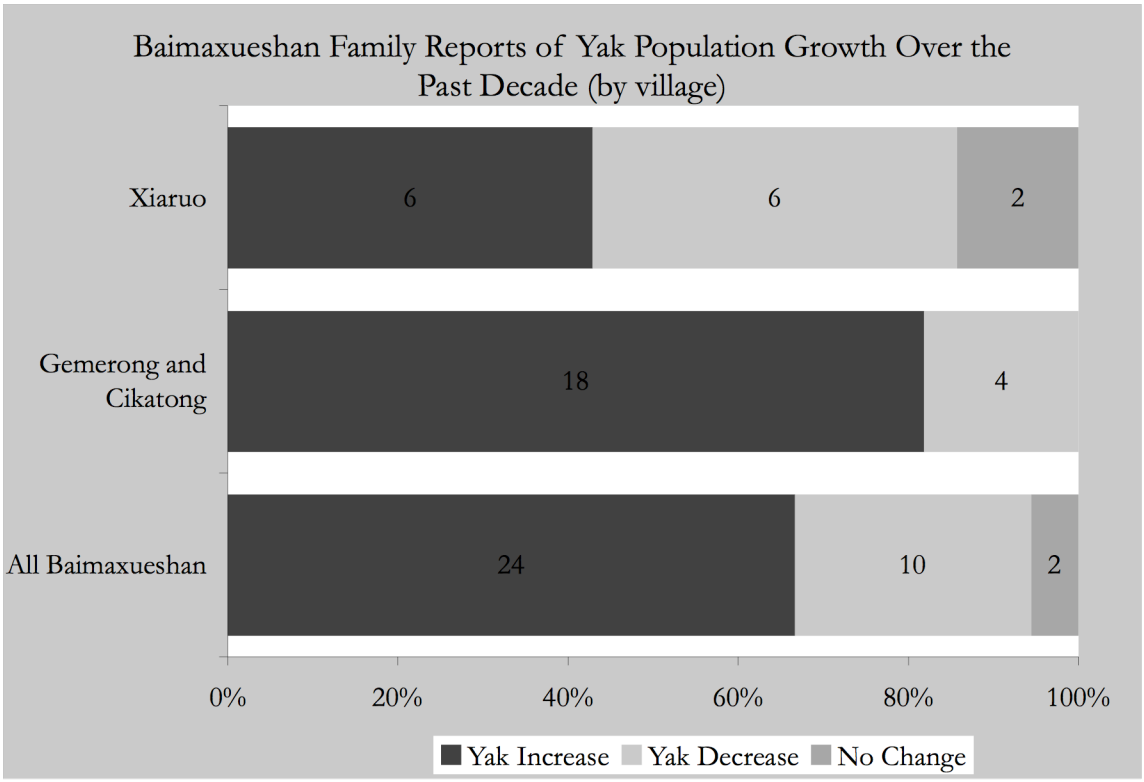



**Figure 4.1**: Yak husbandry expansion from 1995-2005

The household of a typical interviewee in Gemerong or Cikatong currently holds about 15 head of cattle and has an average household size of 5 or 6 people, giving an average of approximately 3 cattle per household member in these poorer regions of Baimaxueshan. This figure, however, represents average cattle holdings of families in Gemerong and Cikatong which specialize in animal husbandry rather than NTFP foraging or other livelihoods. Among poorer households in Gemerong and Cikatong that do not specialize in animal husbandry, 4-5 head per family is more common. Farmers in lowland Xiaruo, who do not specialize in animal husbandry, typically hold between 5 and 10 head per family— more cattle than their poor, highland non-specialist neighbors, but less than Gemerong and Cikatong animal husbandry specialists. Of households that have increased their cattle holdings and specialize in animal husbandry, herd sizes across the board have approximately doubled over the past decade, usually representing an increase of 8 or 9 cattle per family.

| | Cikatong and Gemerong Yak Herders | Cikatong and Gemerong NTFP Collectors | Xiaruo Farmers |
|---|---|---|---|
| average # of yaks per family | 15 | 4-5 | 5-10 |

**Table 4.1**: Average number of yaks among families in different villages

Overall, these changes are dramatic, particularly at the natural village level. In a small natural village along the public road on the south side of Cikatong, for example, the village head reported an increase from 60 head in 1981 to 260 head today for the entire village. In another village along the north of Cikatong, the village head estimated that the village currently holds over 200 cattle, up from 60 in the early 1990s.

Similar trends in the increase of cattle herd sizes are reported in local government records and by researchers in other areas of Baimaxueshan. A WWF-sponsored research team from the Yunnan Center for Community Development Studies and the Yunnan Cattle and Pasture Research Center in 2004 found that in southern Cikatong's Duosong Village, the number of cattle grazing on summer alpine rangelands has increased from 30 head 15 years ago to 240 head today. Similarly, in Niangjiuding Village, locals report an increase from 150 head of cattle 30 years ago to over 600 today.

Because survey results and interviews with reserve management indicate that every family in a village tends to hold at least a few cattle, these increases seem more a phenomenon of current cattle holders increasing their herd size rather than non-holding families entering the animal husbandry industry. Additionally, immigration is limited in Baimaxueshan villages, so the number of households in a village is generally static over the past decade. Overall human population growth in Baimaxueshan in the past decade is negligible when compared to growth in cattle population (reserve management 2005).

Local and county government records also provide overall estimates of cattle populations in Baimaxueshan Nature Reserve and Deqin County, based upon survey and observation of summer alpine rangelands, which are useful to understand the scope of the animal husbandry industry in this area. Deqin county as a whole is estimated to currently have approximately 86,000 head of cattle. In southern Baimaxueshan Nature Reserve, including Xiaruo, Cikatong, Gemerong Administrative Villages and surrounding areas, the total nears 20,000 head of cattle (WWF ICDP 2004).

Furthermore, nearly all interviewed households report that they plan to increase their herd sizes in the near future, regardless of past changes in herd size. Out of 56 households interviewed, 49 said they will increase their cattle holdings, while only 2 planned to reduce their herd size, and 5 would not change. Of the 49 households that plan to increase their herd size, the average desired target herd size was typically up to 1.5 times the size of their current herd. What is more, while most all individual households reported plans to increase herd sizes in the near future, most all also said they expect their village neighbors to do the same.

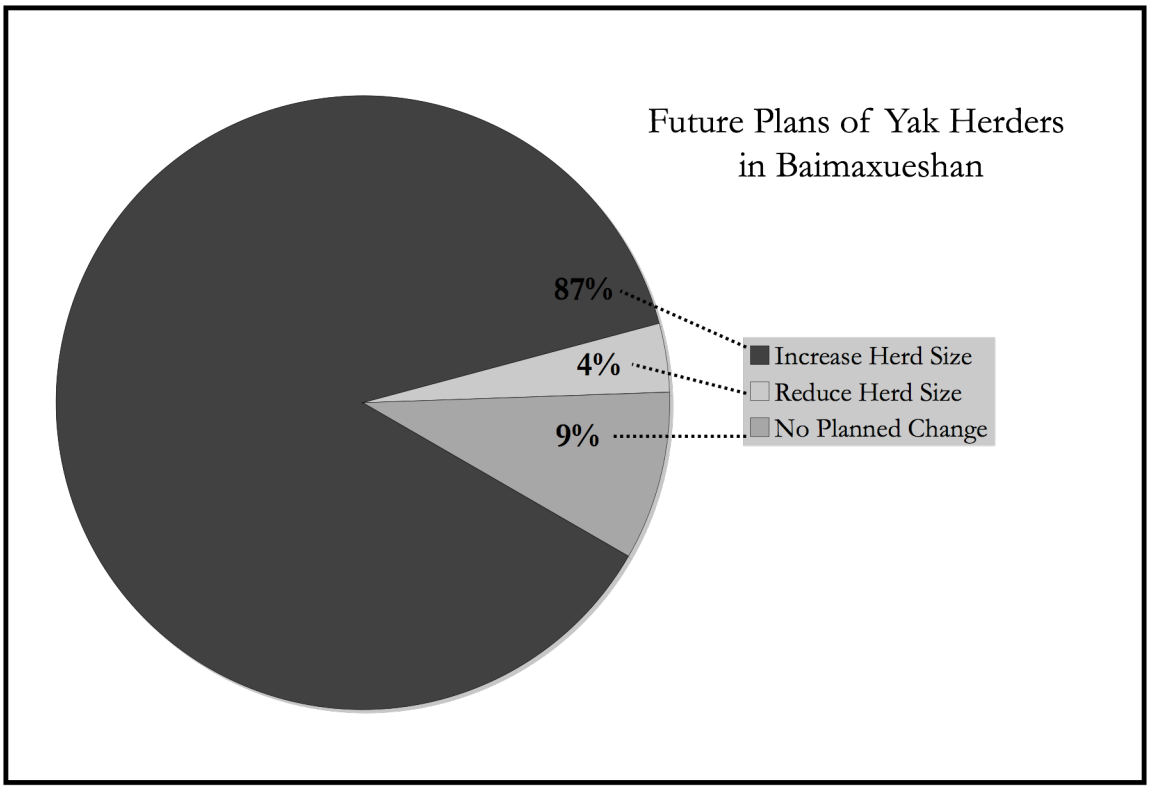



**Figure 4.2**: Yak expansion plans

*-Determinants-*

No single force has brought about rapid yak husbandry expansion in Baimaxueshan. Instead, a number of government policies, ecological interactions, economic developments, and social customs all contribute to this phenomenon. These forces can be divided into five primary categories, of varying importance. The three most important of these forces are: (1) restrictions on livelihood alternatives from anti-logging conservation policy; (2) growing regional tourism; and (3) a strong cultural preference for investment in yak husbandry. Two other factors, which also influence yak expansion in Baimaxueshan, but are less important, include: (4) increases in wildlife predation on cattle herds; and (5) in-kind encouragement of yak husbandry expansion by local government.

1. Livelihood Choice

Logging and the trade in northwest Yunnan Province's abundant wood resources traditionally has been an important source of household income for this region. At the household level, wood products were needed for house and fence construction, carpentry, and fuel for cooking and fodder warming. Timber was gathered and harvested freely to meet family needs, and it was traded locally for cash income. Later, starting in the early 1960s, local township and village enterprises (TVEs) began processing timber products for sale at relatively small scales. In the early 1970's, however, logging in Diqing Autonomous Prefecture took on national economic importance with clearcutting and processing by large state-owned enterprise (SOE) monopolies that employed thousands on a seasonal basis. Logging revenues in Deqin peaked in the early 1990's, when taxes from regional operations represented 80%, or more than 50 million RMB yearly (Hillman 2003, Xu and Wilkes 2004), of the prefecture governmental tax income (though estimates by Stedman-Edwards, 2002, put logging revenues much lower, nearer 20-30% of county expenditures, when central government subsidies to overall Prefecture budget are included).

Today, however, the timber industry in Baimaxueshan contributes less than 2% of local residents' incomes (Zhao et al 2004). There are two reasons for this. The first is the National Nature Reserve Law, by which timber harvesting for trade and sale is prohibited within Baimaxueshan Nature Reserve in an effort to protect threatened forest habitat. Under this policy, small-scale timber gathering and harvesting is permitted for personal use only in certain areas of the Reserve, but use of even this limited resource requires the purchase of an annual use permit. Such restrictions have legally been in effect in the Reserve since its founding, but have only been strictly enforced in most areas for the past 15 years. The second prohibition on timber harvest for residents of Baimaxueshan is the Natural Forest Protection Program (NFPP), a central governmental flood-prevention policy, which, in 1998, unilaterally prohibited the logging of upland forests across 12 provinces in western

China and shut down all state logging firms within one year. While the NFPP did not directly affect forests within Baimaxueshan, which were already protected under nature reserve status, the NFPP did cease logging operations carried out by the Deqin County Timber Company directly over the Reserve's border (Stedman-Edwards 2002).

Because legal sources of extractive income are tightly controlled in Baimaxueshan, and because development and infrastructure levels are such that non-extractive income sources are not accessible to most of the population, any policy that further restricts livelihood options is likely to have obvious economic consequences. As such, it has been predicted numerous times since 1998 that the NFPP might lead to economic depression in the region (Zhao 2001, Chan 2002, Xu and Wilkes 2004, Wu pers comm 2004), and that it would noticeably change the composition of livelihood activities within individual families (Xie et al 2001, Hillman 2003, Zheng 2004). In Baimaxueshan, for example, economic pressure from lost jobs relating to the NFPP was thought to be leading to overharvesting of NTFPs, in part justifying the 2001 WWF ICDP project in the Reserve (WWF ECPE 2004).

According to survey results, however, the direct effect of the NFPP itself on Baimaxueshan livestock production has been weak. Of 31 livestock-raising households interviewed in Xiaruo and Cikatong Administrative Villages, only 6 reported family members participating in logging-related work a decade ago, before the NFPP. Additionally, for each of these 6 families, logging was listed only as a second or third source of income, typically behind animal husbandry or NTFP collection. Only 2 of these 6 households which once participated in logging have now begun animal husbandry to raise income. It does not seem then that the NFPP has directly contributed to recent increases in yak herd sizes in Xiaruo or Cikatong through income source substitution.

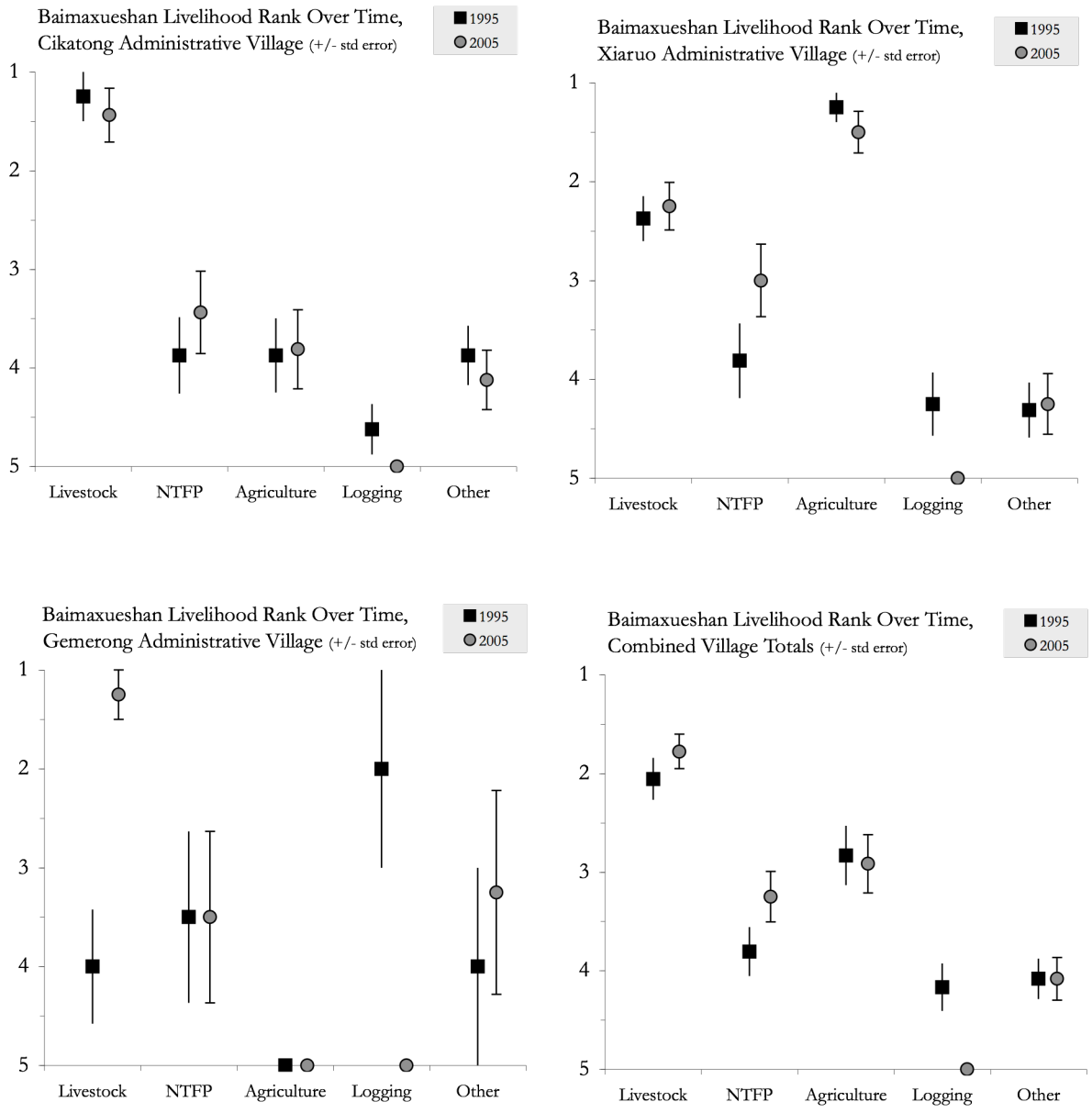



**Figure 4.3**: Change in livelihoods from 1995-2005 with inter-village variability

Here, however, exists the strong possibility of response bias. Because timber extraction in Baimaxueshan has been prohibited under nature reserve law since long before the 1998 NFPP, and because many of the authors' interviews were conducted with Nature Reserve Management staff acting as translators, interviewees might have been hesitant to report any engagement whatsoever in the logging industry—even concerning logging-related employment in TVEs or SOEs

*outside* the Reserve that was mostly legal before 1998 (logging in some areas was actually considered illegal "poaching" carried out in excess of regional extraction limits set by the Deqin County Logging Quota Management System—see Stedman-Edwards 2002 for more). It is also possible that outside logging was simply not practiced by residents of Xiaruo and Cikatong due to these areas' relative centrality in the geography of the Nature Reserve.

