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Human Activities and Global Environmental Changes: Implications for the People and Landscapes of the Tibetan Plateau

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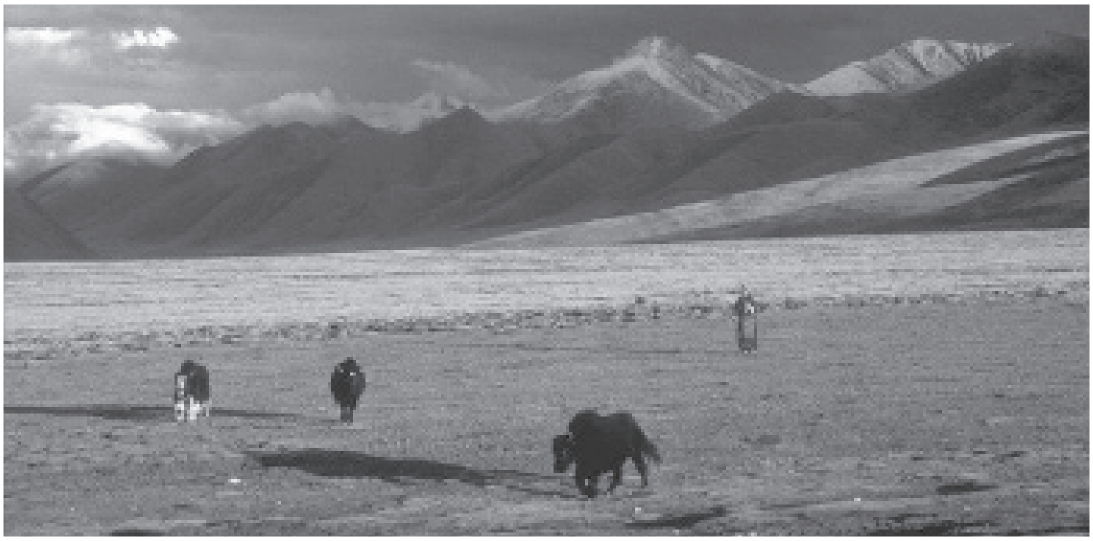


Rangeland with yaks on the Tibetan Plateau Photo: Julia Klein

"Contrary to popular Western belief, there is regional variation in the biological, physical, and cultural features of the Tibetan people and landscapes. These cultures and landscapes are not static and lost in time; rather, the people and ecosystems of the Tibetan Plateau are facing profound changes of the modern world, the causes of which are often beyond their control."

This paper challenges the commonly held Western perception that the people and landscapes are similar across the entire Tibetan Plateau region and that they are also unchanging over time. In this paper, I describe the broad spatial patterns in ecological, physical, and cultural features across the Tibetan Plateau. Moreover, I assert that the Tibetan people and landscapes are facing contemporary challenges of the changing modern world, often collectively referred to as global environmental change. Here I discuss two of these changes: anthropogenic climate warming and pastoral land use change. I introduce an ecological study I initiated on the northeastern Tibetan Plateau which examines the independent and combined effects of experimental warming and grazing on several measures of rangeland quality. These variables include vegetative diversity, plant productivity, and soil carbon storage. The results of this study suggest that the rangelands on the northeastern Plateau may be vulnerable to climate warming; grazing can mitigate some of these negative effects. Current rangeland degradation that has often been attributed to overgrazing may, in fact, be a response to ongoing anthropogenic climate change.

INTRODUCTION

The landscape and people of the Tibetan Plateau evoke a romantic image in many Western minds, one where nomadic pastoralists live on the high, arid Plateau pursuing their timeless and enduring yak-raising traditions. While pastoralism is the main land use activity on the Tibetan Plateau, this static vision of the Tibetan landscape and people is overly simplified and ignores both spatial and temporal variation of physical, biological, and cultural features of the Tibetan landscape and people. The purpose of this paper is to widen the scope of our understanding of the Tibetan landscape and people by providing an overview of the general spatial variation in bio-physical properties across the Plateau, and discussing how these features have been changing over the last few decades. With respect to this second point, this paper will highlight two specific changes that are unfolding on the Tibetan Plateau, namely climate warming and pastoral land use change. The last section of this paper will introduce an ecological study which has been examining these dynamics on the northeastern region of the Tibetan Plateau. I will discuss some results from this study and the potential implications of these findings for the rangelands of the northeastern Tibetan Plateau. I present this information in order to foster a deeper understanding of the region, an appreciation for the contemporary challenges facing the Tibetan people and landscapes, and a greater sense of the complex dynamics that are unfolding there.

