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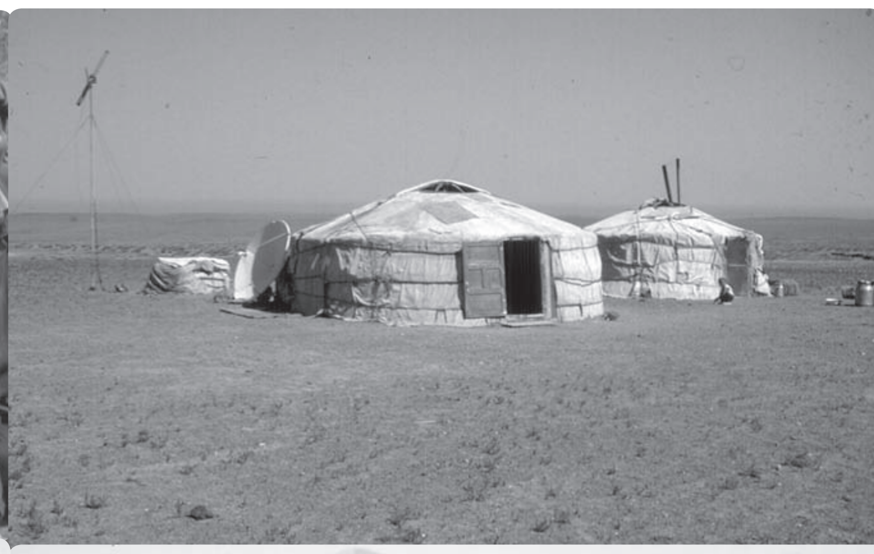
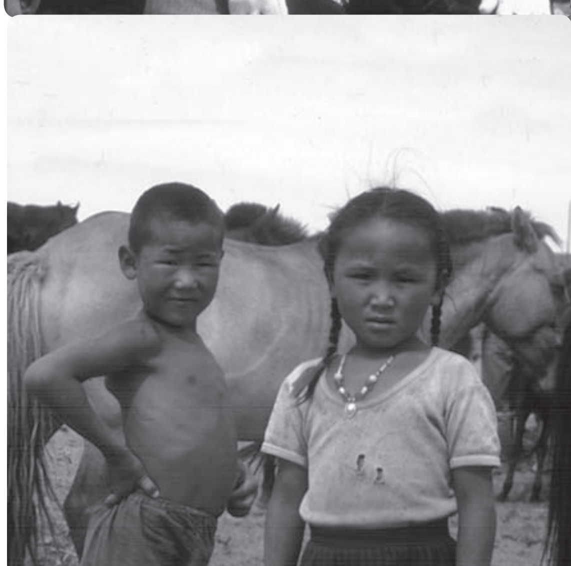
Rangelands of Central Asia:

Proceedings of the Conference on Transformations, Issues, and Future Challenges





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Abstract

The 11 papers in this document address issues and needs in the development and stewardship of Central Asia rangelands, and identify directions for future work. With its vast rangelands and numerous pastoral populations, Central Asia is a region of increasing importance to rangeland scientists, managers, and pastoral development specialists. Five of the papers address rangeland issues in Mongolia, three papers specifically address studies in China, two papers address Kazakhstan, and one paper addresses the use of satellite images for natural resource planning across Central Asia. These papers comprise the proceedings from a general technical conference at the 2004 Annual Meeting of the Society for Range Management, held at Salt Lake City, Utah, January 24-30, 2004. As the 2004 SRM Conference theme was "Rangelands in Transition," these papers focus on an area of the world that has experienced dramatic socio-economic changes in 20th Century associated with adoption of communism and command economies and the subsequent collapse of the command economies and the recent transition to a free market economies. The changes in land use and land tenure policies that accompanied these shifts in socio economic regimes have had dramatic impacts on the region's rangelands and the people who use them.

Keywords: Pastoralism, pastoralists, Kazakhstan, Kyrgyz Republic, Uzbekistan, Turkmenistan, Tajikistan, Mongolia, Pastoral Provinces China, biodiversity, traditional ecological knowledge, sustainable grazing.

Acknowledgments

We thank the International Affairs Committee and The Society for Range Management for their support for the symposium "Rangelands of Central Asia: Transformations, Issues and Future Challenges." A special thank you goes to Mr. Henning Trozelli with Dow Agrosciences and to Dr. Richard Reading with the Denver Zoological Foundation for their generous financial support. We thank Mr. Daniel Miller, U.S. Agency for International Development, who was instrumental in pressing for this symposium and in helping define topics. We appreciate all those involved in our symposium, but especially wish to recognize the authors of the papers for their willingness to participate and work within our time schedule and guidelines in order to provide a final product for the symposium. We extend our thanks the staff of the Rocky Mountain Research Station Publishing Services Group editing and procedural advice. Lastly, for all of us that have worked in Central Asia we feel extremely fortunate to have experienced the goodness, hospitality, and resilience of the pastoralists using these rangelands and we offer them a special thank you and our hope for a rewarding life on the rangelands of Central Asia.

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Rangelands of Central Asia:

Proceedings of the Conference on Transformations, Issues, and Future Challenges

In conjunction with the 57th Annual Meeting for the Society for Range Management, Rangelands in Transition

January 24-30, 2004
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Compilers:

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Preface

The objective of the Society for Range Management's International Affairs Committee's symposium "Rangelands of Central Asia: Transformations, Issues, and Future Challenges" was to bring together social scientists, ecologists, and development specialists to define and discuss current issues in the development and stewardship of the region's rangelands, and identify directions for future work. As defined in this symposium, Central Asia encompasses the republics of Kazakhstan, Kyrgyz Republic, Uzbekistan, Turkmenistan, Tajikistan, Mongolia and the Pastoral Provinces of western China. Historically, regional borders have varied with the shifting balance of powers between the region's dominant nomadic populations and sedentary societies; but, pastoralism has remained a way of life for numerous ethnic groups throughout the region. Over 75% of Central Asia's land area is rangeland. These rangelands provide humans with multiple goods and services including fuels, fiber, food, water, and carbon storage; in addition to holding significant scenic and biodiversity values. With its vast rangelands and numerous pastoral populations, Central Asia is a region of increasing importance to rangeland scientists, managers, and pastoral development specialists.

Central Asia is a land of extremes in climate, elevation, resources, and cultural diversity. The climate is continental with local conditions influenced by orographic factors. Elevations range from over 8,000 m in western China to 154 m below sea level in the Turpan Basin. Annual precipitation varies from 25 mm in the deserts of Central Asia to over 1,000 mm in many high mountain rangelands. For millennia, these extremes have shaped a wide range of pastoral cultures, leading to a wealth of largely untapped and unstudied indigenous knowledge, which is reflected in traditional management practices and institutions. Similarly, these environmental extremes have given rise to a diversity of vegetation types and habitats, many of them critical for biodiversity and endangered species.

Western scientists and development specialists had very limited access to this part of the world until the opening of China's borders in the 1980s and the collapse of the Soviet Union and associated socialist states such as Mongolia in the early 1990s. As is common in rangelands throughout the world, these areas receive relatively little attention or investment from development and research funding agencies because of their remoteness, low productivity, and perhaps a view of livestock as harmful to the environment. Participants in our symposium share the goal of improving rangeland conditions to enhance their environmental benefits, including biodiversity conservation, carbon sequestration and watershed management, while providing for the well-being and diversity of indigenous Central Asian cultures. These pastoral societies have relied on livestock both for their livelihoods and as a major part of their cultural beliefs and traditions for centuries.

In keeping with the 2004 SRM Conference theme "Rangelands in Transition," our symposium on Central Asia focuses on the implications of the dramatic socio-economic changes that have occurred throughout this area in 20th Century. The social, ecological and land-use changes associated with adoption of communism and command economies and the subsequent collapse of the command economies are of special importance. Thus, a significant unifying theme among the countries of the region was their conversion to command economies in the early to mid- 20th Century and their transition to market economies late in the 20th Century. The changes in land use and land tenure policies that accompanied these shifts in socio economic regimes have had dramatic impacts on the region's rangelands and the people who use them. Management changes, whether driven by economic necessity or political mandate, threaten sustainable rangeland use and have, in some areas, reduced the ability of these lands to produce forage, browse, fuels, and wildlife. These transformations have also challenged pastoralists and in many cases threatened their livelihoods and well-being. In this symposium we explore the historical antecedents and the human and ecological consequences of these changes, while seeking to expand the dialogue about solutions that may lead to a more sustainable future for Central Asian pastoralists and the rangeland landscapes they rely on.

Our symposium included 13 papers, five poster presentations, and a panel discussion. The proceedings is comprised of 11 papers. Five of the papers address rangeland issues in Mongolia, three papers specifically address studies in China, two papers address Kazakhstan, with one of these papers comparing aspects of Kazakh Steppe to the Northern Great Plains of the U.S., and one paper addresses the use of satellite images for natural resource planning across Central Asia. We have therefore grouped the papers by country, with the papers on Mongolia presented first since it was the country with the most papers. However, an overriding theme with many of the papers was the need for mobility and flexibility in livestock management and its importance in land tenure arrangements and in the need for planning with pastoral communities.

In their paper "Conserving Biodiversity on Mongolian Rangelands: Implications for Protected Area Development and Pastoral Uses" Rich Readings and others provide an overview of Mongolia's rangelands and biodiversity values and discuss challenges and issues facing Mongolia. Conserving biodiversity and rangelands are intertwined and the authors believe that strengthening protected areas management; increasing ecotourism; instituting socially acceptable grazing reform and land use; management of wildlife throughout the entire nation; and finding ways to integrate solutions for both sustainable pastoralism and conservation while minimizing unproductive conflict are key aspects for Mongolians and other to build upon.

Maria Fernandez-Gimenez paper "Land Use and Land Tenure in Mongolia: A Brief History and Current Issues" stresses that history does matter in understanding the current pastoral land use patterns and in discussions regarding land reform system taking place in Mongolia today. She stresses that mobility and flexible grazing strategies adapted to cope with harsh and variable environment remains a cornerstone of Mongolian pastoralism.

Likewise, Sabine Schmidt in her paper "Community Led Natural Resource Management and Conservation in Mongolia's Gobi" describes the importance of understanding the need for livestock mobility for sustainable management. She describes how mobility and traditional ecological knowledge have been used as keys for developing participatory project for improved livelihoods and conservation of resources through co-management between pastoralists and other government and non-government entities.

Ryan Maroney describes his study in western Mongolia to determine pastoralist's views regarding grazing and conservation issues for the protection of argali in "Community Based Wildlife Management Planning in Protected Areas: The Case of Altai Argali in Mongolia." He finds that pastoralists generally have a strong conservation ethic (also referred to in Reading and others and Schmidt in this issue) concerning the protection of argali, but in his study area are unwilling to alter grazing practices for the benefit of wildlife without compensation. However, he stressed his study shows a local receptiveness to integrated management programs incorporating collaboration and census building to achieve pasture and management and biodiversity conservation.

Douglas Johnson and his co-authors report on their work in collecting over 1,300 seed accessions of grasses and forbs across the major ecological zones of Mongolia. Following the collections evaluations at three sites in Mongolia selected the most promising indigenous forage species for revegetation of abandoned lands, restoration of deteriorated areas, especially around overgrazed villages, and in use in mined land reclamation. The need for restoration of deteriorated areas an important need raised in our symposium.

Dennis Sheehy and others in "Rangeland, Livestock and Herders Revisited in the Northern Pastoral Region of China" provide an overview of China's rangelands, livestock numbers, conditions and problems, and policies affecting rangelands. They describe a development project initiated in 1987 and revisited in 2003 to illustrate changes and problems in policy and provide recommendations for "bottom up" resource planning to improve management of grazing lands.

Stephen Reynolds discusses a program that has improved incomes, the availability of social services, and decreased risks for pastoral families in his paper "Providing Winter Bases for Transhumant Herders in Altai, Xinjiang China." The program has combined elements of mobile pastoralism and sedentary agro-pastoral development to improve livelihoods; but, he stresses that maintaining mobility for a portion of year is critical for sustainable use natural resources.

Camile Richard and others in "The Paradox of the Individual Household Responsibility System in the Grasslands of the Tibetan Plateau, China" discuss problems with China's Grassland Law that tends to allocate grasslands based on the Individual Household Responsibility System model (individual property rights) in an area where common property rights are advantageous associated with both socio-economic and the ecological context. They discuss models for policy implementation that allow for flexibility in legal tenure contract and management arrangements that better reflect the de facto common property situation in areas.

Carol Kerven and others in "Fragmenting Pastoral Mobility: Changing Grazing Patterns in Post-Soviet Kazakhstan" examine animal nutrition and economic factors associated with livestock for Kazak pastoralists in Kazakhstan. They report an increase in mobility of larger flocks, following a period when mobility virtually ceased, as animal numbers rebound from the mid 1990's population crash.

Rangelands cover vast areas of the Central Asia and as such could have a substantial effect on global carbon budgets. In "Scaling Up of CO_2 Fluxes to Assess Carbon Sequestration in Rangelands of Central Asia" Bruce Wylie and others map gross primary productivity, total ecosystem respiration, and net ecosystem exchange for the Kazakh Steppe for 2001 using pooled data from the Northern Great Plains of North America and the Kazakh Steppe. Their data provides a 1 km quantification of carbon dynamics at a 10-day time step that can be used for carbon monitoring, quantification of environmental drivers to carbon fluxes, and validation or training data for biogeochemical models.

In the paper "Comparison of Satellite Imagery for Pastoral Planning Projects in Central Asia" Matthew Reeves and Don Bedunah discuss sources of low cost or free satellite data for resource management planning activities. Many of the papers in this proceeding discuss the need for resource management planning with pastoralists, and at times, satellite images may offer a way for resource specialist to develop base-map for development of resource management plans.

The papers have been peer reviewed by reviewers selected by the authors. Opinions expressed are those of the respective authors and are not necessarily the opinions of the compilers or of the U.S. Department of Agriculture. We thank the Rocky Mountain Research Station of the U.S. Department of Agriculture, Forest Service for publishing the proceedings. The Forest Service through its International Programs division and various other entities has an interest in the natural resource management and research in Central Asia. The Rocky Mountain Research Station has a long commitment toward an understanding and study of multiple-use of U.S. rangelands and understands the need sound management of the rangelands of Central Asia. Many participants of the symposium voiced a concern that a missing component of past management of many Central Asian rangelands has been a study and commitment to multiple-use management. Therefore, we appreciate the involvement of the Rocky Mountain Research Station in the publication of our proceedings.

Contents

Conserving Biodiversity on Mongolian Rangelands: Implications for Protected Area Development and Pastoral Uses

Richard P. Reading, Donald J. Bedunah, and Sukhiin Amgalanbaatar

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Donald J. Bedunah is Professor of Rangeland Resource Management, Department of Forest Management, College of Forestry and Conservation at The University of Montana, Missoula, MT. He completed a B.S. degree in Range Science from Texas A&M University, an M.S. degree in Range Science at Colorado State University and a Ph.D. in Rangeland Ecology at Texas Tech University. He first began working in Central Asia in 1991. His work has been predominately in western China and Mongolia working with development agencies and conservation organizations.

Sukhiin Amgalanbaatar is a Research Biologist with the Institute of Ecology at the Mongolian Academy of Sciences, President of the Argali Wildlife Research Center, and a Research Associate with the Denver Zoological Foundation. He received a M.S. in Wildlife Biology from the Mongolian National University and is currently working on completing his Ph.D. He has worked on a variety of wildlife and protected areas projects since the mid-1980s working for the Mongolian Forestry and Hunting Institute, World Wide Fund for Nature – Mongolia, and German Technical Advisory Agency (GTZ) before taking his current position.

Abstract—*Mongolia is a sparsely populated country with over 80 percent of its land used by pastoralists for extensive livestock grazing. Mongolia's wildlife and pastoralists have faced dramatic challenges with the recent rapid socioeconomic changes. Livestock numbers increased dramatically in the 1990s following the transition from communism to democracy and capitalism. Yet, limited industrialization and cultivation and relatively low rates of natural resources exploitation leave geographically large areas of the nation with few adverse impacts. In addition, the nation's heritage is strongly conservation oriented. As a result, Mongolia's protected areas system has been growing rapidly and its grasslands support the largest populations of several globally important species. Alternatively, several challenges exist, including growing pressure to exploit the nation's vast mineral reserves, the potential for conflict between pastoralist and conservation objectives, and insufficient conservation capacity to manage and protect natural resources. Arguably, a unique opportunity exists in Mongolia to develop economically while maintaining healthy and productive grasslands that support large populations of native flora and fauna. We suggest that doing so will require strengthening protected areas management; increasing ecotourism; instituting socially acceptable grazing reform; beginning to manage wildlife throughout the entire nation; and finding ways to integrate solutions for both sustainable pastoralism and conservation while minimizing unproductive conflict.*

Keywords: *wildlife, endangered species, nature reserves, ecotourism, culture, argali, snow leopard.*

Bedunah, Donald J., McArthur, E. Durant, and Fernandez-Gimenez, Maria, comps. 2006. Rangelands of Central Asia: Proceedings of the Conference on Transformations, Issues, and Future Challenges. 2004 January 27; Salt Lake City, UT. Proceeding RMRS-P-39. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Introduction

Mongolia is a vast (>156 million ha), sparsely populated, central Asian nation of about 2.5 million people (NSO-Mongolia 2004). Over 80 percent of the country, or about 126 million ha, are used by pastoralists for extensive livestock grazing (MNE 2001; Sheehy 1996), and these extensive grazing lands represent the largest remaining contiguous area of common grazing in the world (World Bank 2003). Mongolia has been grazed by livestock for millennia and livestock numbers were estimated at 1.97 million horses, 1.79 million cows and yaks, 0.26 million camels, 10.76 million sheep, and 10.65 million goats in 2003 (NSO-Mongolia 2004). Limited industrialization and cultivation and relatively low rates of natural resources exploitation leave geographically large areas of the nation with little adverse anthropogenic impacts. As such, Mongolia represents an opportunity to realize positive and significant conservation objectives. However, several important challenges also exist, especially as Mongolia embraces a free market system and pressures, both internal and external, to utilize and develop the nation's vast mineral reserves increase without the development of sound environmental laws and regulations. Whether or not Mongolia can balance economic development with nature conservation remains to be seen, but arguably a unique opportunity exists in Mongolia to develop economically while maintaining healthy and productive grasslands that support large populations of native flora and fauna.

The Context of Rangeland Conservation

Adequately conserving Mongolia's rangelands requires a sound understanding of the ecological, social, and cultural context and values of these rangelands. Henwood (1998a; 1998b) stressed the low levels of protection for temperate grasslands. He stated that the world's temperate grasslands were the most beleaguered biome, as only 0.7 percent of the world's temperate grasslands fall within the global system of protected areas. Mongolia represents an opportunity to conserve and protect the biodiversity of its grasslands and provides an opportunity to increase the World's protected grasslands. We briefly discuss Mongolia's biodiversity, protected area systems, current and historical use of rangelands, important cultural considerations, the history of conservation efforts in the country, and threats.

Biodiversity

Mongolia retains a substantial amount of its "natural" biodiversity and although biodiversity values are not as great as in many tropical systems, they are still considered high. Two of the world's most biologically outstanding ecoregions, the Daurian Steppes and the Altai-Sayan Mountains, lie partly within Mongolia (World Wildlife Fund 2000). More than 2,823 species of plants inhabit Mongolia (Gunin and others 1998) and indeed, the Mongolian steppe represents one of the largest contiguous unaltered grasslands in the world (WWF 2000). As a result, some species persist in impressive numbers, such as the millions of Mongolian gazelle (*Procapra gutturosa*) that still roam the eastern steppes, and other wild species persist in relatively healthy population in Mongolia; starkly contrasting neighboring regions (Lhagvasuren and others 1999; Reading and others 2000; 2002). The ability of Mongolia to maintain its natural biodiversity largely stems from its long history of pastoralism, low human population (per-capita land area is the largest in the world; World Bank 2003) and lack of industry and crop agriculture. Mongolia also boasts a long history of protecting special areas and a strong cultural tie to the land. Both flora and fauna have benefited from the small amount of land area transformed by cultivation and from only limited introduction of exotic plants.

Grazing lands dominate Mongolia's land area, with over 80 percent of the land area categorized as rangeland. Forests represent the next largest land type, with about 10 percent of the area categorized as forest. Arable lands, urban areas, and water each comprise about 1 percent of the land area (Bedunah and Miller 1995; World Bank 2003). Mongolia's vegetation zones based on geography and climate include the High Mountain Belt, the Mountain Taiga Belt, the Mountain Forest Steppe, the Steppe, the Desert Steppe, and Desert (Hilbig 1995; Johnson and others, this proceedings). For more detailed vegetation descriptions see Hilbig (1995) and Gunin and others (1999). Livestock graze all of these vegetation zones, with areas grazed by several of the "five types" of Mongolian livestock (camels, horses, sheep, goats, and cattle, including yak).

The vegetation zones result from 1) a severe continental climate characterized by very cold winter temperatures (as low as –52 °C) and high summer temperatures of >40 °C in the Gobi; 2) elevation changes that range from about 4400 m on the western border in the Altai Mountains to 500 m in the eastern steppes; and 3) short growing seasons, especially in the high mountains and northern part of the country. A low precipitation regime (100-400 mm) extends over about 82 percent of the country. For most of the nation, the precipitation is relatively variable, both spatially and temporally, resulting in a "non-equilibrium ecological system. Scoones (1999) provides an overview of non-equilibrium dynamics and how this new paradigm offers opportunities for interactions between social and natural sciences. In these systems, plant-herbivore interactions are weakly coupled and environmental degradation from livestock grazing is often wrongly blamed for "natural" conditions (Behnke and Scoones 1993; Ellis and Swift 1988). However, ecological systems are complex and exhibit a continuum between equilibrium and non-equilibrium characteristics, and livestock can significantly impact vegetation attributes even in areas considered to be dominated by 'non-equilibrium dynamics' (Fernandez-Gimenez and Allen-Diaz 1999).

Mongolia's fauna, like its vegetation, represents a mixture of species from the northern taiga of Siberia, the steppe, and the deserts of Central Asia. The fauna of the country includes at least 136 species of mammals, 436 birds, 8 amphibians, 22 reptiles, 75 fish, and numerous invertebrates (http://www.un-mongolia.mn/archives/wildher/biodiv.htm). Animal species inhabiting Mongolia's rangelands exist relatively intact, especially compared to other grassland ecosystems worldwide. People have extirpated few species from Mongolia's grasslands and one species that went extinct in the wild, the Przewalski's horse (*Equus przewalski*), has been successfully reintroduced into 2 regions. Today, of the species known to previously inhabit Mongolia in historic times (the past 1,000 years), only the dhole (*Cuon alpinus*) remains absent from Mongolia's rangelands, although the nominate subspecies of saiga (*Saiga tatarica tatarica*) has also disappeared.

Several additional species are considered threatened or endangered in Mongolia, but even many of these persist in much larger populations than in surrounding nations. For example, Mongolia boasts the world's largest populations of many ungulates, including Mongolian gazelle, goitered gazelle (*Gazella subgutturosa*), khulan or Asian wild ass (*Equus hemionus*), Mongolian saiga (*S. t. mongolica*), argali (*Ovis ammon*), and wild Bactrian camel (*Camelus bactrianus ferus*) (Amgalanbaatar and others 2003; Mix and others, 1995; 2002; Reading and others 2001). Similarly, small carnivores, such as Pallas' cats (*Otocolobus manul*) and corsac foxes (*Vulpes corsac*), appear to exist in relatively large populations. Large carnivores, such as snow leopards (*Uncia uncia*), are faring less well; however, relatively large populations of wolves (*Canis lupus*) are common across much of Mongolian rangelands.

The situation is similar with the country's avifauna, although many species of birds are declining due primarily to mortality outside of Mongolia. Birdlife International (2003) lists 4 species of grasslands birds that inhabit Mongolia as Vulnerable: the imperial eagle (*Aquila heliaca*), lesser kestrel (*Falco naumanni*), great bustard (*Otis tarda*), and white-throated bushchat (*Saxicola insignis*). The latter may only retain a breeding population in Mongolia. Mongolia's grasslands support relatively large populations of most of those species, as well as cinereous vultures (*Aegypius monachus*) and saker falcons (*Falco cherrug*), especially compared with surrounding areas. Henderson's ground jays (*Podices hendersoni*) and Houbara's bustards (*Chlamydotis undulata*) survive in the more arid desert and desert steppe communities.

Riparian and wetland systems embedded within Mongolian rangelands are home to globally significant populations of waterfowl and wading birds, including several species of cranes. Birdlife International (2003) lists seven globally important bird areas in the steppe wetlands of Mongolia. The only breeding population of the conservation-dependent Dalmatian pelican (*Pelicanus crispus*) in East Asia, nests in Airag Nuur in western Mongolia (Birdlife International 2003). In addition, these wetlands are particularly important for breeding populations of several globally vulnerable or endangered species, such as swan geese (*Anser cygnoides*), white-naped cranes (*Grus vipio*), relict gulls (*Larus relictus*), white-headed ducks (*Oxyura leucocephala*), and non-breeding populations of the critically endangered Siberian crane (*G. leucogeranus*) and vulnerable hooded crane (*G. monacha*) (Birdlife International 2003). A wide variety of less threatened species of water birds also depend on Mongolia's steppe wetlands.

The status of Mongolia's herptifauna, invertebrates, fishes, and smaller mammals remains less studied and therefore more poorly understood. In all probability, most of these species are thriving or at least faring better in Mongolia than in surrounding nations because of the small number of dams and other hydrological projects and the previously mentioned low levels of industrialization, cultivation, and exotic species introductions in Mongolia.

Protected Areas

Mongolia boasts a centuries old tradition of nature conservation using protected areas (Johnstad and Reading 2003). Chinggis Khan created Mongolia's first protected area to protect game species nearly 800 years ago and Bogdkhan Mountain Strictly Protected Area, first established in 1778, represents one of the world's oldest continuously protected areas (Chimed-Ochir, 1997; Enebish and Myagmasuren 2000). Nevertheless, creation of a comprehensive system of protected areas developed slowly until the 1990s. Following the political and economic transformation of 1991, Mongolia has shown a strong commitment to establishing a modern network of protected areas based upon principles of landscape ecology (Enebish and Myagmasuren 2000; Reading and others 1999). In 1992, the Mongolian Parliament or "Ikh Khural" adopted a goal of placing 30 percent of the nation in some form of protected status (Chimed-Ochir 1997). Enebish and Myagmarsuren (2000) also provide a time frame and list potential areas for protected designations that will meet the goal of 30 percent of the total area of Mongolia protected by 2030. Since 1992, Mongolia has rapidly increased the number and area of protected areas (fig. 1) and in 1994, the Mongolian Parliament passed a new "Protected Areas Law"

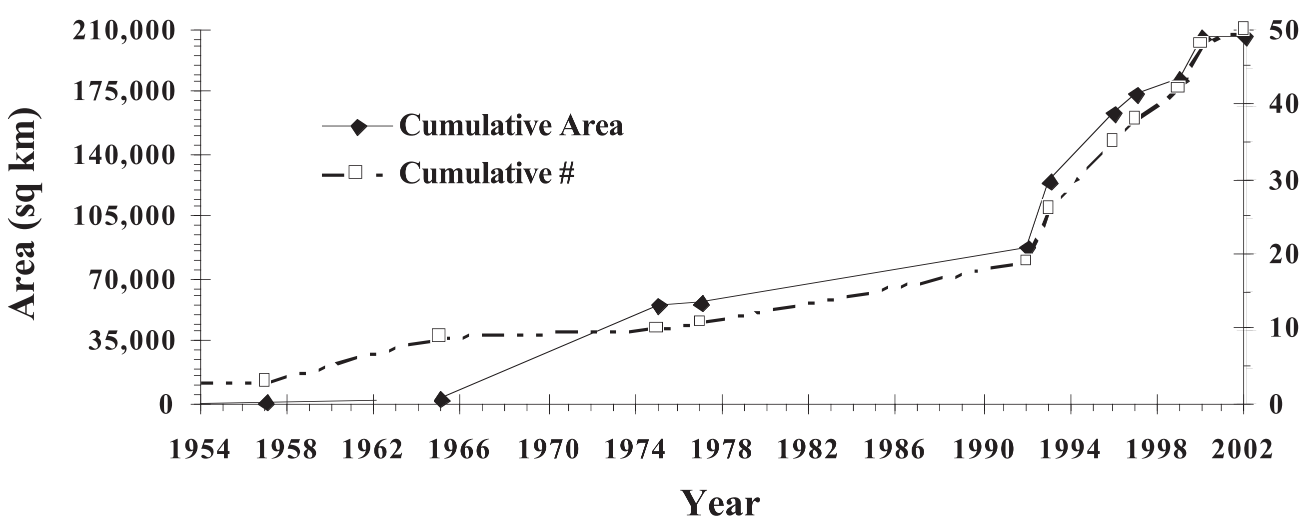


Figure 1—Increase in the area and number of protected areas in Mongolia (1954-2002). Note the rapid increase in both number and area of protected areas from 1992-2002.