In Gemerong, however, the story differs. The land area covered by Gemerong Administrative Village was only annexed into southern Baimaxueshan Nature Reserve in 2000, and was actively logged by SOEs up until shortly before it entered the Nature Reserve. Gemerong is interesting, therefore, because it offers a glimpse at forgone resource extractive value for other areas of Baimaxueshan and because it directly illustrates the sort of income source substitution predicted for other areas in the Reserve.

When logging was widespread in this area, it represented the primary form of income for 70% of families in the administrative village (Gemerong village head pers comm. 2005). Every interviewee in Gemerong reported wood cutting or timber truck driving as main source of income a decade ago, and very few families held any livestock at all. Today, however, yak husbandry is far and away the primary livelihood activity in the area, with nearly every family participating and planning to double current herd sizes in the near future. When asked why yak husbandry has become so popular in Gemerong over the past decade, residents explicitly answered that it is to replace lost logging revenue.

2. Tourism Demand

Products of yak husbandry in Baimaxueshan include leather, meat, milk, yogurt, and, most importantly, butter. Yak butter is typically churned, by hand, immediately following daily milking on summer alpine rangelands, and formed

into "bricks" which are wrapped for easy transportation down into one's village. At this point, some of the bricks (about 60kg worth per year) are stored for personal consumption by the yak-holding family, and the rest are transported to the administrative village center for sale to traders who transport the fresh butter in trucks to larger markets in towns outside the Reserve.

A growing center of demand for yak butter is the town of Zhongdian, approximately 3 hours by bus east of Baimaxueshan. Zhongdian Township, renamed "Shangri-la" by Zhongdian County commerce officials in 2002 in an effort to encourage tourism and replace tax revenues lost to the NFPP, lies at the end of the "Ancient Tea Horse Road" tourist trail. Since the construction of an airport in 1999 equipped to handle three times daily flights of Boeing 737s from Kunming, Chengdu, and Lhasa, and a 7 million RMB restoration of the gold-gilt rooftop of the Songzalin Buddhist Monastery just outside of town, domestic, "overseas Chinese", and international "eco" and "ethnic" tourism in Zhongdian has exploded. In 2002, following massive government and private investment, annual tourist numbers reached 1.28 million, up from only 42,300 in 1995 (Kolas 2004). In 2001, tourism tax revenues to local government were 68 million RMB, greater than the sum of logging revenues before the NFPP (Diqing Statistical Yearbook 2001). In 2004, tourism revenues from overseas and international sources alone in Diqing Prefecture were 3 times 1998 levels (Qiu 2005).

With 1.28 million tourists has come increased demand for culinary and religious yak butter products. Traditional Tibetan yak butter tea, a regional specialty, is a steaming mixture of water, tea leaves, toasted ground barley powder, ground hemp seeds, salt, and a generous wedge of fresh-churned melted yak butter. Prominently served in a 2 liter pot with each meal in Zhongdian and Deqin tourist and local restaurants alike, yak butter tea is claimed to alleviate symptoms of altitude sickness (Zhongdian Township is 3200m above sea level), and is sought out by both "eco" and "ethnic" tourists alike as an authentic taste of Tibetan life in

northwest Yunnan. Yak butter is also used extensively in local Buddhist monasteries, including the 800 monk Songzalin Monastery, in which tens of thousands of yak butter prayer candles are kept continuously lit before divine iconography, and the yak butter itself is used by monks to create holy sculptures of the Buddha, the Arhats, and countless bodhisattvas. Downtown Zhongdian is thick with the scent of slowly melting yak butter.

Past WWF researchers, local village leaders, and township cadres in Baimaxueshan point to this increase in Zhongdian's near-inelastic demand for yak butter as the main driver behind the growth in yak butter wholesale prices over the past decade, even as Reserve yak populations have grown over the same period. Current yak butter wholesale prices range between 70 and 110 RMB per 4kg "brick", depending on quality, and a single female yak might produce anywhere between 3 and 70 bricks of butter per year, depending on breed, age, and grassland quality, though average production levels today are closer to 8 bricks annually per cow. Even at this level of production it is not uncommon for a single family with relatively large yak holdings to be able to produce in one year hundreds of bricks of butter in excess of personal consumption needs. These can then be sold for thousands or tens of thousands of RMB income in particularly good years (8 RMB ~ 1 USD). This means that even in a "short" production year, a family with a stable herd can count on a few thousand RMB in renewable income from their milk-producing yaks.

Primarily because of high market butter prices, cattle holding families have not experienced the economic depression predicted above from the fallout of the 1998 NFPP, but actually report great increases in income over the past decade. When asked, cattle owners across southern Baimaxueshan reported that household incomes had generally increased, sometimes dramatically, over the past decade. 32 families out of 36 interviewed reported incomes that were "higher" or "much higher" than a decade ago, with 4 or 5 families stating that their current incomes are over 10 times their income a decade ago, mostly due to increases in yak butter

sale prices and better infrastructure for reaching local markets (namely, the partly-paved public road which runs through the center of southern Baimaxueshan). No quantitative figures exist to describe producer price elasticities for yak husbandry in Baimaxueshan, but, qualitatively, the same families that reported the largest gains in income over the past decade also had some of the greatest increases in yak herd sizes.

Additionally, families who reported plans to increase herd sizes in the near future often qualified their desire against the availability of funds to purchase young cattle, which now sell for up to 1000RMB per head, up from only 250RMB a decade ago. In a good year then, if butter prices are high and family labor abundant, butter profits are often reinvested by purchasing young cattle on the market to increase herd size. In this way, cattle herds, particularly in poorer and more remote areas of Baimaxueshan, act as a storage pool for family wealth when rural banking options and credit providers are limited.

The multiplying effect of increasing butter prices on Baimaxueshan yak populations cannot be overstated. Such a phenomenon would be true most anywhere in the world. In Tibetan Baimaxueshan, however, these economic production forces are rivaled, and possibly even exceeded, by deep-rooted cultural perceptions of yak husbandry.

3. Cultural Preference

Any illustration of animal husbandry in Baimaxueshan would be incomplete without consideration of the Tibetan socio-cultural importance placed on yaks. Of course, it is analytically difficult to separate cultural influences on increasing yak populations from other contemporaneous economic, environmental, and legal forces. Moreover, no argument is made that *increasing* cultural preference among yak herders in Baimaxueshan is responsible for increases in yak populations.

Instead, this section seeks to characterize the value that Tibetans in Baimaxueshan place on their yak herds above and beyond expectations from Western "rational" economic frameworks. This strong cultural preference, in turn, has worked synergistically with the market mechanisms described above to increase the rate of yak growth more than might otherwise be expected.

Of 20 Tibetan villagers asked what form of livelihood they felt to be personally most satisfying and would most enjoy doing regardless of the income provided by that occupation, 19 answered that yak husbandry would be most desirable. Of course, such a response can still be biased by implicit understandings of the monetary value and economic stability provided by animal husbandry when compared with less stable (though sometimes more profitable) occupations such as gathering of NTFPs. Indeed, some interviewees qualified their pro-livestock responses by explaining that livestock were very "stable". The meaning of this descriptor, though, assumes a new connotation in the context of other explanations given about livestock, including points made that, "it is good for the family," or, "it feels good to raise yaks," or even, "I enjoy doing it, and hope that my children and even their children will continue to keep my herd."

Especially for the more elderly segment of the herding population in Baimaxueshan, yak herding is seen as noble profession to be pursued— with or without monetary gain. During the course of household interviews, one elderly man of about 60 years of age, who had actually been forced to sell off some of his yak herd due to his physical inability to care for them, lamented, "My greatest hope and happiness in this life would be to own a herd of 20 yaks before I die, but I think I am now too old to ever achieve this." At the time he was interviewed, this man owned 7 yaks, and had never previously owned a herd exceeding 12 yaks in size. This man, a Tibetan, did draw some income from butter sales and also reported that he enjoyed the "stability" provided by raising yaks. However, he also habitually sold only a small percentage of the butter he produced for cash; each

year, he would try to make 3000RMB from butter sales, and then he would keep the rest of the butter—sometimes more than could be easily used— for personal consumption.

In fact, in many of Baimaxueshan's more rural villages, where yak populations are large and rangeland resources are relatively extensive, families might choose to keep an inordinate amount of the yak butter they produce for personal consumption rather than sell it on the market for profit. For example, local agricultural bureau cadres and reserve staff estimate that a single family will use no more than 15 "bricks" (60kg) of butter in a year for tea, cooking, and candles. Some families, however, reported regularly retaining over 60 bricks per year, even when market prices were high.

Unexpected economic choices extend beyond butter sale substitution preferences to herd husbandry management as well. One example is the traditionally low cull rate for milk-producing cows in Baimaxueshan: approximately 1% according to estimated from WWF researchers (Zhao et al 2004). Because one cow might produce on average 1000RMB worth of butter in a single year, and the sale price of one adult animal to Bai or Hui Muslim ethnicity meat traders is only approximately 1000RMB, it makes economic sense that cows would be retained for milk production year after year. However, household interviews indicate that most herders prefer to retain their full stock of cows even beyond a particular animal's period of milk-producing usefulness. Instead of being sold for meat, these creatures are typically kept near homes in the village, or even led to alpine rangelands in the summer, but not milked. Economically, then, these animals present a drain on labor, fodder, and rangeland resources, but provide no obvious market benefit to their owner.

A similar story can be told of typical yak herd sex composition in Baimaxueshan. Precise numbers vary, but experienced yak holders tended to state their ideal

cow:bull herd sex ratio as 7:3. Herders reported that this ratio (already quite low by American dairy standards) would allow for increased milk production while ensuring reproductive longevity of the herd. However, in practice, out of 25 herders interviewed, only 11 actually had attained a herd sex ratio with cows outnumbering bulls, with just a few approaching the 7:3 ideal. 7 herders, on the other hand, had more bulls than cows, and 7 others had an even ratio. Bulls in Baimaxueshan are rarely used for labor, and differences in manure production between bulls and cows are small, so the rationale for keeping and caring for this number of bulls instead of selling them for cash income is not obvious. Occasionally, prized bulls are rented for siring services within a village for 100RMB, but this formal practice is not particularly widespread as idle bulls are common in Baimaxueshan, and even then, the income provided is relatively small. Considering that these relatively non-productive bulls might comprise up to 40% of Baimaxueshan alpine rangeland grazing pressure, the environmental and economic ramifications of this sex composition are potentially huge.

Another Tibetan cultural tradition which has bewildered poverty and development workers in Baimaxueshan and other nearby Tibetan areas is livestock feeding custom. Namely, during the winter months when yaks herds are kept enclosed within the village and fed a slop of harvested fodder and water, most families will go to great lengths to ensure that this fodder is first well-cooked and thoroughly warmed before being served to the herd. Doing this involves purchasing the right to gather firewood (as required by Reserve regulations), and tending a near-continuous fire outside the home. Gastrointestinally, however, yaks are able to digest raw grains without problem. Yet, even after numerous education campaigns by local government, NGOs, and Reserve staff, the practice continues in most areas of Baimaxueshan. In addition to the labor inputs desired, WWF estimates that heating yak fodder represents up to 20% of a household's timber use.

Economic explanations do exist to describe some of these management patterns, but are incomplete. For example, the low cull rate and relatively large bull population could be explained through non-atomistic buyers, barriers to trade, poor information, or high transaction costs. In extremely rural areas, without basic communication or transportation infrastructure, it may not be convenient or possible to identify buyers, trade, or achieve a market equilibrium price and quantity. This explanation is quite reasonable, but it does not explain away the overall trends described above. Other issues, including the opportunity cost of butter retention or the direct cost of fodder cooking are not satisfactorily addressed through economics alone.

Baimaxueshan Reserve staff, Tibetans themselves, who work on a regular basis to fight human poverty and food shortages in the Reserve, suggest that this "inefficient" tendency not to trade excess butter with even very small marginal values for cash which could be used to purchase food, clothing, or medicine is due to Tibetan cultural values which do not traditionally equate money with "happiness" (or welfare). Such an explanation, however, walks a fine line between, on one hand, exhibition of pride for an indigenous cultural heritage and, on the other hand, a somewhat offensive stereotype and dismissal of a culture's ability to reason "rationally" (in economic terms). Indeed, the latter sentiment, which paints the phenomenon more as a cultural *disability* to understand, rather than a cultural *difference* in understanding, is often heard casually from Han ethnicity Chinese immigrants and visitors in northwest Yunnan's cafés and hotel lounges (as well as a few representatives from academia, NGOs, and government). Such cultural stereotyping though does not accord with prominent historical and contemporary observations of the Tibetan business sense, from the expert hagglers in market stalls of Zhongdian, to the intrepid traders of the Ancient Tea Horse Road, to the yak herders who face daily trade-offs in Baimaxueshan itself.

To better understand the concept of "happiness" in Baimaxueshan, it is useful to supplement economic frameworks with cultural anthropological observations of Tibetan yak-herding societies. Tibetans in northwest Yunnan traditionally equate the perception of wealth with two factors: size of house, and size of livestock herd (WWF-MPO 2004). In particular, ownership of pure breed yaks or yak hybrids is considered to represent a family's social status within a natural village (Zheng 2004). Both Zheng (2004) and Hui (2005) mention how yak ownership helps to build social capital for a particular holding family within a community through gift-giving in times of community need, mourning, or celebration—furthering the social-network standing of yak-holding families.