In this paper, the “Tibetan Plateau” refers to the regions of the physical Tibetan Plateau that are currently considered within the borders of China: these include the Tibetan Autonomous Region and regions of Qinghai, Sichuan, Gansu, and Yunnan Provinces. These areas are also known as Amdo, Kham and U-Tsang.

PATTERNS OF PHYSICAL, BIOLOGICAL AND CULTURAL FEATURES ACROSS THE PLATEAU

Forty- to sixty million years ago, the Indian and Eurasian plates collided; the result of this continent-to-continent collision was the 2.5-million-square-kilometers Tibetan Plateau. At an average elevation of 4,000m, the Plateau is an elevated landform bounded by the Himalayan mountain range to the south and several ranges, such as the Arjun, Kunlun, and Qilian ranges to the north. The Plateau is further dissected by several mountain ranges that are oriented in an approximate west to east direction. More than six of Asia’s major river systems originate on the Tibetan Plateau and on the order of 10^9 people live on or downstream of the Tibetan Plateau.

At a gross scale, elevation generally increases, while temperature and precipitation decrease, from the southeast to the northwest of the Tibetan Plateau. For example, mean annual temperatures are generally >-2ºC and mean annual precipitation is generally >300 mm in the east and southeast; in contrast, mean annual temperature and precipitation are <-10ºC and <50mm in the northwest.

With the exception of the southeast river valley region, where there are extensive forest systems, and some other riparian and deep valley systems, the Tibetan Plateau is primarily a tundra, or treeless landscape. Just as physical and climatic features change across the plateau, so do the vegetative communities. Chang (1981) describes the mesic, alpine meadow in the eastern region, where vegetative cover is approximately 100%. By contrast, in the cold high desert of the northwest, vegetative cover can be less than 10%.

While biological and physical features of the landscape are regionally differentiated, so are the histories and cultural practices of the inhabitants of these landscapes. There are three main regions of Tibet: Amdo in the northeast, Kham in the southeast, and U-Tsang in the central and western regions. Each region has its distinct dialect and unique cultural traditions, identity, and history (Parmee 1972).

Figure 1.
Study region. The star indicates the approximate location of the experiment.

While the patterns described above hold in general, at meso and micro scales, factors such as topography, microclimate, history of glaciation, human activities, and regionally-specific policies and socio-economic histories foster exceptions to these broader patterns.

A COMMON THREAD: ANIMAL HUSBANDRY

Despite the regional variation in biological, physical, and cultural features across the Tibetan Plateau, there are common ways in which inhabitants of the Tibetan Plateau have traditionally survived. As of 1983, less than one half of one percent of the land area of the Tibetan Autonomous Region was under cultivation (Sun 1983). The natural vegetation forms the basis of Tibetan society; people rely on animal husbandry to convert plant energy into usable food and food products on which they survive. Yak, sheep and goats form the fabric of this culture; these animals provide food, shelter, clothing, and fuel among other amenities. Animal dung is a critical source of fuel in a treeless landscape. Animals also provide the mobility that enables the travel and trade that has been integral to the survival and persistence of some peoples on the Tibetan Plateau. Animals are also important status symbols and provide social cohesion during community events such as horse races and festivals.

Most people on the Plateau rely on animals to convert plant matter into usable products; however, people also directly harvest and utilize plants for various purposes. For example, inhabitants of the Tibetan Plateau harvest medicinal plants (and animals) for personal use and for commercial purposes, including as trade items and as cash earnings. Vegetation and soils from the rangelands are also directly harvested for fencing material, bedding, and other household uses, such as brooms and scrubbers.