(Wingard and Odgerel 2001). This law, which went into effect in 1995, recognizes four primary categories of protected areas in Mongolia: Strictly Protected Areas, National Parks, Nature Reserves, and National Monuments (table 1).

As of 2002, Mongolia's 50 protected areas covered more than 20.68 million hectares -- over 13 percent of the country (fig. 1). The network includes Strictly Protected Areas (50.7 percent of the total area protected in Mongolia), National Parks (40.1 percent), Nature Reserves (8.8 percent), and Monuments (0.4 percent) (Johnstad and Reading 2003). As of 2003, there were also 552 relatively small provincial protected areas scattered throughout the nation, covering 3.1 million ha (Anonymous 2003).

Rangelands remain under-represented in the Mongolian protected areas system, with only 1.97 percent of steppe, 2.73 percent of forest-steppe, and 3.41 percent of desert-steppe ecosystems protected (Enebish and Myagmarsuren 2000; Johnstad and Reading 2003). As is common with most nations, protected areas dominate in regions little utilized by people, such as high mountains, desert, and border regions. Still, the inequity in the distribution of protected areas by biome has been recognized by Mongolian conservationists and many conservationists advocate rectifying this situation with new protected areas proposals (for example, Enebish and Myagmarsuren 2000).

According to the Protected Areas Law, Mongolian Strictly Protected Areas and National Parks should be divided into zones with different management regimes (Wingard and Odgerel 2001). Using the Biosphere Reserve model, Strictly Protected Areas and National Parks are managed with zones that ideally lead to increasing nature protection toward the center of the protected area. Under the law, protected area zonation includes pristine, conservation, and limited use zones for Strictly Protected Areas and special, travel and tourism, and limited use zones for National Parks. The level of protection afforded to natural features, flora, and fauna varies by zone, differing even between limited use zones in Strictly Protected Areas and National Parks. In addition, the 1997 Mongolian Law on Buffer Zones permits the creation of multiple use zones around protected areas that permits even greater development and use of natural resources than do the internal zones of protected areas (Wingard and Odgerel 2001). Thus far, buffer zones have only been established for Strictly Protected Areas and National Parks.

With the significant land area placed in protected area status and the potential for a much larger area to be placed in protected status, there is a need to understand how well protected areas in Mongolia conserve resources and how they may impact historical communal land use. Management plans and actions within protected areas remain rudimentary for most protected areas in Mongolia (Johnstad and Reading 2003; Reading and others 1999). Notable exceptions do occur where international aid organizations have invested resources (for instance, Khustain Nuruu and Gobi Gurvan Saikhan National Parks) (Reading and others 1999). For example, although most, if not all, protected areas have established management zones where pertinent, these zones have meant little in terms of actual management to date (Bedunah and Schmidt 2004; Johnstad and Reading 2003; Maroney, this proceedings). As we discuss below, most protected areas receive insufficient resources and lack the expertise to even develop management plans, let alone implement management actions that vary by zones. Nevertheless, there is evidence of progress toward improved management and establishment of a system of protected areas is a good first step for protecting and conserving natural resources (Reading and others 1999; Schmidt, this proceedings) and may help pastoralists to maintain their livelihoods (Bedunah and Schmidt 2004).

Pastoralism—Pre 1990s

Pastoralism has been the dominant land use in Mongolia for millennia, and at first appearance, Mongolian's maintain livestock in much of the same ways as their ancestors. Grazing systems are transhumant with winter bases for protection of livestock from severe winter conditions. Traditionally, herders moved their livestock to make the best use of available forage and water on their allotted spring, summer, autumn and winter pastures, and they required skill to ensure that livestock were sufficiently fat going into winter to reduce winter losses. However, changes during the 20th century altered pastoral systems with ramifications for sustainable use of grazing lands. We briefly describe some of the historical aspects of the pastoral

Table 1—Mongolian Protected Area Designations.

Designation	Definition
Strictly Protected Areas	Areas whose natural conditions are very well preserved; represent areas of natural and scientific importance; and are protected to ensure environmental balance. Human use is severely restricted.
National Conservation Parks	Areas whose natural conditions are relatively well preserved, and which have historical, cultural, scientific, educational, and ecological importance.
Nature Reserves	Areas protected for conservation, preservation, and restoration of natural features, resources, and wealth. Reserves are designated as Ecological, Biological, Paleontological or Geological.
National Monuments	Areas protected to preserve the natural heritage of unique formations and historical and cultural sites. Areas are designated as Natural Monuments or Historical and Cultural Monuments.

system, recent changes, and ramifications for sustainable use of rangelands. For detailed reviews of pastoral social economic units, historical land tenure and pastoral systems see Bazargur and others (1993), Fernandez-Gimenez (1999), Germeraad and Enebish (1996), Humphrey (1978), and Jagchid and Hyer (1979), Muller and Bold (1996), and Sneath (1999).

For several centuries prior to the communist era (pre-1921), land tenure was feudal and stock management transhumant with family groups as units. Livestock were herded using seasonal migrations and a rotation of moves, often fairly rapidly, over an area. Each herder owned a winter camp that usually included a corral and at least a small amount of shelter. In years of poor forage, herders traveled further to find adequate pasture. The distance herders moved their livestock or camps depended on the ecological characteristics of their grazing lands; herders in less productive zones, e.g., the Gobi, moved livestock greater distances and were "more nomadic" than herders in the steppe. Also, herders with many livestock would move more often and over greater distances because the number of livestock necessitated more moves. Feudal officials allotted grazing areas on the principle that a person with many herds should have more and better land (Humphrey 1978). Grazing was allowed only within the circuit of common lands (khoshuun) held by the feudal lord and migration outside would bring some kind of punishment for the herder and possibly his prince.

With Mongolia's independence from China in 1921, and a move toward Soviet communism, the feudal system was abolished, religion strictly suppressed, and administrative units altered from the larger khoshuun to the smaller *sum* districts. In general, little formal regulation occurred during this period, migrations of livestock were reduced, but some customary rights remained within administrative units and traditional neighborhood groups worked together (Fernanedez-Gimenez 1999). The first attempt to form herding collectives was in 1928. However, the majority of the herders refused collectivization and the policy of compulsory enforcement was abandoned. In the 1950s, the government gave existing collectives massive aid and strongly encouraged people to join. Private herders were heavily taxed, but at this time, joining a collective permitted some ownership of private stock. By 1960, the government enacted a compulsory law that required all herders to join a collective. The goal of collectivization was to create a surplus of livestock products to feed urban populations, both in and out of Mongolia. These herding collectives, called "negdels," occupied territories the size of a *sum*, a subdivision of a province. The government assigned each collective herds and a territory. It further subdivided each territory into land assigned to herding brigades to carry out the main work. Brigades were specialized to manage only certain kinds of herds and further divided into units called "suur," which generally consisted of three or four households. Suur were further specialized to manage one area, perhaps only castrated rams, or one- and two-year-old lambs, or rams and male goats, or cross-bred sheep, or goat kids separated in autumn.

During collectivization several livestock and range management problems were reported. Separating goats and sheep in winter apparently caused heavy winter losses of goats in some areas because the sheep kept the goats warm in winter. Large, specialized herds also concentrated grazing use and changed forage use patterns. Herders preferred to remain close to the services provided by *sum* centers, threatening to overuse nearby pastures, but apparently the brigade councils sent suurs out to distant pastures (Humphrey 1978). Livestock movement was strongly regulated, but the long distance movements possible in earlier times were much more restricted.

By the early 1990s, livestock collectives collapsed with the dismantling of the command economy. The collectives distributed their property in two phases in 1991 and 1992, with a large share of the herds distributed among members (Bruun 1996). New herding households attained an almost unlimited and unprecedented freedom of choice with respect to lifestyle, livestock management, and economic activities (Brunn 1996), with little or no formal regulatory structures to control livestock grazing. This "new freedom" also moved risk from the collective to the individual household. In many areas, and likely all of Mongolia, the lack of strong formal or informal institutions to regulate livestock movement led to declining mobility and increasing out-of-season grazing and trespassing and associated conflicts (Agriteam Canada 1997; Fernandez-Gimenez 1999; Swift and Mearns 1993).

Livestock Numbers

Total animal numbers did not fluctuate greatly as Mongolia moved into collectivization (fig. 2). In fact, animal numbers were somewhat higher in the 1930s and early 1940s compared to collective period (1960s to 1990). This is somewhat surprising because collectivization led to increased inputs, such as veterinary support, greater mechanization in hay production, increased livestock movement, and development of water sources, and because a push for more production accompanied the command economy. However, Mongolian rangelands were apparently close to being "fully stocked" by the 1930s. Sheehy (1996) estimated that there are approximately 60 million sheep forage units available in Mongolia and in 1940 livestock sheep units were about 56 million. Collectivization also introduced changes in the proportion of types of livestock raised in different ecological zones and other management changes that reduced the efficiency of livestock production. For example, during collective times birth rates for private livestock exceeded those for collective livestock (Bedunah and Miller 1995).

After the central government relinquished control over livestock production in the early 1990s, livestock numbers increased rapidly from about 25.2 million head in 1993 to over 33.5 million head in 1999 (Byambatseren 2004; NSO-Mongolia 2004). Livestock numbers reached an all time high in 1999, as calculated as total numbers or on an animal equivalent basis (Sheep Forage Units) (fig. 2 and 3). Numbers of goats increased most dramatically, rising 215 percent from 1990 – 1999 (fig. 2 and 3), resulting in a growing preponderance of goats in Mongolia overall (fig. 4). Horses and cattle numbers also increased dramatically, rising 140 percent and 135 percent, respectively (fig. 2 and 3). It difficult to assess the accuracy of historic

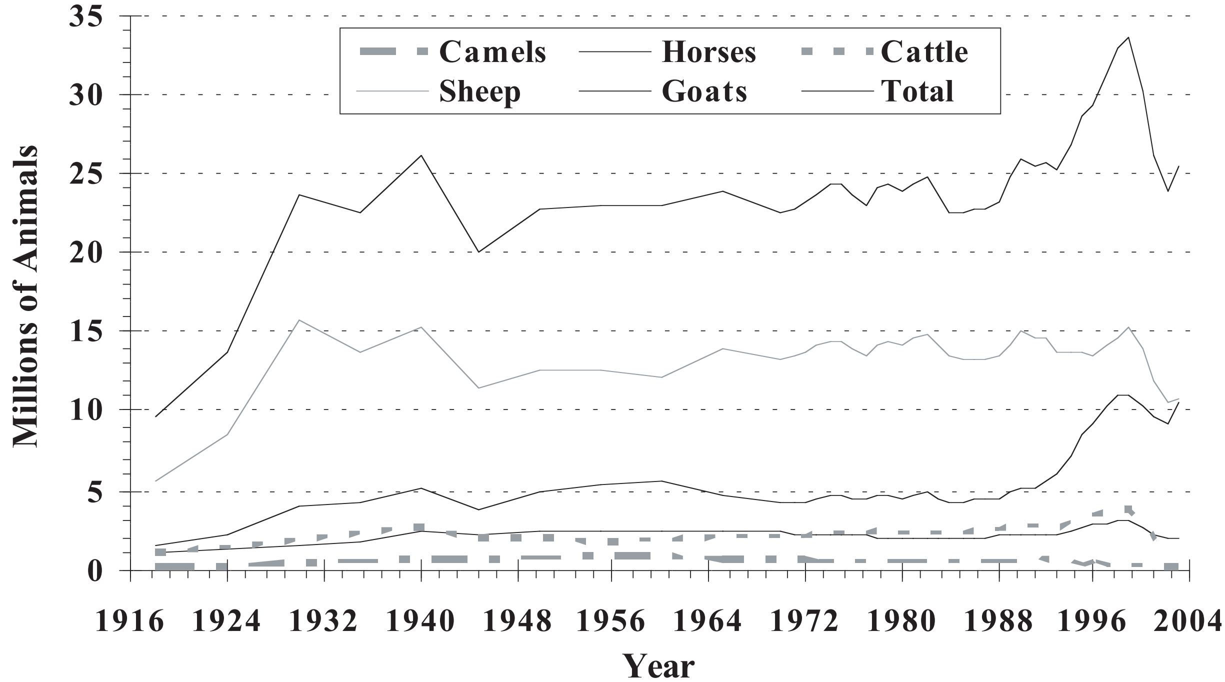
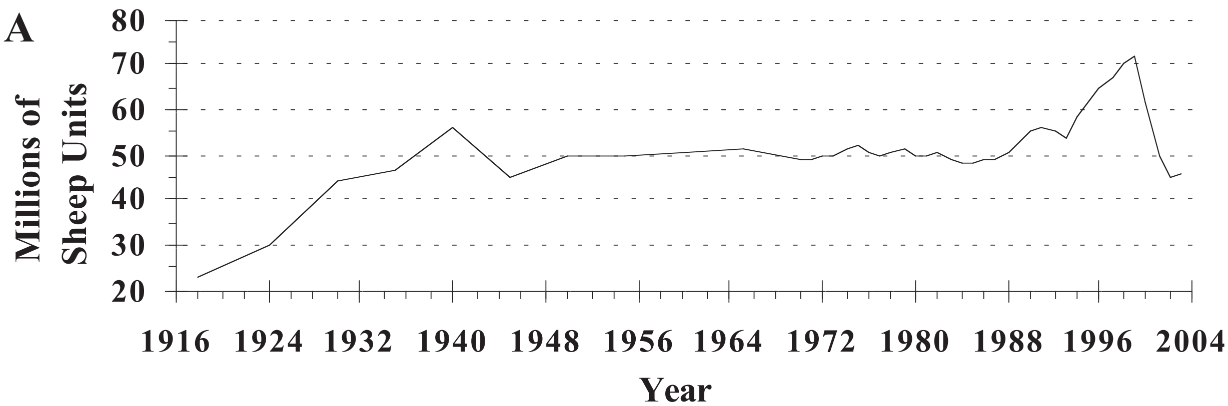


Figure 2—Livestock trends in Mongolia, 1918-2004. Data Source: Mongolian National Statistical Office (Byambatseren 2004; NSO-Mongolia 2004).

A



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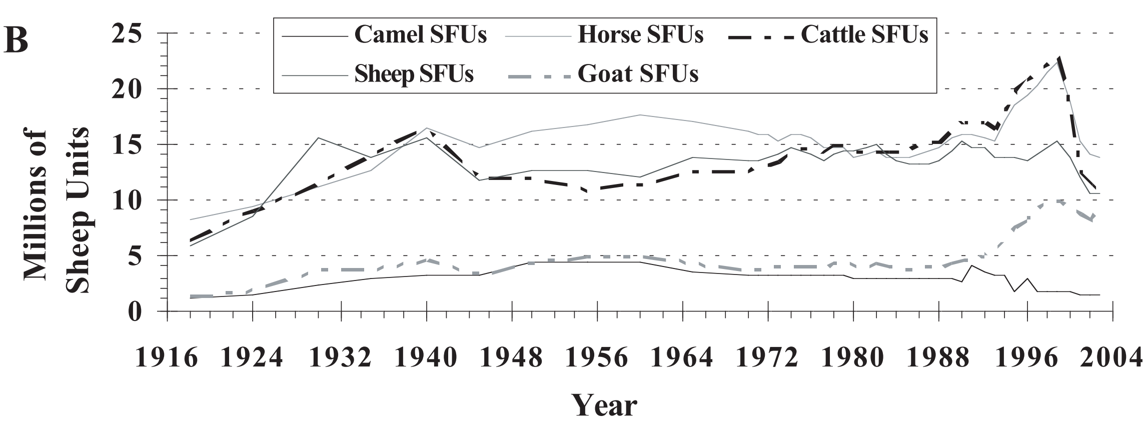
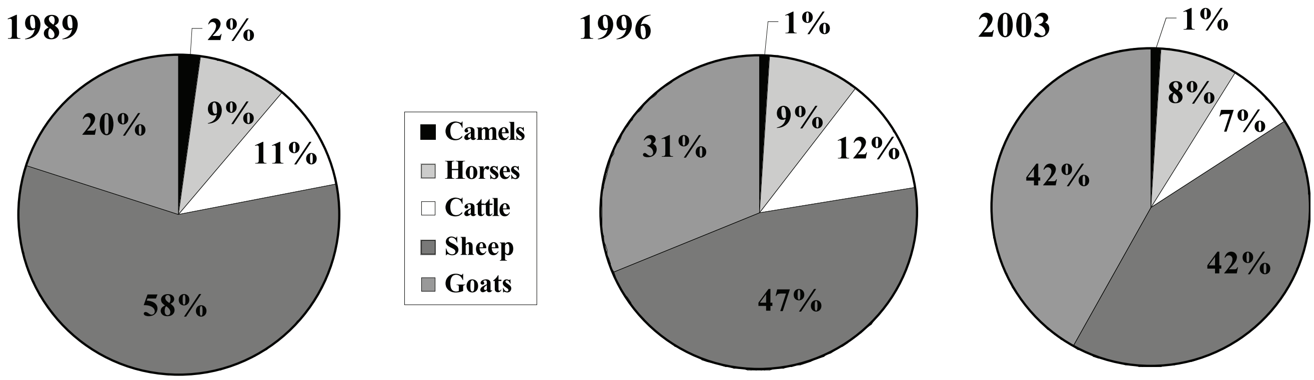


Figure 3—Livestock trends in Mongolia using Sheep Forage Units, 1918-2002. **A.** All species combined. **B.** Each species individually (note that cattle includes yak). Sheep Forage Units (SFUs) seek to standard livestock grazing by placing different species as sheep equivalents. In Mongolia, SFU per type of animal is 5 SFU per camel, 7 SFU per horse, 6 SFU per cow or yak, and 0.9 SFU per goat.



Data Source: Mongolian National Statistical Office (Byambatseren 2004, NSO-Mongolia 2004).

Figure 4—Change in the percentage of each type of livestock in Mongolia, 1989-2003.

livestock numbers, but during the communist era (pre 1992) it is likely that livestock estimates were accurate. During the late 1990s, it became more difficult to evaluate accuracy and Kennett (2000) reported that estimates were often 25 percent lower than actual numbers, as herders under-reported their holdings to reduce taxes paid on livestock.

The increased livestock herds in the 1990s were undoubtedly related to greater numbers of herding families (fig. 5) and increases in numbers of livestock for many herders (fig. 6). The increase in the number of herders possibly resulted from Mongolia's "culture of pastoralism." Many Mongolians consider pastoralism to be an ideal lifestyle and thus returned to their "roots" as herders because they were now free to do so and because they retained the knowledge of, or at least were not too far removed from, herding and pastoralism. However, for some people herding became a necessity as they lost their jobs and other livelihood opportunities disappeared with the collapse of the command economy. The degree to which these individuals retained herding as part of their past likely influenced their ability to transition into this

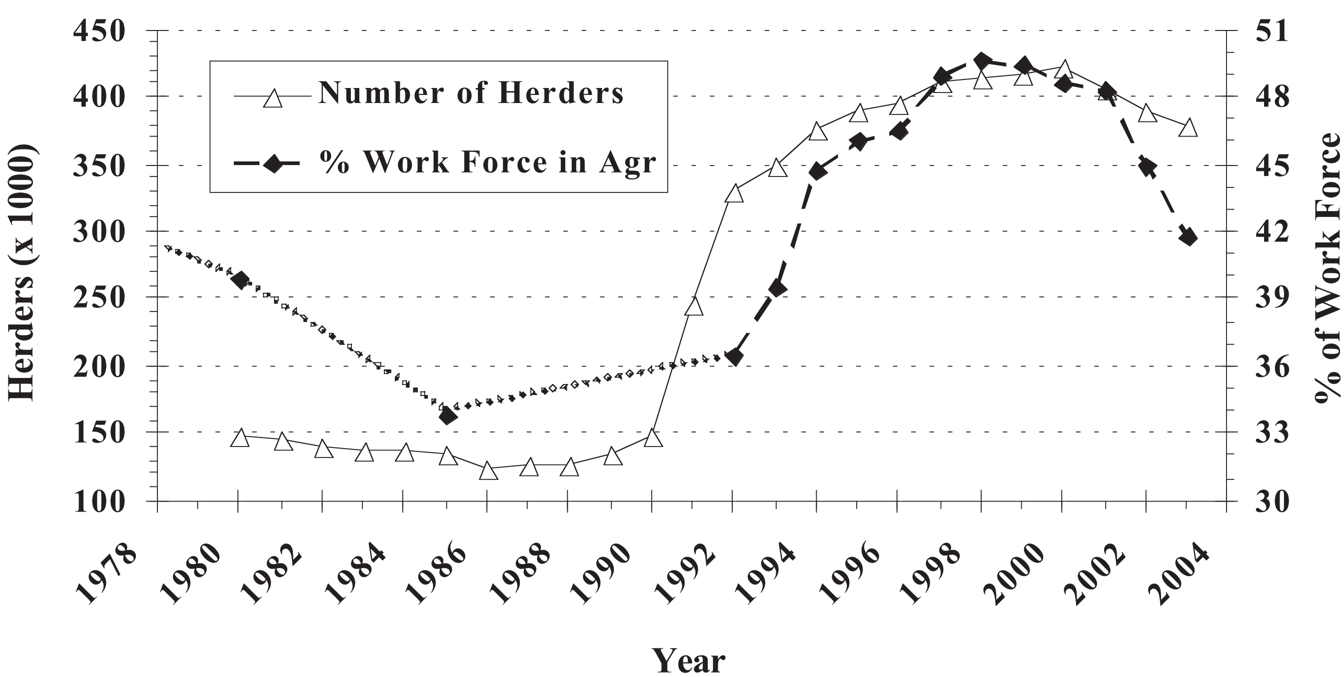


Figure 5—Change in the number of herders in Mongolia and the percentage of the Mongolian workforce engaged in agriculture (the vast majority of whom are herders).

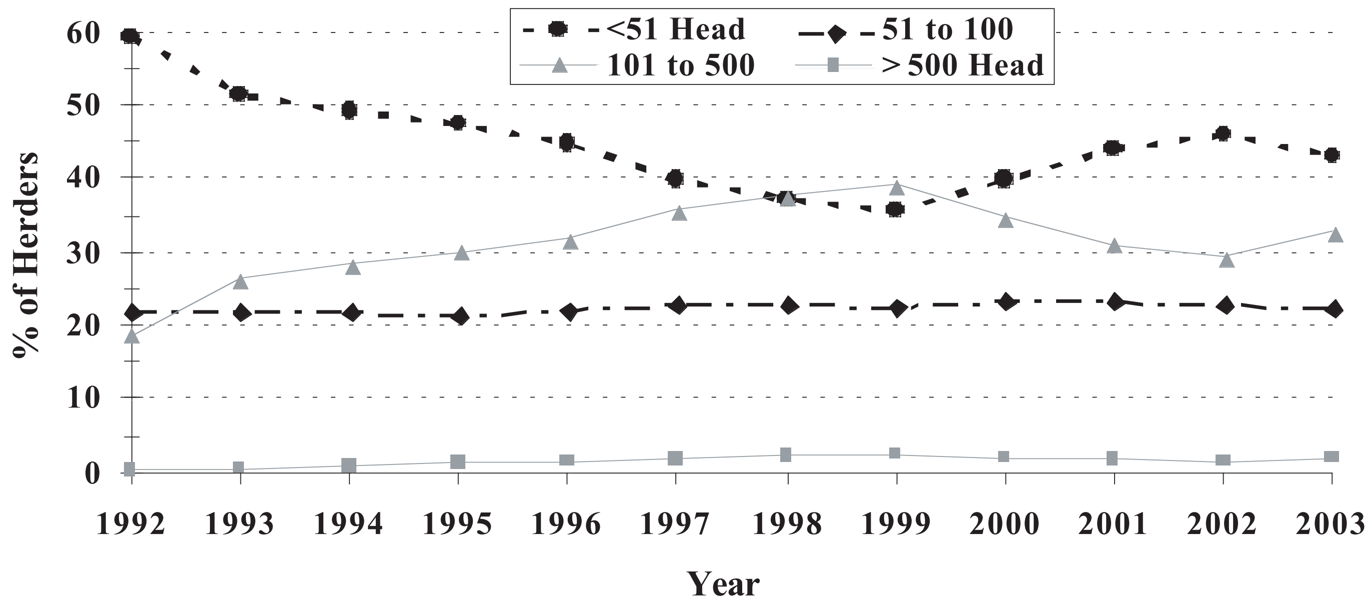


Figure 6—Change in distribution of herd sizes over time in Mongolia. Data Source: Mongolian National Statistical Office (Byambatseren 2004; NSO-Mongolia 2004).

occupation; while most apparently succeeded, others failed and the number of herders decreased each year between 2000 and 2003 (fig. 5). From 1992 to 1999 the number of "small herds" decreased, medium sized herds was generally stable, and large herds increased (fig. 6). Increasing mean herd sizes reflects a general increase in wealth. Despite growing pastoral wealth, a large percentage of herders maintained small herds (< 100 animals), while only a few herders owned very large herds. This disparity in wealth is a recent phenomenon on the rangelands of Mongolia, not seen since the feudal lords controlled livestock wealth.

In the winter of 1999-00, and again in 2000-01, dzuds (a general Mongolian term for various winter conditions during which livestock cannot forage) struck much of Mongolia causing severe livestock losses (table 2) and a reduction in average herd sizes (fig. 3 and 6). Summer droughts undoubtedly made the impacts of winter dzuds more severe, but determining the extent to which overstocked ranges increased drought severity is difficult to quantify. The large losses of livestock during this period exceeded any since the 1944-45 dzud (table 2). These losses not only impacted pastoral livelihoods, but the national economy; the overall Mongolian economy grew a mere 1 percent in 2001 and 3.9 percent in 2002 (Mearns 2004). The Government of Mongolia (2003, from Mearns 2004) estimated that without the dzud impacts, economic growth from 1999 to 2002 would have been on the order of 8 percent.