Sometimes, this cultural preference is taken to extremes. In Baimaxueshan's Yongdui and Dari Administrative Villages, WWF field teams conducting group interviews among livestock holders in 2004 found that some households had even begun openly competing to create the largest yak herd. When these competing households were brought together in a group meeting to discuss yak expansion, they admitted that the primary goal of this expansion was household pride.

Perhaps even more pertinent, Hui (2005) found through a series of sociological surveys of agro-pastoral Tibetan households conducted throughout 16 villages in Zhongdian County that cultural values were repeatedly identified alongside practical agricultural and economic advantages to yak ownership, just as reported in Baimaxueshan. Specifically, Hui records that yak ownership in these Tibetan areas represents "a manifestation of wealth," is useful in "serving in rituals," provides "psychological satisfaction as good company," (particularly for elders) and, possibly most importantly, "characterizes 'Us Tibetans' [sic]" (2005). To the herders of northwest Yunnan, Yak ownership is intimately connected to the very definition of what it means to be Tibetan—a cultural importance without a price.

4. Wildlife Predation

A primary goal in the formation of Baimaxueshan Nature Reserve was recovery of endangered megafauna. To combat one direct human threat to wildlife, all hunting—a traditional supplementary source of food, clothing, and medicine products—is prohibited under Reserve regulations in Baimaxueshan and the 1988 National Wildlife Conservation Law in surrounding areas. In this respect, Reserve conservation goals have been very successful—particularly for animals whose primary persistence threat was hunting by humans rather than habitat destruction. Few official counts of wildlife exist, but both villagers and reserve staff report increases in sightings of leopards, bears, and wolves (presumably *Uncia uncia, Neofelis nebulosa*, *Ursus thibetanus*, *Ursus arctos spp,* and *Canis lupus*) in particular, over the past 10-15 years.

Predation indirectly (and seemingly counter-intuitively) affects yak populations in Baimaxueshan because of the uncertainty and risk it directs towards domesticated herd persistence. 24 of 32 households interviewed in Xiaruo and Cikatong Administrative Villages reported increased wildlife predation as an important concern or problem currently faced in yak husbandry. On average, these households lose approximately one or two yaks, usually juvenile, to predation each summer grazing season. For some households, that number reaches as high as 3-4 head per year. According to local Forest and Agricultural Bureau officials in Xiaruo, villagers who lose cattle to predation are supposed to be compensated between 300-400RMB per lost head with funds coming from local, provincial, and national sources. Even these officials admit though, and locals often protest, that actual compensation is typically much lower, approximately 70RMB per head, if anything.

Because of increasing levels of predation, and because livestock herders are legally restricted from "defensive" hunting in alpine rangelands (poaching of certain protected species being punishable by the death penalty), herders report pressure to

increase cattle herd sizes to populations higher than ideal levels. This way, if and when livestock are lost to predation, the economic impact in each family will be softened. Larger-than-desired herds are seen, therefore, as a sort of insurance against the uncontrollable and damaging force of predation.

Of course, it is not entirely clear how much this factor in isolation would contribute to expansion of yak populations in Baimaxueshan, as many herds might be growing only at the replacement rate of predation. Furthermore, some of the few herders interviewed who have reduced their herd size over the past decade or who do not plan to further increase their herd size in the future cited the trouble and personal danger presented by increased wildlife predation as one of their primary reasons for *giving up* yak husbandry. Generally though, the impact of increased wildlife predation does still seem to be an increase in Baimaxueshan's yak populations, but a muted one.

5. Government Encouragement

Local policymakers in Baimaxueshan and Diqing Prefecture have identified yak husbandry as the preferred mechanism of economic development for some of the region's poorest populations. Local cadres report that this focus on yak husbandry has intensified since the 1998 NFPP, particularly in areas left behind by much of Zhongdian's tourism boom, as planners struggle to find new and compatible sources of revenue for local communities. Township and prefecture planners, agreeing with local academics, generally regard the NFPP as having been a major blow to household incomes in rural Diqing. "Most everybody who was fit could gain some logging related income before the NFPP," reported Cadre Yu, vice village head of Xiaruo Township and head of the Xiaruo Forestry and Agriculture Bureau. Although such impressions of the widespread importance of post-NFPP lost income do not fully corroborate the village-scale heterogeneity reported above in

this thesis, the resulting relief plans trace the same phenomenon reported all across Baimaxueshan: yak husbandry expansion.

According to interviews with local policymakers, local government supports the expansion of yak husbandry in Baimaxueshan because of its economic profitability and stability, its cultural acceptance, its perceived sustainability when compared to forest extraction, and the lack of a need for existing large land holdings, strong tenure rights, or expensive infrastructure such as agriculture might require. This support of yak husbandry generally comes in 2 forms: (1) "guaranteed" compensation for livestock losses due to wildlife predation; and (2) donations of hybrid yak-cattle stock to improve lineages. Together, these programs do ultimately encourage expansion of yak husbandry in Baimaxueshan, though track records are poor enough that they do not play as large of a role as the macro-policy, economic, or cultural factors detailed above.

Compensation from wildlife predation on yak herds, and the reality of the program's shortcomings, are discussed above. Because increases in predatory wildlife in a nature reserve might otherwise provide a disincentive to raising livestock locally, compensation guarantees are stipulated for national-level nature reserves under Article 14 of the State Wildlife Conservation Law, and are meant to act as a safety net for herders. This program, required of National-level nature reserves by central policy, is administered by local administrative village ranger stations and township forestry bureaus in Baimaxueshan. According to Yunnan Provincial regulations ("Compensation Rules for the Damage of People Property by Protected Terrestrial Wildlife", Articles 9 and 67), however, fiscally responsible for the program is shared equally by provincial and prefectural governments (as opposed to central government), and is drawn in part from the Yunnan Forestry Bureau's pool of nature reserve funding. Over the past decade, as compensation claims have increased concurrently with yak herd populations and wildlife pressures, provincial program funding has actually been capped, to the point where

compensation today is only 10-20% of actual claim value (Li 2003). In this sense, Baimaxueshan's wildlife compensation program today is essentially defunct.

In the past, blood-line development in the form of pedigree lineage stock donations has been a popular way for local governments and international NGOs to address yak husbandry and rural poverty in northwest Yunnan, to mixed success. Often, donating parties have assumed that Tibetan yak herders in this region would benefit from the high milk production levels of European or Indian milk cow breeds, essentially ignoring a long history of indigenous knowledge systems and local breeding practices (Ma 1998). Today, the yak-cattle hybrids descended from those remaining non-native pedigrees that did not promptly succumb to altitude sickness or the extreme Himalayan temperatures are widespread (making up as much as 50% of current Baimaxueshan bovine populations), but generally regarded as being of lesser value than the hardy full-blood yak breeds. One reason for this is the quality of these animals milk production: these hybrids are smaller than normal yaks and can typically produce more milk annually than yaks, but the butterfat content of this milk is relatively low (5-6% compared to 15% for purebred yaks), making it less attractive than yak milk for producing butter, the economic and culinary currency of the industry.

Today in Baimaxueshan, local governments are still involved in improving the genetic stock of local yak populations, though more modestly than in the past. In Xiaruo Township, for example, nearly 50 pedigree yaks might be introduced per year, purchased from nearby Zhongdian rangelands where extensive yak breeding occurs. These yaks are then distributed among natural villages in the township to be shared among that villages' herding families. Local Forestry Bureau officials are particularly proud of these programs, as such donations are thought to improve the profitability of yak husbandry in the reserve and simultaneously draw more families into an economically and legally stable livestock-based livelihood and out of forest-based resource extraction, which is viewed as being mostly incompatible

with Reserve conservation goals. Indeed, noted recent expansion in Baimaxueshan's yak populations is regarded with pride and a sense of accomplishment for essentially hitting two birds with one stone: reducing ecological impact to Nature Reserve forests while simultaneously fighting entrenched poverty throughout rural Baimaxueshan.

However, as the next section of this thesis will address, such success over the past decade might not have come without a price. Namely, when Xiaruo Forestry Bureau officials heading the livestock development program were asked if they thought rapid yak population growth in Baimaxueshan might contribute to alpine rangeland degradation and, eventually, economic losses for local herders, they replied that other than few invasive plants, rangeland degradation was not currently a problem in their opinion. Moreover, these cadres reported that they did not anticipate rangeland degradation becoming a problem for at least 30 years, so there was no need for concern. Such optimism is striking— and troubling— considering the contrasting views of Reserve Management staff, personal accounts by yak herders, and quantifiable trends of alpine land cover change as recorded by satellite imagery that all point to extensive rangeland degradation in Baimaxueshan over the past decade.

Alpine Rangeland Degradation:

> Increased overall grazing levels by growing yak herds is unsustainably pressuring alpine rangeland resources in Baimaxueshan.

This hypothesis was investigated through a combination of NDVI-based remote sensing analyses of yearly land cover change in Baimaxueshan from 1994-2002 and field surveys with experienced yak herders and other stakeholders who described changes observed over the past 12 years. Whereas, above, the drivers of yak expansion varied between administrative villages but the effect was consistent, here, the effect itself varies noticeably with geographic position across the Reserve. Generally, however, analysis of these data together suggests:

> Overgrazing by yaks has decreased the value of rangeland resources to Baimaxueshan's rangers, and this degradation has been exacerbated by prohibition of traditional land management practices, including forest clearing and periodic rangeland burning. Moreover, the effect from each of these drivers will only intensify under local projections for anthropogenic global climate change.

"Sustainability" has become so prominent in academic and social discourse that the term itself suffers from many competing definitions and often comes loaded with normative viewpoints. Avoiding the finer points of this debate, this thesis uses the term "unsustainable" simply as a descriptor for a phenomenon which occurs at a rate greater than that of background trends so that a fundamental (and unhappy) shift in conditions might be reasonably forecast to occur and which would not otherwise occur. For Baimaxueshan yak husbandry, "unsustainably pressuring" alpine rangeland resources might mean that rangers choose to graze so many yaks on one rangeland that cows can no longer produce acceptable levels of milk off of

meager allotments of grass, and rangers must find new grazing lands, sell livestock, or endure severe economic hardship. Similarly, "unsustainably pressuring" alpine rangeland resources might also mean that substantial human conflict arises over usage rights where none or very little previously existed. The following analysis, therefore, ultimately treats "sustainability" in essentially unsubstitutable and anthropocentric, as opposed to biocentric, terms.

In this sense, rangeland resources in Baimaxueshan *are* being unsustainably pressured, resulting in land cover change; that is, "degradation" (which itself can lead to changes in land use). Analysis of remotely-sensed imagery of Baimaxueshan's alpine rangelands from 1994-2002 objectively and quantitatively indicates land cover change. This data by itself, however, is of little value without an accompanying interpretation of what that change might actually be "on the ground" and what it could mean in terms land use. "Degradation" of alpine rangelands, for example, could have many meanings on the ground. From a remote sensing perspective, it is tempting to define "degradation" as a decrease in mean NDVI over a certain region between image dates. Presumably, such a trend would indicate falling leaf area index, canopy density, or overall biomass. However, when analyzing a once-yearly time series of remotely-sensed imagery, such as done in this thesis, it is difficult technically to directly measure mean changes in inter-annual vegetation. Plant phenology, seasonal weather patterns, and atmospheric variability are all first-order effects which can overpower other environmental signals in land cover change, such as grazing effect on alpine rangelands. See, for example, the chart below which shows simple mean NDVI in Baimaxueshan over the period of interest:

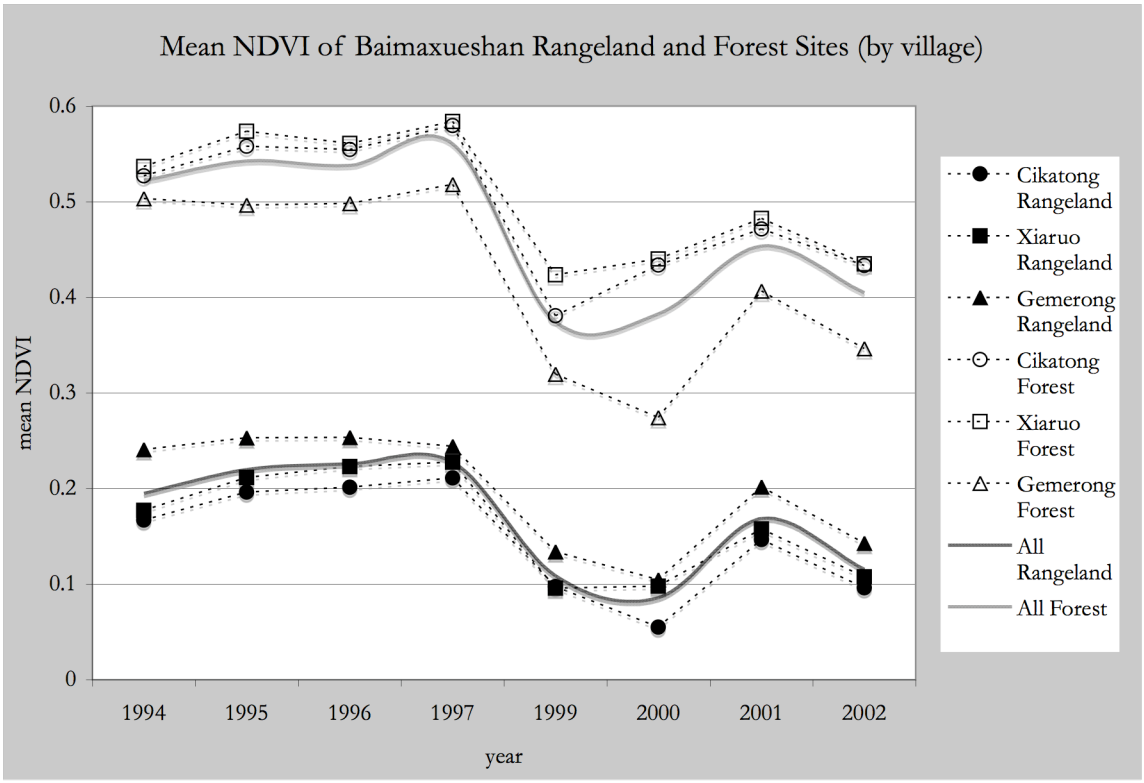



**Figure 4.4**: Non-robust NDVI trends over time

Apart from the illustrating that mean rangeland NDVI is (expectedly) lower than that of forest sites, this chart essentially illustrates yearly variation in atmospheric and phenological effects, which are of little interest because of the complexity and error they introduce. Moreover, interviews with local yak herders indicate that rangeland change over the past 12 years has come in the form of unfavorable changes in vegetation composition, including relative increases in invasive, inedible herbaceous, and woody plant species, in addition to overall reductions in total plant biomass. Therefore, metrics other than mean NDVI must be used in order to usefully measure rangeland vegetation change.

To simplify, therefore, rangeland "degradation" here will refer to the following two phenomena: changes in plant composition (*quality* measure) and reductions in plant biomass available to each yak (*quantity* measure), both of which are unfavorable to yak rangers. Both quality and quantity in this analysis are measured

primarily through changes in NDVI *standard deviation* over individual rangeland patches and by the *relative* differences between rangeland and forested areas' interannual mean NDVI trends.

*-Phenomena-*

According to satellite data, alpine rangelands in Baimaxueshan degraded over the period from 1994 to 2002. This degradation is expressed through many metrics.