The relative proportion of time devoted to various endeavors—such as animal husbandry, medicinal plant harvesting and trade—depends on historic and political factors. It also depends on where people are situated on the topographic-climatic-vegetative continuum describe above.

TEMPORAL TRENDS

Not only are there regional differences in physical, biological, cultural, and socio-economic features of the Tibetan people and landscapes, but there are also profound changes which are occurring over time to affect the Tibetan people and landscapes. Below we describe two of these changes.

Climate change

Global environmental changes refer to a suite of large-scale, environmental changes that result from human activities and which are having significant impacts on the global environment. These include climate warming, changes in atmospheric composition (including increases in carbon dioxide and other greenhouse gases), land use/land cover change, and losses in biodiversity (Walker and Steffen 1997).

The atmospheric concentration of CO_2 has increased 31% since 1750. Roughly seventy-five percent of the anthropogenic emissions during the past twenty years are due to burning of fossil fuels; deforestation and other land use changes account for much of the remaining anthropogenic emissions (IPCC 2001). These levels are predicted to increase by 75 to 350% above the 1750's level by the year 2100, under the various emission scenarios of the Intergovernmental Panel on Climate Change (IPCC 2001). As a result of increasing greenhouse gases in the atmosphere, global mean surface temperatures have increased by 0.6±0.2°C over the 20th century; according to the IPCC, most of the warming observed over the past fifty years is "attributed to human activities" (IPCC 2001). Globally averaged surface air temperature is projected to increase by 1.4 to 5.8°C by 2100 relative to 1900, over all of the IPCC scenarios. There is evidence from many regions of the world that climate warming is already affecting ecosystems in measurable ways (Walther et al. 2002).

Global environmental changes are, by definition, changes whose effects manifest on a global scale. Often the effects of these perturbations are not borne solely by the party(ies) largely responsible for emitting them. For example, while the U.S. contains approximately 5% of the world's population, it is responsible for approximately 22% of global CO_2 emissions (McElroy 1997). There are no boundaries to the distribution of CO_2 in the lower atmosphere; CO_2 mixes globally within a year. Industrialized societies are more buffered from the effects of global changes than less developed societies, which are more directly tied to their natural resource base. Therefore, subsistence based societies may bear a disproportionate burden of the effects of global environmental change and may also be unduly vulnerable to these changes. We currently have little knowledge regarding how ecosystems of the world (on which subsistence-based societies still depend) will be affected by global environmental changes.

Several lines of observation— including ice core data, surface measurements and interviews of pastoralists— provide evidence that the Tibetan Plateau is experiencing recent climatic warming (Thompson et al. 1993, French and Wang 1994, Thompson et al. 2000, Klein 2003); moreover, the region is predicted to experience "much greater than average" increases in surface temperatures in the future with anthropogenic warming (Giorgi et al. 2001). Alpine systems may be particularly vulnerable to climate changes due to 1) the strong control of climate in structuring and regulating alpine ecosystems; 2) inhibited migration due to topography and lack of soil formation in alpine regions; 3) short growing seasons; and 4) snow-albedo feedbacks. The IMAGE model predicts climate warming will decrease the aerial extent of the alpine and arctic tundra more than any other biome on Earth (Walker et al 2001) and that 20% of the flora of the Tibetan Plateau and Himalayas will be lost with climate warming (Alcamo 1994). Anthropogenic climate change is not only predicted to alter mean temperature and precipitation regimes, but also to increase the frequency and intensity of extreme weather events (Cubasch et al. 2001). While severe spring snowstorms have long been part of life on the Tibetan Plateau (Goldstein and Beall 1990, Cincotta et al. 1992, Miller 1998), there is evidence for both increasing spring snow accumulation during 1980–1993 compared to the previous decade, 1962–1977 (Zhang et al. 2004), and for increased snow accumulation days beginning in the mid-1980s (Niu et al. 2004). Since the domestic herbivores rely primarily on natural vegetation, there can be high animal mortality when deep and persistent snows prevent animals from accessing their main forage source.