Since the mid-1990s, indices of Mongolian herder wealth have increased as the percentage of pastoralists owning jeeps or

Table 2—Livestock losses in Mongolia through drought and dzud over the last 60 years. Source: http://www.un-mongolia.mn/archives/disaster/

		Losses (# of Head)	
Years	**Type of Disaster**	**Adult Stock**	**Young Stock**
1944 – 45	Drought + dzud	8,100,000	1,100,000
1954 – 55	Dzud	1,900,000	300,000
1956 – 57	Dzud	1,500,000	900,000
1967 – 68	Drought + dzud	2,700,000	1,700,000
1976 – 77	Dzud	2,000,000	1,600,000
1986 – 87	Dzud	800,000	900,000
1993	Dzud	1,600,000	1,200,000
1996 – 97	Dzud	600,000	500,000
1999 – 00	Drought + dzud	3,000,000	1,200,000
2000 - 01	Drought + dzud	3,400,000	?

trucks, motorcycles, or televisions, and with access to electricity (usually through solar panels or wind mills) continues to rise (fig. 7) (Byambatseren 2004; NSO-Mongolia 2004). However, as with livestock figures, these statistics belie the fact that most herders remain poor. The Mongolian government considers a herd size of about 150 animals as the minimum necessary to maintain a household's livelihood (World Bank 2003). In 2002, about 75 percent of herding families retained herds smaller than this threshold (fig. 6) (World Bank 2003). Of course, many of these families obtain additional income from other sources. Indeed, herding represents supplementary income for many people whose incomes are too low to sustain themselves and their families. Thus, overgrazing increasingly degrades areas around towns and cities (Ferguson 2003).

We suggest that stabilizing and improving the health of the nation's livestock herd is crucial to the long-term stability of the nation, especially given the importance of livestock production to such a large proportion of the population. Mearns (2004) stressed the neglect of the livestock sector in development priorities and thus the decline in agricultural productivity. In the past, Mongolians stressed the need for creating reserve pastures and forage reserves (hay and other supplements) for times of shortages and for providing ways of protecting animals from unfavorable conditions (Minjigdorj 1995). Although the level of hay production that occurred during the highly subsidized Soviet period is impractical today, we argue that historic practices of using reserve pastures and native hay production are necessary to avoid dramatic livestock losses and ensure food security. This requires a more moderate or conservative level of stocking to ensure better animal condition and less pasture degradation. Potential causes of pasture degradation can be complex and are often ultimately attributable to complex institutional changes. However, ultimately animal numbers that are not in balance with forage resources will impact rangelands and the animals (both livestock and wildlife) that use these grasslands. Ward and Ngairorue (2000) discuss the extremely long-term nature of declining productivity or desertification brought about by heavy grazing in arid habitats. For in-depth discussions of issues and concerns regarding desertification and identification of desertification see Leach and Mearns (1996) and Swift (1996). We believe there is a strong need for research to better understand grazing impacts to ecological systems in Mongolia. For example, the much greater numbers and percentage of goats (fig. 2 and 4) have no doubt impacted shrub communities by increasing browse use. Thus, researchers need to quantify long-term impacts or changes that may negatively impact natural resources.

Mongolian Culture and Conservation

"Mongolians have a deep reverence for their environment and a close symbiotic relationship with the natural world (UNDP 2000: 34)." The roots of Mongolian culture stretch back thousands of years and emanate from animistic beliefs that still strongly influence thoughts and practices in the country, especially among some minority groups (Finch 1996; Germeraad and Enebish 1996). Tibetan style Buddhism arrived in Mongolia in the 1500s and quickly and profoundly affected the culture of the nation (Gilberg and Svantesson 1996). Although ruthlessly repressed by the communist government in the 1930s, the influence of Buddhism remains powerful today and is experiencing a marked resurgence (Bruun and Odgaard 1996). Buddhism teaches love and respect for nature that usually translates into strong support for conservation (Germeraad and Enebish 1996; World Bank 2003).

After a brief period as a Buddhist theocracy, Mongolia became the world's second communist nation in 1921. Yet, even under communism the country's policies maintained support for

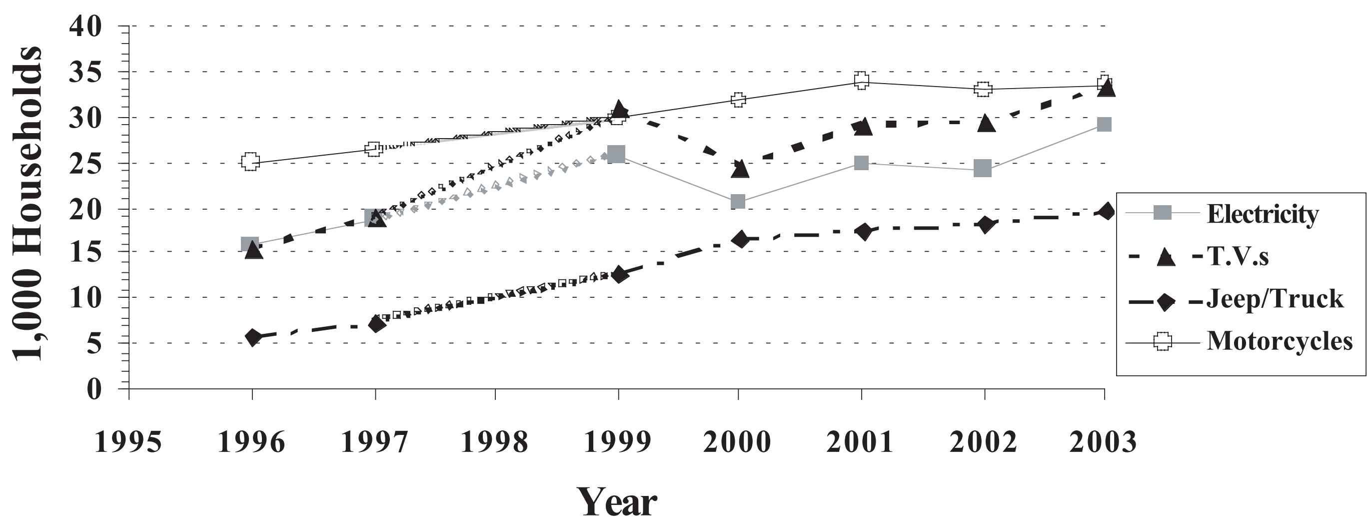


Figure 7—Changes in indices of Mongolian herder wealth over time. Note: no data for 1998. Data Source: Mongolian National Statistical Office (Byambatseren 2004; NSO-Mongolia 2004).

conserving and protecting the wildlife and natural resources of the nation. With the shift from communism to democracy and capitalism in the early 1990s, the government made an initial, strong drive for conservation, reflecting the desires of most of the populace (UNDP 2000). Yet that same shift to a free market economy hastened economic growth and has more recently resulted in policies directed at natural resources exploitation (Ferguson 2003). Given the vast, untapped mineral wealth, rapidly changing policies regarding resource development, and low standard of living affecting most Mongolians, it is perhaps not too surprising that the last few administrations have faced numerous corruption scandals, with several officials convicted and sent to prison. Unfortunately, modern approaches to conservation have not kept pace with this altered political and economic landscape.

Today, most Mongolians still embrace nature conservation, at least in word (UNDP 2000). This attitude appears particularly prevalent in rural areas, including pastoralists. For example, when the government removed a portion of a National Conservation Park in the Gobi, the local people rallied and petitioned for its return (unsuccessfully). Similarly, many pastoralists lobby for the creation of new protected areas (Reading and others 1999). Most protected areas in Mongolia allow grazing by domestic livestock, and even areas that prohibit livestock by law remain largely unmonitored and pastoralists continue to use most of these areas at least periodically. As these parks begin to grapple with issues of grazing management, including restricting livestock numbers and creating zones of livestock exclusion it will be interesting to see how pastoralists react (Reading and others 1999).

A romanticized view of nomadic pastoralism and nature conservation continue to pervade the psyche of most Mongolians (Germeraad and Enebish 1996; Reading and others 1999). Yet, increasing desires to "westernize" and improve standards of living challenge these traditional values. Cultural changes in urban Mongolia appear meteoric to us and are increasingly affecting rural Mongolia as well. Balancing tradition with change affects all nations, of course, but in Mongolia that change comes coupled with the disruptive transition from communism and a command economy to democracy and a free market. And in Mongolia, pastoral nomadism arguably defines their traditional culture more than in most other nations with a relatively large pastoral component. Pastoralism certainly comprises a larger portion of Mongolia's economy (15.9 percent in 2003) than most other nations (NSO-Mongolia 2004). So, effectively conserving Mongolia's rangelands would not only help ensure a sustainable rural economy, but also help preserve the nation's cultural and natural heritage (Reading and others 1999).

The new constitution and variety of new laws passed since 1991 codify the strong conservation values of most Mongolians. The constitution guarantees every citizen the right to a healthy environment. In keeping with this mandate, the Mongolian parliament, or Ikh Khural, passed a number of new environmental laws since the early 1990s (Wingard and Odgerel 2001). While these laws and subsequent regulations represent an important first step, their effectiveness is limited by a serious lack of implementation and enforcement (for example see Amgalanbaatar and others 2002). Similarly, as we noted above, Mongolia has rapidly expanded its protected areas network in recent years, but that expansion has not enjoyed a commiserate increase in the capacity of the Mongolian Protected Areas Bureau to manage the new reserves (Johnstad and Reading 2003; Reading and others 1999). To help address this short-coming, several international aid organizations (such as the United Nations Development Programme, German Technical Advisory Cooperation or GTZ, the Ministry for International Cooperation of the Netherlands, the U.S. Agency for International Development or USAID); non-governmental conservation and environmental organizations (such as the World Wide Fund for Nature-Mongolia, Mongolian Association for the Conservation of Nature and Environment, Denver Zoological Foundation, Philadelphia Academy of Natural Sciences, International Crane Foundation, Wildlife Conservation Society); and universities (for example University of Montana, Columbia University, Colorado State University) have developed and begun implementing programs to train protected areas staff, develop management plans, involved local people, and provide much needed funding (Johnstad and Reading 2003).

The end of communism also led to a rapid increase in the number of non-governmental organizations (NGOs) focused on the environment and nature conservation, and by 2003 there were several environmental NGOs registered with the government (Anonymous 2003). Indeed, Mongolian conservationists recognized the need to increase the effectiveness of the growing number of small environmental NGOs by creating an umbrella organization, the Union of Mongolian Environmental, Nongovermental Organizations (UMENGO) in 2000 (Mooza 2003). NGOs are becoming increasingly involved in conservation initiatives, but lack of resources and professional capacity limit the effectiveness of most of them (Anonymous 2003). Still, the overall capacity of Mongolian environmental NGOs grows yearly and enthusiasm among members remains high, boding well for the future (Mooza 2003).

Threats & Challenges to Rangeland Conservation

Mongolia's rangelands persist largely unfragmented and only minimally degraded (UNDP 2000). Still, threats and challenges to maintaining this situation are growing, primarily in the form of increased natural resources exploitation, growing conflicts between pastoralism and conservation, and a lack of conservation capacity to address these issues.

Natural Resources Exploitation

Mongolia harbors vast reserves of many natural resources that have largely gone untapped until recently. The country's mineral wealth includes vast deposits of gold, copper, uranium, fluorspar, and molybdenum (MNE 2001; Sanders 1996). Additionally important minerals include iron, silver, tin, tungsten, zinc, lead, phosphates, and nickel (MNE 2001). Vast coal deposits and more modest oil and gas reserves also exist throughout large portions of the nation. Since the transition to a free market economy, mining activity has increased dramatically (Brooke 2003; Ferguson 2003; UNDP 2000). For example, gold production increased by over 11 times (1,100 percent) from 1993 to 2000 as the number of mines increased to 150 (MNE 2001). In addition, numerous wildcat mines illegally excavate gold throughout the country. By 2004, companies already licensed 29.9 percent of Mongolia's territory for exploration and mining and over 6,000 significant deposits of 80 minerals have been found (Mineral Resources Authority of Mongolia 2004).

Because minerals represent 15 to 20 percent of the nation's GNP and 57 percent of its exports (MNE 2001; Mongolian National Mining Association 2004), the mining industry exerts tremendous influence on environmental management in Mongolia. As the Mineral Resources Authority of Mongolia (2004: 6) states, "[Mining] opportunities are facilitated by a supportive government attitude and alluring foreign investment business environment." Although mining companies are required to prepare Environmental Impact Assessments, undertake reclamation activities, and place 50 percent of their environmental protection budget in a government account prior to beginning work (Wingard and Odgerel 2001), the Mongolian Ministry for Nature and Environment states that "none of these laws are enforced" (MNE 2001: 17). As mining continues in the absence of law enforcement, companies have simply ignored environmental mitigation and restoration requirements (Brooke 2003; Ferguson 2003).

Pressure for increased mining activity continues to mount and Farrington (2005) suggests the largest threat to the protected–area system from mining has come from within the government itself. In June 2002, the Ministry of Nature and the Environment proposed deprotecting 434,000 ha of land in 10 protected areas and at the same time, the Mineral Resources Authority of Mongolia proposed deprotecting an additional 1.5 million ha of land in 8 protected areas (Farrington 2005). These motions were later rejected by the Mongolian parliament, but a new proposal in December 2003 proposed deprotecting 3.1 million ha or approximately 15% of Mongolia's protected-areas system, in four different protected areas so that the areas could be opened to mining (Brooke 2003; Farington 2005). The Mongolian conservation community has strenuously opposed such actions, as have most local people (Anonymous 2004; Brooke 2003; Johnstad and Reading 2003). Nevertheless, the precedent was set in the early 1990s when the government deprotected a portion of Three Beauties of the Gobi National Conservation Park to permit the establishment of a gold mine. In addition to resource extraction, talks are underway to deprotect portions of border parks to allow the construction of transportation corridors (rail lines and paved roads) to facilitate the exportation of natural resources to Russia and especially China (Anonymous 2004; Birdlife International 2003).

Despite the increasing extraction of minerals from Mongolia, the nation's refining industry has not developed (Wingard and Odgerel 2001). As a result, a source of economic development is being lost. Similarly, mining and taxation laws generous to extractors permit companies to exploit natural resources, while paying modest taxes and royalties to the government (Anonymous 2004;Brooke 2003). For example under the Minerals Law of Mongolia, passed in 1997 and amended in 2001, exploration fees are US$0.05/ha for the 1st year, US$0.10/ha for the second and third years, and then rises to US1.50/ha by the seventh year (Ariuna and Mashbat 2002). Mining fees are US$5.00/ha for years 1 to 3, US$7.50/ha for years 4 to 5, and US$10.00/ha thereafter (Ariuna and Mashbat 2002). There are no customs fees or limits on repatriated money earned from mining (Wingard and Odgerel 2001). Mining royalities are set at 2.5 percent for all minerals, except gold (7.5 percent) (Ariuna and Mashbat 2002). In addition, the government is not required to approve business or operational plans; foreigners can work for extraction companies; and firms can export raw materials (Mineral Resources Authority of Mongolia 2004). Given this situation, the benefits to Mongolia seem meager.

Conflicts Between Pastoralism and Conservation

Pastoralists remain among the staunchest supporters of conservation initiatives in Mongolia, including the creation of new protected areas, yet their knowledge of the meaning of terms like "biodiversity" and of Mongolian environmental laws and conservation activities remains low (Anonymous 2003). Still, conflicts between pastoralism and conservation do arise and require attention. For example, Agriteam Canada (1997) raised concerns over additional constraints placed on herders by the establishment of large protected areas. They reported that in Khustain Nuruu Nature Reserve, established for the reintroduction of Przewalskii horse, a reduction in total area available for herders in Altanbulag *sum* created conflicts associated with a loss of traditional winter and spring camps. Establishment of the Gobi B Ecological Reserve also reportedly reduced winter grazing areas for local herders (Agriteam Canada 2003). We found no information on conflicts associated with removing domestic livestock from protected areas established before the 1990s; however, O'Gara (1988), in describing the success of the Khokh Serkhi Strictly Protected Area for conserving wildlife, reported that within five years of its establishment in 1977, all pastoralists and their livestock had been removed. We do not know how the removal of pastoralists was achieved or the impacts on those pastoralists, but we assume that displacement of pastoralists did impact their lives. A more recent study reported that the creation of Gobi Gurvan Saikhan National Park was a positive influence on some communities of pastoralists living in the park, largely because of planning and support by GTZ (Bedunah and Schmidt 2004). Bedunah and Schmidt (2004) reported that the pastoral issues identified in Gobi Gurvan Saikhan National Park were not associated with the park, but were issues faced by the entire country associated with the lack of land-use controls for addressing livestock grazing. This situation has arisen during the transition from the command economy to free-market system because of a lack of institutional controls and thus a deterioration to more or less free access of grazing lands (see Fernandez-Gimenez 1999; Mearns 2004).

Just after the transition to democracy, Sheehy (1996) suggested that most of the grazing land in Mongolia remained in good or excellent condition, and that degraded pastures responded favorably to reduced grazing pressure. At the time range scientists considered only about 11 million ha, or 7 percent of Mongolia's land area, of pasture land as degraded. However, livestock numbers rose markedly during the 1990s (fig. 2 and 3), resulting in greater degradation and increased desertification, especially in the more marginal desert steppe and desert regions (Amgalanbaatar and others 2002). By 2001, government officials reported that over 70 percent of total pastureland was degraded and 7 percent was heavily degraded (MNE 2001; UNDP 2000); although, a recent World Bank report (2003) disputes these figures as likely being too high and not based on valid studies.

The increased degradation of pasturelands in Mongolia, whatever the current level, has been attributed to global climate change, vehicular damage, and especially over-grazing of relatively fragile rangelands (MNE 2001; UNDP 2000). Over-grazing resulted from an increase in the national livestock herd, drought, and poor management of livestock (for example reduced livestock movement by many pastoralists) associated with a loss of land use controls or institutional development for ensuring sustainable grazing management. The rapid increase in livestock, from 24.7 million in 1989 to about 33.6 million in 1999 (Byambatseren 2004, NSO-Mongolia 2004) (fig. 2), has been attributed to 1) reduced livestock prices that encouraged herders to maintain live animals rather than selling them for slaughter and 2) an increasing number of pastoralists as many urban residents turned to pastoralism as a way of life following the collapse of communism and a loss of other livelihood opportunities (MNE 2001; Sheehy 1996; UNDP 2000; World Bank 2003). Following two severe winters coupled with large expanses of drastically over-grazed pastures, the national herd size dropped dramatically to 23.9 million head by 2002 (Byambatseren 2004) (fig. 2). Persistent droughts undoubtedly exacerbated overgrazing in some areas, but herders did not reduce animal numbers to balance animals with forage resource when conditions called for such actions. Reportedly, over 7 million head of livestock died (World Bank 2003). Of course, wildlife also suffered from these impacts. At our argali research site in Ikh Nartiin Chuluu Nature Reserve, we witnessed the starvation deaths of dozens of argali and ibex as little forage remained following heavy livestock grazing.

The increased numbers of nomadic herders and livestock also meant increased displacement of wildlife from traditional pastures. For example, in western Mongolia, pastoralists are pushing higher and further into the mountains, increasing the stress on the ever more fragmented and declining argali populations that remain (Amgalanbaatar and Reading 2000; Amgalanbaatar and others 2002; Mallon and others 1997; Schuerholz 2001). We also recently discovered that domestic guard dogs predate on argali sheep (Reading and others 2003). Indeed, domestic dogs represent one of the major sources of mortality for argali at our study site.

Pastoralists also displace wildlife by poaching (Pratt and others 2004). Although the extent of poaching remains largely unstudied (but see Zahler and others 2004), we have observed poachers throughout Mongolia at all times of the year while conducting our research, suggesting that it represents a significant source of mortality for ungulates. Pratt and others (2004) examined reasons for rising poaching in Mongolia. Much of the increase occurs because of the rising market value of game animals in Asian markets and for meat, coupled with declining standard of living many people are facing during this difficult transition to a market economy. Pastoralists also readily admit to poaching wolves and snow leopards out of concern for livestock depredation. Although both species are faring relatively well in Mongolia, they remain heavily persecuted. Mongolian pastoralists do not actively herd or guard large livestock species, such as horses, cows, yaks, and camels. Instead, they permit these animals to roam relatively freely until required for slaughter, to provide products (for example milk, wool), or to serve as beasts of burden. As such, many depredations undoubtedly go undetected. Alternatively, many pastoralists blame large carnivores, especially wolves, for most large livestock losses that occur, despite the fact that disease, malnutrition, and other factors (theft and poisonous plants) probably represent the majority of missing animals.

An additional cause of mortality to wildlife, and a continued threat, is indiscriminate use of rodenticides. For example, the Mongolia Agricultural Ministry initiated massive Brandt's voles (*Microtus brandtii*) poisoning programs because of the perception that the voles compete with livestock. The poisons, zinc phosphate and bromadiolone, were applied to grains and broadcast across vast expanses of steppe (Birdlife International 2003; Natsagdorj and Batbayar 2002). The pesticides kill far more than voles and other rodents, however, and massive die-offs of several species of birds, small mammal carnivores, and even livestock have been reported (Birdlife International 2003; Natsagdorj and Batbayar 2002; Zahler and others 2004). Ironically, the reason for the increased vole populations is likely associated with overgrazing and the subsequent shorter vegetation. Short vegetation enables voles populations to expand due to increased ability to detect predators (Natsagdorj and Batbayar 2002; Birdlife International 2003). The loss of vole predators will exacerbate the problem by facilitating future population irruptions at shorter time intervals (because there are fewer predators, whose slower population growth means they require more time to recover from the mass poisoning campaigns), to help stem the growth of vole populations.

Despite the generally high level of support that most pastoralists express for conservation, conflicts do arise with some conservation initiatives. Perhaps the most of important of these are the loss of traditional grazing rights and restricted rangeland access that come with the establishment of new protected areas. This source of conflict has the potential to increase dramatically, as protected areas become increasingly better and more actively managed. Although most protected areas permit some level of continued grazing by domestic animals, most also include or permit establishing special zones where grazing is restricted or prohibited for the benefit of wildlife (Wingard and

Odgerel 2001). In addition, many protected areas will require more active grazing management to sustain the unique plant and animal communities they were established to protect. As park managers remove pastoralists from protected areas, limit the number of livestock they graze, or restrict the seasonality of grazing, the potential for conflict rises.

Lack of Conservation Capacity

Arguably the greatest challenge to successfully conserving Mongolia's rangelands is the lack of conservation capacity that currently exists in the nation. A joint government-independent assessment found that Mongolia lacked adequate conservation capacity to conduct effective conservation actions (Anonymous 2003). Luckily, however, this challenge is probably the most easily addressed. The national assessment of conservation capacity found that problems stemmed primarily from too few staff, inadequate or inappropriate professional training of staff, lack of experience among conservation professionals, and insufficient resources, both for field and office work (Anonymous 2003).

Poor environmental monitoring and law enforcement well illustrate the lack of conservation capacity in Mongolia. Currently, monitoring and law enforcement are almost nonexistent. The government itself readily admits this problem (MNE 2001). Lack of monitoring and enforcement stems from several factors, including lack of resources to monitor, lack of political will to prosecute, corruption, lack of adequate training, and the vast size of the nation (especially, relative to available resources) (Anonymous 2003).

Mongolia remains a very poor nation (NSO-Mongolia 2004). The nation's sparse resources mean that environmental monitoring usually receives inadequate funding. Mongolia invests only US$2 per km^2 in protected area management, well below the global mean of US$893 per km^2 or even the mean among developing nations of US$125 per km^2 (Anonymous 2003). A mere 194 rangers patrol the nation's 20.7 million ha of protected areas and only 1 ranger per *sum* patrols the rest of the nation (Anonymous 2003). And although every *sum* (like a county) employs an environmental ranger, most lack the resources necessary to permit the ranger to actually leave the *sum* center to monitor natural resources exploitation activities, patrol against poaching, and collect data on the state of the environment. To a lesser extent, the same is true for rangers of protected areas (*sums* are actually responsible for managing Nature Reserves, but most go unmanaged). As such, most natural resources exploitation occurs without any governmental oversight, especially for small operations (Anonymous 2003). Natural resources exploitation will likely continue unless political will to counter this exploitation is generated.

Similarly, most rangers possess little to no equipment or training (Anonymous 2003). Some rangers have benefited from limited training and equipment provisioning by international aid organizations, conservation organizations, and universities. Yet, generally such equipment and training remain insufficient, especially relative to the size of the enforcement task. Even when rangers are able to monitor their territories, they must confront poachers unarmed; they lack the means to determine whether or not mining activities are negatively impacting the environment; they generally do not have the capacity to collect evidence for effective prosecution; etc. As such, even when monitoring occurs, it is usually ineffective (Anonymous 2003). As a result, most pastoralists, resources extractors, and others are able to operate with little regard to the law or their impacts to the environment.

Lack of conservation capacity is not restricted to government agencies. Mongolian environmental NGOs face many of the same constraints as the nation's agencies. Of the 120 environmental NGOs, only 37 actively engage in activities; most remain simply organizations on paper (Anonymous 2003). Even the 37 most active environmental NGOs struggle—80 percent of these lack stable finances, 60 percent have no permanent office space, and 25 percent are without paid staff (Anonymous 2003). Only 20 environmental NGOs employ >1 staff members and only 4 employ >10 (Anonymous 2003). Finally, most environmental NGOs suffer from the same lack of resources and training as do the government agencies, seriously constraining their effectiveness.

Improving Prospects for Conservation

Opportunities for successful conservation of Mongolia's rangelands in a manner that sustains both the pastoralist traditions of the nation and the wildlife of the steppes remain within our grasp. Yes, Mongolia is changing rapidly and threats are growing; but, Mongolian pastoralists are among the greatest allies of conservationists in that country. Better cooperation and integration of government agencies, Mongolian environmental NGOs, international donor and conservation NGOs, and local people arguably offers the best path toward more holistic and sustainable conservation of Mongolian rangelands.

Strengthening Protected Area Management

Mongolia's protected area system is currently under attack from natural resources extraction interests (Johnstad and Reading 2003). The government largely supports the industry's initiatives, and many people believe that some change is likely. Not only does natural resource extraction threaten wildlife and scenic values, but it also may threaten customary grazing lands. We suggest that those opposed to the deprotection process need to engage those favoring the process in a constructive dialog to ensure wildlife and cultural values are considered and valued.

Although establishing new protected areas or expanding existing ones may be difficult given efforts to reduce the current system, many areas deserve protection to preserve important wildlife habitats and should be pursued. For example, some of the crucial breeding grounds of Mongolian gazelle remain unprotected and thus subject to development or degradation. As the wildlife of Mongolia is increasingly better studied, additionally vital habitats undoubtedly will be discovered and delineated. Biologists should work quickly to determine where these areas lie and conservationists should then move rapidly to protect them. In addition, most protected areas remain too small and isolated to protect viable populations of dependent wildlife species (Johnstad and Reading 2003). Conservationists should determine the size and location of habitats required to conserve focal species. In many cases, protecting some form of linkage (for example corridors or small "stepping stone" reserves) may be easier and more effective than expanding reserves.

Finally, but perhaps most importantly, the capacity of Mongolia's protected areas agency requires serious improvement. A report issued by the Mongolian government and independent evaluators recommends improving conservation capacity through increased training; more and better equipment; better fund raising; improved and more frequent collaboration and cooperation with Mongolian and international environmental NGOs and donors; and better public awareness and education program, including training and empowering local people to assist with conservation through grassroots community groups (Anonymous 2003). Such recommendations hold outside of protected areas as well. Conservationists should work with local people to determine areas that remain vital to wildlife, but cause minimal conflict with pastoralists. Community-based management then should be developed to manage these areas (Johnstad and Reading 2003). Such community-based systems may provide a method of improving management at lower costs, while simultaneously reducing conflict.