One important measure of both quality and quantity is the relative interannual variation in mean NDVI of each sample site. This metric for interannual "evenness" of vegetation levels can then be compared to the same readings from nearby forested sites to correct for natural variation in Baimaxueshan atmosphere and flora. The table below contains the interannual range of mean NDVI values for 6 rangeland and 6 forested sample sites in each of 3 administrative villages, divided by the interannual mean for each of those same sites. Results are aggregated both by administrative village and by all of Baimaxueshan:

| -sample site- | **Cikatong** | **Xiaruo** | **Gemerong** | **All Baimaxueshan** |
|---|---|---|---|---|
| *Rangeland 1* | 0.86 | 1.67 | 1.05 | - |
| *Rangeland 2* | 0.68 | 0.99 | 0.90 | - |
| *Rangeland 3* | 0.66 | 0.66 | 0.95 | - |
| *Rangeland 4* | 1.19 | 0.84 | 1.11 | - |
| *Rangeland 5* | 1.27 | 0.67 | 1.11 | - |
| *Rangeland 6* | 3.40 | 1.12 | 0.41 | - |
| *Forest 1* | 0.32 | 0.51 | 0.26 | - |
| *Forest 2* | 0.39 | 0.47 | 0.74 | - |
| *Forest 3* | 0.21 | 0.38 | 1.24 | - |
| *Forest 4* | 0.25 | 0.37 | 0.66 | - |
| *Forest 5* | 0.73 | 0.24 | 0.67 | - |
| *Forest 6* | 0.84 | 0.23 | 0.66 | - |
| ***All Rangeland*** | 1.34 | 0.99 | 0.92 | **1.09** |
| ***All Forest*** | 0.46 | 0.37 | 0.71 | **0.51** |

**Table 4.2**: Interannual range of NDVI mean values for each sample site

As shown by the table above, interannual variations of NDVI (and hence, biomass, leaf area index, vegetative density, etc.) within one rangeland are large and uneven in each village in southern Baimaxueshan when compared to nearby forested areas. The magnitude of this phenomenon varies by administrative village and is less pronounced in Gemerong than in Xiaruo or Cikatong. Generally, however, this interannual variation is important because it means that a yak ranger is less able to depend on a particular rangeland to provide the grazing resources required by his livestock in a particular year. Because low productivity often leads to low per cow milk yields, a lack of "guaranteed" minimum grazing resources threatens a ranger's economic security—compromising the very "dependability" cherished by yak raisers.

Another similar metric that can be derived from NDVI measurements of Baimaxueshan's land cover and which gives a slightly different perspective on rangeland degradation is the yearly trend in the standard deviations of NDVI readings within a single sample site. This trend is correlated with the composition of land cover within a single patch: a low standard deviation suggests homogenous land cover, while a high standard deviation indicates more heterogeneous vegetation. This analysis generally treats heterogeneity in rangeland patch vegetation cover as a form of degradation, as it often means that a site either contains bare, unvegetated patches or is undergoing floral succession or "encroachment" by the surrounding forest. Both of these phenomena decrease the amount of grassy grazing resources available to Baimaxueshan's yaks. The table below shows trends in NDVI standard deviation for southern Baimaxueshan's 3 administrative villages (standard deviations for each village-year are divided by the corresponding mean NDVI reading for that village-year to correct for differences in rangeland and forest NDVI magnitudes):

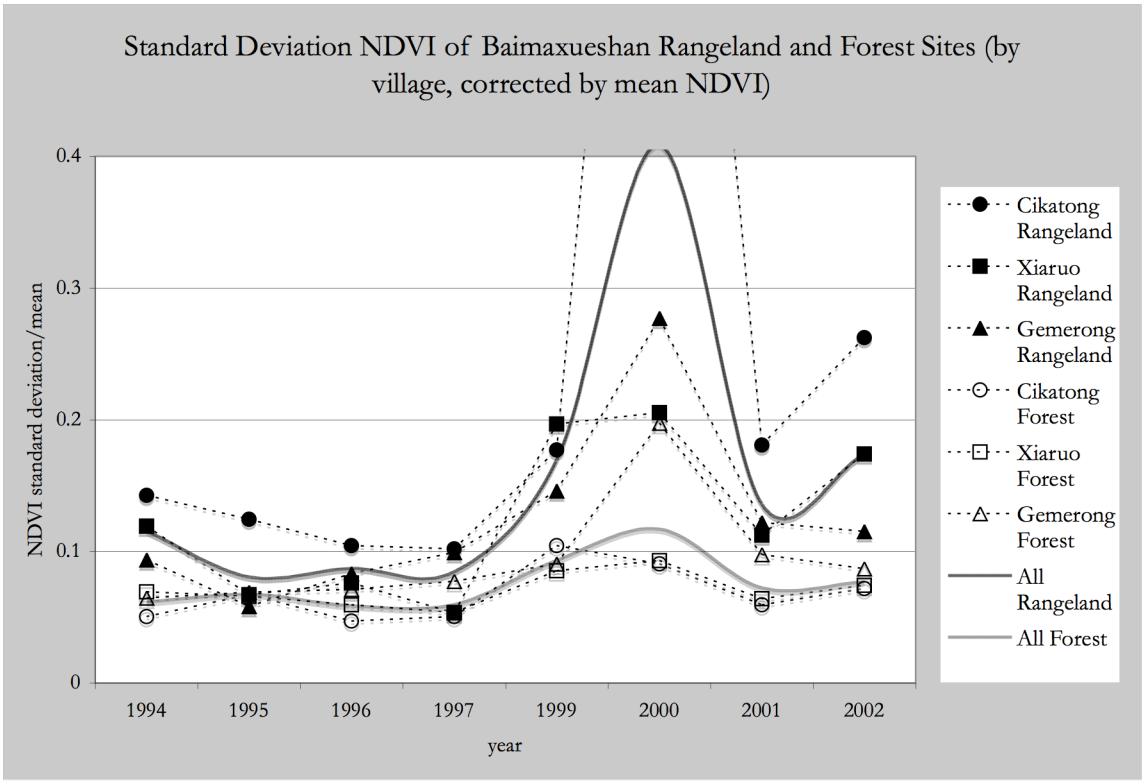



**Figure 4.5**: Average forest and rangeland NDVI standard deviation for each village

Notice that, across southern Baimaxueshan, rangeland sites generally appear to have higher relative standard deviations than nearby forested areas, and that this difference is increasingly pronounced over time as forested areas remain more or less constant and rangeland areas begin to increase. This suggests that, in the aggregate, heterogeneous land cover-based alpine rangeland degradation in Baimaxueshan is increasing over the same time frame, noted above, that yak populations themselves are increasing. Probable drivers for this correlation are discussed below.

But while these general Reserve-wide land cover trends are illuminating, they do not convey the inter-village and inter-patch variations in land cover change which are important to understanding the localized nature of rangeland degradation in Baimaxueshan.

One example of inter-village variation in rangeland degradation is in Xiaruo Administrative Village. As described above, lowland Xiaruo is primarily a farming community, and average household incomes exceed those of its highland neighbors: Cikatong to the north, and Gemerong to the south. With its desirable location along the paved main road and the Zhuba River, Xiaruo is also the center for commerce, transportation, and government services in southern Baimaxueshan. Xiaruo's farmers raise yaks primarily to collect their manure for use as a "free" crop fertilizer, and devote far less time to butter processing or sale—a time and labor-intensive process for which opportunity cost is high for farmers with extensive irrigated landholdings. As a result, yak goods and services in Xiaruo are relatively substitutable, and local yak demand is elastic when compared to Cikatong and Gemerong Administrative Villages. Based upon survey data from above, Xiaruo yak populations, though not insignificant in size, have not noticeably increased over the past decade.

In turn, Xiaruo's NDVI trends differ from those of its more yak-dependent neighbors. Specifically, alpine rangelands surrounding Xiaruo appear to be of better overall quality than those of Cikatong and Gemerong, and there is little noticeable trend in degradation of Xiaruo's rangelands. In terms of NDVI standard deviation within land cover patches, Xiaruo's rangelands in each year are on average 21% (median 22%) more homogenous (higher quality) than those of its neighbors, even when corrected by relative NDVI means. For comparison, standard deviations of Xiaruo's forests are in right line with those of Cikatong and Gemerong.

Interestingly, Xiaruo's general lack of rangeland degradation relative to its neighbors could be biasing local government rangeland management policies towards being over-optimistic. When Baimaxueshan Forestry Bureau officials proposed (above) that rangeland degradation is not a large problem in Baimaxueshan, and should not be addressed for at least 30 years, they are not accounting for geographic autocorrelation. If these officials, based in Xiaruo

Administrative Village but who in fact hold jurisdiction over most of southern Baimaxueshan (including Cikatong and Gemerong) are evaluating policy decisions based solely on the condition of (more easily accessible) rangelands in their immediate vicinity, then the prospects for rangeland management legislation helpful to Cikatong and Gemerong, where rangeland degradation *is* occurring, are dim.

Even Xiaruo, however, is not a clear-cut standout from other southern Baimaxueshan villages in terms of NDVI measurements of alpine rangeland land cover. For example, in certain indicators, Gemerong's rangelands appear to be less degraded, in terms of absolute NDVI, than even Xiaruo's. This is particularly true for measurements of minimum NDVI readings of vegetation cover within a single rangeland patch. Minimum NDVI values in Gemerong's rangeland patches for each year from 1994-2002 have a median value 41% higher than Cikatong and Xiaruo, Gemerong's neighbors to the North. This consistently high minimum could indicate that, whatever mean vegetation cover or composition, a certain quantity of vegetation (possibly palatable to yaks) is likely to exist across the entire rangeland patch, without bare spots (which would be characteristic of overgrazing). A dependably high lower-bound of available vegetation for grazing would be extremely valuable to yak herder who must deal with risk in managing a large herd.

Gemerong rangelands also exhibit NDVI values suggestive of high quality in each year relative to its neighbors. Rangeland patch maximum NDVI values are on average 23% (median 24%) higher than in Cikatong or Xiaruo. Taken alone, a high maximum NDVI within a single rangeland patch might be evidence of floral succession (tree regeneration) in that patch, which would decrease the value to rangers. However, absolutely, Gemerong's maximum NDVI values have a median of only .25, while forest cover in Gemerong has a much higher median NDVI value of .45 (average forest maximums are even higher, approximately .52). Though a spectral mixing analysis would be required to increase confidence, it would seem

from these threshold data that Gemerong's rangelands are not experiencing extensive (or, at minimum, pixel-sized) tree growth. Moreover, considering that mean NDVI values for Gemerong's rangelands are on average 30% (median 35%) higher in absolute terms than those of its neighbors (with mean forest NDVI values actually 16% lower, on average), it would seem that Gemerong's rangelands exhibit some of the highest levels of plant biomass, leaf-area index, and canopy density in southern Baimaxueshan—in this case, all indicators of high quality rangeland.

The relatively high quality of Gemerong's rangeland is not entirely surprising. Although the rate of increase in Gemerong's yak population is quite high, especially since  entering the Reserve in 2000, very little yak grazing occurred before that time owing to ample income opportunities from logging and the region's relative abundance of Lisu ethnicity villagers, whose culture places less of an emphasis on yak herding. Despite trends, then, absolute yak population in Gemerong today is smaller than in other villages to the north. Additionally, because this analysis' time series of satellite imagery does not extend beyond 2002 due in part to technical errors in the Landsat7 ETM+ sensor, it is probable that land use change effects on Gemerong alpine rangeland land cover are not captured within the 2 year window of rapid yak population growth. Considering this, NDVI data on Gemerong's relatively ungrazed rangelands provide a useful point of comparison against rangelands in Cikatong and Xiaruo—making Gemerong rangelands' 30% mean NDVI margin over its neighbors all the more illuminating.

Intra-village variation in land cover is also described by the satellite imagery. In some administrative villages, rangeland patches will share relatively similar NDVI trends over time, while in other villages, differences between rangelands only a few kilometers apart can be quite striking. In Xiaruo, for example, the trend difference of NDVI standard deviation between at least two rangeland patches is noticeable (called out below):