As discussed above, the people of the Tibetan Plateau are directly tied to the climate system—via their rangelands and their animals. Herd movement, success, wealth, and survival are dictated by climate. Climatic change could therefore have profound effects on the livelihoods of Tibetan pastoralists.

Land Use Change

Concurrent with these changes in climate, there are also changes to the pastoral land use dynamic. Since the 1980s, pastoral policies have been initiated to allocate long-term use rights of pastures, which were traditionally used and managed in a communal manner, to individual households. This has resulted in rangeland privatization, fencing, and the settling of a traditionally nomadic people (Miller 1999). This imposition of a new style of rangeland management is altering the long-standing patterns of pastoral land use in the region. Mobility has been an essential component of traditional rangeland management on the Tibetan Plateau. As pastoralists rely on natural vegetation, they need to track the vegetation and be opportunistic in taking advantage of favorable conditions in which to graze their animals. Studies of similar pastoral management changes in China (Williams 1996) and in other rangeland systems of the world (Heady 1972) demonstrate how these policies can result in increased grazing pressures on the rangelands.

In addition to the changes to the pastoral land use system initiated in the 1980s as described above, China launched a campaign to "Open up the West" in 1999. This campaign involves large investments in large-scale infrastructure projects as well as investments in major environmental protection projects (Yeh, in press); these two investment foci are having large impacts on pastoral land use. First, the expansion of agriculture, infrastructure, and development projects—processes that began prior to 1999 but have accelerated since the 1999 campaign—are reducing the amount of available rangeland. Moreover, the implications of large-scale projects— such as the Golmud to Lhasa railroad— for the ecological, and socio-economic status of Tibetan herders are unknown, but are potentially profound. The second emphasis of the "Open up the West" campaign has resulted in a new grassland policy which removes grazing from some rangelands either temporarily, or in some cases permanently (Yeh, in press). This policy is based on the perception that these rangelands are degraded and that the Tibetan pastoralists are responsible for this degradation (Yang 1992, Guo 1998, Wang 1998). All of these projects and policies are being implemented to different degrees across the Plateau, creating a complex and dynamic pastoral land use system in various states of transition.

EXPERIMENTAL RESEARCH PROJECT

While the policies described above are based on the assumption that Tibetan pastoralists are mismanaging and overgrazing the rangelands, rigorous scientific evidence for this assumption is lacking. In fact, some have suggested that climate warming might be responsible for the on-going vegetation changes on the Tibetan Plateau (Chen 1998). Since there were no studies that explicitly tested the independent and combined effects of grazing and climate changes on the Tibetan rangelands, I initiated such a study in 1997. The broad goal of this work was to investigate the independent and combined effects of experimental warming and grazing on soil carbon cycling, biodiversity, and rangeland quality. I established this study at the Haibei research station (HARS), a facility run by the Northwest Plateau Institute of Biology, Chinese Academy of Sciences. HARS is situated at latitude 37°29'N, longitude 101°12'E. Mean annual temperature is -2ºC. Mean annual precipitation is 500mm, over 80% of which falls during the summer monsoon season. Mean elevation of the valley bottom is 3,200m. A detailed site description can be found in Zhao and Zhou (1999).

There are two main habitats in the region: winter-grazed meadow situated along the valley floor, and summer-grazed shrubland situated on the higher slopes encircling

Experiment site under snow PHOTO: JULIA KLEIN the valleys. The meadow is dominated by an assemblage of forbs and graminoids; the shrubland is dominated by a deciduous shrub, Potentilla fruticosa. The specific vegetative assemblages depend on habitat and grazing history. The alpine meadow and shrub vegetation which occur in this region comprise approximately 35% of the area of the Tibetan Plateau (Zhao and Zhou 1999). In 75x75cm plots, there average 30 plant species, most of which are C3, perennial plants. Soils are described as Mat-Cryic Cambisols at the meadows and Mollic-Cryic Cambisols at the shrublands (Gu et al. 2005, Zhao et al. 2005). The main domestic livestock in the region are yak, sheep, and horses. Excluding forested areas of the southeastern Plateau, it is in this more mesic, productive northeastern region of the Tibetan Plateau that most carbon is stored, that the highest density of domestic animals occurs, and biological feedbacks to climate may be most important. Furthermore, this is the region which is most affected by current land use policies.