Tourism

Many conservationists advocate nature-based tourism as an alternative to natural resources exploitation. In Mongolia, such eco-tourism is unlikely to provide benefits to offset losses from foregoing exploitation. Although generally increasing, few tourists visit Mongolia each year. Officially, 50,835 tourists visited Mongolia in 2002 (Byambatseren 2004). Because of the Severe Avian Respiratory Syndrome (SARS) scare, tourism dropped to 21,890 visitors in 2003; although some portion of the 180,558 people that visited Mongolia for "private purposes" were probably also tourists. (NSO-Mongolia 2004). Of tourists that visited Mongolia in 2003, 78.9 percent came from East Asia and the Pacific and 17.6 percent came from Europe (NSO-Mongolia 2004). In addition, the majority of these tourists likely came for cultural-based tourism, not ecotourism. Although cultural tourism in Mongolia requires conservation of rangelands, a small proportion of the nation's territory can accommodate the vast majority of that tourism. Therefore, while locally important, tourism will likely not facilitate efforts to conserve Mongolia's rangelands.

Still, nature-based tourism in Mongolia potentially represents a much larger source of additional revenue for conservation than is currently being realized. Protected areas in Mongolia generated about 30 percent of their budget from tourism (primarily), international aid, and collection of fines, which could be much higher if all fines issued were collected (Anonymous 2003). Ecotourism is increasing in Mongolia (Johnstad and Reading 2003). Further increasing ecotourism and associated revenue requires additional capacity building in this sector as well, including improved infrastructure (accommodations, travel, etc.); better trained, more knowledgeable guides; and more aggressive marketing. Most high end ecotourism to date has focused on fishing and trophy hunting, but we believe could be expanded, especially if improvements in law enforcement led to more and better wildlife viewing opportunities. However, tourism comes with its own ecological and socioeconomic impacts that largely remain unaddressed in Mongolia (Johnstad and Reading 2003). As such, conservationists must strengthen their capacity to develop and manage ecotourism in a socially and ecologically sustainable manner.

Grazing Reform

Perhaps the greatest opportunity for improving rangeland conservation in Mongolia lies with grazing reform. Currently, the absence of any functioning formal structure for managing rangelands precludes effective conservation. Instead, grazing management lies in the hands of thousands of independent, semi-nomadic pastoralists, often with differing skill levels and goals. After several years of livestock declines and continually degrading rangelands, most pastoralists and government officials realize that a problem exists and livestock controls are necessary. Most are open to, if not actively searching for, solutions. Schmidt (this proceedings) suggests that community organizations of herders is improving this situation and indeed, the process has begun with a conflict-laden land reform process currently underway.

Obviously, to succeed, any grazing reform requires the involvement of pastoralists during its development and implementation from the beginning. Yet, we also believe that wildlife biologists and conservationists should be included in discussions directed at grazing and rangeland management reform in Mongolia. Thus far, these interests have been excluded from active involvement in the grazing reform process. We believe it is crucial. In the U.S., public lands are to be managed for multiple-use. In Mongolia, there is appreciation of land for watersheds, aesthetic, and biodiversity values, as well as a lack of monitoring and management for ensuring these values. In fact, there seems to be a prevalent attitude by many Mongolians that livestock are a part of the natural system and thus are unlikely to degrade or negatively impact other values.

How best to manage grasslands to protect and conserve biodiversity and cultural diversity will depend on a number of variables. However, it seems logical that where grazing is practiced best management practices (BMPs) and resource management plans should be developed for the particular area. In some ways it may seem unnecessary to recommend BMPs for Mongolian herders who have a long history of herding; however, with the changes in the 20th Century and a generation of "new herders" we strongly believe that development agencies should help Mongolia develop an extension service that can develop and demonstrate grazing practices that will protect biodiversity and conserve rangelands under the changing social and economic conditions impacting pastoralists. The BMPs could be developed in a general way for regions, but for each particular protected area the BMPs should be based on the goals of that protected area. For example, in protected areas where argali are the major species of concern and their primary use is during the winter, park plans should reduce livestock grazing, especially sheep and goat grazing because of the high dietary overlap on argali winter range. Restrictions would vary, but in this example it may be best to completely restrict livestock grazing with the knowledge that some transient horse, camel, yak and cattle grazing will likely occur as these animals are not herded. Resource management plans would provide the means for herders and park officials to develop plans cooperatively and to understand each other's objectives. Multiple-use planning with communities of pastoralists using protected areas, based on grazing association use of public lands in the U.S. may provide a model to meet a number of resource objectives in many of the protected areas used by pastoralists.

Wildlife Management

Mongolia lacks a wildlife management agency. All wildlife outside of protected areas remains largely unmonitored and almost completely unmanaged (other than limited monitoring by *sum* rangers). Yet, obviously, most of Mongolia's wildlife persists outside of protected areas, suggesting the need to expand management throughout the nation. We suggest that wildlife species could be managed as indicators of rangeland health and well-managed pastures should support large populations of native wildlife, especially ungulates.

A wildlife management agency, perhaps based on a Western wildlife agency could be created and funded via institution of a permit hunting system. Additional funds could be garnered from tourism taxes. Game species, including non-trophy species such as marmots, require active management if populations are to remain viable (Zahler and others 2004). Given the prevalence of hunting in Mongolia, such a program should generate substantial revenues.

Integrated Solutions and Conflict Reduction

Finally, our ability to develop sustainable pastoralism and nature conservation on Mongolia's steppe will require that we develop integrated solutions and avoid unproductive conflict. This, in turn, depends on effectively employing interdisciplinary approaches and working with the full complement of stakeholders. We firmly believe that sustainable pastoralism and conservation of Mongolian rangelands are fundamentally linked. As such, both should proceed in tandem. Conservationists should work closely with herders to develop management plans that consider and address both issues. In the case of protected areas, protected areas staff should involve herders at levels of the planning and implementing processes (Pimbert and Pretty 1995). Outside of protected areas, herders may well be the ones to initiate range management changes. It is less clear which government agencies and officials should work in unprotected landscapes. The Ministries of Agriculture, Mining, and Nature and Environment all can appropriately participate, as can local aimag and sum governments. In some cases (e.g., border areas), the Defense Ministry may also be included.

Herders must recognize that legislation requires government officials to follow certain regulations and officials should make herders aware of pertinent laws and recognize the constraints that herders face in trying to make a living on Mongolia's rangelands. Even with increased understanding and respect, conflicts will inevitably arise. Not all conflict is bad, as well-managed conflict can lead to better ideas, creativity, and innovation. Community-based approaches to conservation offer a variety of methods to help local people and conservationists avoid and manage conflict (Ghimire and Pimbert 1997; Western and Wright 1994). An in-depth discussion of such approaches goes beyond the scope of this paper. We support such initiatives; however, we stress that they must go well beyond traditional sustainable development approaches that often have focused on development while giving short shrift to conservation (Brandon and others 1998a; Frazier 1997). Similarly, a variety of environmental dispute resolution methods exist to help avoid and manage conflict (Wollondeck and others 1994; Wondolleck and Yaffee 2000). Such methods should be employed before conflicts become intractable and the people involved become so distrustful they are unable to work together.

Conclusions

Proper management of Mongolia's rangelands is critical for ensuring a productive livestock industry, maintaining livelihood options of pastoral cultures using these rangelands, and supporting the natural diversity of flora and fauna. Vast expanses of rangelands extend unfragmented and largely unaltered by crop agriculture or industry throughout the nation. In general, rangelands retain their natural potential although degradation caused by livestock grazing is a critical problem, especially near towns and watercourses. Few introduced exotics have established and much of the historic flora and fauna survive, often in relatively large, apparently healthy populations. Yet, since the end of communism and command-control economy in the early 1990s, Mongolia has been changing rapidly. Several challenges have emerged and now face conservationists interested in preserving sustainable pastoralism and wildlife populations on the steppe. We propose developing a variety of interdisciplinary approaches that link conservation biology, range management, and the social sciences to address these threats and increase the chances for effective rangeland management that is sustainable and enjoys enduring public support. This requires a concerted effort by state and local government as well as support at the local or user level. The international conservation community is committed to helping Mongolia, but success in conservation requires acceptance by and planning with those most dependent on the rangelands. Others have stressed that livestock overgrazing has been greatly exacerbated by of a loss of institutional capacity (loss of control by government or community control), a loss of historic norms in cooperation and management, etc. Protected areas that restrict livestock grazing may have some future, detrimental impacts on individual households; however, in general grazing in protected areas should allow modest additional development with pastoralists by combining efforts to preserve flora and fauna and pastoral cultures. We propose that protected areas work with pastoral communities to develop conservation plans, including grazing management plans, monitoring, and BMPs, that permit adaptive management of grazing lands. This requires that the government agencies enter into cooperative agreements with each other (for example, the Ministries of Agriculture and Nature & Environment) and with local people to ensure the conservation of Mongolian rangelands and native species, as well as sustainable pastoralism for local people grazing those lands.

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Pastoral Community Organization, Livelihoods and Biodiversity Conservation in Mongolia's Southern Gobi Region

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Abstract—*In this paper I describe processes and impacts of collective action by mobile pastoralist communities, and of external support strategies to strengthen local institutions and cooperation in Mongolia's southern Gobi. The need for pastoral mobility triggered the processes leading to community organization, and the emergence, or re-emergence, of local informal institutions. Their growing role in natural resource management, conservation, rural self-governance and service delivery, and the onset of self-organization and scaling-up without external input may suggest success in terms of developing institutional capacity, and of strong local ownership of donor supported activities. With the development of a participatory monitoring system, evidence is mounting of positive social, economic and environmental impacts of collective action facilitated by community institutions, both for pastoral and non-pastoral rural livelihoods in the Gobi region.*

Keywords: *livestock mobility, collectives, participatory monitoring, self-governance, nomadic livestock management.*

Introduction

I describe the development of community organization among pastoralists in Mongolia's Southern Gobi Region and describe how community organization has provided a number of benefits, environmentally and to the livelihoods of the people. The need for community organization has been triggered by the need of herders for mobility and appropriate services, and supported through participatory analysis and planning. First, I provide a background on pastoral institutions in Mongolia and on mobility as a strategy for sustainable dry lands management. In the next section, I explain the rationale for the approaches taken, both from the viewpoints of pastoralists and from that of conservation and development practitioners, and how approaches converged towards the same objective of conservation. Here I also refer to the methods and tools that we applied in participatory research and planning.

I dedicate the main section of the paper to the processes of community self-help initiatives and institutional strengthening, of mutual learning and improved local cooperation, and elaborate on the environmental, economic and social impacts felt to date by local communities. I also report on our first quantitative data on impacts derived from a participatory monitoring and evaluation system that was jointly developed by local communities and project workers.

To conclude, I revisit the theme of pastoral institution and offer an interpretation of the role and significance of the community organizations that have emerged in the Gobi. Finally, I summarize what lessons may be learned from our work in the Gobi for conservation and development policies and practice. I have intended this contribution as a critical reflection on approaches and strategies for integrating conservation and local livelihoods, and to share experiences in programming support to sustainable pastoralism of which the development agenda is set by pastoralists themselves.

The work I describe has been undertaken in the framework of two projects of Mongolian-German Technical Cooperation ("Nature Conservation and Buffer Zone Development," 1995-2002, and "Conservation and Sustainable Management of Natural Resources – Gobi Component" 2002-2006), currently implemented by the "Initiative for People Centered Conservation" (IPECON) of the "New Zealand Nature Institute" (NZNI). The area concerned includes 13 districts (soums) in Omnogobi, Bayankhongor and Uvurkhangai aimags (provinces) in Mongolia's South (fig. 1). It represents a significant portion of one of Mongolia's major ecological zones, the arid and semi-arid Gobi that encompasses 40% of the country. The Gobi region is an ancient cultural landscape of desert and desert-steppe ecosystems, utilized by nomadic, and sedentary, populations for thousands of years as illustrated in numerous

Bedunah, Donald J., McArthur, E. Durant, and Fernandez-Gimenez, Maria, comps. 2006. Rangelands of Central Asia: Proceedings of the Conference on Transformations, Issues, and Future Challenges. 2004 January 27; Salt Lake City, UT. Proceeding RMRS-P-39. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

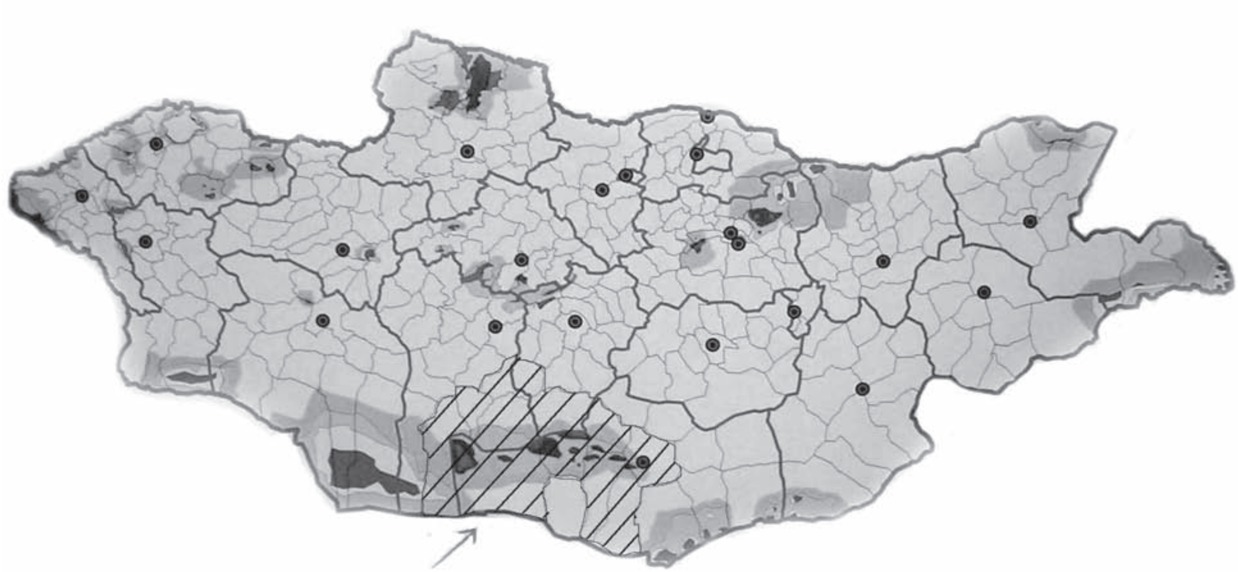

Figure 1—Map of Mongolia showing project area (cross-hatched). The project area encompasses 13 districts in the South Gobi, Bayankhongor, and Uvurkhangai Provinces.

petroglyphs (fig. 2). The region is one of the country's major tourist destinations due to its outstanding historic and ecological conservation values. It includes Gobi Gurvan Saikhan National Park with globally significant prehistoric and paleontological sites, habitat of globally endangered species such as snow leopard (*Uncia uncia*) and argali (*Ovis ammon*), as well as Wetlands of International Importance (Ramsar Sites). Data and discussions on ecology, biodiversity conservation, protected area management and pastoralism are provided by numerous papers including Bedunah and Schmidt (2000; 2004), Reading and others (1999) and Retzer (2004).

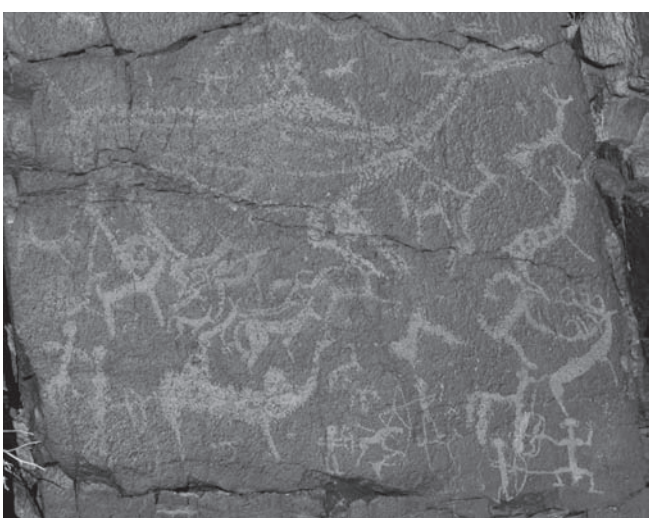

Figure 2—An example of petroglyphs found in the southern Gobi. The Gobi region is an ancient cultural landscape used by nomadic populations for thousands of years.

In recent history, Mongolia was dominated by the Soviet Union to which it was a provider of meat and raw materials. After the collapse of the Soviet Union, Mongolia underwent immense socio-economic changes. Its own production system, based on collectives and state owned farms and factories, collapsed. The loss of employment in the collectives led to migration to rural areas and the emergence of new herding households. Neglect of pasture water supplies, particularly on remote pastures, lead to concentration around functioning wells. Many pasture areas degraded around water points and near administrative centers. Export markets for Mongolian pastoral products had ceased to exist after the Soviet Unions disintegration. The new herding was for subsistence or mere survival. Poverty and vulnerability were exacerbated by several years of winter disasters (dzud) causing loss of livestock and livelihoods and starting a reverse trend of rural to urban migration.

Pastoral Institutions and the Role of Mobility for Sustainable Drylands Management

Since the decline of tribal organization and herd management that existed in the times of Chinggis Khan, large territories were allocated to clergy and nobility while on the local level, pasture management was rested with local herder communities. During the socialist period, livestock and pasture management was the mandate of rural collectives (negdel). After 1990, following the collapse of the authoritarian government and the central command economy, the rural collectives disintegrated and rural infrastructure deteriorated and most government services ceased to exist. Private herds, generally of several kinds of livestock but mostly in low numbers per herd, were grazed on state owned land. Probably for the first time in known history, Mongolian herders were operating individually with little or no control on land use. For in-depth descriptions and discussion of pastoral institutions throughout history and during the recent socio-economic and political changes a number of sources exist (Erdenebaatar 1996; Fernandez-Gimenez 1999, 2002; Humphrey and Sneath 1999; Mearns 1993, 1996; Mueller and Bat-Ochir 1996; Upton 2003).

Nomadic livestock herding has often been blamed for land degradation and threatening biodiversity, especially in the past. The case for mobility as a rational strategy for sustainable dry lands management has recently been established (Behnke and Scoones 1993; Ellis and Swift 1988) and mobility is probably the single most important element in the traditional management and knowledge systems of pastoral cultures in arid areas. Today, the contribution of mobile pastoralism to biodiversity conservation and to national economies is gaining greater recognition among social and natural scientists and development practitioners. Recent initiatives such as the "Dana Declaration on Mobile Peoples and Conservation," the development of a "Worldwide Initiative for Sustainable Pastoralism" and the support to the establishment and strengthening of the "World Alliance of Mobile Indigenous Peoples" represent this new recognition.

Approach to Institutions, Community and Participatory Practice

When the processes described here began, participatory analysis with local herder communities revealed that they perceived a lack of formal institutions to regulate pasture management and recognized a need for collective action to fill this vacuum. The following planning with and support to communities of pastoralists and rural center citizens addressed immediate needs of livelihoods and of the restoration and sustainable use of the natural resource base. While this was to lead into a focus on human and institutional capacity building, it was not based on a strategic approach to institutions or on a thorough analysis of existing informal institutions. Upton (2003) provides a preliminary analysis of the approach in relation to the informal institutions in one local study area.

The project was originally conceived by Mongolian and international scientists and conservationists, supported by provincial government and central government institutions mandated with protected area management, and agreed between the Mongolian and German governments. While planned jointly among these partners, it lacked active grassroots involvement nor was its conception driven by local communities. However, as analysis and planning with the pastoral communities would show, the project objectives of "nature conservation" were not at all perceived by pastoralists as contradictory to their own objectives. When the role of external support was changed into a more facilitative one, and the project approach shifted from subsidy and externally driven to a self-help and self-determined approach the responsibility for implementation of activities was devolved to local community groups. As a result, the maintenance, restoration or improvement of mobility became a focus of the project. It soon became apparent that the "project" objective of "nature conservation" translated into the Gobi herders' objective of "mobility."

Participatory approaches to conservation and community development among pastoralist peoples have been described as difficult (McCabe and others 1992; Upton 2003). In the initial stages of our work, and sometimes to this day, the notion of "community" has met with doubt and skepticism in Mongolia. Several factors may have prompted such sentiments and perceptions. After the experience of Socialist collectivization, feelings against cooperative arrangements did exist among herders. Incidents of fraud by middlemen who had promised herders to market their products, caused distrust for cooperation in joint marketing. A general lack of organized delivery of services and a lack of information contributed to a situation in the early to mid nineties where individual households struggled with the new challenges of a market-driven economy and of increasing pressures on their natural resource base. Using scarce and highly variable resources, herder households in the Gobi tend to camp alone or in very small groups rather than in "Khot Ail" (groups of households) as in other parts of the country. This may have exacerbated the perception of outsiders that there are no "communities" among Gobi pastoralists. It is suggested here that this disregard for the notion of community in rural Mongolia is based on a narrow interpretation of community, that associates community with a more formally and spatially defined group, like a village or settlement, and on a lack of understanding of the institutions or norms inherent to a group of herding households who manage local pasturelands communally. A more in-depth analysis that we undertook with groups of herders indeed showed that mechanisms of cooperation were in place. These probably represented customary institutions and norms that had prevailed or were re-emerging. Also, when the interventions described here started, the social, economic and ecological situation had become so dire that the initiatives for collaboration among herders were driven by the need to survive under very adverse conditions.

Under these circumstances, our approach sought to address immediate survival needs of people and livestock while developing sustainable mechanisms for the long term. But the approach to institutions was not strategic and not based on thorough prior analysis. Rather, we accepted that the situation with regard to local institutions was extremely dynamic and complex. When we began to work with groups of local households, these were households that utilized pastureland together, with varying degrees of problems or conflicts. In many cases, they probably were "People of One Well," but a dysfunctional well at the time. The threat was that they would become people of a slum in an urban center or the capital city as their livelihoods deteriorated with the collapse of sustainable grazing.

Our approach was not explicit "institution building" in a sense of building institutions that were externally conceived. The approach was to strengthen collective action and self-help initiatives that emerged, while making the best effort to maximize inclusion and participation. This implies that the approach to the notion of "community" recognized that communities are not homogeneous groups. Our methods and attitudes attempted to facilitate functional participation of all. It considered in its application of tools of participatory action research to include men and women, young and old, poor and rich. Our approach was mindful of power relations, differences in access to information, and capacity to communicate and express concerns.

As this paper describes general processes, detailed methodological descriptions are not provided. The tools and methods used in appraisals and planning with communities typically included mapping (natural resources, social, mobility), seasonal calendars in relation to men's and women's workloads, resource use, income and expenditures, ranking and scoring on wealth and wellbeing and income sources, venn diagrams for institutional analysis, household livelihood analysis, changes and trends in local environment and biodiversity, analysis of problems and opportunities, weaknesses and strengths. (fig. 3-5). We also included semi-structured interviews with key informants, interviews with focus groups and transect walks. Often, facilitators left the initial community meetings when problems and opportunities had been identified and the group had begun to plan collective action. At this stage, the facilitators offered to come back if the group felt they wanted support in planning. Tools and findings are documented in numerous unpublished field reports. While the PRA exercises provided a wealth of information and insights into local natural resource management issues and livelihoods, the primary objective was to initiate local community action.

A Chain of Processes - from Restoring Pastoral Mobility to Improving Governance

In the early surveys and PRA exercises, herders frequently expressed the need for regulation of pasture use and for an institution to coordinate herders' movements. While the district governments are formally charged with this responsibility, livestock herders frequently rated the local government as the least relevant institution in their lives. This need for restoring and coordinating pastoral mobility provided the initial and primary rationale for community organization among herders. This organization set in action a series of processes that eventually was to lead to improved governance in local target areas.

A 2002 Workshop with community leaders in Bogd soum (Uvurkhangai aimag) sought to evaluate factors for successful leadership and organizational development of community organizations. The jointly identified factors clearly reflected principles of good governance, such as transparency, joint decision-making, and accountability for use of funds.

Figure 3—Elderly community members discussing changes in the environment and natural resources over the last decades in the area near Orog Lake (Bogd Soum, Bayankhongor Province.

Figure 4—Community members preparing a profile of ecological zones.

Figure 5—Community members discussing natural resource map of their local area.

Findings of the workshop also indicated that the most successful groups (in terms of social cohesion and effective implementation of activities) were those where elders supported young people who took initiative and where men supported women who took on a leadership role. Typically, well functioning groups had a leader identified by consensus, a council, a community fund established through contributions by all member households, and a community center, the latter mostly being a communal ger (yurt) for meetings and other joint activities.

The first of these community centers was established in the Middle Beauty mountains (Bayan bag, Bayandalai soum, South Gobi aimag) by local herder women who believed that a "mobile community center" would serve needs better than a meeting house in the bag (smallest administrative and territorial unit) center. The women were not able to attend bag center meetings because of their responsibilities in care of small livestock and their children at the summer campsites. Their response was the mobile community center that traveled with them when they moved to new pastures. The center and the community group, now named "Shine Ireedui" ("New Future") were to become a rural center for organizational development and learning.

The success of the group, namely the completion of a resource use contract with local authorities, led to numerous exchanges for experience sharing. Individuals and groups from the region began to visit the "successful" herder community to learn about their processes of organizational development, their community norms, their planning and implementation of communal activities and natural resource management, and their cooperation with government and other organizations. The learning was not confined to inter-community learning. District governors and other officials attended training with the community organization that was becoming a model in the region. By going through the process of developing their organizations, communities themselves had learned about principles of good governance, and government organizations benefited by learning from them. Moreover, the strengthened community organizations became more able and active partners in collaborative management of natural resources and in addressing rural development issues, and they began to demand better services from government and to more effectively communicate their concerns.

The Environmental, Economic and Social Impacts of Community Organization

As of 2004, over 70 community organizations are active in the project area. The majority of these are rural livestock herder households, fewer groups are in rural district centers and the South Gobi provincial center. While household incomes of these are derived predominantly from non-livestock production or activities, livestock-based incomes also contribute to household livelihoods. In turn, household incomes in the rural herder groups are increasingly supplemented through income from diversification, on top of traditional income from livestock, other natural resources and trading.

A workshop in 2004 with 46 leaders of community organizations identified interventions the groups have engaged in and expertise that is being developed on the community level. The areas of intervention include pasture management, livestock quality improvement, dairy processing, services and products for tourism, organizational management and training, waste management, fuel and energy efficiency, small enterprise development, and rural micro-finance (community fund management) (fig. 6). Moreover, community organizations are actively involved in biodiversity conservation and park management by providing volunteer rangers, rehabilitating and protecting water resources, protecting medicinal plants, establishing grazing reserves and managing community conserved areas. An innovative formal agreement between district government, national park administration and the "Shine Ireedui" herder community organization pioneers the transfer of management rights and responsibilities of a "community conserved area" within Gobi Gurvan Saikhan National Park that includes core zone of the protected area. The willingness of local government to transfer the management rights to the community was in part due to the social coherence and demonstrated adherence to group norms on grazing management. In the initial two years of the organization, only one household reportedly did not

Figure 6—A community of poor households with few livestock has diversified income sources by the manufacture of building blocks (Bogd Soum, Uvurkhangai province).

respect the agreed upon dates for moving camps and livestock to other pastures, and now was experiencing group pressure from member households who demanded adherence to community norms. The group norms for pasture management of the "Shine Ireedui" herder community included:

- Rotational grazing;
- Agreements on moving dates;
- Reserving winter pastures;
- Educating, and negotiating with outsiders (which allows for reciprocity in cases of adverse natural conditions when non-member herder households would have to utilize pasture within the area managed by the group);
- Mutual support in preparing winter camps and in risk management; and,
- Commitment to alternative fuel and fuel efficiency, and the protection of shrubs (that are a reserve grazing resource for livestock in the Gobi);

In 2004, the community leader of "Shine Ireedui" community (Gantuul. 2004) reported that the four most visible local impacts of community organization were: (1) improved nature conservation; (2) maintenance of mobility of herder households; (3) improved skills in collaborating with each other and with local government; and, (4) better skills on resolving conflicts. Other perceived changes since community organization include acknowledgement by local government of the local institutions and shared governance. The community, as opposed to single households, received services and had better access to information. Particularly women-headed households benefited in this regard.