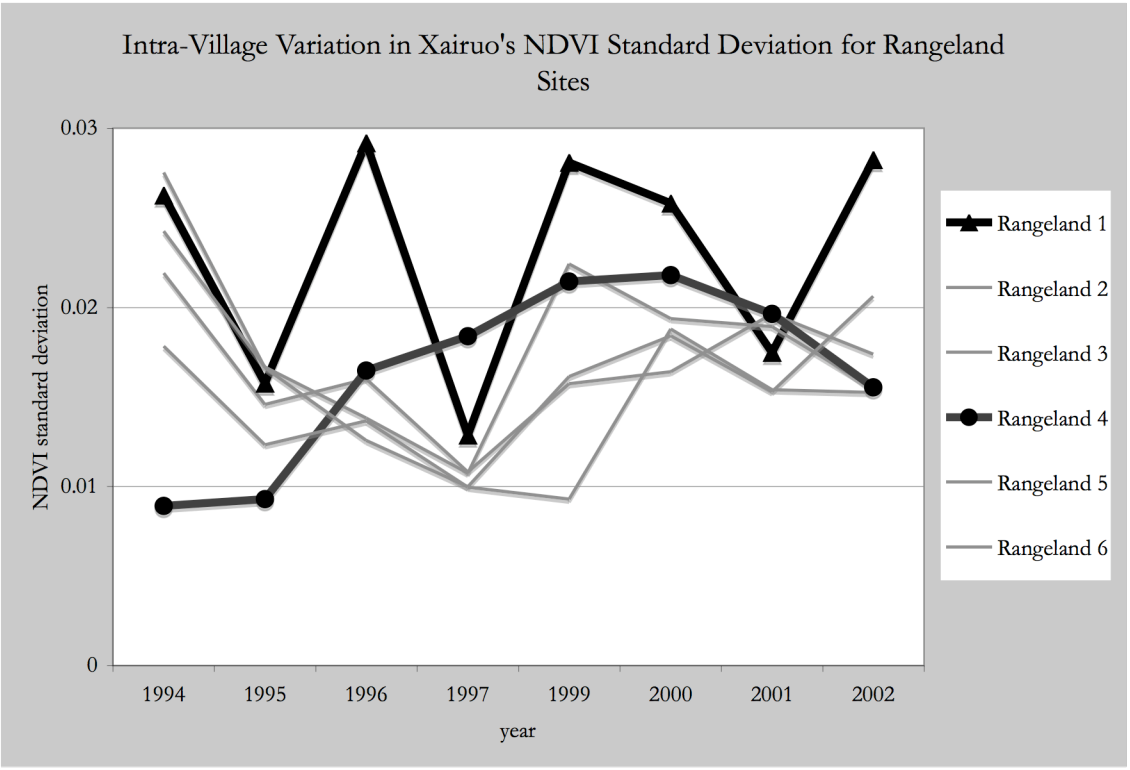



**Figure 4.6**: Temporal variability among neighboring Xiaruo rangeland sites 1 and 4 (line chart)

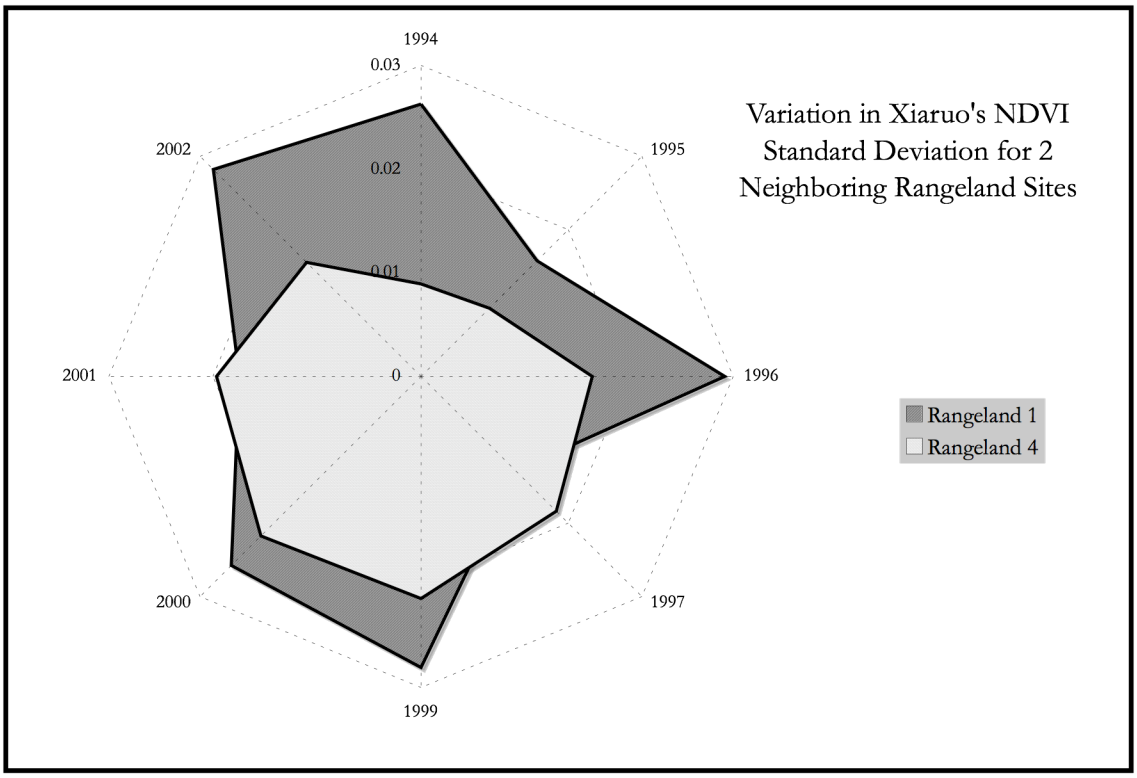



**Figure 4.7**: Temporal variability among neighboring Xiaruo rangeland sites 1 and 4 (radar chart)

Such variation in the NDVI standard deviation, and hence quality, of neighboring rangelands which surround a single administrative village suggests that even geographically similar grazing sites in Xiaruo either have vegetative communities with different grazing response patterns or face very different regimes of land use from one another. If variations in vegetation composition are primarily responsible for such data, then one likely explanation might be a prevalence of invasive plant species in that rangeland, a serious management dilemma currently faced by many Baimaxueshan rangers and discussed in further detail below. If, on the other hand, such NDVI variations are caused by differences in land use patterns, this phenomenon could be the result of traditional (and generally judicially-supported) tenure arrangements that grant rights of exclusion to certain natural village-level ranger communities, or even individual families within a single natural village.

Alternately, the human-scale experience of geographic distance itself could explain variations in land cover as a function of differences in land use. That is, Xiaruo rangeland sites #1 and #4 might be relatively close to each other in cardinal direction terms, but they are days apart when considering human, or yak, travel time. Moreover, when comparing land cover and land use in Baimaxueshan it is important to consider what might be a geographic variable more apt than cardinal direction on the rugged edge of the Qinghai-Tibetan Plateau: altitude. In this case, the altitudes of Xiaruo rangelands #1 and #4 actually only vary by about 150m, a relatively small figure for Baimaxueshan. However, even this difference might be enough to shift land cover vegetation or micro-climate patterns, as outlined above, by, for instance, 100mm of precipitation per year and 2 degrees Celsius. A 150m altitude difference could also represent a radical shift in land use by yak rangers, from, for instance, a spring and autumn mixed use rangeland to an exclusively summer use alpine pasture. Either one of these shifts would result in the observed variation in satellite-measured NDVI.

The chart below illustrates altitude-based land cover correlation in Baimaxueshan. Mean NDVI trends are shown for the 4 rangeland patches sampled between 3900m and 4100m from across all of southern Baimaxueshan:

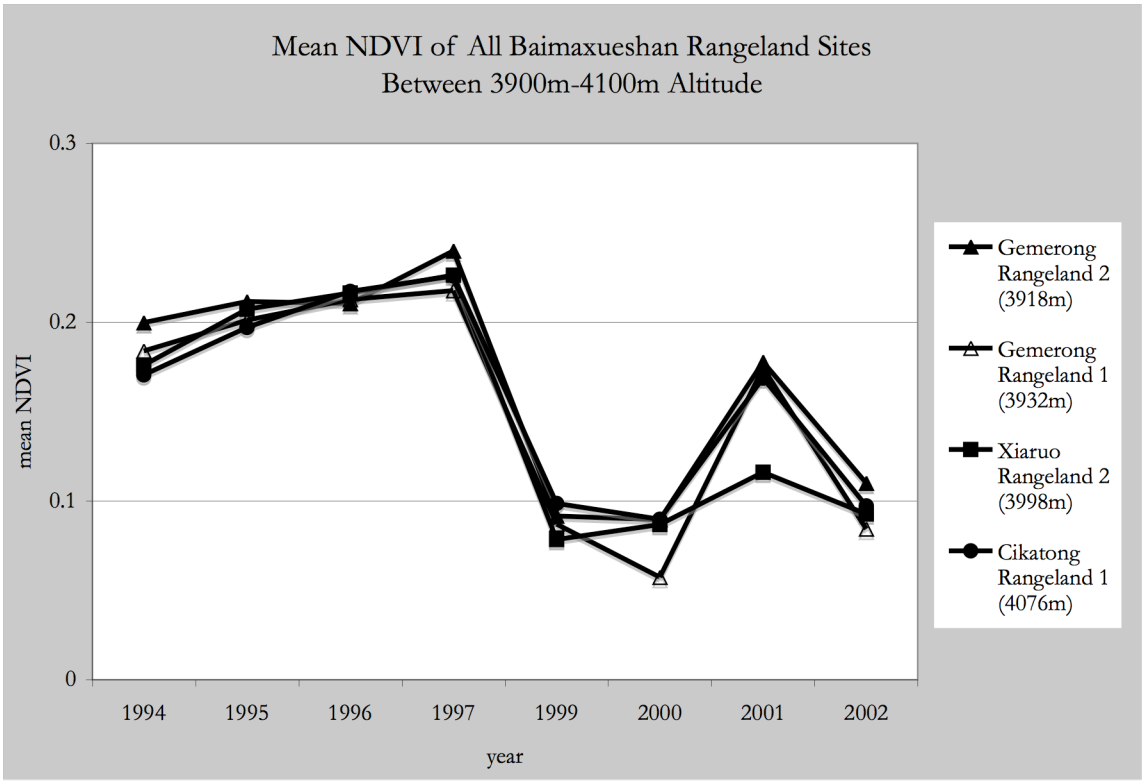



**Figure 4.8**: Similarity of rangeland NDVI across villages but within one altitude band

As can be casually observed, mean NDVI values for these sites are quite similar, even over time, despite their being more than 100km apart from each other (as is the case with Gemerong rangelands 1 and 2 and Cikatong rangeland 1). Similar trends are found for other Baimaxueshan altitudinal ranges as well across various metrics. The correlating factor in these cases seems to be a shared and narrow altitudinal band, which has important ramifications for what rangeland management schemes which might otherwise focus only on cardinal direction geographic units.

In a sense, this illustrates a shortcoming in the use of remote sensing imagery for a rugged alpine region such as Baimaxueshan, where rapid changes in altitude can seemingly confound interpretation of land cover or land use regimes. On the other hand, the vertical complexities of such alpine topography also make it a perfect object of remote sensing analysis, because with such a high degree of ruggedness, in-person traditional field measurements in Baimaxueshan's summer rangelands would be so technically and logistically onerous as to prevent them from ever being done.

Until this point, discussion of Baimaxueshan rangeland degradation has been limited to describing changes in land cover as recorded by satellite imagery. However, due to the uncertainty inherent in what might otherwise be a blind and "objective" technology-based analysis, it is important to "ground truth" findings from satellite data with more direct observations. Ideally, such ground truthing could independently verify or negate every observation drawn from a satellite analysis through comprehensive field investigation. As described above, though, this is all but impossible in Baimaxueshan for the scope of this investigation. Instead, this analysis leverages household survey data collected from around southern Baimaxueshan to construct a general, Reserve-wide human-impact reference frame against which to compare satellite findings.

Foremost, household surveys in southern Baimaxueshan suggest that most yak herders have personally noticed a decline in quality of alpine rangelands over the past decade. Out of 56 yak herders interviewed, 47 reported some sort of alpine rangeland degradation relative to 10 years ago, with an even spread across Cikatong, Xiaruo, and Gemerong administrative villages. Of the 9 herders that did not report rangeland degradation, 5 either did not answer, did not know, or had not noticed a significant change. In fact, only 2 rangers out of all 56, both from the same natural village in northern Xiaruo, reported alpine rangelands being of a higher quality than they were one decade ago. Interestingly, both of these rangers

reported that their rangelands *had* degraded until a few years previously, when their local village committee voluntarily instituted a per-yak rangeland usage fee that decreased the number of grazing yaks in the village and ultimately improved rangeland quality.

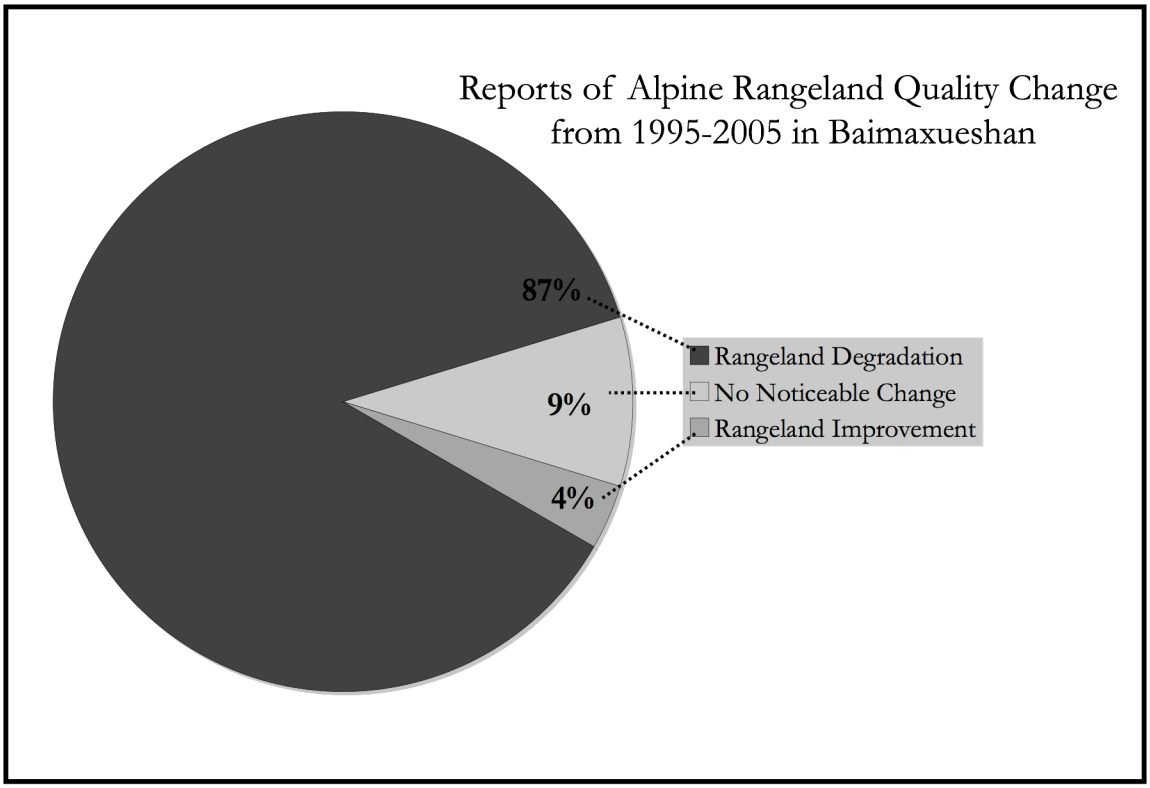



**Figure 4.9**: Alpine rangeland degradation from 1995-2005

Because herders primarily value alpine rangeland as a resource to support yak herds, and yaks are valued primarily for milk and butter production, an implicit indicator of revealed rangeland value are temporal trends in per-cow milk production. Reports of this indicator vary noticeably by administrative village. In Gemerong, where yak herding has only recently begun (mostly post-2000, see above), most respondents reported that per-cow milk production has actually increased over the past decade, typically as a result of the herder's personal increase in skill level through years of experience. In Xiaruo, trends in milk production, just like trends in yak population itself, are mixed. Responses were

nearly evenly split across gains, reductions, or no reported change in per cow milk production over the past decade.

In Cikatong, however, which has seen most of the greatest increases in yak population over the past decade, 12 out of 16 herders reported steep declines in per-cow milk production over the past decade. This was typically attributed to a perceived lack of sufficient rangeland resources available to them to graze their herd. Only 2 herders in Cikatong reported increases in production, and both were novices who attributed their gains primarily to a learning curve. Often, per-cow milk production decline in Cikatong was as much as 50% lower over the past decade, and was cited as one of the main reasons for wanting to continue to *increase* herd sizes so as to maintain total production levels. This rather perverse incentive, whereby overgrazing-induced milk production reduction leads to further yak population increases, was observed time and time again throughout Baimaxueshan, and was often recognized by the interviewee himself as a personally unsatisfactory course of action, but a somewhat effective short-run option nonetheless in the absence of viable alternatives.

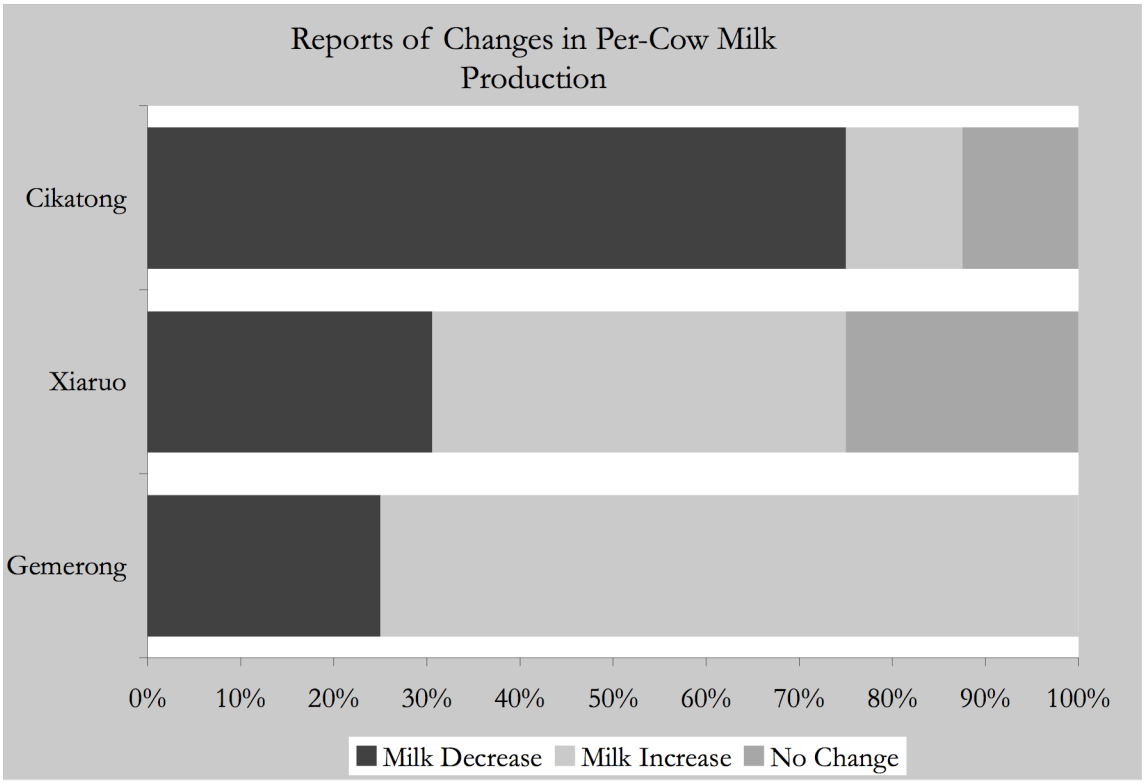



**Figure 4.10**: Decline in average milk production from 1995-2005

Most all herders spoke of rangeland degradation as being an important issue for which they have already or expect to in the future carry out mitigative or adaptive responses in yak husbandry. Somewhat surprisingly though, only 9 yak herders out of 56 reported rangeland degradation as their primary concern in moving forward with yak husbandry. 6 of these 9 lived within Cikatong Administrative Village. In other areas, nearly every interviewed herder reported the threat to themselves or their yak herds from wild animals as the number one problem faced as a Baimaxueshan yak herder. In this sense, it seems that the damages to yak herders resulting from rangeland degradation in Baimaxueshan, though acknowledged as important and troubling, are both gradual and temporally dispersed enough so as to rarely come to the fore in the way that a violent animal attack might. This raises the issue that some form of education, organizational, or coercive measures might be ultimately necessary to instigate change in Baimaxueshan rangeland management.