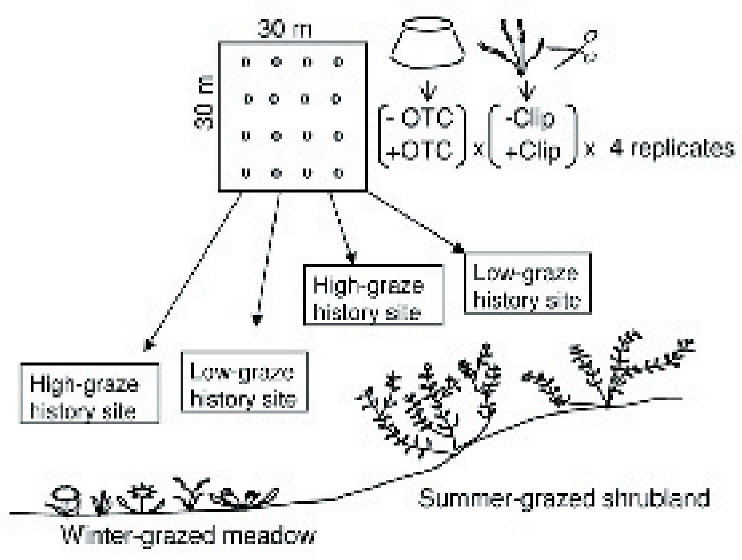
I established this experiment in both the meadow and shrubland habitats. Within each habitat, I identified sites with “low” and “high” grazing intensity histories, for a total of four sites: high grazing intensity history meadow site (HG meadow), low grazing intensity history meadow site (LG meadow), high grazing intensity history shrubland site (HG shrubland) and low grazing intensity history shrubland site (LG shrubland). Both the grazing intensity and grazing duration differed among grazing history sites. Within each habitat, the low and high grazing history sites were similar in other features—such as slope, aspect, soil type, and distance to the river.

Experimental design

Within each of the four 30 x 30m sites, I laid out 16 plots (for a total of 64 plots). Within each site, I established a complete factorial experimental design where I simulated warming using open top chambers (OTCs) and the defoliation effects of grazing through selective clipping (Figure 1). I placed the conical OTCs on the plots in September 1997. The OTCs, which were 1.5m in diameter at the base, 0.75m diameter at the top and 0.40m high, remained on the plots year-round. I sampled vegetative properties in a 75cm x75cm area centered in the plot in order to avoid chamber “edge effects”. The chambers did not exclude precipitation from the 75cm x 75 cm area. Moreover, the vegetative canopy, including that of the shrubs, was less than 40 cm in height. OTCs are used by the International Tundra Experiment and are commonly employed to study the effects of climate warming on ecosystems (Marion et al. 1997).

The OTCs consistently elevated growing-season-averaged mean daily air temperature at 10cm above the soil surface by 1.0-2.0ºC, maximum daily air temperature by 2.1-7.3ºC and the diurnal air temperature range by 1.9-6.5ºC. By contrast, OTCs had few effects on minimum daily air temperature, mean daily soil temperature and moisture; soil properties were monitored 12 cm below the soil surface. OTCs did, however, elevate soil temperature by approximately 1.0ºC early in the growing season. (Klein et al. 2005) provide a detailed account of OTC and clipping effects on microclimate at these sites.

I began the defoliation treatments in the spring of 1998. In the meadows, traditionally grazed during the winter months, I clipped the plots prior to initiation of growth in the early spring. In the shrublands, traditionally grazed during the summer months, I clipped the plots in mid-July. I clipped plots to approximately 3cm in height, which is the height of the vegetation outside of the fenced plots in the sites with a high grazing history. I removed approximately 30% of total live peak aboveground (AG) biomass in the shrubland sites



I conducted this study at summer-grazed shrubland and winter-grazed meadow. Within each habitat, I identified sites with “low” and “high” grazing intensity history sites, for a total of 4 study sites. In each site, I fenced a 30x30m area, within which I established a fully factorial experimental design, with ‘OTCs’ and ‘clipping’ as the main treatments. There were four replicates per treatment.