Organized communities are able to take better advantage of other government and non-government initiatives, such as credit opportunities for community projects. Through extended cooperation the "Shine Ireedui" Community has been able to improve veterinary care for the livestock of all member households, thereby improving quality of raw materials and entering into an agreement with a leather processing company to supply animal hides. Community organization has taken the lead here to improve veterinary service delivery by the government, development of value added products, marketing of products, ensuring pastoral mobility, and protection of local natural resources. The commitment of households for fuel efficiency through improved household stoves is supporting conservation of shrubs, which in turn has prompted the local government to exempt the group from paying the fuel tax.

At the time of development of the new community organization, most households of the group were poor. Poverty alleviation was an important aspect of the community organizations work. Poverty alleviation was addressed first by communal support (labor and material) to poor and vulnerable households, thus ending their social exclusion. Later, it expanded into micro-credit strategies by providing household loans from the community fund. Access to micro-credit is a crucial step in breaking a cycle of poverty in remote rural areas. As investigation on seasonal household income and expenditure, and on demand for credit had shown earlier, households depend on trader's credit to receive fodder or other needed supplies in fall. When paying back the loan in the spring, after combing cashmere, traders demand payback in cash if cashmere prices are low, and in cashmere when prices are high. Herder households loose out on potential savings or income twice a year. On community level, losses amount to thousands of dollars per season. Household credits from the community fund provide a way out of this dependency, and a tool to better manage risk in livestock husbandry in the harsh environment of the Gobi.

The "Eson Bulag" community of Bayanlig soum, Bayankhongor aimag has been successful in poverty alleviation of member households since being organized. The community of 24 poor households, many of which had become very poor after consecutive winter disasters, has collaborated in cultivation of vegetables and rye, crops that had been previously grown in the area. Most of the people involved had worked as members of a brigade tasked with fodder and vegetable production during socialist times. After witnessing successes in livelihood improvement and social solidarity in a women's self-help group in their soum center, the households opted to work as a group, now voluntarily and with objectives set by themselves (fig. 7). Their modest community fund is used to enable members to participate in public meetings, provide assistance in case of sickness and extend micro-credits to member households. While much of the produce is for subsistence, modest income has been generated through sales in the soum center; among reported use of cash are school supplies for children, enabling them to attend school. Any "savings" are invested in livestock (goats). Now (2004) 15 households own livestock, as compared to 10 households in 1999; in total this community owns 300 livestock (Garvaa, pers. Comm. 2004, internal workshop report).

Figure 7—Leader of "Eson Bulag" community presents community activities in non-livestock sector and results for poverty alleviation among community households (Bayanlig soum, Bayankhongor province).

The examples of organized groups of poor households and their achievements provide sound evidence that the community organization in the Gobi represents a strategy of self-help oriented poverty alleviation and may be a key to rural and urban poverty alleviation in the country. An ongoing Participatory Poverty Assessment, undertaken by the Asian Development Bank in Mongolia's rural areas found that in their South Gobi study areas the "Nukhurlul" (as the community organizations soon named themselves) were viewed by key informants and focus groups of the study as important actors in poverty alleviation. Quantitative analysis, undertaken by the National Statistic Office of Mongolia in the framework of the Participatory Poverty Assessment, is pending (pers. Comm. Tungalag Ulambayar 2004).

The obvious preference of investing in livestock, even by poor and non-herder households, confirms the suggestion of Norton and Meadows (2000) that livestock is social and financial capital. While the "deposit" of savings as livestock may be an expression of the pastoral culture, it may likewise be an indication of the lack of options for rural households to invest savings reliably or profitably. It has to be seen critically in the context of resource conservation and sustainable livelihoods in rural Mongolia, in particular if households of "new" herders (who became herders after the collapse of socialist collectives after 1990) or non-herders, both may lack adequate pasture and livestock management skills, invest in livestock. Alternative saving schemes and rural banking services, building on the positive experiences with the community funds established by "Nukhurlul," may be a key strategy to address economic issues as well as alleviate undue pressure on resources. Livestock insurance schemes may be a viable option for professional herders to commit to lower livestock numbers without running the risk of loosing their livelihood basis through livestock loss in case of winter disasters.

The livestock herders in "Dzuun Bogdiin Uguch," Bogd soum, Uvurkhangai Aimag, provides a case study on impacts of community organization for an economically more advantaged group. In this community, developments included a communal pasture for grazing camels and establishment of rotational grazing (including seasonal movements and the long-distance migrations to fatten livestock before winter, called "otor" in Mongolian). These were considered as the most important elements of the community's strategy to improve pasture and livestock quality (Batkhuyag 2004). The community group has also enlarged the usable pasture area by providing irrigation to 18,000 ha of previously unused pasture. Fencing is being used to prevent grazing of degraded pasture and allow for recovery, until it is moved to other areas in need of rehabilitation. A community reserve pasture has been established to provide a grazing resource for emergencies. A well has been repaired and further expanded the usable pasture area. Breeding stock has been brought from other provinces to improve livestock and livestock products. These activities were largely made possible through cooperation of the households in sharing of labor and in the management of the community fund. Reported impacts included very few livestock losses during dzud (winter disaster), a communal annual income from livestock and livestock products of 35 million Tugrik (approx. $30,000 USD), and community support for one student for tertiary education.

To better capture, and quantify if possible, the impacts that community organization and the resulting processes described above are having on the local environment and livelihoods, a monitoring and evaluation system was established. The monitoring and evaluation is based on indicators that were developed with local communities for their local areas and thereby provides a tool for local planning, for monitoring change at household and community level, and it enables communities to adjust their strategies for improving their livelihood through sustainable use of natural resources. In community meetings every 6 months, changes are discussed and data are compiled (fig. 8). The indicators used as defined by the Nukhurlul include:

- **Environmental Indicators**

Fuel/Firewood Management. Indicators included use of improved stoves; use of briquettes or dung as fuel; a reduction or lack of shrubs stored as firewood; and, the regeneration of shrublands previously used for firewood.

Pasture Management. Indicators included the area of pasture protected by the Nukurlul collectively; the number of households practicing rotational grazing; and amount of area reserved for making hay.

Soil Conservation. Indicators included the number of planted trees, percent survival of trees; and a decrease in damage from vehicles on Nukhurlul managed areas.

Community Conserved Areas. Indicators included the amount of area reserved for use in different seasons, amount of wetlands and saxual (*Haloxylon ammodendron*) "forests" protected; and if the conserved or protected areas are marked and explained by use of signs.

Livestock Management. Indicators included a decrease in livestock losses; number of households with adequate winter/spring shelters for livestock; number of households keeping written records on livestock breeding and management; and, improved water use and development such as the number of wells repaired in community managed areas.

- **Economic Indicators**

Non-livestock income and value added livestock Income. Indicators included the number of households that have increased their income from non-livestock sources; the number of households that have increased their income from value-added livestock products, the development of market links established by the Nukhurlul for products; and, a reduction in number of very poor households.

Access to Credit. Indicators included the establishment and amount of community funds, percentage of funds in circulation, and the number of households receiving credit from the community fund.

- **Social Indicators**

Social indicators were a decrease in number of school dropouts, increased numbers of households joining the Nukhurlul, and a general aspect regarding the improved capacity and development of people in the Nukhurlul.

The monitoring and evaluation system is still evolving and indicators are being adjusted to maximize their relevance to local conditions. Community organizations and extension workers are being trained in data collection and the project-staff strive to gather sound data on conditions. Data available so far support the suggestion made above that community organization is becoming a key strategy in poverty alleviation, through social solidarity that leads to collective action in labor and marketing, ends social exclusion and enables poor households to access micro-credits. The "Eson Bulag" (Bayanlig soum) community fund increased from about $20 USD to nearly $450 USD within six months in 2004. One household emerged from extreme poverty and nine households received micro-credits. Community organization enabled households to transport and market products and to cooperate with other

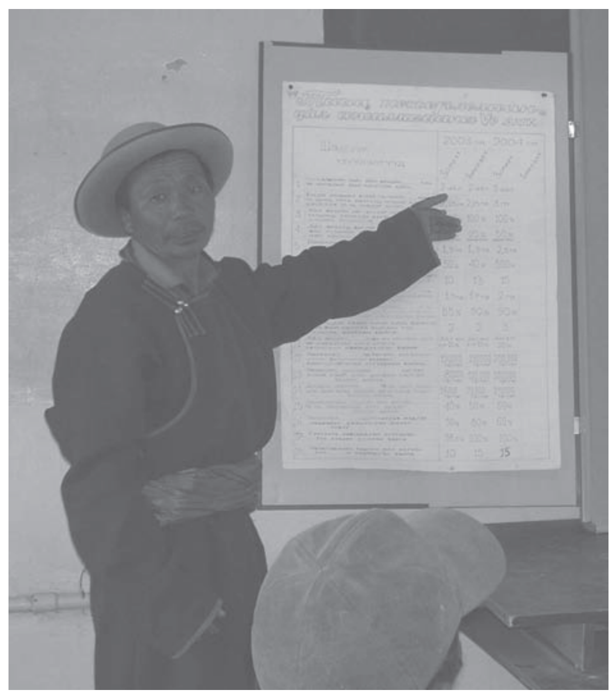

Figure 8—Community leader of "Taats" community (Baruun Bayan Ulaan Soum, Uvurkhangai aimag) presenting results of community action, recorded in Participatory Monitoring and Evaluation System.

organizations (Rentsenmyadag 2004). Preliminary analysis of poverty-related indicators of all community organizations suggest that in the first six months of 2004, 102 households emerged from extreme poverty, and that household incomes increased on average by 10,000 Tugrik over this period.

The monitoring system has also produced data to indicate positive impacts on pasture and risk management. Since community organization has been underway 985 more households practice rotational grazing. Areas for fodder growing, hay preparation and reserve pastures to specifically to reduce winter dzud risks have been increased. The participatory monitoring and evaluation system is still to be refined, and rigorous analysis of data needs to be undertaken. Nevertheless, our experience so far shows the system to be a viable and a valuable planning and evaluation tool.

Community Organizations—New Pastoral Institutions?

When revisiting the issue of local institutions that this contribution referred to earlier, a new picture is emerging with the strengthening of the community organizations. The impacts described above and the priority that most community groups assign to communal pasture management demonstrate the role of community organizations as local institutions for pasture management. The "Nukhurlul" may offer a modern adapted approach to institutions of mobile pastoralism in the Gobi, and perhaps in all of Mongolia's grasslands. It may be argued that sustainable grasslands management in itself is a major contribution to biodiversity conservation considering the high diversity of grassland plant communities. However, I suggest here that community organizations in the Gobi could, with appropriate technical guidance and policy support, become important institutions for biodiversity conservation. Community organizations are responsible for the management of areas in Gobi Gurvan Saikhan National Park (see above, "Shine Ireedui" community) and for local protected areas such as "Khuren Khad" (Baruun Bayan Ulaan soum, Uvurkhangai). District governments are allocating territorial units to community organizations (all of Bogd soum, Bayankhongor aimag, and one bag in Bulgan soum of South Gobi aimag) and community organizations are engaged in protecting conservation values including wetlands, local protected areas, and prehistoric sites. It is fair to say that community organizations are becoming recognized local institutions.

Community organizations are contributing to park management and protection by providing volunteer rangers, allocating certain valleys to households for guardianship against poaching and other illegal activities. The role and potential of community participation in law enforcement has been examined by Swenson (2004) in Mongolia's Bayan Olgii aimag. Here, community organization has taken place following exchanges with community leaders from the Gobi and facilitation supported by NZAID. The above-described contract between the park authority, soum government and community organization places into practice community participation in protected area management by assigning the management rights and responsibilities within a the National Park to the Nukhurlul. The innovation here is that the community-managed area includes the core zone of the park. Considering Mongolia's ambitious goal of placing 30% of its territory under formal protection, the system of "Community Managed Areas" that is evolving may present a viable solution to achieve conservation management and protection of such a large area. Even more so since resources for protected area management are scarce. However, for this effort to be successful, we recommend the government develop enabling policies, provide for enforcement of laws, and funds need to be made available for extension and necessary technical input in conservation management and ecology.

The models of community participation in the management of an established park, as well as the evolving "community managed areas" are a valuable contribution to the international discourse on innovative governance of protected areas, and on discussions on new categories of protected areas, such as "community conserved areas," and "protected landscapes." Relevant discussions on the paradigm shift in protected area management and case studies on innovations in the governance of protected areas have been provided by Jaireth and Smyth (2003) and Phillips (2003). The notion of community-managed areas, with defined borders (fig. 9), provokes questioning in the context of mobile pastoralism. As far I could establish in field interviews with community representatives and from information gathering from extension workers, the "community managed areas" do not restrict mobility of herders. Rather, they are core areas that the self-defined groups of herder households consider themselves stewards of while the seasonal pastures of the same group extend beyond these areas. Neither seasonal movements nor reciprocity and flexibility in case of droughts or other disasters that require diversion from usual grazing areas and possible transgression into other groups usual areas, are perceived as being limited through the defined community conserved areas. It appears that mobility as a management strategy is not being compromised while communities have developed a strategy to improve protection of local resources and biodiversity conservation. The experiences in the Gobi are supporting the notion promoted in the Dana Declaration that "mobile peoples are still making a significant contribution to the maintenance of the earth's ecosystems, species protection, and genetic biodiversity" (Dana Declaration, 2002).

The areas currently under protection and management by Nukhurlul, are now being mapped and transferred to a geographic information system. Data on seasonal pasture utilization and campsites will be added, as well as biodiversity and other conservation values identified jointly by community resource persons and outside experts in conservation sciences. Based on these inventories, and with the foundation of functional community organizations and local cooperation, management plans for conservation and sustainable use of natural resources in the community-managed areas can be developed.

It has been suggested, in discussions on improving governance in rural areas, that the Nukhurlul may be emerging units of local self-governance in Mongolia (Tserendorj 2004).

Figure 9—Example of local area (one bag of Bulgan district) being divided into community managed areas. Community managed areas are currently recorded on a geographic information system.

Already, during the 2000-2004 legislative period, parliament members from the South Gobi introduced community organizations under their chosen name of "Nukhurlul" as civil society organizations into Mongolia's civil law. With community organization becoming more widespread, and more vocal and articulate in voicing their concerns, the question arose whether a parallel structure to the territorial administrative (government) structure has been developed through donor support; and, if local government sees community organizations as a threat. We addressed this question in fieldwork and found that key informants from local government (Bayaraa 2004, Altantsetseg 2004) believed that community organizations are contributing to good governance in rural areas, and that they are crucial as institutions for pastoral resource management. So far, we have generally found a very positive attitude of local government officials, at provincial, district and bag level, towards Community Organizations and their activities. Having very few resources at their disposal, local governors are finding that community organization makes their tasks easier, as they can work with community leaders mandated by local households to represent them or obtain information for them.

Lessons Learned for Development Practice?

A project with the objective of strengthening community organization will encounter a dilemma sooner or later. At the onset, the participatory planning process involved the organization of communities. As community organization spreads, project support activities need to be extended to emerging organizations, and strategies to support self-sustained growth of the organizations need to be developed. The approach needs to remain flexible, and management adaptive. Self-sustaining mechanisms for scaling-up need to be recognized, understood, and supported.

To date, numerous community groups and officials from other provinces, as well as staff of other donor supported programs in rural development and natural resource management, including a group from neighboring China, have visited the "Shine Ireedui" and other community groups in the Gobi project area. Community-led learning and experience sharing began through word of mouth that triggered visits by individuals and groups to households that had organized to work together in resource management and livelihood improvement. These mechanisms have resulted in the formation of new groups, both in and beyond the project region. They have also contributed to the dissemination of knowledge on livelihood strategies, such as various diversifications into non-livestock based income generation, and on local technology innovations relevant to resource conservation such as technologies for improved fuel and energy efficiency that help reduce firewood use.

A workshop with community leaders presented an opportunity to learn about the genesis of groups, their organizational strength and vision for the future. Community leaders grouped community organizations into three categories according to their different type of genesis. Of 46 community organizations, 15 were formed without any external input and facilitation, but solely through local initiative after learning about other organized communities. The spontaneous formation of these groups can be seen as an encouraging sign that the mechanism of community organization, originally encouraged through external facilitation and initiated by joint appraisals of problems and opportunities related to natural resource management and livelihood development, is sustainable and that the project supported interventions enjoy a high degree of local ownership. Thus, a donor-assisted program is merely supporting development, the agenda of which is set by the pastoralists themselves.

Community based learning mechanisms are not limited to inter-community exchanges. Training by the community leader of community resource persons who can sustain community activity independent from the leader was also found to be a factor to strengthen organizations. The ongoing project seeks to support these mechanisms by providing capacity development on community level for training, facilitation and other management skills. The processes of self-organization, of experience and knowledge sharing that communities are applying still need to be fully understood in order to provide support as needed. The community led learning seen in the Gobi may be the emergence of "Herders Field Schools," a pastoral equivalent to the concept of "Farmers Field Schools" developed by farmers communities and supported by development practitioners in South Asian and African countries (CIP-UPWARD 2003).

The process of consensus building on land use, developing norms for natural resource management, the emergence and strengthening of institutions, and the development of cooperation among different stakeholders, all take time as well as flexibility and adaptability. Such processes may take decades even in countries with well-established institutions and mechanisms for decision-making. Too often, donor supported projects are planned for too short periods. This applies even more for countries that are undergoing major transformations, like Mongolia, and are developing a new institutional and legal framework. Short timeframes of donor projects promote the tendency of project workers to take shortcuts rather than allowing the time needed for participatory processes. Our project support has concentrated on facilitation, and material and financial assistance is, with few exceptions, provided as co-funding. This principle is applied to capacity development as well; participants in training sessions are expected to at least contribute to the cost if not cover fees entirely.

An important strategy for empowerment of local communities has been the development of linkages, on local, national and international level. The participation of representatives of livestock herder communities in a number of international events has been facilitated. As a result, members of rural communities in the Gobi have shared their experiences with pastoralists from many countries in events like the "Mobile Peoples Workshop" at the "World Parks Congress" in Durban 2004, at the "Karen Meeting of Livestock Keepers on Animal Genetic Resources," 2003, the "Eco Agriculture Conference in Nairobi, 2004" and most recently, the "Global Pastoralist Gathering," 2005, in Ethiopia. Participation in the events enabled representatives to form alliances to promote the role of mobile pastoralists in conservation and to advocate extensive livestock husbandry as an adapted, modern management strategy for dry lands. The shared experience of common concerns and experiences has empowered participants to articulate their concerns more effectively and to foresee challenges that may lie ahead for them. For herders in Mongolia, where currently intensive versus extensive livestock husbandry and changes in tenure of pasture land are being discussed, these international experiences may prove crucial in advocating enabling policies to maintain pastoral livelihoods and rational management of arid lands through mobility. International linkages have added another dimension to the empowerment of people to develop their own institutions and set their own development agenda.

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The work presented here is a joint effort of many people and groups who have worked tirelessly over the years to bring community organization and conservation forward, to learn and to share experiences. The author has coordinated the efforts and compiled this paper with the input of members of the project team, namely Rentsenmyadag and Tungalag Ulambayar. Altanchimeg Chimeddorj and Enkhchimeg have played key roles in supporting communities in developing their organizations and livelihoods. In all districts, project extension workers have been crucial in maintaining links between communities, local government and project staff. Kamal Kar, consultant for social and participatory development, has initiated and guided the process of community organization, based on his extensive experience in rural development. His input, guidance and training over the years have been crucial and invaluable. The author wishes to express sincere thanks and gratitude to the whole team. Don Bedunah, in the early phases of the project, has made valuable contributions as a rangeland expert to the project, and supported the team over the years through his interest and through facilitating opportunities to present our work. Sincere thanks to him as well.

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Land Use and Land Tenure in Mongolia: A Brief History and Current Issues

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Abstract—*This essay argues that an awareness of the historical relationships among land use, land tenure, and the political economy of Mongolia is essential to understanding current pastoral land use patterns and policies in Mongolia. Although pastoral land use patterns have altered over time in response to the changing political economy, mobility and flexibility remain hallmarks of sustainable grazing in this harsh and variable climate, as do the communal use and management of pasturelands. Recent changes in Mongolia's political economy threaten the continued sustainability of Mongolian pastoral systems due to increasing poverty and declining mobility among herders and the weakening of both formal and customary pasture management institutions. The paper concludes by suggesting how history can inform current policy, and offering options for addressing current unsustainable pastoral land use patterns. A historical understanding of pastoral land use and land tenure should benefit consultants, policy-makers, and ultimately the herders and rangelands of Mongolia.*

Keywords: *pastoralist, nomad, common pool resource, common property, land tenure, rangeland management*

Introduction

The premise of this essay is that history matters, and that to understand current pastoral land use patterns and policies in Mongolia, a historical perspective is useful. Further, a firm grasp of the historical relationships among land use, land tenure, and the political economy of Mongolia is essential for anyone engaged in current policy discussions over land reform and rangeland management in Mongolia. As this historical overview illustrates, pastoral land use patterns have shifted over time, partly in response to changing political and economic regimes. However, the fundamental characteristics of pastoral livelihood strategies have not changed greatly; mobile and flexible grazing strategies adapted to cope with harsh and variable production conditions remain the cornerstone of Mongolian pastoralism. Similarly, although land tenure regimes have evolved towards increasingly individuated tenure over pastoral resources, pasturelands continue to be held and managed as common property resources in most locations, although these institutions have been greatly weakened in the past half century. The most recent changes in Mongolia's political economy threaten the continued sustainability of Mongolian pastoral systems due to changes in both pastoral land use and land tenure. Developing solutions to these problems requires an understanding of the past as well as the present.

In this essay, I will first briefly review the history of pastoral land use and land tenure in Mongolia up until the emergence of democracy and livestock privatization in the early 1990s. This account is drawn from both primary and secondary literature on Mongolian history, including the accounts of early explorers, scientists, and missionaries, as well as translations of Mongol law, and history texts in both English and Mongolian. Second, I will draw on data gathered in 1994-1995 to discuss how livestock privatization affected pastoral land use and land tenure in one particular area of Mongolia. Third, I will report on the 1994 and 2003 Land Laws and their implementation, based on my reading and analysis of the laws and interviews with herders and local and national officials in 1999. Finally, I will offer some conclusions about how history can inform current policy, and some possible options for addressing current unsustainable pastoral land use patterns.

Land Use and Land Tenure 1206-1990

The first important development in the emergence of formal rights over pasture in Mongolia took place when Chinggis Khan granted fiefs to his political allies in order to solidify his political power. The nobles to whom he granted such territories

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assumed control over the pastures within their boundaries and had the authority to tax and demand labor from the inhabitants of these areas (Jagchid and Hyer 1974). This marked the first time that groups of herders were associated with specific or fixed territories.

The second major development followed the reintroduction of Tibetan Buddhism into Mongolia in 1586. A religious social hierarchy was established that mirrored the quasi-feudal secular social order. Powerful lamas were granted their own territories and commanded labor and tribute from their subjects, or *shabinar*, who tended the monasteries' herds. The Buddhist church became a dominant political and economic force in Mongolia, with monasteries serving as the hubs of trade and centers of political power, in addition to providing education and spiritual guidance (Miller 1959). The emergence of the monasteries is important because they became among the largest livestock owners and land holders in Mongolia, and had significant influence on pasture use and allocation.

In 1691, the northern and western Mongols submitted to the authority of the Manchus (or Qing Dynasty) and became their colonial subjects for just over 200 years. A Manchu colonial administration was superimposed on the existing Mongol political and social organization, rigid territorial lines were drawn and enforced around principalities, and a colonial legal code was issued. The Manchus divided the *aimag* of the three Khalkha khans into first 34 and later 100 military-territorial units called *khoshuun*, which replaced the principalities (Bawden 1968). (*Aimag* are the largest administrative division in Mongolia, equivalent to provinces or states.)

During this period, new written laws codified aspects of the customary law of the steppe, including the "first come, first served" rule of claiming campsites and adjacent pasture. Herders, who had previously been allowed to move from one *khoshuun* to another, changing allegiances between princes, were prohibited from leaving the *khoshuun* of their birth (Riasanovsky 1965). The land within a given *khoshuun* was under the exclusive authority of its prince, and was controlled by the hereditary nobility, unless they ceded a portion to a monastery. The nobility thus had the right to allocate pasture within the *khoshuun*, and this was done with varying degrees of specificity (Vladimirtsov 1948). Even in these early times, access to pasture was sometimes limited for the poor, not because they were explicitly excluded, but because they lacked the resources to move to the best pastures. Dispute resolution mechanisms existed and, despite the rigid boundaries, provisions for reciprocal interterritorial use agreements among *khoshuun* existed in the case of droughts or *dzuud* (severe winter storms) (Natsagdorj 1963). In some areas, quasi-private rights to hay, winter shelters and winter camps began to emerge, particularly the more fertile northern areas of Mongolia (Maiskii 1921, Natsagdorj 1963).

Patterns of pastoral land use varied widely across Mongolia depending on local geography, ecology and politics. However, in virtually all areas of the nation some repeated pattern of seasonal movement (transhumance) took place between winter, spring, summer and autumn pastures. Transhumance, punctuated by occasional movements outside the typical seasonal pattern, appears to have been a critical adaptation to the harsh and highly variable climatic conditions in Mongolia, and enabled herders to take advantage of a variety of different habitats at different times of year, according to the nutritional demands of their animals. Regulation of seasonal movements unofficially controlled land use and access to resources, constituting a de facto tenure system. In many areas the timing of movements was signaled by the movement of the noble's camp and herds. In some *khoshuun*, grazing was prohibited in certain areas. For example, in what is now eastern Bayankhongor *aimag*, marshlands around Orog Lake were used for fattening monastery animals in the fall and were patrolled and strictly protected at other times of year (Simukov 1935 (1993)). Communities also played a role in informally regulating seasonal movement, as the following quotation from the journal of Russian explorer Pozdneyev illustrates. This passage also indicates that the poor were hindered by lack of access to transportation. "This was a nomadic move from winter pastures to summer pastures; it was, of course, very late, but in general the very poor Mongols here seldom move, first, because it is very difficult for them, due to the lack of transportation, and second, because of the extremely limited scale on which they raise cattle, the community does not press their moving, taking into consideration the fact that they do not consume much grass…" (Pozdneyev 1892 (1971)).

To provide one concrete example of movement patterns, figure 1 shows a map of pre-revolutionary seasonal migration routes in the Erdene Bandidaagiin Khotagiin Khoshuun, which comprised several *sum* (administrative districts) in present-day Bayankhongor Aimag. This *khoshuun*, the territory of the powerful Buddhist lama, the Lamiin Gegen, stretched from the crest of the Khangai to the arid expanses south of Ikh Bodg Mountain in the Gobi Altai. Soviet geographer Simukov, who documented the migratory patterns of six distinct groups of herders and livestock through interviews in the 1930s, emphasized the monastery's important role in directing the movements of herders and in allocating and controlling pasture use in specific parts of the *khoshuun* (Simukov 1935 (1993)).

In 1924, after ten years of autonomy from Chinese rule and three years of transition, the Mongolian People's Republic was founded. By 1925 both secular and religious feudal systems had been abolished, together with the administrative unit of the khoshuun. Three hundred *sum* were established as administrative districts (Bawden 1968, Cheney 1966). During this period, there was little formal regulation of movements. Instead, herding communities enforced customary rights and movements within their territories (Simukov 1935 (1993)).