Just as discussion of land cover data, above, offered quantitative metrics for remotely defining rangeland "degradation", Baimaxueshan's yak herders tend to associate alpine rangeland quality with three main variables: (1) reduced availability of edible grasses to yak herds as a result of competition with other villagers' yaks (overgrazing effect); (2) overall shrinkage in grass-covered area as a result of tree growth in from rangeland edges (forest conservation law effect); and, (3) high ratios of inedible to edible plant species in rangeland vegetation composition as a result of the spread of invasive plant species or poor soil-nutrient quality (fire management prohibition effect). Moreover, (4) with the onset of anthropogenic global climate change in the alpine landscape of northwest Yunnan, the scope of unsustainable human land use in Baimaxueshan will only widen in the mid- to long-term.

*-Determinants-*

1. Yak Expansion and Overgrazing

The most common descriptor for rangeland degradation reported across Cikatong, Xiaruo, and Gemerong Administrative Villages was reduced overall grass availability or the presence of bare spots in alpine rangeland. Nearly all of the 47 rangers who reported some sort of degradation cited this decrease in all vegetation cover as an important factor. Without being prompted, interviewed herders widely attributed this decrease in vegetation as being a direct result of the simultaneous increases in total yak populations they had observed grazing in alpine rangelands every summer season.

A survey of southern Baimaxueshan herders in 2004 found historical livestock densities to be relatively low, with approximately 60-100 *mu* (15 *mu* = 1 hectare) of alpine rangeland available to each yak (Zhao et al 2004). This figure is well within sustainability guidelines formulated by Officials from the Deqin County

Bureau of Agriculture and Livestock, who suggest that 32.2 *mu* of high quality summer rangeland are required to sustain 1 yak (with corresponding estimates for other rangeland types, including mixed-use forested rangeland). Following these guidelines and government land cover classifications, Deqin County's total rangeland carrying capacity should not exceed 56,722 yaks. These same officials report, however, that increases in yak populations around the entire county recorded since 1987 are both unsustainable and, by them, uncontrollable. A recent estimate puts Deqin County's yak population above 85,000—just over 50% more than government sustainability guidelines suggest (WWF ICDP 2004). Officially, China's National Grassland Law and Desert Prevention and Transformation Law call not only for these carrying capacity figures to be published locally, but also incentives and punishments at the local level to prevent such overstocking measures, but, in practice these measures are rarely enforced (see government subsidies to animal husbandry development, above).

Evidence in this thesis of overgrazing-based reductions in rangeland grass yield come primarily from the direct observation of Baimaxueshan's rangers. Some debate exists, however, as to the universal validity of rangeland "equilibrium" theory (Dyksterhuis 1949, Milchunas et al 1988, Westoby et al 1989, Cingolani et al 2005). So-called "non-equilibrium" theorists argue that climatic or stochastic factors are far more important in determining rangeland yield loss than biotic factors (generally, Milton et al 1994, and in northern China, Feranandez-Gimenez and Allen-Diaz 1999, Ho 2001). Much of this disagreement, however, stems from non-context specific generalizations about the interaction of grazers with rangelands worldwide. Steinfeld et al address this issue in a 1997 study commissioned by the FAO, WB, USAID, and EU find that high intensity ruminant grazing in "semi-arid" rangelands with rainfall between 600mm and 800mm per year (Baimaxueshan alpine rangelands average ~700mm) does lead to substantial loss in grass yields over time. With this finding, and because of personal observations made by Baimaxueshan rangers and other rangeland users in nearby

areas of similar topography and climate (see below), overgrazing can indeed be said to be causing loss of overall vegetation productivity in Baimaxueshan alpine rangelands.

Loss of overall alpine rangeland vegetation as a result of overgrazing has also been noticed in northwest Yunnan counties other than Deqin. Yuan and Wilkes (2000) find in a survey of neighboring Gongshan County that livestock populations in ethnic Nu villages increased rapidly over the 1990s and contributed to the degradation of alpine rangeland there as well. They do note "bald spots" in Gongshan rangelands, but attribute them more to rooting by pigs than to overgrazing by cattle. Pigs, however, are far less of a concern in Baimaxueshan's overwhelmingly yak-based livestock population (due to a Tibetan aversion to pig raising and the comparatively high altitude of Baimaxueshan's rangelands to which yaks are better adapted). Reduction in alpine rangeland grass yields as a result of overgrazing has also been noticed in neighboring Zhongdian County (Ma 1998, Chan 2004, Xu and Wilkes 2004, Hui 2005), though, again, to a lesser degree than in Baimaxueshan. Grass yield reduction has not been observed to be an important part of rangeland degradation in Zhongdian County's TuoMunan Village (Xie et al 2001), where the spread of invasive species and lack of crop area for growing winter fodder is argued to be a more pressing concern to local herders.

All of these Zhongdian County studies do, however, describe actions undertaken by the Zhongdian Bureau of Animal Husbandry, starting with the 1992 "Grass and Livestock Development Project", to address rangeland degradation through assignment of individual tenure rights, fencing of winter fodder fields, and introduction of exotic high-yield grass species into some rangelands, much as is done in other areas of Western China, to mixed success. Such management techniques have proved far too costly, however, to attempt on summer alpine rangeland (Wu and Richard 1999), and these programs do not exist in Baimaxueshan.

As a result, some local herders throughout southern Baimaxueshan report taking matters into their own hands and manually seeding both alpine and mixed-forest rangeland plots with exotic species of fast-growing grasses (typically Australian in origin). These grasses, bought from local markets, are reported to grow to useful grazing densities in just over one week. Therefore, a yak herder might replant numerous times throughout the summer grazing season to ensure that his herds have enough grassy biomass to put on sufficient weight. While the planting of so-called "artificial" grass in overgrazed areas is actually *mandated* under Article 12 of the National Grassland Law and under the National Desert Prevention and Transformation Law, the introduction of exotic grass species into alpine rangelands is *prohibited* by both National Nature Reserve Law and local Baimaxueshan regulations, putting those herders who practice it in legal limbo.

Official perception of rangeland degradation due to overgrazing is not limited to Tibetan areas in Yunnan's northwest. The "Yunnan Province Grassland Ecology Conservation Construction Plan for 2003-2010", issued by the Yunnan Province Agricultural Ministry and the Yunnan Province Development and Planning Assembly Commission (2003) noted a reduction in primary productivity as a result of overgrazing across the entire province. According to their report, over 83% of Yunnanese grasslands are degraded to some extent, with 15% severely degraded, and over 33% moderately degraded (reprinted in Zhao et al 2004). In comparison with these startlingly high province-wide figures, it would seem that Baimaxueshan's rangelands are relatively healthy, having been historically protected by their comparatively rural and uninviting mountainous location, low human population density, and careful traditional management regimes— a proposition supported by local Nature Reserve managers. Much of the concern over degradation of Baimaxueshan's rangelands centers then not on absolute magnitude, but on the exceptionally rapid pace of change in quality of a resource which is so important to local livelihoods.

2. Inedible Plants and Fire Prohibition

Increasing relative abundance of invasive and yak inedible grass species in alpine rangelands was the second most common reported manifestation of degradation in Baimaxueshan, but with only about two-fifths as many complaints as with overall vegetation reduction. Most complaints about unfavorable vegetation composition came from herders in Cikatong Administrative Village, who have the longest history of and are most dependent on yak husbandry of any other southern Baimaxueshan area (with only 1 complaint each coming from Gemerong and Xiaruo). Each Cikatong ranger who reported this form of degradation attributed the decline to a Reserve-wide prohibition on using controlled burning as an alpine rangeland vegetation management tool. This prohibition has been in effect in Baimaxueshan since the Reserve's inception (with enforcement starting in 1984 in most areas, including Cikatong), though evidence suggests that some burning might have continued until at least the late 1980s (WWF ICDP 2004).

*Rumex nepalensis*, or Himalayan Dock, has been the invasive plant of primary concern in Baimaxueshan alpine rangelands over the past decade. Wilson et al detailed the spread and current extent of this yak-inedible broadleaf perennial herb, native to the Hindu Kush Ranges, in a 2004 survey of Gongshan County's Dimaluo Village, which is immediately adjacent to southern Baimaxueshan Nature Reserve's western border. The Dimaluo survey found that *R. nepalensis* currently exists on approximately half of rangeland areas, and is "actively colonizing and expanding in the rangelands," particularly in areas disturbed by heavy grazing, but the distribution is uneven among even neighboring rangelands. *R. nepalensis*, which is more drought- and cold-tolerant than existing rangeland plant species, was also found to be outcompeting (shading-out) native grasses in many areas, increasing its relative abundance in total vegetative cover.

The recent and accelerating spread of *R. nepalensis*, locally known in Mandarin Chinese as *tudahuang*, can be attributed to: (1) increased abundance of livestock manure on alpine rangelands, which has been found to encourage sprouting of certain *Rumex* varietals (Klimes and Klimesova 1999); (2) increased plant community disturbance from recent heavy grazing pressures; and, (3) the preferential grazing of competing native grasses, with the associated community-level selection pressures. To address this invasion, Wilson et al recommend that limited herbicide applications might be an acceptable form of management given the threat to rangeland values under continued spread (2004). This is the sort of system employed by Baimaxueshan government agricultural bureaus (alongside hand-weeding) in recent eradication projects, but which were so limited in scope (they never extended much beyond easily accessible areas alongside the main lowland road) and lacking in success (having been described by the head of the local Nature Reserve Management Station as "completely worthless") as to never pass the pilot stage of implementation. However, traditional management practices based on indigenous knowledge systems of local herders have the potential to be effective while avoiding hazardous and costly chemical treatments.

One method, in practice today among Xiaruo Administrative Village's farmer-herders, is manure collection. Because sprouting of *Rume*x spp. is thought to be aided by high soil-nutrient levels such as those created under high rates of manure deposit, then management of yak manure levels in alpine rangelands is likely to help slow the spread of this invasive plant. To Xiaruo's lowland farm landholders, who value yak manure as a fertilizer for their fields and actively collect it from alpine rangelands throughout the summer, such a management regime is natural. Compellingly, only 1 yak herder out of 14 interviewed in Xiaruo mentioned invasive species or abundance of inedible vegetation as a form of alpine rangeland degradation, compared with nearly half of Cikatong rangers. Whether Xiaruo's farmer-herders knowingly remove manure as a check against colonization of

invasive species, when other southern Baimaxueshan rangers seemingly do not, is unclear.

Another traditional rangeland management technique that is widely perceived among herders to be so effective that rangelands become unusable without it is the prescribed burn. Tibetan yak herders in northwest Yunnan have used periodic alpine rangeland burning for generations as a way to naturally and efficiently remove buildup of inedible vegetation, such as *R. nepalensis*, *Stellera* spp., and *Potentilla* spp., while recycling soil and plant nutrients (Yuan and Wilkes 2000, Xie et al 2001, WWF ICDP 2004, Xu and Wilkes 2004, Zhao et al 2004). To prevent uncontrolled forest fires as a result of prescribed burning, rangeland managers typically dig trenches, pre-clear bands of border vegetation, or select rangelands that have natural barriers such as a cliff or stone face that can act as a fire break (though there are reports in some areas of poorly controlled or uncontrolled prescribed burning as well, see Chan 2002). The rangeland manager will then set fire to the enclosed meadow area that has become unproductive for livestock grazing. The charred rangeland is then allowed to lie fallow for at least one season of regrowth. Often, prescribed burnings will be repeated in a particular rangeland every 5 years or so as deemed necessary by rangers. A detailed description of the effects of and techniques used in prescribed burning of rangelands in northwest Yunnan has been carried out by the Center for Biodiversity and Indigenous Knowledge, a local NGO, and finds Tibetan fire-based rangeland management in northwest Yunnan both effective and a valuable cultural knowledge asset (see CBIK 2005 and Wu et al 2005).

Supporting the testimonials of experienced Baimaxueshan yak herders, the effectiveness of using controlled burns to manage weedy plant species, encourage the cover native vegetation, and increase productivity and value of rangelands through nutrient cycling (particularly in available phosphorus or nitrogen-limited ecosystems) has been described in modern scientific literature by ecologists,

economists, and professional managers (Bernardo 1988, Menke et al 1996, DiTomaso 2000, Gyamtsho 2002). However, Chinese national land management policy continues to view wildfire as the primary *threat* to forest conservation. In Diqing Prefecture, for example, 99.8% of forest fires between 1985 and 1995 were officially attributed to human action, with over 42% to rangeland or farmland-related burning alone (Xu and Wilkes 2004). To combat this, the Chinese Forestry Bureau pursues an aggressive fire suppression policy nationwide (Shu and Tian 2002), similar to the suppression-based policies employed by the United States National Park Service for nearly a century until abandoned in 1967 as being ecologically unsound (Rothman 2006). As a result, neither local yak rangers nor government land mangers are permitted to employ prescribed burning of any kind within Baimaxueshan.

Such prohibition on prescribed burning both weakens the long-term ecological health of Baimaxueshan's alpine ecosystems and reduces the value of rangeland resources to Baimaxueshan's yak herders year by year. When asked for possible solutions to address the rangeland degradation obvious to the majority of Baimaxueshan rangeland users, resumption of traditional fire-based management techniques was the number one response given by Nature Reserve yak herders. Failure to address this issue at the national level through compromise legislation is likely to lead to continued environmental, economic, and social instability in rangeland communities.

3. Unmitigated Forest Encroachment

Tree growth around and in from the edges of alpine rangelands was reported as the third most common form of alpine rangeland degradation, but with only half again as many total complaints as reported for inedible species. Once again, all but 1 of these complaints came from Cikatong rangers, who also blamed the problem of

tree encroachment into rangelands on Reserve regulations that in some areas levy fines against, and in other areas fully prohibit, the cutting of timber.