Figure 2. Experimental design

and 15% of total peak AG biomass in the meadows, plucking the shrub leaves and stem tips to simulate sheep browsing. I did not clip plants that yak and sheep do not consume (such as Oxytropis spp., and Stellera chamaejasme). To examine how well clipping simulated the effects of actual grazing, in 2000 I established four replicated "grazing control" (GC) plots situated outside of the fenced areas in all four sites. I established these plots more than 5m but less than 15m away from the fence to eliminate any "fence" effect but to be representative of the plots within the fenced area. Pairs of GC plots were approximately 2m apart from each other.

Since local pastoralists continually collect dung from the rangelands (dung is the primary fuel source in the region), I did not simulate the nitrogen addition effect of grazing that has been observed in other rangeland systems (McNaughton et al. 1997). Simulated grazing represented well the actual grazing effect on species numbers and aboveground productivity (Klein et al. 2004, Klein et al., in press). I monitored treatment effects on a suite of vegetative and biogeochemical properties and processes.

Research Findings, Implications for Rangeland Quality, and Future Directions

Vegetative diversity and productivity responded quickly and dramatically to warming. Experimental warming led to a 26-36% decrease in the number of species present (Klein et al. 2004). Warming decreased total aboveground net primary productivity (ANPP) at the meadows, with no effect on total ANPP at the shrublands. At both habitats, warming decreased both palatable and graminoid ANPP. However, warming increased shrub foliar ANPP. Warming decreased Gentiana straminea, an important medicinal plant, and increased Stellera chamaejasme, a non-palatable forage species. Warming effects on foliar N and C:N content were idiosyncratic. The more significant warming effect on forage quality will likely occur through the replacement of relatively higher quality graminoids with lower quality shrubs, with important implications for herd composition (Klein et al., in press). Warming also decreased the delivery of critical ecosystem services (Klein et al., submitted). Grazing effects were generally in the opposite direction as warming effects. Moreover, grazing generally mediated the decrease in rangeland quality due to warming alone. For example, at the high grazing history shrubland site in 2001, warming in the non-clipped plots decreased species richness by nine species, whereas warming in the clipped plots had no effect on species richness. This indicates we cannot always predict the outcome of combined treatment effects based on single study experiments of climate warming or grazing alone. The details of these findings, and the proposed mechanisms behind these results, are documented elsewhere (Klein et al. 2005, Klein et al. 2004, Klein et al., in press, Klein et al., submitted).

This experimental research project is on-going. I will continue to measure key ecosystem variables—diversity, productivity, and carbon storage—to test hypotheses about transient versus longer-term ecosystem responses and issues of resilience and resistance to human activities. However, to test the generality of these findings across space and time, I am augmenting the results from this multi-year experimental manipulation by sampling across landscape scale transects as well as conducting ecosystem modeling. Combining the results from these study techniques can be a powerful way in which to develop a robust understanding of climate-grazing-ecosystem relationships and for predicting future short-term and longer-term ecosystem responses to climate variability and pastoral land use change.

CONCLUSIONS

Contrary to popular Western belief, there is regional variation in the biological, physical, and cultural features of the Tibetan people and landscapes. Moreover, these cultures and landscapes are not static and lost in time; rather, the people and ecosystems of the Tibetan Plateau are facing profound changes of the modern world, the causes of which are often beyond their control. An experimental study which examines the effect of climate warming and grazing on the rangelands of the northeastern Tibetan Plateau demonstrates that the Tibetan Plateau rangelands are vulnerable to anthropogenic climate change. Grazing can mitigate these effects. This research also suggests that current rangeland degradation that has often been attributed to overgrazing may, in fact, be a response to ongoing anthropogenic climate change.

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Yak train descending, Cho Oyu PHOTO: David Le Pagne