By the 1950s herding collectives gained momentum in Mongolia as the government learned to use taxation and social incentives to encourage participation. By 1959, 99 percent of all households in the nation had joined collectives (Rosenberg 1977). Collectivization led to a number of changes in livestock production, too numerous to detail here. Herders tended state-owned livestock for a salary and were allowed to keep a limited number of private animals for subsistence. Herds

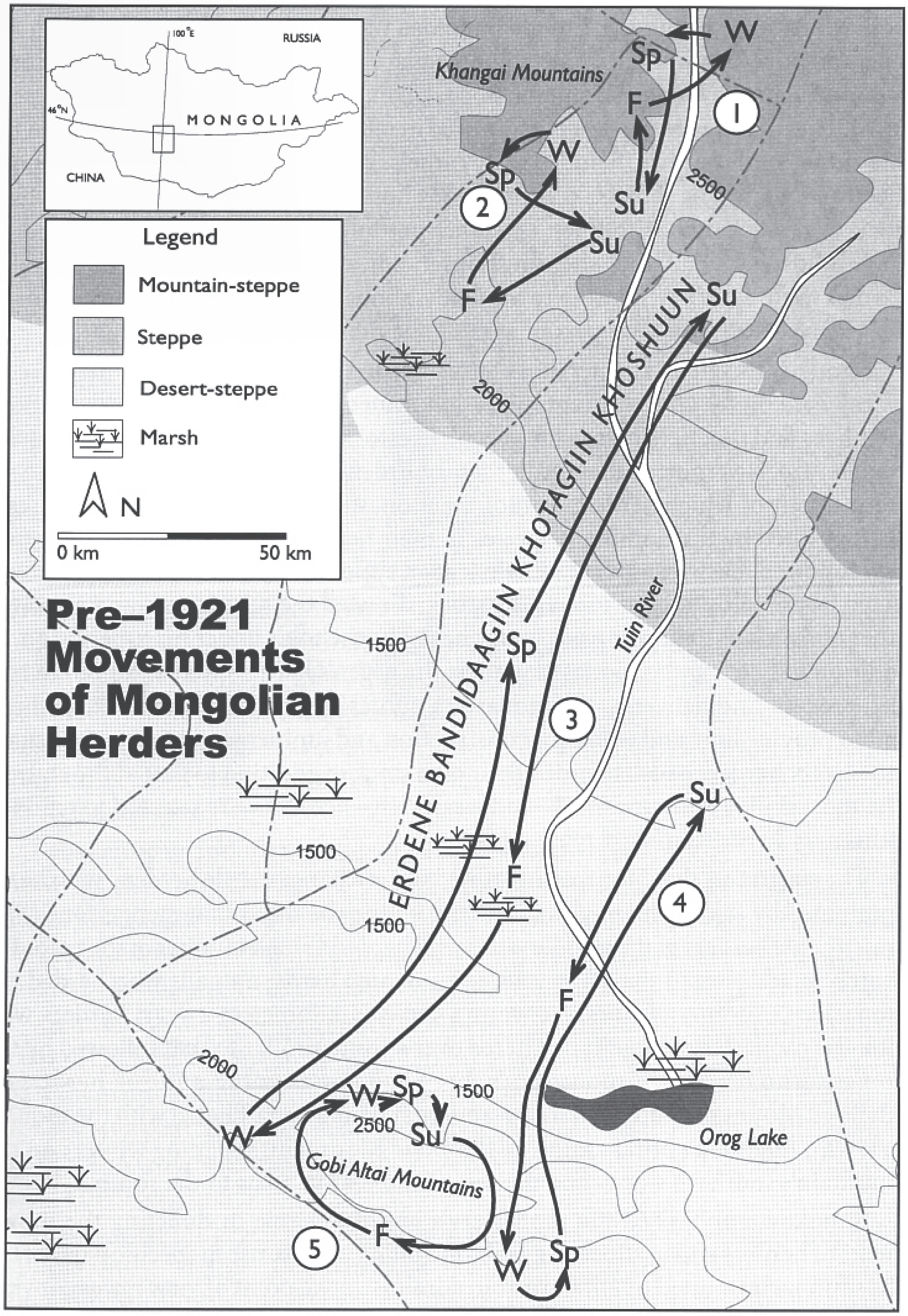

Figure 1—Prerevolutionary seasonal movement patterns of the major groups of herders identified by A.D. Simukov in Erdene Bandidagiin Khotagiin Khoshuun, Mongolia. The numbers in circles represent 5 distinct herding groups in the area: 1. Khangai cattle herders; 2. Cattle herders of the middle wells; 3. Nomadic herders of the monastery's sheep and horses; 4. Herders of the monastery's camels; 5. Cattle herders of Ikh Bogd Mountain. Sources: Simukov 1993; base map adapted from Bayankhongor Aimag Atlas 1989, 7,14. Reprinted with permission from The Geographical Review 89(3), p. 325.

were segregated by species and labor was specialized. There was a campaign to build wooden shelters to protect animals from harsh winter and spring weather, and veterinary services and emergency fodder were provided (for more details see Fernandez-Gimenez 1999).

The collectives allocated pasture, resolved disputes and were empowered to enter into reciprocal, cross-boundary agreements. The collectives also regulated land use and seasonal movements, provided transportation for moves and set aside emergency reserve pasture areas (Butler 1982). Although the scope of seasonal movements was much reduced from pre-revolutionary times, herders were encouraged or forced to make *otor* moves, short-term, long distance moves of a portion of the herd and household (Batnasan 1972, Humphrey 1978). Figure 2 provides an example of seasonal migration routes in Jinst and Bayan Ovoo and several neighboring sum during the collective era. These data are based on the work of Dr. Bazargur and others at the Mongolian Institute for Geography (Bazargur, Chinbat and Shirevadja 1989).

To summarize, with each successive political-economic regime in Mongolia territories shrank, controls over pastoral movements and pasture allocation increased, tenure over resources became more individuated, and the gap between formal and informal regulation widened. Nevertheless, in each of these past eras political institutions allowed flexibility of movement during climatic disasters and enforced movement within territories even as the size of territories diminished. It is also worth noting that throughout much of the past (with the exception of the collective era) lack of transportation limited poor herders' movement and access to pasture. Finally, there is clear evidence that dual formal and informal regulation of seasonal movements existed and was apparently successful in maintaining sustainable patterns of pastoral land use. For the most part formal regulation was enforced by the state or other formal governing institution (e.g. the Buddhist church) while informal regulation was carried out within local herding communities.

Impacts of Privatization on Pastoral Land Use and Land Tenure

In 1990, Mongolia became a democracy and began an abrupt transition to a free-market economy, which included, in 1992, the dismantling of the herding collectives and the privatization of livestock and other collective assets. This transition had several immediate and some lasting impacts on herders' livelihoods, their land-use patterns, and property relations. The combination of increasing poverty and numbers of herding households, coupled with declining terms of trade, lack of social services, and the loss of the formal regulatory institution, led to a decline in the distance and number of seasonal movements, an increase in out-of-season and year-long grazing, and, as a result, an increase in conflicts over pasture and "trespassing" behavior (Fernandez-Gimenez 2001). This set of circumstances can be understood as a vicious cycle or positive feedback loop in which declining mobility leads to increasingly unsustainable grazing practices which exacerbate tensions and lead to conflict. In order to protect their access to key resources in a high-competition environment, some herders then move even less, so that they can maintain control of key pastures and campsites, even if they graze them out of season themselves as a result.

Current Law and Land Use Patterns

In 1994 Mongolia's Parliament, the Ikh Khural, passed the Law on Land, which contained provisions for the regulation, management, and monitoring of pastureland, including of leasing campsites, and possibly pasture (the latter is unclear). Leasing of winter and spring campsites began in 1998. The law was revised and the new Law on Land went into effect in 2003, unfortunately preserving some of the ambiguities of the earlier law. Without going into detail, both laws include provisions for certificates of possession, essentially leases, over winter and spring campsites, and potentially over winter and spring pastures. Summer and fall pastures are to remain open to use by all. Similarly, water and mineral licks explicitly remain open access resources. *Sum* and *bag* (the smallest administrative unit) governors are empowered by the law to regulate seasonal movements and stocking rates; however, as I will illustrate, few of them perceived that they possessed this authority. (For a detailed analysis of the law see Fernandez-Gimenez and Batbuyan 2004 and Hanstad and Duncan 2001.)

By 1999, the reality of implementation of the 1994 law was the following: In the two *sum* I studied in Bayankhongor *aimag*, there were generally many more households than there were campsites and the campsites allocated through contracts had been given, generally, to the most prominent or wealthy household in the *khot ail* (herding camp), leading to inequities in distribution. Trespassing, however, was much lower after implementation in 1999 than it had been in the same areas in 1995. Interviews with local officials suggested that many of them were misinformed about their powers under the law and both herders and local officials confirmed that local government seldom enforced seasonal movements or stocking levels (Fernandez-Gimenez and Batbuyan 2004).

Proposed Solutions to Unsustainable Pastoral Land Use Patterns

Several solutions to the current scenario of pastoral land use have been proposed from different quarters. Some Mongolian scholars, officials and herders view reunification of *sum* into large *khoshuun*-like territories as an answer. This approach would assure that each *sum* had suitable pasture for each season's grazing, overcoming some of the problems with the socialist-era divisions (Fernandez-Gimenez and Batbuyan 2004, Bold 1997). However, this proposal would not seem to solve the problem of unsustainable grazing patterns in areas where

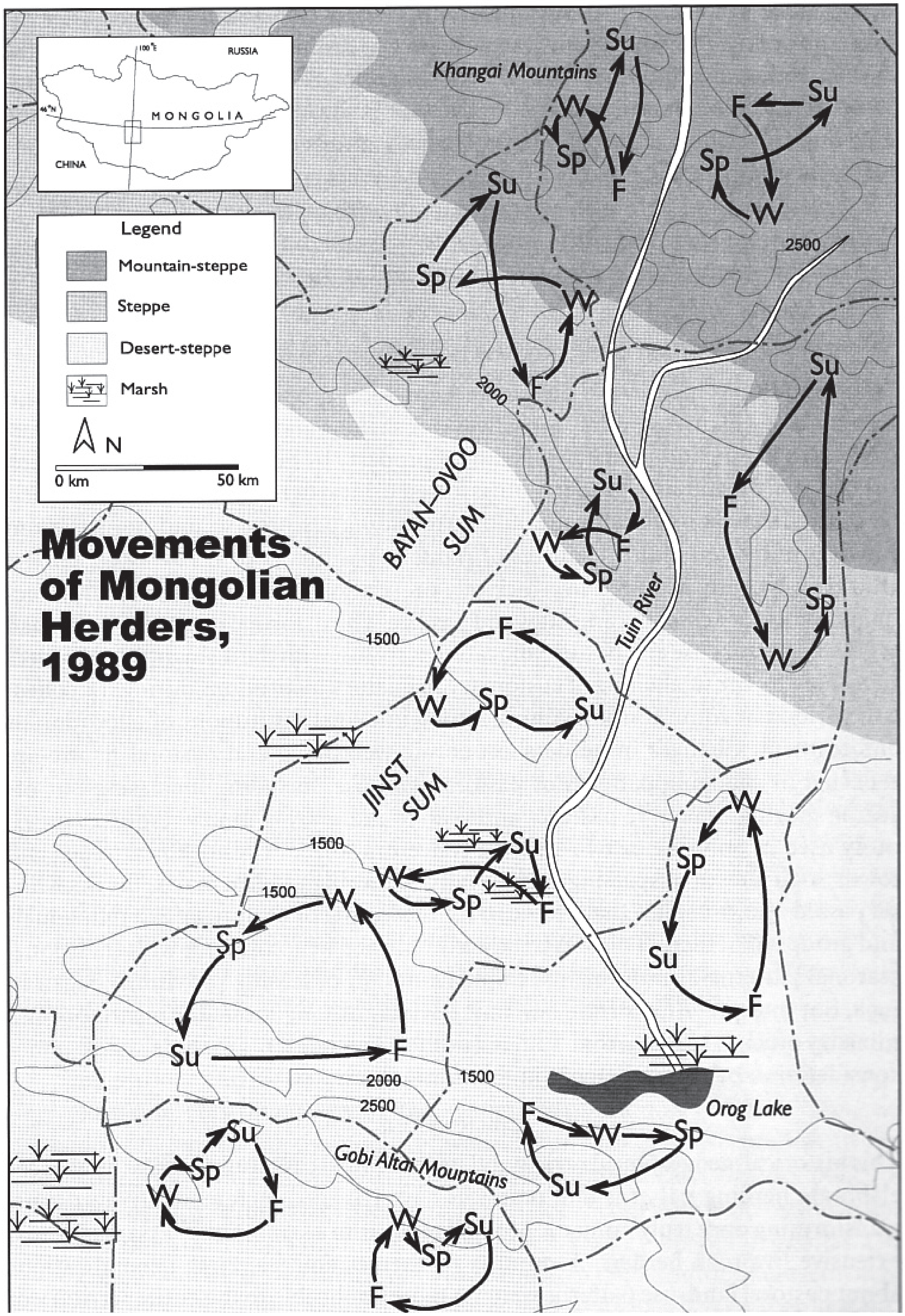

Figure 2—Seasonal movement patterns of herders in Jinst Sum and Bayan-Ovoo Sum and neighboring districts of Mongolia in 1989. Source: Adapted from Bazargur, Chinbat and Shirevadja 1989, 50. Reprinted with permission from The Geographical Review 89(3), p. 336.

landscape-scale overstocking may exist rather than problems with spatial and temporal distribution of grazing, enforcement of movements, or lack of appropriate seasonal pastures.

Other officials, researchers and some pastoral development proponents (both Mongolian and expatriate consultants) advocate a variety of co-management schemes in which groups of herders or herding associations would be granted exclusive rights over pasture areas and would develop rules and regulate use within their boundaries, perhaps with local or *aimag* oversight (Agriteam-Canada 1997, Buzzard 1998, DANIDA 1992, Fernandez-Gimenez 2002). Another group of consultants and some Mongolian officials believe that land registration and titling is the solution and that eventually, Mongolia must look towards privatization and a market in all types of land (GISL 1997). While land registration may be feasible, if costly, privatization of pastureland in Mongolia is, in my view, counterproductive. In the decade I have spent working with herders in Mongolia, I have never heard any pastoralist advocate privatization of pasture. In fact, the opposite is the case. Herders understand that the viability of extensive livestock production in Mongolia depends on flexibility and mobility, which in turn rely on a common property regime (Fernandez-Gimenez 2000). Common property must not be confused with a "free-for-all" open access situation, in which there are no rules, no rights and no enforcement. Rather it denotes successful self-governance by a group of resource users who are able effectively to control access to their territory and influence the resource use behavior of group members (Ostrom 1990). As I have described in the preceding sections, grazing on Mongolia's rangelands was regulated historically both by local common property regimes in which herders allocated pastures and enforced seasonal movements among themselves, as well as by more formal mechanisms imposed by local rulers or the state.

History Lessons and Future Challenges

As Mongolia looks towards its future, it should not forget its past. One reason that pastoralism has been a sustainable livelihood for centuries on the Mongolian steppe is that both herders and governing institutions have recognized the immutability of the environmental constraints of a harsh and variable climate, and have governed accordingly, enforcing and facilitating mobility, and allowing for flexibility in land-use patterns. We have seen that there is a precedent for dual formal and informal regulation, or co-management. We have also seen that today, as in the past, poverty constrained both mobility and access to good pasture. Thus land-use and land tenure issues can only be solved if human well-being and livelihoods are simultaneously brought into the equation. Co-management may hold the greatest promise for improving governance and management of pastures, since there is both a clear need to draw on the knowledge and experience of local herders, and to obtain their support for any regulatory regime, and a need and desire (on the part of herders) for local government to take a more active role in regulating pastoral land use. While tenure formalization may be compatible with this approach, much can be gained by focusing on the regulatory institutions that govern where and when livestock move, rather than who has what kinds of rights. If we address the former, the latter may well take care of itself, as it has for centuries in the past.

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Community Based Wildlife Management Planning in Protected Areas: the Case of Altai argali in Mongolia

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Abstract—*The number of protected areas in Mongolia has increased four-fold since the country's transition to a market-based economy over a decade ago; however, many of these protected areas have yet to realize their intended role as protectorates of biodiversity. Given the prevalence of (semi-) nomadic pastoralists in rural areas, effective conservation initiatives in Mongolia will likely need to concurrently address issues of rangeland management and livelihood security. The case of argali management in western Mongolia is illustrative of a number of challenges facing protected areas management and wildlife conservation planning across the country. In this study, results from interviews with pastoralists in a protected area in western Mongolia indicate that local herders have a strong conservation ethic concerning the importance of protecting argali and are generally aware of and support government protections, but may not be inclined to reduce herd sizes or discontinue grazing certain pastures for the benefit of wildlife without compensation. Because past protectionist approaches to argali conservation in western Mongolia have not achieved effective habitat conservation or anti-poaching enforcement, alternative management strategies may be necessary. Results from this study suggest local receptiveness to integrated management programs incorporating processes of consensus building and collaboration to achieve pasture management and biodiversity conservation and providing direct local benefits.*

Keywords: *Community, argali, wildlife, management, conservation, Mongolia, Altai-Sayan*

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Introduction

Following the 1992 transition from a command to market economy, Mongolia plunged into an economic depression from which it has still not recovered. Over a third of Mongolians live in poverty and per capita income and GPD remain below 1990 levels (Finch 2002). During the last decade, foreign donor aid contributed on average 24 percent of GDP per year (Finch 2002), and Mongolia became one of the highest recipients of foreign aid dollars on a per capita basis (Anon. 2002). A significant portion of this donor aid has been directed toward biodiversity conservation and, with this support, the Mongolian government has developed an extensive network of protected areas.

The number of protected areas has increased from 11 areas covering 3.6 percent of the country prior to 1992, to 48 areas covering 13.1 percent of the land area in 2000 (Myagmarsuren 2000). Moreover, protected area numbers are expected to continue to increase as the Mongolian government moves toward its goal of placing 30 percent of its total landmass under some form of protection (Myagmarsuren 2000). A four-tier system of protected areas was adopted by the Mongolian Parliament in 1994, including the following designations: Strictly Protected Areas, National Parks, Nature Reserves, and Natural and Historic Monuments (Wingard and Odgerel 2001). The Mongolian government, however, has yet to initiate management or conservation activities in many of its protected areas (Reading and others 1999a).

Nearly a third of Mongolians practice some form of pastoralism and the country's 27 million livestock out number the population ten-fold (Anon. 2002). With Mongolia's high livestock numbers and its citizens' predominately pastoral livelihoods, grazing issues affect nearly every aspect of the economy across the country. Although grazing rights of pastoralists are recognized within protected area regulations, certain zones within protected areas are managed primarily for biodiversity conservation. Special Zones within National Parks, for example, can be accessed for grazing only by special permit during instances of pasture shortage (Wingard and Odgerel 2001). Once Mongolia transitions from the current system of paper parks to a regulated and enforced network of protected areas, conflict between residents and protected area administrators will likely increase (Bedunah and Schmidt 2000, 2004).

Some protected areas, such as the Great Gobi Strictly Protected Area, occupy marginal grazing land and their associated resource use limitations do not represent a significant loss to herders. Many protected areas, on the other hand, such as National Parks, harbor not only unique and often fragile ecosystems but thousands of herders and their domestic livestock (Wingard and Odgerel 2001). As a result, range management is one of the most pressing issues facing biodiversity conservation in Mongolia's protected areas.

Rangeland management is not new to Mongolia and grazing lands have been extensively managed here since feudal times in the thirteenth century through the collective period which ended in the early 1990s (Fernandez-Gimenez 1997; Sneath 1999). With collectivization, Mongolian pastoralists lost control of much of their personal livestock, with only 25 percent of herds remaining in private hands, but benefited in numerous ways from becoming members of the *negdel* (local collective) (Potkanski 1993). Collectivization provided regulatory institutions to control regional pasture usage, and combined with increased Soviet-subsidies, allowed for a new level of social welfare previously unavailable to most Mongolians, including: free health care services and education, emergency fodder during harsh winters, access to veterinary programs, mechanized transportation for seasonal movements, retirement pensions, and stable markets in which to sell livestock products (Potkanski 1993; Bruun 1996). Following Mongolia's economic transition in 1992, however, Soviet-style collectives broke down and no regulatory institution has yet filled the void (Mearns 1993; Schmidt 1995; Bruun 1996). Consequently, the last decade has seen minimal or no range management in most of Mongolia and increased pasture degradation is noted for many areas (Fernandez-Gimenez 1997; Bedunah and Schmidt 2000).

Background

Status of Altai argali

The Altai subspecies of argali is the largest wild sheep in the world and occurs in the Altai mountains of Mongolia and adjacent regions of Russia, China and Kazakhstan (Geist 1991; Shackleton 1997; Amgalanbaatar and Reading 2000). Although the Altai argali is one of the most sought after species of wild sheep by trophy hunters and commands high fees, its current population status remain poorly understood (Shackleton 1997; Reading and others 1999b, 2001; Amgalanbaatar and Reading 2000; Schuerholz 2001). Argali populations were once more common throughout large tracts of the Altai (fig. 1). However, habitat disturbance and deterioration resulting from competition with domestic livestock and poaching appear to have contributed to population declines, habitat reduction and fragmentation and, in some cases, localized extirpation of Altai argali in Mongolia, China, Russia and Kazakhstan (Shackleton 1997; Amgalanbaatar and Reading 2000; Paltsyn and Spitsyn 2002).

The Altai argali is now at high risk across its entire range in Mongolia due to dramatic declines or localized extirpations, highly fragmented habitat, and high and increasing densities of humans and domestic livestock (Shackleton 1997; Amgalanbaatar and Reading 2000). The total population of Altai argali in Mongolia is well below 3000 animals (Reading and others 1999c). Similar conditions are documented for Altai argali in adjacent countries, with population declines or extirpations noted in the Ukok plateau, southern Altai, Mogun-Taiga, western Tannu-Ola, Sangilen highland, and the Sailugem and Chikhacheva ranges (Smirnov 1990; Shackleton 1997; Fedosenko 1999; Paltsyn and Spitsyn 2002).

National governments and international regulatory bodies have sought varying degrees of protection for *O. a. ammon* based on these and other findings. The Altai argali is designated as Vulnerable by the IUCN (Hilton-Taylor 2000); carries Appendix II status by the Convention on International Trade of Endangered Species (CITES) and is listed as Threatened on the U.S. Endangered Species List (Johnson 2002). The Peoples' Republic of China list *O. a. ammon* as a Class II species (Shackleton 1997), roughly analogous to the Threatened status accorded by the Mongolian government (Shiirevdamba 1997), while Russia has assigned it Endangered status (Shackleton 1997).

A number of protected areas have been established in western Mongolia and adjacent countries specifically for argali and snow leopard conservation (fig. 2); and proposals exist for the creation of transboundary biosphere reserves in the region (Badenkov 2002). Yet, large portions of known argali distribution remain outside of the current network of protected areas (Shackleton 1997; Reading and others 1999a), and a number of biologists have questioned if even existing protected areas can safeguard argali because the areas lack sufficient funding, resources, training and personnel to carry out basic management activities (Shackleton 1997; Reading and others 1999a; Amgalanbaatar and Reading 2000; Paltsyn and Spitsyn 2002).

Management of argali

Management and conservation activities for argali (wild sheep) *Ovis ammon* in Mongolia historically have been linked to trophy hunting. Although government sanctioned trophy hunting has occurred since the 1960s (Luschekina and Fedosenko 1994), the Mongolian Ministry for Nature and Environment (MNE) has yet to adopt a national management plan for argali (Amgalanbaatar and others 2002). In the absence of formal plans, national conservation and management strategies have focused on increased law enforcement and continued

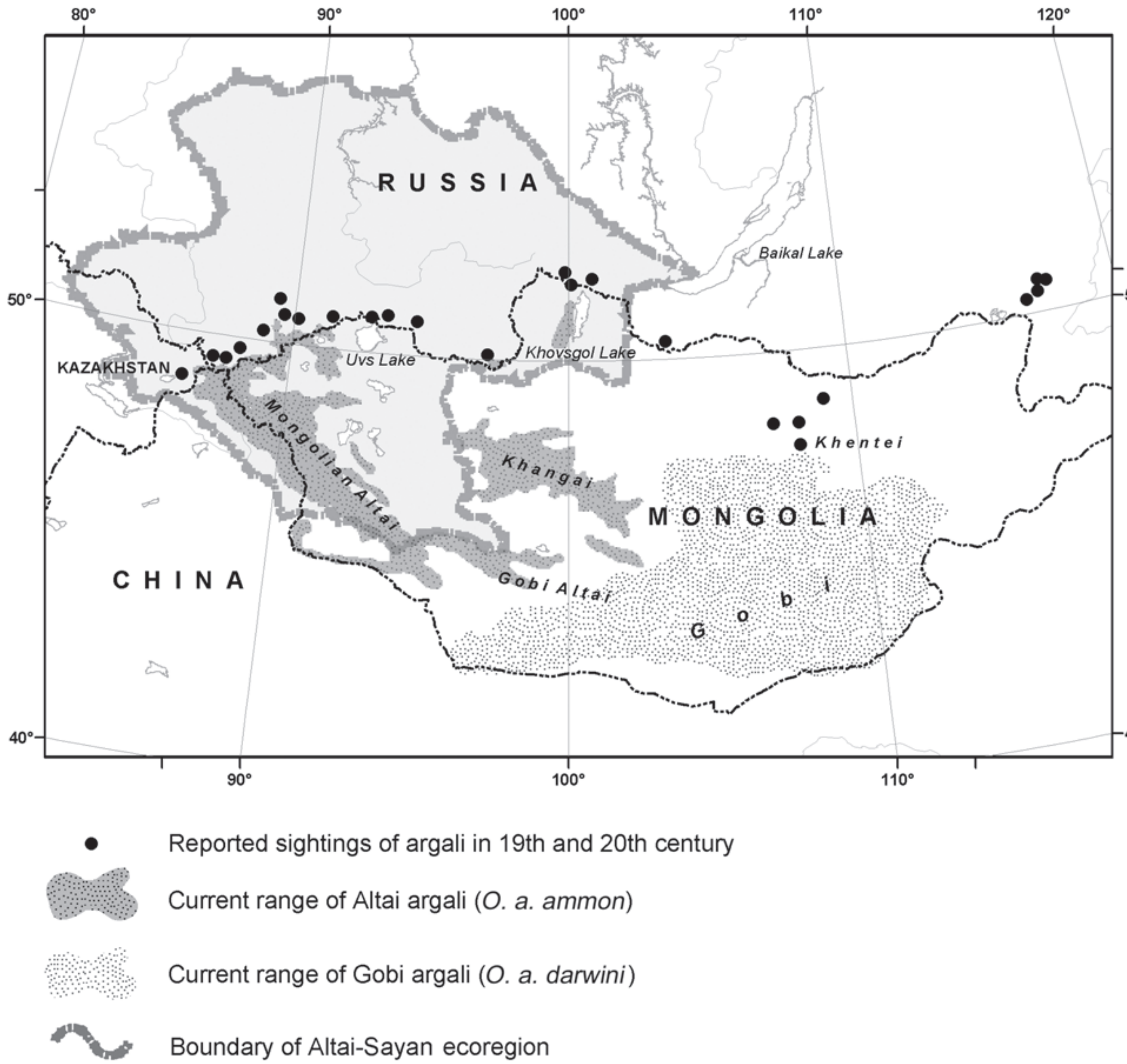

Figure 1—Current range and historic sightings of argali (*O. ammon*) in Mongolia and the Altai-Sayan ecoregion. The southeastern boundary of Altai argali range is unclear due to uncertainty concerning the designation and differentiation of argali subspecies in Mongolia. Past encounters with argali are summarized by Kolosov (1938), Tsalkin (1951), Smirnov (1990), Luschekina and Fedosenko (1994). (modified from Maroney and Paltsyn 2003).

development of protected area administrations (see Mallon and others 1997; Amgalanbaatar and Reading 2000; Working Group 2000). These efforts, however, largely have overlooked the direct involvement of or impacts on pastoralists within argali habitat.