The prohibition against cutting young immature trees that grow in or, more commonly, around the edge of traditional meadow rangeland areas is probably the single Nature Reserve policy which most directly pits broadly-defined forest conservation ideals against the persistence of existing traditionally managed alpine rangeland ecosystems and the herders who depend upon them. Though complaints against this policy, which leads to rangeland degradation, are currently not as widespread as those against the fire prohibition, it is obvious that floral succession and encroachment by woody, inedible vegetation such as *Quercus*, *Larix*, and *Rhododenra* spp are a major concern for yak-herding rangeland managers who observe the slow degradation of rangeland resources and are physically capable of overcoming it (Bao et al 2001), but are legally powerless to do so. Moreover, because many of Baimaxueshan's alpine rangelands are technically located within the most restricted "core" land use zone of the Reserve, successfully dealing with tree and shrub growth has been all the more vexing.

In addition to alpine rangelands, mid-altitude mixed forest rangeland areas in Baimaxueshan are also experiencing similar increases in woody biomass in the absence of traditional human management. The author observed this phenomenon directly while visiting a mixed forest rangeland at 3000m, above Cikatong Administrative Village, where regeneration of small deciduous tree and shrub species in the understory of the predominantly *Pinus yunnanensis* mature forest was widespread. When interviewed, the rangers present indicated that four different families had been using this mixed forest rangeland for over 20 years, but that new tree growth was now becoming so dense and, as a result, the grass so thin, that they all planned to move on to other pasture areas within two or three years. Officials from local Agriculture and Animal Husbandry Bureaus in Baimaxueshan

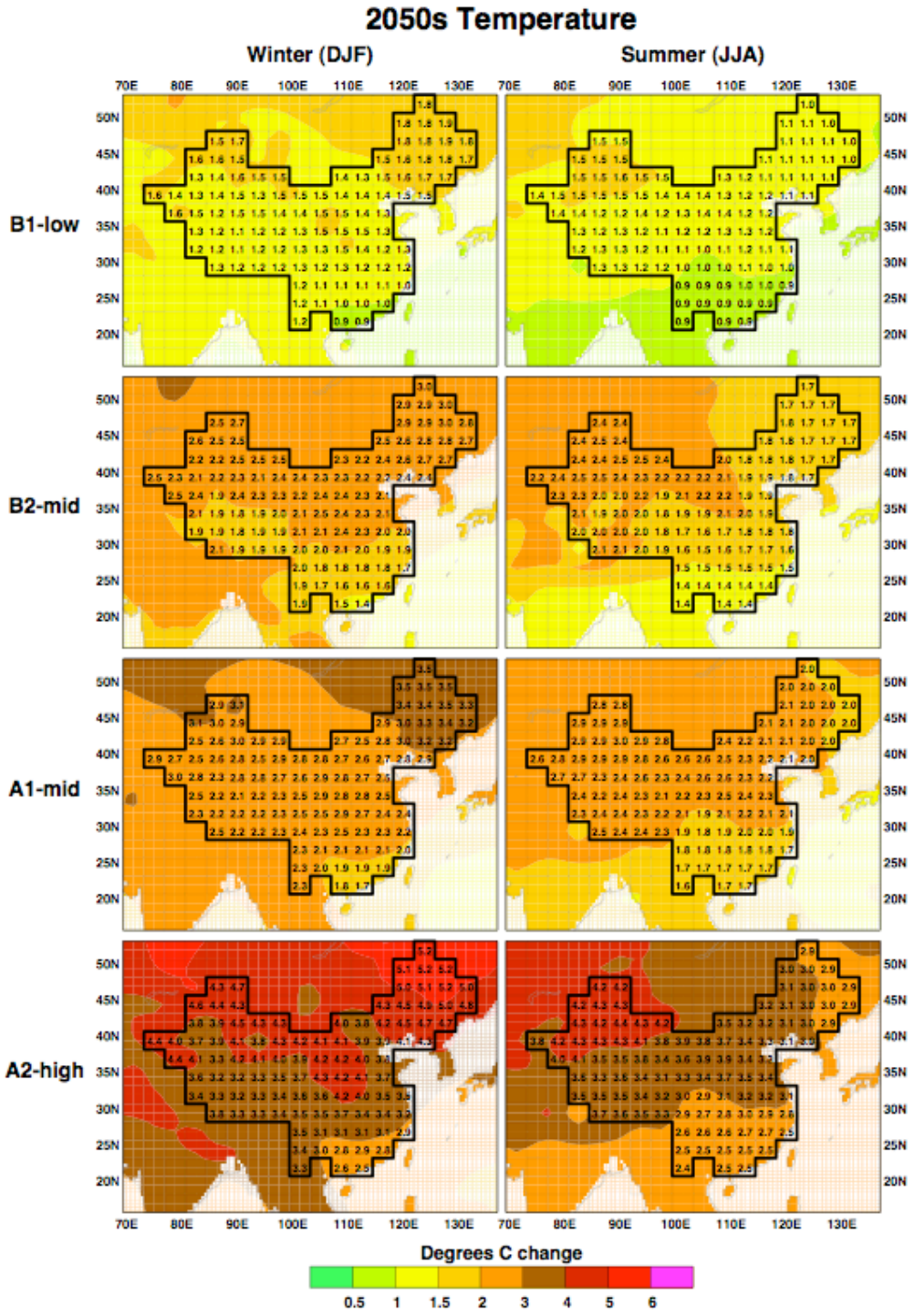
predict that tree growth and encroachment onto rangelands will become a major source of conflict with yak herders in the near future.

4. Global Climate Change

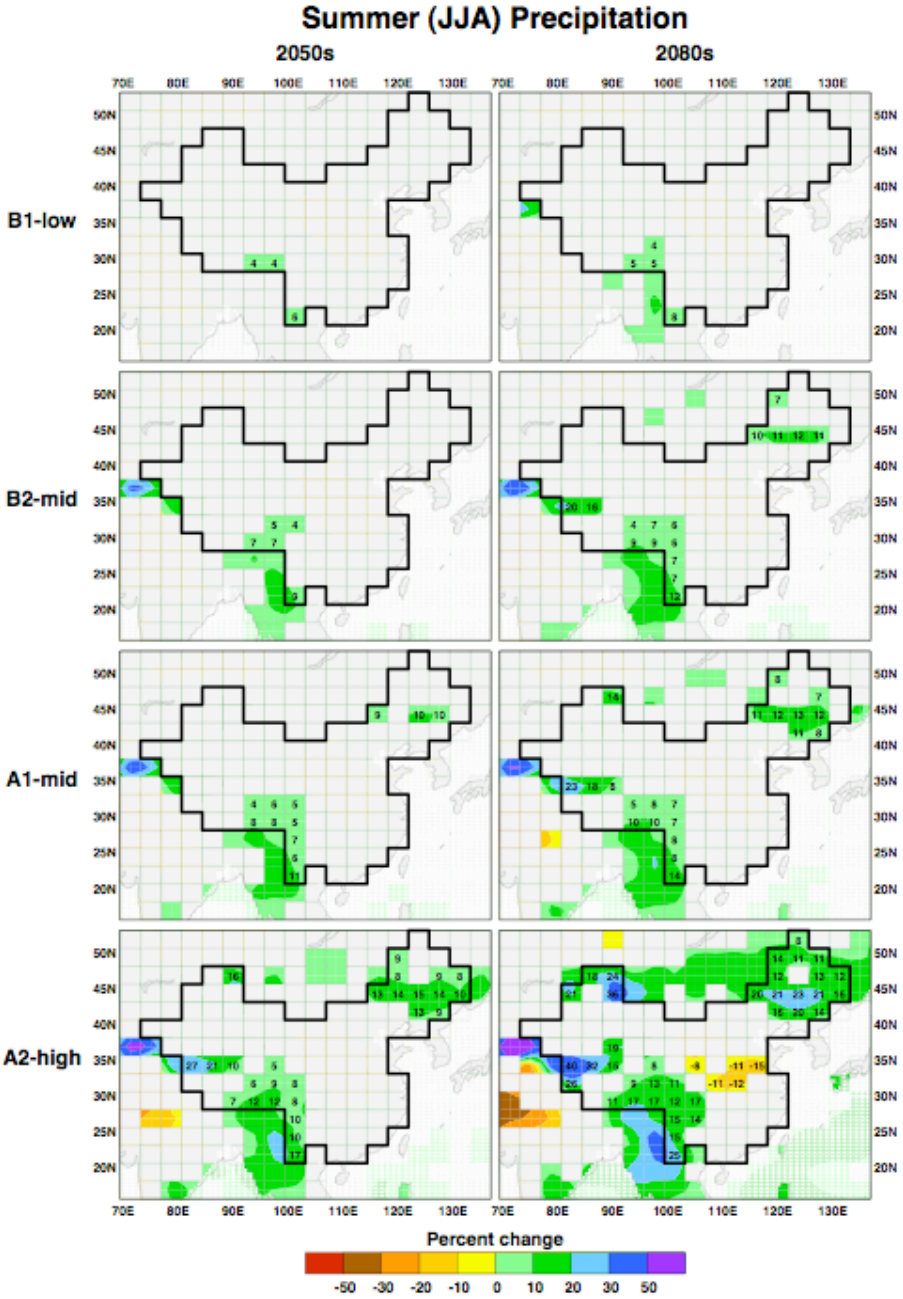
Notwithstanding the more proximate forms of anthropocentric (including policy-induced) rangeland degradation detailed above, the alpine meadows of Baimaxueshan, like other alpine grassland ecosystems along the Hengduan Mountain Ranges, are also extremely susceptible to climatic disturbances such as those forecast by numerous computer models of anthropogenic, carbon-dioxide induced, global warming and global climate change over the coming century (Salik 2006). In particular, according to temperature and precipitation models released in 2006 by the Inter-Governmental Panel on Climate Change (IPCC), global warming disturbances will likely lead to reduction in alpine grassland land cover as tree lines advance up to higher altitudes, floral communities shift in composition, and invasive grass and weed species accelerate their colonization.

Owing in part to the area's steep relief, which induces numerous seasonal and altitude-based micro climates, projections for anthropogenic climate change over the next century in the Three Parallel Rivers region of Southwest China are varied. Baker et al (2005), through interpolation of a collection of regional models, predict changes specifically for Baimaxueshan Nature Reserve's alpine grassland ecosystems. With a spatial resolution of only 2km, they forecast a yearly mean temperature increase of 3.8 degrees Celsius in the period 2070-2099 as compared with a reference period of 1970-1999, noting that the reference period itself already underwent a .6 degree Decade/decade temperature increase relative to earlier parts of the century. In total, Baker forecasts a temperature increase of over 5.0 degrees Celsius over a 100-year period, which is more than twice many current forecasts for worldwide average temperature increase due to anthropogenic climate change. Regional IPCC and WWF models (Hulme and Sheard 1999, IPCC 2006)

also note that much of this temperature increase will occur during the winter months, and will also be accompanied by gradual increases in both winter and summer precipitation (15% by 2080) and reductions in snowfall. Years of "extreme climate", counting both temperature and precipitation anomalies towards either extreme, are also expected to increase by as much as an order of magnitude (see Wolong Nature Reserve, climatically and topographically very similar to Baimaxueshan Nature Reserve, in Baker et al 2005).




**Map 4.1:** IPCC models for changes in mean winter and summer temperature for a 30 year period centered at 2050, referenced from a 30 year period centered at 1975. Projections from 4 model scenarios are given. The region around Baimaxueshan Nature Reserve is the tile at the point of the large right hand angle cut-out along China's southwest border (image from Hulme and Sheard 1999).




**Map 4.2:** IPCC models for changes in peak-season precipitation for 30-year periods centered at 2050 and 2080, referenced from a 30 year period centered at 1975. Projections from 4 model scenarios are given. The region around Baimaxueshan Nature Reserve is the tile at the point of the large right hand angle cut-out along China's southwest border (image from Hulme and Sheard 1999).

Alpine rangelands in and around Baimaxueshan can be thought of as "island"-like habitat fragments surrounded by a matrix of mid-altitude temperate mixed deciduous and coniferous forests. Because of this spatial arrangement, a primary concern is that with the predicted rising winter temperatures over the next century, these grassland fragments will be "pushed" up to higher altitudes on steep mountain slopes as temperate forests expand their range and encroach into current grassland habitat. Jan Salik, currently working in the area with the Global Observation Research Initiative (GLORIA), predicts that many alpine ecosystems in northwest Yunnan will simply be "pushed right off the mountains" according to local models for global climate change (NPR 2006). In fact, IPCC estimates predict a complete loss of permafrost regions along China's Qinghai-Tibetan Plateau with as little as a 2 degree Celsius temperature increase, a situation which could arrive within half a century (2006).

Predictions for long-term climatic change in the region are likely to exacerbate the numerous forms of rangeland degradation outlined above. One manifestation of this might be increased forest encroachment of rangelands. Conifers and tall rhododendron shrubs will become more competitive as the grasslands warm, increasing the overall biomass in the meadows through rapid floral succession. However, the overall speed of migration could actually be slowed in this environment due to the generally slow growth rates for plant species at high altitudes. The threat exists, then, for loss of genetic diversity along the lower edges as meadow grass species are "pushed out" by temperature increases before mid-level forests can colonize along their new upper boundary (the same "squeeze" would occur in the meadow itself, as grass species along the upper boundary are slow to colonize, or more threatening yet, are blocked entirely by rugged topography).

Phenological changes and reductions in snowfall could also contribute to increased colonization and success rates of invasive species. Shen et al (2004) have already documented in detail the advance of invasive *Rumex nepalensis*, a grass inedible to yaks, introduced from the Western Himalaya region, and which proliferates under "broad ecological tolerances". Most important to note is that this invasive species, like many others in temperate grasslands, is noted to colonize most effectively in already disturbed areas. Such climate change-induced disturbances are already visible in alpine meadow ecosystems, where community composition and peak biomass levels are heavily controlled by plant phenology. With current warming, IPCC researchers have recorded flowerings occurring 3-4 days earlier in the year as a result of 1 degree Celsius mean warming, and leaf fall 2-7 days later (2006). This change in timing could open invasive-prone niches in grassland ecosystems knocked out of equilibrium by warmer winters.

Additionally, invasive species stand to become more competitive as snowfall rates decrease, winter rain becomes more common, and winter snow cover periods shorten. Currently, the period of the winter monsoon, from October-March, is crucial to alpine grassland ecosystems as the ground is blanketed in thick snow cover for months on end. Through this natural period of stress, hardy native grass species go dormant while any warm climate invasives from lower altitudes are killed off. As the climate warms, this adaptation by native species will become less and less of an advantage, particularly if fast-maturing invasives are able to sprout first after a year of light snowfall.

For yak herders who rely on the winter snow cover phenomenon described above to "reset" the community composition of the grasslands each year so they are once again suitable for grazing, such a climatic change could be devastating. If winter snow cover is reduced, or if grassland fragments shrink even further, the risks to local families increases dramatically. The loss of economic stability from yak herding could exacerbate drive local residents to unsustainably pressure what

natural resources remain, whether that be through the "catch-22"-type continued increases in yak population mentioned above, or even moving into other extraction-based income activities, such as the illegal logging of (projected-to-expand) upland forests.

Buffeted by forces both near and far, and in the absence of robust management regimes, the future of Baimaxueshan's rangelands, and that of its rangers, is under threat.

Conservation policy, along with other important features of local context, is driving unsustainable land use in Baimaxueshan. In turn, such land use is contributing to alpine rangeland degradation, a phenomenon which undermines both conservation and development opportunities for the Nature Reserve.