In recognition of these shortcomings, recent discussions to reform Mongolia's trophy hunting practices have led to proposals for Community Based Wildlife Management (CBWM) programs for trophy hunting (Schuerholz 2001; Amgalanbaatar et. al. 2002). Although the market-based approach to management and conservation that underlies trophy hunting proposals allows for local involvement in a select number of viable trophy hunting locales, it does not address significant argali populations in protected areas where trophy hunting is not permitted.

This study addresses Altai argali *Ovis ammon ammon* in non-trophy hunted areas of western Mongolia and adjacent countries. The Altai-Sayan ecoregion, as defined by Olson and Dinerstein (1998), encompasses much of recognized *O. a. ammon* distribution (fig. 1), and serves as a useful bioregion to address conditions and conservation challenges unique to Altai argali including transboundary-zones, larger human and domestic livestock populations, and high ethnic and cultural diversity (Maroney and Paltsyn 2003).

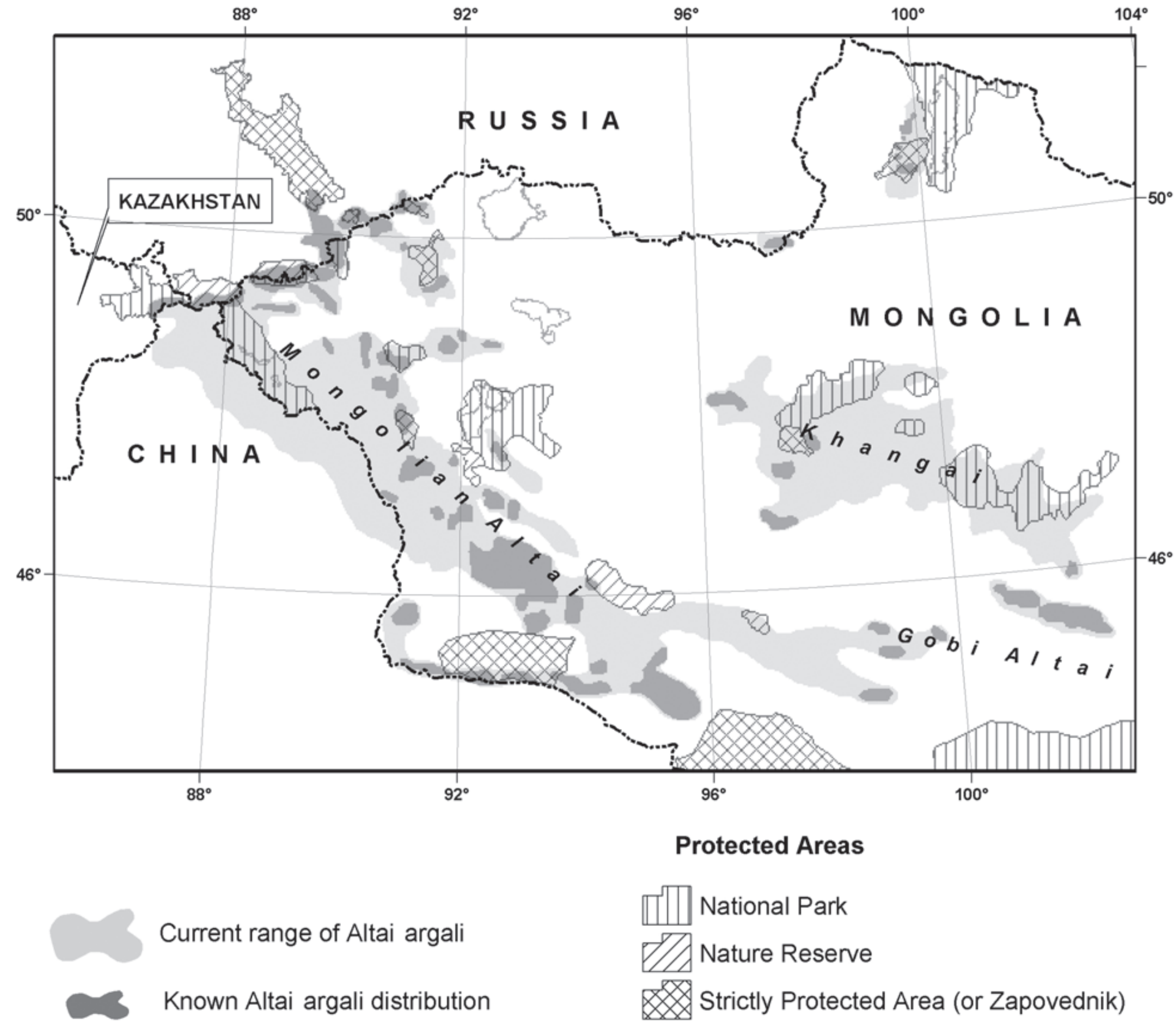

Figure 2—Protected area network and known range and distribution of Altai argali *O. a. ammon* in western Mongolia and the Altai-Sayan ecoregion as described by Fedosenko (2000), the Mongolian Institute of Biology (upub. Data, 2001), Maroney and Davarkhbayar (upubl. Data, 2002), and Paltsyn and Spitsyn (2002). Argali distribution in the Chinese Altai remain approximate due to incomplete field surveys. (modified from Maroney and Paltsyn 2003).

Until more direct investments in biodiversity conservation are possible in areas that lack argali trophy hunting opportunities, management and conservation initiatives may have to rely on a system of incentives and benefits other than the financial compensation provided by CBWM trophy hunting programs. Integrated approaches to management and conservation that recognize local livelihood security needs and incorporate the ecological knowledge of resident people can lead to more informed and effective management and conservation programs (Reading and others 1999a; Fernandez-Gimenez 2000; Siebert and Belsky 2002; Schmidt and others 2002). In this study, results from interviews with pastoralists in a protected area in western Mongolia provide insight into local resource use patterns and community concerns, and attitudes toward wildlife.

Study area – Siilkhemiin Nuruu National Park

Siilkhemiin Nuruu (Sailugem Range) National Park (SNNP) is located in Mongolia's westernmost province of Bayan-Olgii (fig. 3). SNNP was created in 2000 primarily for the protection of argali and is divided into two sections, which cover a combined area of 140,080 ha (Myagmarsuren 2000). Spanning portions of Ulaankhus and Nogoon Nuur provincial counties, SNNP is one of four protected areas under the management of the Mongol Altai Nuruu Special Protected Areas Administration (MANSPAA) in Bayan-Olgii province. As with many protected areas in the region, MANSPAA and its three rangers in SNNP have had little involvement in the area due to limited resources.

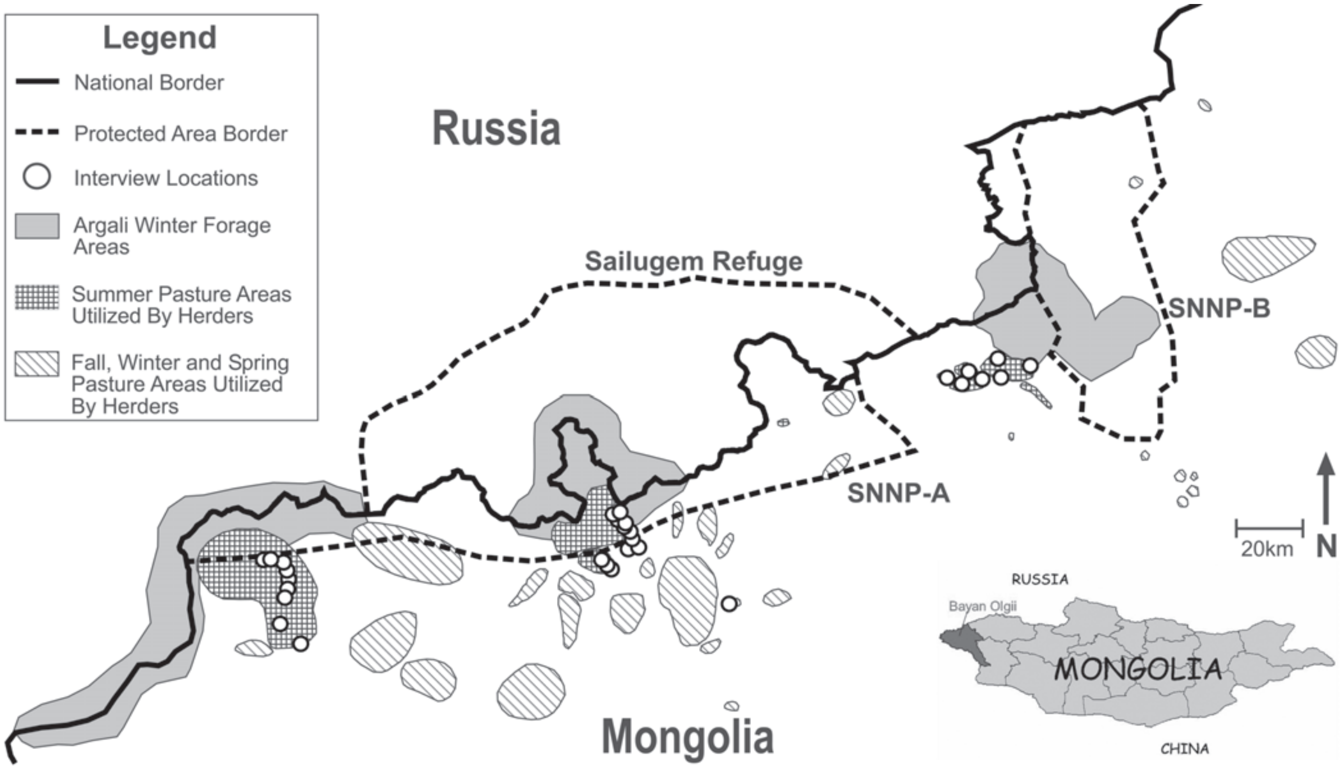

Figure 3—Siilkhemiin Nuruu National Park (SNNP) is divided into A and B zones. SNNP A-Zone is adjacent to Russia's Sailugem Refuge. Interview locations and predominate seasonal pasture usage of herders interviewed are illustrated. Argali winter forage areas identified by Maroney and Davarkhbayar (2004) are also depicted. Seasonal movement patterns of pastoralists prevent direct observation of argali for many in SNNP.

The Sailugem mountains form part of the Mongolian-Russian border and intersect the Chikhacheva range at the borders of the Altai and Tuvan republics. This alpine and mountain steppe environment is characterized by high plateaus, broad valleys, and undulating hills ranging in elevation from 2473 m at the Bor Borgusen river to 4029 m at Ikh Turgen peak (fig. 4). Weather in this region is characterized by a strong continental climate with severe winters, a short growing season, and approximately 300-400 mm of annual precipitation (Hilbig 1995).

Pastoralists have grazed livestock in the region that makes up SNNP for over 3000 years, and extensive petroglyph sites throughout the eastern portion of the park document the rich history of former inhabitants' interaction with wild ungulates and other wildlife dating back to the late Pleistocene (Jacobson and others 2001). In the mid 1800's, Kazakh nomadic pastoralists from Xinjiang began entering the area that is now far-western Mongolia, and have seasonally grazed livestock there for several generations (Finke 1999). Kazakhs now comprise the largest ethnic minority group in Mongolia and in Bayan-Olgii province they constitute over 90 percent of the population (figs. 5 & 6) (Finke 1999). In addition to transhumant pastoralists, several Mongolian National Border Posts are located along the length of SNNP and many are inhabited year round by soldiers, their families, and livestock herds.

A dramatic increase in the number of privately owned livestock occurred in many areas of Mongolia over the last decade (Bedunah and Schmidt 2000). These trends are present in the counties where SNNP is now located and the total number of livestock in this area has more than doubled since 1992 (Bayan-Olgii Office of Statistics 2002). Consequently, overgrazing is an increasing concern for many pastoralists in and around the park.

Resource use regulations in national parks in Mongolia are designated into Special, Travel and Limited Use Zones (Wingard and Odgerel 2001). The MNE, however, has not yet finalized the boundaries of these zones in SNNP. In addition to park zones, military regulations prohibit all activity within 5 km of the Mongolian-Russian border (Colonel Yo. Ganhuu pers. comm. 2002). During the consecutive *zuud* years of 2000 and 2001, local herders petitioned and received grazing access to border areas in SNNP and continued to graze these areas in 2002 and 2003. With park zonation unclear and access to border regions approved, uncontrolled livestock grazing is widespread in all regions of the park.

Argali in SNNP make seasonal, transboundary migrations and are known to winter in Mongolia predominately on relatively sheltered southern slopes (Davarkhbayar and others 2000). As is true for much of western Mongolia, habitat disturbance and

Figure 4—Siilkhemiin Nuruu National Park is a landscape of alpine and mountain steppe characterized by high plateaus, broad valleys, and open grasslands. A petroglyph of an argali sheep is present in the foreground (photo R. Maroney).

Figure 5—Kazakh pastoralists in western Mongolia (photo R. Maroney).

Figure 6—Autumn camp for pastoralists in Siilkhemiin Nuruu National Park B-Zone (photo R. Maroney).

overgrazing have displaced many argali to marginal pastures in SNNP (Davarkhbayar and others 2000). In addition, poaching of argali for meat and sport is a noted problem in SNNP (Maroney and Davarkhbayar 2004), although the full extent of the problem is unknown.

Adjacent to SNNP, the Sailugem or Khosh Agach Refuge (241,300 ha) is located on the Russian side of the Sailugem range and was created in 1973 for protection of argali (fig. 3) (Paltsyn and Spitsyn 2002). Poaching by both local residents and visiting Russian hunters is commonly reported for this area (Maroney and Paltsyn 2003); however, lower stocking rates create significantly less grazing competition between argali and domestic livestock than found in SNNP (Paltsyn and Spitsyn 2002). Cooperation between the governments of Mongolia and Russia for management of these protected areas currently does not occur.

Methods

Interviews lasting approximately 25 minutes were conducted with 98 individuals from distinct family units in SNNP between August 6-10, 2002 (fig. 3). A 36 item questionnaire regarding local perceptions and general ecological knowledge concerning Altai argali was developed and utilized to provide respondents with an opportunity to share their knowledge, opinions and experiences pertaining to a variety of wildlife and range management issues. Individuals were selected for interview based on their summer quarters' proximity (≤2 km) to a predetermined course through known inhabited areas of SNNP. The first adult encountered from each family unit, frequently the male, head of household, was solicited for interview. Many Kazakh herders in SNNP find speaking Mongolian either difficult or uncomfortable, therefore, interviews were conducted in Kazakh by two assistants trained in interview methodology. The author observed all interviews and participated in discussions when appropriate. Male (n=77) and female (n=21) respondents ranged in age from 18 to 82 years (median = 41 years). During previous fieldwork in SNNP, some pastoralists were hesitant to discuss open-ended questions concerning wildlife poaching or grazing conflicts. By utilizing a questionnaire format and incorporating questions in which respondents are asked to rank general categories of threats to wildlife, herders could address controversial issues without self implication. Additionally, all respondents were informed that their responses would be confidential.

Results and Discussion

A large majority (91 percent) of pastoralists in SNNP believed it is important to protect argali and 93 percent expressed interest in receiving further information on protected areas and their environmental regulations (table 1). Following interviews, several individuals even indicated a willingness to participate in argali conservation efforts. When respondents were asked why they thought conservation of argali was important, most remarked that argali are "rare and magnificent animals" deserving of protection. A minority (6 percent), considered protection of argali unnecessary and viewed them as a nuisance that could limit access to certain pasturelands. Typical comments from this latter group included:

> These argali are not our responsibility and do not need our protection. They only come into Mongolian border territory and really belong to the Russians.

Results indicate pastoralists in SNNP are generally aware of and support environmental laws concerning argali. Most (94 percent) respondents knew they were in a protected area and 77 percent were aware that argali are a protected species (table 1). Interviews with Mongolian pastoralists conducted in 1998, by Bedunah and Schmidt (2004) in Gobi Gurvan Saikhan National Park, also documented a majority (83 percent, n=77) of pastoralists were aware of the local protected area. However, only 37 percent of their respondents had any knowledge of land use regulations associated with the park's Special Zone (Bedunah and Schmidt, 2004). Once Special Use Zones are defined and managed for argali in SNNP and herder's access becomes restricted, it is likely that the 6 percent of pastoralists currently opposed to argali conservation will find increased support for their views.

Only 18 percent of respondents thought that argali range had decreased and most believed that argali numbers were either increasing (40 percent) or stable (26 percent) in SNNP (table 2). These findings support the general perception documented by McCarthy (2000), who found a majority of herders (n=57) in Mongolia's three western provinces believed that argali populations were increasing (37 percent) or stable (37 percent), while only 26 percent thought argali number were declining. It is significant to note that a majority of pastoralists surveyed in western Mongolia believe that argali numbers are either stable or increasing, contrary to reports by Mongolian and foreign biologists.

This discrepancy can be partially explained by considering argali displacement by herders and livestock, herder seasonal movement patterns and general ecological knowledge. Argali are highly mobile and easily displaced by the seasonal movements of herders and livestock (Harris and Bedunah 2001; Schuerholz 2001). Therefore, it is unlikely that many pastoralists are able to observe argali unless they make an effort to do so. Outside of formal interviews, a number of herders reported that they cannot regularly view argali, because "*argali move away from people and do not return until we move to different seasonal pastures*." Known spatio-temporal land use patterns of pastoralists in SNNP support this claim, revealing that many herders do not come into direct proximity of argali because they only inhabit argali winter forage areas during the summer and early fall (fig. 3). As many herders' seasonal movements preclude regular observation of argali, it is probable that these pastoralists do not have sufficient experience to speak accurately about population trends. Gender issues also factor into general awareness levels and ecological knowledge of pastoralists in SNNP. A high proportion of the respondents who were uncertain of argali population and range trends were women.

Table 1—Pastoralists' responses to selected questions concerning argali conservation and grazingland use in SNNP (n=98).

Question	Yes	Uncertain	No
Is it currently possible for argali and livestock to co-exist in the same area?	28%	12%	60%
Do argali in SNNP stay in Mongolia all year?	2	16	82
Do herder and livestock movements affect argali movement patterns?	51	18	31
Is it important to protect argali here?	91	3	6
Do you know that you live in a protected area or its buffer zone?	94	0	6
Do you know that argali are a protected animal both in Mongolia and Internationally?	79	0	21
Would you like more information about the protected area network and environmental laws here?	93	0	7
Does any form of land use management currently exist to avoid grazing conflicts?	34	3	63
At present, do local herder communities or local county governments work together in any way?	7	3	90

Note: some rows' percentages do not add to 100 due to rounding.

Table 2—Pastoralists' responses to selected questions concerning argali conservation and grazingland use in SNNP (n=98).

Question	Increase	Unchanged	Decrease	Uncertain
Do you desire more, less, or the same number of livestock for your family?	55%	38%	3%	4%
Do you think the number of argali in your area is currently increasing, decreasing, or stable?	40	26	21	13
Is argali range currently increasing, decreasing, or unchanged?	7	58	18	16
Has the condition of rangeland improved (increased), decreased, or remained unchanged in the last five years?	21	18	56	4
If the number of herders and livestock continue to increase in this area, will the population and range of argali increase, decrease, or stay the same?	12	45	29	14

Note: some rows' percentages do not add to 100 due to rounding.

Of the 21 women interviewed, half (52 percent) indicated they were not informed enough to comment on argali because they seldom discuss issues involving wildlife with the men of their families and do not often venture far from their homes.

Pastoralists that use remote areas when argali can be regularly observed, however, likely have more informed views on trends in argali population and range. In speaking with a herder who has observed argali and other wildlife from one such winter home during the course of his lifetime, he described with regret the current status of argali:

> Argali have become frightened of humans and livestock and don't mingle with our flocks anymore. Large rams are becoming less common and there are many mountains that no longer have argali.

Even without regular observation of argali, most (82 percent) pastoralists are aware of general argali movement patterns (table 1), and, as mentioned previously, realize that humans and domestic livestock can displace argali. A majority of respondents (60 percent) believed that argali and livestock could not co-exist in the same area (table 1), and half (51 percent) of the pastoralists acknowledged that herder and livestock movements affect argali movement patterns (table 1). When respondents were asked how an increase in herder and livestock numbers would affect argali in the area, however, the largest number (45 percent) believed argali population and range would remain unchanged (table 2).

Only a small number (14 percent) of those interviewed reported to have hunted or knew specifically about a case of someone hunting argali in the area; while, in a separate question regarding the types of hunters, over half (52 percent) of the respondents claimed no knowledge of argali hunting. While some pastoralists have limited experience with argali and likely do not know about hunting issues, several respondents in informal discussions following interviews conceded that their concern over speaking of hunting a protected species prevented them from openly discussing issues of poaching. It is likely that some respondents chose not to answer questions concerning poaching because they feared reprisal even though all respondents were notified prior to interviews that the information obtained through the questionnaire would remain confidential. These findings differ from reports by Reading and others (1998, 2001) and Amgalanbaatar and others (2002), who found discussions with herders in other areas of Mongolia concerning poaching of argali open-natured, and the findings illustrate the variety of perceptions within Mongolia towards government authority.

Respondents willing to rank categories of poachers perceived Russian border soldiers (52 percent) to be the most common group hunting argali, followed by 41 percent who considered non-resident Mongolian and Russian visitors the second largest group (table 3). Respondents recognized fellow pastoralists as poachers with 25 percent ranking herders as the most common poachers, while 22 percent believed herders were the second largest group (table 3). When asked to rank threats to conservation of argali in the area, the largest number (38 percent) of respondents indicated that natural predators are the leading threat. Responses were mixed, however, and many considered both poaching and overgrazing serious threats (table 4).

A majority (63 percent) of respondents indicated that no form of land use management is in place to avoid grazing conflicts, and 90 percent reported no cooperation between local county governments or resident pastoralists (table 1). Accordingly, community involvement in conservation activities will likely be difficult to pursue, as many pastoralists make decisions on movement patterns and resource use independently or only with small family groups.

Table 3—Ranking of the most common groups to poach argali in SNNP as perceived by local pastoralists. Each row value represents the percent of people ranking that column category as the number 1 (2) group to poach (n=98).

Rank of Group	Herders	Visitors M	Visitors R	Visitors B	Visitors ∑	Foreign Trophy Hunters	Border Soldiers M	Border Soldiers R	Border Soldiers B	Border Soldiers ∑	n
1	**25%**	4%	0%	4%	8%	2%	6%	**52%**	4%	63%	48
2	**22**	13	13	16	**41**	13	0	19	6	25	32

M = Mongolian, ***R*** = Russian, ***B***= both
Note: some rows' percentages do not add to 100 due to rounding.

Table 4—Ranking of threats to conservation of argali as perceived by pastoralists in SNNP. Each row value represents the percent of people ranking that column category as the number 1 (2 or 3) threat (n=98).

Rank of Threat	Overgrazing	Poaching	Predators	Natural Disasters (Zuud)	Uncertain (no response)
1	25%	29%	**38%**	0%	9%
2	31	**36**	18	2	13
3	**32**	18	32	1	17

Note: some rows' percentages do not add to 100 due to rounding.

Management implications for SNNP

Forage competition with livestock, disturbance associated with people and livestock, and habitat loss resulting from range deterioration are significant threats to the future of Altai argali populations in SNNP. These threats are not specific to SNNP, but are occurring throughout the Altai-Sayan ecoregion. Management of rangeland for the benefit of wildlife is often difficult as it generally involves restrictions or changes on the resource use patterns of resident pastoralists (Amgalanbaatar and others 2002). As protected areas begin to be managed for wildlife, increased conflict between herders and protected area authorities can be expected (Harris and Bedunah 2001; Bedunah and Schmidt 2004).

When livestock numbers were lower, habitat partitioning between argali and domestic herds occurred and provided some degree of separation between livestock and wildlife in the region (Schuerholz 2001). However, seasonal movements of herders and livestock now increasingly encroach on argali habitat that was previously lightly grazed or ungrazed by livestock. This change in livestock use largely displaces argali into marginal areas inaccessible or otherwise unsuitable to livestock (Luschekina and Fedosenko 1994; Schuerholz 2001). Schuerholz (2001) believed that high mortality rates would characterize argali populations displaced into areas without sufficient winter forage, or if existing argali winter forage areas are not managed appropriately. Consequently, identification, protection and, in some cases, reclamation of historic argali winter forage areas should be a key component of conservation and management programs for argali (Luschekina and Fedosenko 1994; Harris and Bedunah 2001; Schuerholz 2001).

To successfully develop and implement a multiple use management strategy to protect wildlife habitat within SNNP, real benefits must be provided to local stakeholders willing to work toward shared conservation goals. As demonstrated in this case study, many pastoralists revere argali, are aware of national environmental laws and recognize that some level of range partitioning is necessary to provide argali with sufficient pasture resources. These herders have a strong conservation ethic concerning the importance of protecting argali, but more than half (55 percent) desire additional livestock and less than a third (29 percent) believe an increase in livestock numbers will negatively impact argali population and range (table 1). As a result, many pastoralists may not be inclined to limit or discontinue grazing certain pastures for the benefit of argali. Moreover, even if pastoralists were so inclined, community institutions are not in place to coordinate such range management. Development of effective programs and community incentives to reconcile pastoralists' cultural value for argali with their material needs and desires for increased domestic herds is likely the greatest challenge facing argali conservation in SNNP.

A public education campaign that acknowledges the cultural respect of pastoralists for argali and draws attention to recent declines for argali in the greater region could encourage local stewardship and reduce incidents of poaching (Amgalanbaatar and Reading 2000), but would not address the underlying economic factors influencing pastoralists' decisions concerning resource use patterns and herd sizes. Indeed, much of the biodiversity loss which occurs in Mongolia and elsewhere is perpetrated by individuals who value nature, but act in what they believe is their own economic self-interest to support themselves and their families (Ferraro and Kiss 2002). Programs that provide direct compensation to create economic incentives are often more successful in achieving their conservation goals (Bruner and others 2001; Ferraro and Kiss 2002), and argali trophy hunting has the potential to provide considerable funding (Harris and Pletscher, 2002; Hofer 2002).

If CBWM trophy hunting programs are successfully established and managed, they could subsidize argali conservation programs outside of hunting reserves. Alternatively, protected areas that can support sustainable argali trophy hunting operations could petition the MNE for revision of environmental law to sanction CBWM trophy hunting programs in protected areas or their buffer zones, as suggested by Bedunah and Schmidt (2004). In either case, development of sustainable trophy hunting programs will take considerable time. In the interim, management activities in protected areas are needed and incentives could be developed to encourage community groups to form and work with protected area administrations and other government bodies toward conservation of argali and argali habitat.

Many herders in Mongolia are familiar with and value the benefits that previous Soviet-era community institutions provided before their breakdown in the early 1990s. During socialist times, the *negdel* coordinated joint management of livestock production and provided for both economic and social needs of community members (Bruun 1996). The development of community institutions in SNNP could provide benefits to local pastoralists and facilitate the development and implementation of collaborative management strategies and should be initiated by MANSPAA. Additionally, identifying and working with key informants from these communities could increase success rates of collaboration and provide MANSPAA with detailed information concerning SNNP's wildlife.