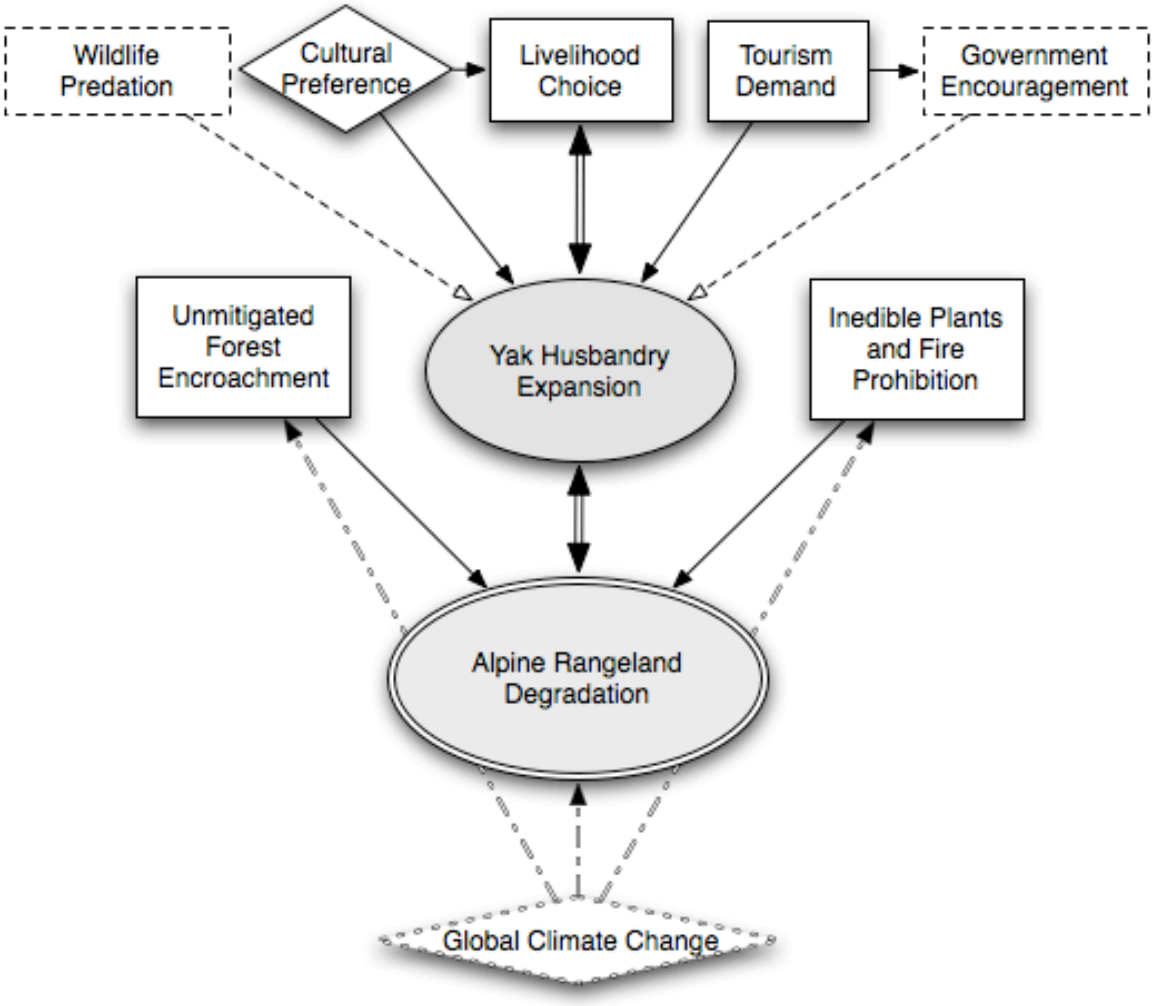



**Figure 5.1**: Relationship in determinants of yak husbandry expansion and rangeland degradation

The effects, however, are mixed. Some determinants of unsustainable yak husbandry land use in Baimaxueshan, such as livelihood choice or fire

management prohibitions, are strongly and directly influenced by conservation regulations. For other determinants, such as eco- and ethnic-tourism demand for yak products, the relationship is more obscure. But, only the Tibetan cultural affinity for yaks and the specter of global climate change seem to be wholly exogenous of conservation policy.

It would be easy to suggest macro-level policy changes that might refocus conservation or development efforts region-wide to the benefit of Baimaxueshan's yak herders. For example, this could be as simple as shifting environmental conservation priorities in the National Nature Reserve Regulations to explicitly include protection of grassland ecosystems in addition to forest ecosystems, and then translating these modified priorities into complementary regulations at the provincial and local levels. Alternately, great benefit for grassland and forest ecosystems alike could be had by updating State Forestry Administration policies to include ecosystem management through controlled fire regimes (a path chosen by the United States National Park Service nearly 40 years ago). However, such broad top-down solutions could not come without significant cost, training, or delay. Moreover, while they might be effective for yak herders in Baimaxueshan (or for other livestock herders in upland southwest China), such policy change is ultimately context aspecific; and understanding how important local context has been in shaping Baimaxueshan's yak husbandry situation, it would be altogether unsurprising if what worked in northwest Yunnan failed in Inner Mongolia.

Instead, if policy changes are indeed to be pursued at the national level, more progress might be had in introducing legislation that supports the use of indigenous knowledge in management of natural ecosystems. This might be particularly successful within China's vast network of national nature reserves which generally lack sufficient staff, capacity, and local flexibility to achieve given conservation objectives while simultaneously facing the reality of an existing human population's development and resource needs. By allowing state ecosystem

management to complement and adapt to traditional techniques which have shown to be historically effective in a particular area (whether that be Baimaxueshan, Inner Mongolia, or anywhere), then nature reserve managers might be able to turn the *complication* of indigenous human populations into a *asset*. Local environmental, economic, and cultural variability could in fact contribute to wise and just management. For Baimaxueshan and other nature reserves with similarly high proportions of indigenous ethnic minorities, support for a minority-managed "autonomous" nature reserve could even come from a strengthened Chinese Law on Regional Ethnic Autonomy that recognizes the cultural value of indigenous knowledge systems for resource management.

This is not to suggest, however, that Chinese nature reserve management should be completely decentralized, or that indigenous knowledge-based management is comprehensively superior to existing regimes. Take, for example, Baimaxueshan yak herders' stated ideal herd sex ratio (7f:3m) or actual reported ratios (~1f:1m). Not only have herders failed to realize their own sex ratio objectives facing only minor contextual constraints, but also this very "ideal ratio" appears (at least from the outside) to be extremely low when compared with Western small-scale diary standards closer to 10f:1m. Of course, Baimaxueshan's yak herders could still be perfectly justified with this preference given their special knowledge of local conditions, but it is also likely that these same herders are falling victim to market failures (in a broad sense) or imperfect information outside of their control and which prevents them from achieving context-specific resource and development optimization. A similar argument could be made for the Tibetan traditional practice of (seemingly unnecessarily) cutting timber to cook yak fodder in the winter (discussed above). Given this, it would seem that some degree of top-down management in nature reserves has value. Minimally, though, adaptation and sensitivity to local knowledge systems could nevertheless be pragmatic and just.

Whatever the precise form of macro-level policy changes, action focused at this broad and distant scale is insufficient for the clear and present threats in Baimaxueshan. National policy change in China can be unpredictable, opaque, and above all, out of reach of ordinary people. Moreover, to ignore local solutions would be to discount the very wealth of indigenous knowledge systems upon which the above policy recommendations rest. The following suggestions focus on concrete steps that herders in Baimaxueshan could execute *themselves* at a grass-roots level.

Firstly, Baimaxueshan yak herders and local level managers should resist recommendations to establish family-level tenure rights to alpine rangelands. Some scholars and government officials believe that assignment of individual tenure rights to grazing lands could do for herders today what the (highly successful) Household Responsibility System did for Chinese farmers in the late 1970s with the transition from inefficient agricultural communes to productive individually-managed farms. Assignment of such strictly defined personal property rights is often offered as the economically rational solution to a Hardin-esque "tragedy of the commons", a model which assumes dispersed damages from overexploitation of a resource by self-maximizing individuals in an unmanaged system. Theoretically, rangeland tenure would address this problem by granting individual herding families powers of exclusion for their assigned grazing plot, thereby giving them a personal incentive to sustainably manage that particular plot to ensure future productivity. However, the assumptions of Hardin's model may not be entirely applicable to Baimaxueshan's herding communities.

Far from being *unmanaged* systems, Baimaxueshan's alpine rangelands are in fact *communally-managed*. At the natural village level, herding households in Baimaxueshan ostensively function as a cohesive unit rather than atomistic self-maximizing individuals. In many natural villages, one or just a few individuals will actually be responsible for taking an entire village's yak herd to summer

rangelands, as this individual is seen as being most skilled or fit among all villagers to do so. Often, this head-herder will receive a small stipend of cash, butter, or labor in return for providing yak grazing management and milking services to his neighbors. Additionally, because of traditionally strong intra-village bonds in general, what befalls or benefits one family is likely to affect the entire natural village. If a family member falls ill, a neighbor might volunteer to fill his work. Or, if one household happens to produce a surplus of butter, it might be shared through a natural village's tight familial and interpersonal networks. In this way, Hardin's benefits to resource overexploitation are neither realized by the individual alone, nor are his predicted damages to the community dispersed. So, yak management in Baimaxueshan is much more akin to a "natural village responsibility system" than the inefficient and poorly managed agricultural communes of the 1970s, which shared neither the scale nor the historical precedent of informal village-based networks. To say nothing of the costs and logistical effort involved in fencing or otherwise enforcing individual household demarcations at 4500m, assignment of formal individual tenure rights in Baimaxueshan would be inappropriate in the face of existing traditional management systems.

If the natural village in Baimaxueshan acts implicitly as a cohesive unit though, what village-based management failure accounts for the seemingly irrational (and counter-productive) yak population growth over the past decade? In part, this could be due to inadequate formalization of traditional intra-village networks that exist explicitly to manage scarce alpine rangeland resources. Specifically, without a special village level forum with voluntary association but binding commitments that addresses yak husbandry expansion, then the flow of information from rangeland to village or from household to household might not be robust enough to respond to Baimaxueshan's dynamic ecological and economic environment. Also, without an "objective" formalized structure in place for yak husbandry management within each village that both represents and sanctions the actions of each herding

household, it could be difficult on individual and inter-personal levels to achieve compliance with the expressed goals of the village as a whole.

A second recommendation, then, is to strengthen and formalize organic natural village level community networks for the specific purpose of sustainably managing yak husbandry and alpine rangeland resources. In conversations with herding families in Cikatong and Xiaruo in particular, such a course of action seemed to have broad support from those rangers who noticed alpine rangeland degradation and village-wide yak husbandry expansion, but who felt that informal village networks in their current forms were incapable of organizing other herders in ways that could successfully address existing and future land use threats. Generally, these herders expressed a desire not to develop new institutions, but to instill enough of a sense of urgency within their communities to instigate a strengthening from within. As an added benefit, many herders felt that having a village-recognized and empowered council for dealing with yak husbandry could also be valuable in bringing a cohesive front to current or future *inter-village* alpine rangeland usage disputes, such as negotiating right-of-passage through another village's territory or in leasing out grazing rights to village outsiders.

In forming such management organizations, though, it is important that the impetus be assumed voluntarily from within the village itself rather than requisitioned from above by Nature Reserve Management or some other government entity. Through a series of secondary contingent valuation-type surveys taken in southern Xiaruo to determine a crude measure of herding families' willingness to pay for sustainable management of alpine rangeland resources, interviewees spoke time and time again of their willingness to participate in agreements that physically or economically restricted use of rangelands, but only if such restrictions were organic. That is, these herders would only assume binding restrictions for the sake of long-term rangeland sustainability that were conceived and enforced wholly by their natural village and for the good of their natural village as opposed to distant

nature reserve conservation goals. This way, they felt, villagers could trust that usage restrictions were really in their best interest now and in the future. Otherwise, if herds size restrictions were mandated from the "outside" by Nature Reserve Management, they would likely protest the regulations and comply only under strict enforcement (which Reserve Management lacks the capacity to carry out). This does not mean, of course, that there is no place for local government or non-governmental entities in contributing to sustainable land use among Baimaxueshan's herding communities; such organizations could be extremely useful in providing initial forums for or organization of village committees. These groups could even offer management advice, if requested by the natural village networks. For long-term success and efficiency, however, these "outside" stakeholders should play an auxiliary rather than authoritative role.

Such strengthening of small-scale traditional management networks would not be without precedent in Baimaxueshan. As a centerpiece of the WWF-China Baimaxueshan ICDP, similar local management committees were established to ensure the future sustainability of NTFP collection in the Reserve, with particular attention given to regulations that govern the sale and collection of *matsutake* mushrooms. This system, which rose from the severe over-harvesting of NTFPs following the 1998 NFPP and has since spread to over 50 natural villages in Baimaxueshan, is based on principles of comanagement. Regulations that limit *matsutake* minimum harvest size and particularly damaging harvest techniques are developed through community organizations that include stakeholders from both nearby natural villages and Nature Reserve Management stations through educative rather than coercive means. For affected villagers, participation is initially voluntary, but regulations (which vary slightly by community), once agreed upon, are binding and enforced by both Reserve Management and other villagers at the marketplace. Such a management structure, which often rests on extensive negotiations, is indeed time-consuming and does require a certain level of training and education among both villagers and Reserve Management. However, the

results of this work with NTFPs has been extremely positive, with villagers averaging greater incomes from the sale of larger mushrooms supported by a healthy NTFP ecosystem.

The success of the Baimaxueshan NTFP community comanagement model lends support for a similar system that would address yak husbandry and alpine rangeland degradation. Moreover, once strong village-level networks are established, this management structure could support other conservation and development initiatives which would otherwise be impossible. Opportunities abound. One fruitful path might incorporate the active branding of Baimaxueshan yak butter as a "green product", thereby leveraging Baimaxueshan's position as a nature reserve. With proper distribution channels, such eco-branding efforts could fetch higher per unit prices for Baimaxueshan butter products in "eco-tourist"-conscious Zhongdian. In this way, Baimaxueshan yak herders' current competitive disadvantage against butter-producing neighbors outside of the Reserve (who are not restricted in the environmental impacts of their yak husbandry practices such as Reserve herders are) could in fact become a valuable advantage in the marketplace. Similarly, a village committee could gradually restrict yak population expansion and institute fallow periods for alpine rangelands deemed to be at particular risk so as to increase total milk (and butter) production from a smaller, more productive, and more efficient yak herd. Or, even more ambitiously, such village level organizations could become agents of policy change within the Reserve. For example, both yak herders and Reserve Management might gain from remapping land use restriction zones within Baimaxueshan to better reflect the range and habitat of protected wildlife versus the extent of productive alpine rangelands for grazing. Specifically, from results of land cover analysis in this thesis, it seems that land use zones based carefully upon altitude, rather than cardinal direction geography, might most accurately describe ecological zones in Baimaxueshan. All of these management strategies promise to contribute to environmental conservation and human development together, but none would be

possible given the perverse incentives that yak managers would otherwise face in the absence of village comanagement networks.

For all the complexity of environmental, economic, political, and cultural forces in Baimaxueshan, it would seem that future change ultimately lies in the hands of Baimaxueshan's people. From the snowy peaks of Cikatong to the plunging streams of Gemerong, resources and capacity untold ensure a sustainable path for both humans and the environment as one. Through management and cooperation– plus a few rounds of yak butter tea— all stakeholders stand to gain. And following from those wholly Tibetan ideals of respect, compassion, and insight, there lies hope for today, and for future crossroads yet ahead in Baimaxueshan.

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