Elsewhere in Mongolia, herders living in protected areas in the Gobi and other regions of western Mongolia have recently formed community groups to improve their livelihoods and better interact with protected area administrations (Schmidt and others 2002; Bedunah and Schmidt 2004). The conservation and development projects described by Schmidt and others (2002) and Allen and McCarthy (1999), have employed a diverse set of strategies and incentives that have met with positive results in these communities. Some of the benefits these projects have provided to community groups committed to conservation, and applicable to SNNP, include: the development of performance based small business opportunities, the creation of locally owned and operated information and resource centers and the support of community requested training for livelihood improvement (Allen and McCarthy, 1999; Schmidt and others 2002).

Regional management implications

Of the noted threats to conservation of Altai argali, habitat loss and deterioration caused by grazing competition is likely the most significant (Schuerholz, 2001), and range management of these communal lands is essentially a community oriented process requiring collaborative approaches (Schmidt and others, 2002). Management plans for argali in the Altai-Sayan could be developed collaboratively with resident communities and participation encouraged with direct benefits. Moreover, protected area administrations and local government organizations should act to facilitate this process to ensure that management and conservation goals are adequately addressed.

Conclusion

Within SNNP as well as the greater Altai-Sayan ecoregion, transboundary zones, high cultural and ethnic diversity, relatively large human and domestic livestock populations, and fragmented wildlife habitat create difficult obstacles to the formation of regional protected area management plans. Developing and implementing effective community based management and conservation strategies to resolve grazing conflict between pastoralists, protect important wildlife habitat, bridge transboundary zones, and ensure the livelihoods of resident pastoralists will be extremely difficult, but the alternative of employing solely protectionist approaches has not proven successful in many areas of Mongolia and will inevitably result in increased conflict between resident pastoralists and government authorities. Anti-poaching measures and protection of core wildlife zones are necessary, but should not be the only interaction protected area administrators or government officials have with herders. A policy shift from a primary focus on law enforcement activities toward more integrated management incorporating participatory approaches and providing direct local benefits offer the potential to improve conservation effectiveness while developing links between communities and governments.

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Collection and Evaluation of Forage Germplasm Indigenous to Mongolia

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Abstract—*Mongolian rangelands are biologically diverse and productive, and are ecologically similar to rangelands in the western U.S. Plant communities in Mongolia have evolved and adapted to sustained grazing pressure from wild and domesticated animals. Changing economic and social conditions in Mongolia and overgrazing are threatening plant diversity and range condition. Joint U.S./Mongolia plant collection trips were conducted in Mongolia during 1994, 1996, and 1998 to collect seeds of important forage species. The collecting teams traveled about 20,000 km and made more than 1,300 seed collections of grasses and forbs across the major ecological zones of Mongolia. These collections were equally shared, and the U.S. portion of the seed was incorporated into the U.S. National Plant Germplasm System. Subsequent projects funded through the Food For Progress (PL-480) Program and the U.S. Department of Agriculture's Foreign Agricultural Service allowed evaluations of the seed collections for forage and conservation use at three sites in Mongolia. These evaluations identified the most promising indigenous forage species, which included: Agropyron cristatum, Allium species, Astragalus adsurgens, Bromus inermis, Elymus dahuricus, Elymus gmelini, Elymus sibiricus, Festuca lenensis, Hordeum bogdanii, Medicago falcata, Poa pratensis, Polygonum divaricatum, Psathyrostachys juncea, Puccinellia macranthera, Puccinellia tenuiflora, Stipa capillata, and Stipa krylovii. These species appear to have the greatest potential for use in Mongolia to revegetate abandoned wheat fields, restore deteriorated areas around villages, and rehabilitate areas disturbed by mining. A project through the U.S. Embassy in Mongolia is providing funding to increase seed of the most promising collections and make seed available for use by Mongolian herders and land managers. Besides the direct benefit of providing seeds for restoration and conservation efforts in Mongolia, knowledge gained from this work will be applicable to the possible use of these species for livestock and conservation purposes in the western U.S.*

Keywords: *Mongolia, forage, grazing animals, plant materials, revegetation, restoration, reseeding, conservation*

Introduction

Because much of the original literature on Mongolia is published in Russian or Mongolian languages, references are almost impossible to obtain, read, and cite for most English speakers. In this publication, background information on Mongolia was obtained from Jigjidsuren and Johnson (2003) who cite the original sources of information.

Mongolia is a country without a seaport in Central Asia that is located between about 42 ° to 52 °N latitude and 88 ° to 120 °E longitude. Mongolia is situated south of Siberia and north of the People's Republic of China, and equal in size to Alaska (>1.56 million ha^2). Mongolia extends for 2,400 km from the Altai Mountain Range in the west to the Great Khyangan Mountains in the east, and for 1,260 km from the Great Sayan Mountains in the north to Orvog Gashuun Hill in the South Gobi.

Bedunah, Donald J., McArthur, E. Durant, and Fernandez-Gimenez, Maria, comps. 2006. Rangelands of Central Asia: Proceedings of the Conference on Transformations, Issues, and Future Challenges. 2004 January 27; Salt Lake City, UT. Proceeding RMRS-P-39. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Mongolia is a climatic analog of the Intermountain, Northern Rocky Mountain, and Great Plains Regions of the western U.S. January is the coldest month of the year with a mean temperature of –35 °C in the northern parts (with the lowest temperature of –50 °C at the Great Lake Depression and mouth of the Tes River) and –10 °C in the Southern Gobi. Summers are short, and mean July temperatures range from 18 to 26 °C with a maximum of 40 °C. Mean annual precipitation is 200 to 300 mm in north Mongolia, 400 to 500 mm in the high mountains, and less than 100 mm in south Mongolia. Most of the precipitation in Mongolia is received between mid-June and the end of August. Variations in temperature and precipitation in Mongolia create seasonally harsh conditions. Winters are generally long, cold, and dry, whereas the spring season is cold, dry, and windy. Extended drought periods and severe winter snowstorms are common in Mongolia. These dry, temperate climatic conditions have favored the development of extensive grass and shrub steppe grazing lands.

Small and large lakes, streams, and rivers are abundant in northern Mongolia. Major rivers originating from the Altai, Khangai, Khentii, and Khuvsgul Mountains drain into the Pacific Ocean Basin, while small ones flow into small lakes. Of the more than 3,800 streams and rivers in Mongolia, the Selenge River is the largest with a total length of 600 km. The Selenge River is fed by converging tributary rivers such as the Tamir, Khanui, Tuul, Orkhon, Delger, and Egii Rivers with a water collection area of about 400,000 km^2. The Kharaa and Eroo Rivers converge with the Tuul River that originates on the southern slopes of the Khentii Mountains.

The topography of Mongolia is similar to that of the western U.S. Mongolia has deserts, high mountains, saline soils and lakes, fertile valleys, forests, and vast expanses of steppe. These lands have supported grazing animals for thousands of years, cover an area of 1.26 million km^2, and have the capacity to support large numbers of grazing animals. These natural pastures are grazed yearlong by pastoral livestock and wild herbivores. Higher-yielding natural pastures are harvested as hay for winter supplemental feed. Mongolian grasses and legumes evolved under sustained grazing pressure and are well adapted to grazing.

Because of their adaptation to grazing and the climatic and topographic similarities between Mongolia and western North America, many of the grasses and legumes found in Mongolia hold potential for use as forage species in pastures and rangelands of the Intermountain, Northern Rocky Mountain, and Northern Great Plains Regions of the western U.S. Prior to 1994, forage germplasm from northern Mongolia was poorly represented in the collections of the U.S. National Plant Germplasm System. Because of changing economic and social conditions in Mongolia at that time, rangeland areas in Mongolia were being threatened by overgrazing. Large herd size, uncoordinated herding patterns, and the development of mineral resources were beginning to threaten species diversity and were leading to increased soil erosion and weed infestation in Mongolia. Consequently, it was important that Mongolia's unique forage grass and legume germplasm be collected while the natural grazing lands in northern Mongolia remained in relatively high ecological condition. As a result, three joint U.S./Mongolia forage germplasm collection expeditions were conducted during 1994, 1996, and 1998. These collections were subsequently evaluated in trials at three locations in Mongolia.

This paper gives general background information concerning the vegetation zones of Mongolia, summarizes the results of the three U.S./Mongolia forage germplasm collection trips made in Mongolia during 1994 to 1998, highlights the subsequent evaluations of these collections, and describes recently initiated efforts to increase seed of the promising collections.

Major Vegetation Zones of Mongolia

Mongolia has six major vegetation zones, each having different topography, elevation, temperature, rainfall distribution, soils, and vegetation (fig. 1). Mongolia's major vegetation zones and the percentages of land area occupied by each are: alpine tundra (4.5 percent), mountain taiga (3.8 percent), mountain steppe and forest (23.3 percent), grass steppe (25.9 percent), desert steppe (21.5 percent), and desert (15.4 percent). The vegetation zones and the general descriptions of their topography, climate, flora, and fauna are as follows:

Alpine

The alpine zone is located at different elevations depending upon the mountain ranges. The lowest elevation of the alpine zone in the Khuvsgul and Khentii Mountains ranges between 2,000 to 2,200 m above sea level, in the Mongol Altai Mountain Range between 2,300 to 2,400 m, in the Gobi-Altai Mountains between 2,700 to 2,900 m, in the northern Khangai Mountains between 2,300 to 2,500 m, and in the southern Khangai Mountains between 2,700 to 2,800 m. This zone receives an annual precipitation of 400 to 500 mm, and the soils are clumpy tundra soil. Xerophytic and mesophytic cold-tolerant plants are predominant in this zone. The Mongolian alpine vegetation is markedly different from European and Middle Asian alpine vegetation. The Mongolian alpine zone has few herbaceous plants, but is abundant in species from Poaceae, Kobresia, and Cyperaceae, which are suitable for transhumant grazing during the summer.

Taiga

The taiga zone spans across a small territory covered with ashy, meadow, and turf permafrost soil. This zone occupies 3.9 percent of the total land area of Mongolia and is scattered throughout the Khuvsgul, Khentii, and Khangai Mountain Ranges. Mean annual precipitation in the taiga is 300 to 500 mm with a minimum of 250 mm. Taiga is rich in forage plants suitable for reindeer. Steppe vegetation can be found in mountain valleys within the taiga zone.

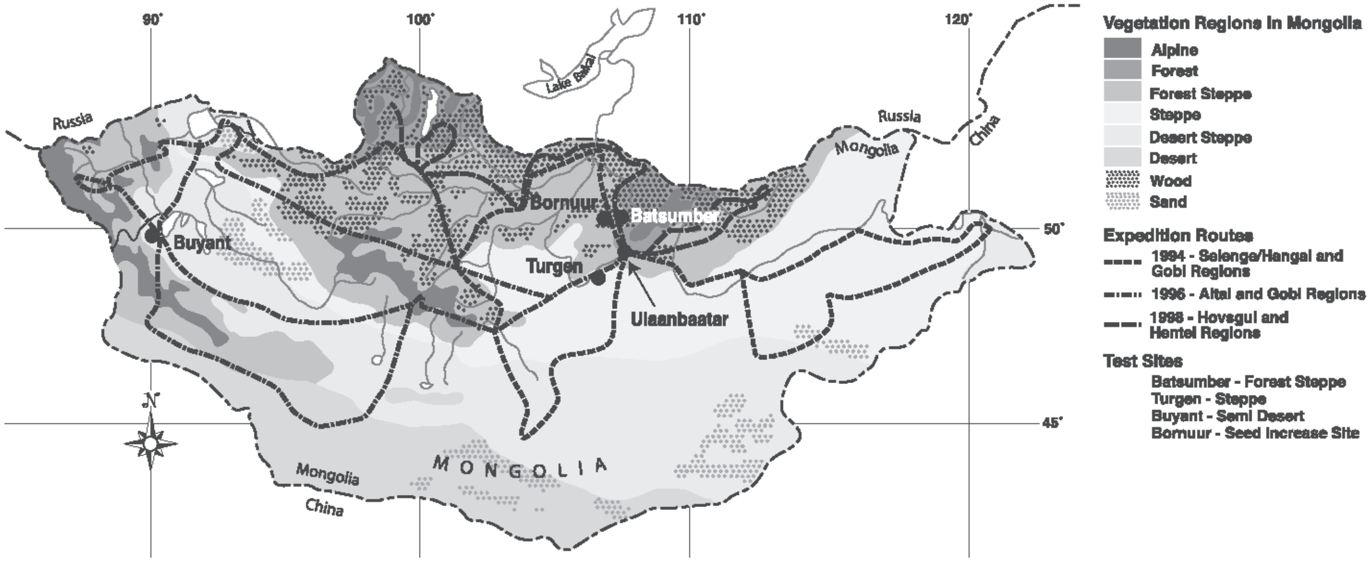

Figure 1—Map of Mongolia showing the major vegetion zones of Mongolia, germplasm collection routes (1994, 1996, and 1998), germplasm evaluation sites (Batsumber, Turgen, and Buyant), and location for the seed increase project (Bornuur).

Forest Steppe

The forest steppe zone stretches from the lower slopes of the Altai, Khuvsgul, Khangai, and Khentii Mountains to the steppe zone. This zone occurs at an elevation of 850 to 1,400 m above sea level in the Khentii Mountains, 1,000 to 12,000 m in the Northern Khangai, 1,400 to 1,500 m in the Eastern Khangai, and 1,800 to 2,000 m in the Mongol Altai. Zonal variations are pronounced especially in the Mongol Altai where the steppe zone spans beyond the forest steppe, and along the southern slopes of the mountain desert-steppe that joins the forest steppe. Average annual precipitation in the forest steppe is 300 to 400 mm. The growing season (frost-free period) lasts from 112 to 125 days, and spring and autumn periods are arid. Carbonated and non-carbonated fine black-brown soil is widespread in this zone. The Altai Mountain Range is covered with carbonated fine brown soil. The forest steppe is dominated by perennial grasses (*Stipa, Cleistogenes,* and *Festuca*), forbs, and shrubs (*Artemisia*). Fertile riparian meadows are located along the rivers. Forest steppe is highly suitable for farming and intensive livestock production.

Steppe

Xerophytic vegetation is a characteristic feature of the steppe zone. The Mongolian steppe stretches from the so-called "pushti" steppe of the Hungarian Danube to the Manchurian steppe of East Asia. The Mongolian steppe is different from other steppe zones in that it is dominated by shrubs and sub-shrubs such as *Caragana* and *Artemisia*. Fertile carbonated and non-carbonated black and sandy soil prevails in this zone. Saline soil is found along depressions and channels as well. Mean annual precipitation in this zone is 125 to 250 mm. The northern portions of the Mongolian steppe and Khalkh River Basin are highly suitable for cultivation.

Desert-Steppe

The desert steppe was formed at the junction of Mongolian steppe and Central Asian desert. Brown soil of steppe-like desert prevails in the desert-steppe zone, and only the northern edges are covered with carbonated fine soil. Salt marshes are common. Mean annual precipitation is 100 to 125 mm. Non-irrigated areas are not suitable for cultivation.

Desert

The northern edge of the Central Asian Desert passes through the territory of Mongolia. Gray desert soil prevails with alabaster covering the southern Gobi-Altai. Sand dunes, drifting sand, and salt marshes are common. Mean annual precipitation is less than 100 mm; however, sometimes there is no precipitation for the entire year. Vegetation is scarce in this zone. Shrubs grow intensively during the rainy seasons. Mongolian deserts can be divided into sandy and stony desert types, and oases occur occasionally in this zone.

Grazing in Mongolia's Vegetation Zones

High mountain grazing land (alpine tundra) has an annual standing crop yield (dry weight) that ranges between 100 to 850 kg/ha. Lichen grazing land at the highest altitude is used for summer grazing of reindeer. Lichen-*Carex* grazing land is used for summer grazing of yak. *Caligonum* shrub and *Kobresia* meadows are used for summer and autumn grazing of yak and cattle. Alpine shrub and meadow grazing land is used for summer and autumn grazing of yak and cattle; swamp grazing land is used for summer grazing of cattle. *Poa* grazing land is used yearlong by all livestock.

Grazing lands in forest steppe and grass steppe zones predominate in Mongolia and exhibit the highest forage yields. Forest grazing land has annual standing crop yields ranging from 400 to 600 kg/ha. *Betula-Pinus* forest, *Larix* forest, and *Betula-Populus* forest grazing lands are used primarily for summer grazing by horses, cattle, and large wild herbivores. Forest with an extensive shrub understory is grazed during the summer by all livestock except camels. Swamp steppe grazing land is dominated by grasses (*Koeleria, Carex, Poa, Agropyron,* and *Puccinellia*) and *Carex* species in association with forbs, and have annual standing crop yields ranging from 180 to 800 kg/ha. Swamp steppe grazing land is used yearlong and is generally most suited for horses and cattle.

Forest and grass steppe zones have the highest number of livestock and have annual standing crop yields ranging from 250 to 800 kg/ha. These regions are dominated by grasses including *Cleistogenes, Stipa, Aneurolepidium, Elytrigia, Festuca, Helictotrichon,* and *Koeleria;* various *Carex* species; and forbs including *Artemisia, Filifolium,* and *Allium*. The shrub *Caragana* is often present in the community as a co-dominant. Plant morphological characteristics such as awns on *Stipa* species may limit use of some grazing land by livestock to certain seasons. Most forest steppe and grass steppe grazing land is grazed yearlong by all livestock except camels. Red deer is the major wild herbivore grazing in forest steppe areas, while gazelles are the most common wild herbivores in grass steppe areas.

Desert steppe and deserts generally exhibit low standing crop yields, but provide a high diversity of vegetation communities, soils, and land forms. The effect of these specialized communities is to create "patch" grazing for livestock and wild herbivores. Desert steppe is dominated by grasses, herbs, and shrubs with annual standing crop yields ranging from 170 to 400 kg/ha and was the original habitat of the Mongolian wild horse (*Equus ferris*). Annual standing crop yield ranges from 100 to 330 kg/ha. Desert grazing lands are especially suited to grazing by camels, sheep, and goats and provide habitat for a number of wild herbivores.

U.S./Mongolia Forage Germplasm Collections in Mongolia

The overall objective of the three U.S./Mongolia germplasm collection expeditions in 1994, 1996, and 1998 was to collect forage germplasm in Mongolia that was tolerant to grazing, extreme dry and cold conditions, and salinity. There was interest in using these materials in ongoing plant breeding programs in both Mongolia and the U.S. for reclaiming deteriorated rangeland areas and providing improved pastures. The Mongolians hoped to identify promising germplasm for revegetating abandoned croplands and stabilizing sand dune areas.

A wide diversity of grasses, forbs, and shrubs with potential importance and adaptation to North America are present within the Mongolian flora. The main focus of the three germplasm collection trips was to collect grasses in the genera: *Agropyron, Agrostis, Alopecurus, Bromus, Elymus, Elytrigia, Festuca, Helictotrichon, Hordeum, Koeleria, Leymus, Poa, Psathyrostachys, Ptilagrostis, Stipa,* and *Trisetum* (table 1). Although collection of grasses was the primary focus of these collection trips, because of the scarcity of Mongolian collections in the U.S. National Plant Germplasm System, collections of other agriculturally important germplasm were made when opportunities arose. Collections of various leguminous forage species were made from the genera: *Astragalus, Hedysarum, Lathyrus, Medicago, Melilotus, Onobrychis, Trifolium,* and *Vicia* (table 1).

Because of the long distances involved and the generally poor road conditions throughout Mongolia, two teams were organized to make collections each year (fig. 1). The Research Institute of Animal Husbandry in Ulaanbaatar provided a taxonomist, agronomist, interpreter, and driver for each team during the collection period. Local Mongolian officials were contacted throughout the trip and provided specific information concerning preferred collecting areas. Voucher herbarium specimens were collected for taxonomic verification at the Research Institute of Animal Husbandry in Ulaanbaatar. After the field collection phase of the trip was completed, the teams returned to Ulaanbaatar where the collections were taxonomically verified, collections were cataloged, seed was rough cleaned and evenly divided, and export approvals obtained. All necessary procedures and requirements for collection documentation and inspection required by the Mongolian Government were followed.

The U.S. portion of the seed collections were labeled with a quarantine permit prior to returning to the U.S. Seed packages were carried back to the U.S. as luggage and given to USDA-APHIS officials at the U.S. port of entry airport who forwarded the seed to Plant Germplasm Quarantine Center in Beltsville, Maryland. Seed was inspected and fumigated as necessary, and then sent to the USDA-ARS Forage and Range Research Lab at Logan, Utah for final threshing, cleaning, and cataloging. Seed collections and accompanying passport data were sent to the Regional Plant Introduction Station at Pullman, Washington, for entry into the U.S. National Plant Germplasm System. The most promising collections are being evaluated at the USDA-ARS Forage and Range Research Laboratory to determine their adaptation and potential use in germplasm enhancement programs for the western U.S. Triticeae grass collections were examined by USDA-ARS cytogeneticists and taxonomists at Logan, UT to evaluate their genomic and taxonomic relationship to other Triticeae grasses.

Table 1—List of species and number of accessions collected in Mongolia (1994, 1996, 1998).

Achillea alpina
Achnatherum splendens (9)
Aconitum baicalense
Aconitum barbatum (2)
Aconitum septentrionale (2)
Acorus calamus
Adenophora stenanthina (2)
Agrimonia pilosa
Agriophyllum pungens
Agropyron cristatum (57)
Agropyron desertorum
Agropyron geniculatum
Agropyron krylovianum
Agropyron michnoi (5)
Agropyron pectinatum (2)
Agrostis clavata (7)
Agrostis mongolica (9)
Agrostis trinii (9)
Allium altaicum (4)
Allium anisopodium (6)
Allium bidentatum (8)
Allium clathratum
Allium leucocephalum (3)
Allium lineare
Allium maximowiczii
Allium mongolicum (3)
Allium odorum (10)
Allium polyrhizum (10)
Allium schoenoprasum (7)
Allium senescens (21)
Allium splendens (3)
Allium vodopjanovae
Alopecurus alpinus
Alopecurus arundinaceus (5)
Alopecurus brachystachyus (7)
Alopecurus pratensis (3)
Alopecurus ventricosus
Amaranthus retroflexus (2)
Amaranthus spp.
Amblynotus rupestris
Amethystea caerulea
Amygdalus pedunculata (2)
Androsace incana
Androsace septentrionalis
Anemone crinita
Arabis pendula
Arachis hypogaea
Arenaria capillaris (2)
Artemisia anethifolia
Artemisia commutata
Artemisia frigida (10)
Artemisia gmelinii
Artemisia laciniata
Artemisia santolinaefolia
Artemisia scoparia
Artemisia spp.
Asparagus dahuricus
Aster alpinus (2)
Aster tataricus (2)
Astragalus adsurgens (32)
Astragalus austrosibiricus (3)
Astragalus brevifolius (2)
Astragalus dahuricus (6)
Astragalus frigidus (2)
Astragalus inopinatus (3)
Astragalus melilotoides (4)
Astragalus minetus
Astragalus mongholicus (5)
Astragalus oroboides (2)
Astragalus patenti-pilosus (3)
Astragalus propinquus (5)
Astragalus scoberianus
Astragalus spp. (4)
Astragalus tenuis (9)
Astragalus tibetanus (2)
Atragene tangutica
Atriplex fera
Beckmannia syzigachne (7)
Betula fruticosa
Betula fusca (2)
Brassica juncea
Brassica spp.
Bromus inermis (24)
Bromus ircutensis
Bromus japonicus
Bromus pumpellianus (8)
Bromus squarrosus
Bupleurum bicaule (4)
Bupleurum sibiricum
Cacalia hastata
Calamagrostis epigea (4)
Calamagrostis langsdorffi (2)
Calamagrostis macrolepis
Calamagrostis purpurea (4)
Caragana bungei
Caragana jubata
Caragana leucophylla (4)
Caragana microphylla (7)
Caragana spinosa
Caragana stenophylla (3)
Carex duriuscula (3)
Carex enervis
Carex karoi
Carex korshinskii
Carex pediformis (2)
Carex pseudofoetida
Carex spp.
Carex stenocarpa (3)
Carthamnus tinctorius
Carum buriaticum
Carum carvi (4)
Ceratoides papposa (2)
Chamaenerion angustifolium (2)
Chenopodium aristatum
Chloris virgata (3)
Cirsium esculentum
Cleistogenes songorica (7)
Cleistogenes squarrosa (8)
Clematis hexapetala
Convolvulus arvensis
Convolvulus gortschakovii
Corispermum declinatum
Cotoneaster melanocarpa (4)
Dasiphora fruticosa
Delphinium grandiflorum (2)
Deschampsia sukatschewii
Dianthus versicolor (3)
Dontostemon integrifolius
Draba nemorosa
Echinops dahuricus
Elaeagnus moorcroftii
Eleocharis intersita
Elymus angustus (2)
Elymus brachypodioides (3)
Elymus chinensis (12)
Elymus confusus (2)
Elymus dahuricus (27)
Elymus excelsus (4)
Elymus gmelinii (11)
Elymus komarovii
Elymus ovatus (3)
Elymus paboanus (4)
Elymus racemosus (2)
Elymus secalinus (7)
Elymus sibiricus (31)
Elymus spp.
Elymus strigosus
Elymus transbaicalensis
Elytrigia aegilopoides (4)
Elytrigia nevskii (2)
Elytrigia repens (2)
Eragrostis minor (5)
Erigeron acer
Eriogonum mongolicum
Erodium stephanianum
Erysimum flavum
Festuca altaica (4)
Festuca dahurica
Festuca komarovii
Festuca lenensis (15)
Festuca litvinovii
Festuca ovina (6)
Festuca rubra (2)
Festuca sibirica (6)
Festuca venusta (2)
Filifolium sibiricum (2)
Galium vaillantii
Galium verum (2)
Gentiana barbata (2)
Gentiana decumbens (2)
Geranium pseudosibiricum
Geranium vlassovianum
Geum aleppicum
Glycine hispida
Glycyrrhiza uralensis (6)
Goniolimon speciosum
Gypsophyla dahurica
Halenia corniculata
Halerpestes salsuginosa (2)
Halimodendron halodendron
Haloxylon ammodendron
Haplophyllum dauricum (3)
Hedysarum alpinum (11)
Hedysarum collinum
Hedysarum fruticosum (5)
Hedysarum inundatum (2)
Hedysarum sangilense
Helictotrichon mongolicum (4)
Helictotrichon pubescens
Helictotrichon schellianum (11)
Hemerocallis minor (2)
Heracleum dissectum (3)
Heteropappus hispidus (3)
Hierochloe glabra (2)
Hierochloe odorata
Hordeum bogdani (4)
Hordeum brevisubulatum (11)
Iris bungei (3)

Table 1 (Continued)

Iris dichotoma
Iris lactea (4)
Iris ruthenica
Iris tigridia
Isatis costata
Juncus filiformus
Juncus gerardii (2)
Juncus leucochlamus
Juncus salsuginosus (2)
Jungia fleuxosa (2)
Kalidium foliatum
Klion tatarskii
Kobresia bellardii (2)
Kobresia prostrata (6)
Kobresia sibirica
Kochia prostrata (2)
Kochia scoparia
Koeleria alpina
Koeleria altaica (2)
Koeleria cristata (2)
Koeleria glauca (2)
Koeleria gracilis (2)
Koeleria macrantha (12)
Koeleria mukdenensis (3)
Larix sibirica
Lathryus pratensis
Lathyrus quinquenervius
Leibnitzia anandria
Leontopodium leontopodioides (2)
Lepidium apetalum
Lespedeza daurica (10)
Lespedeza hedysaroides (2)
Leymus chinensis (20)
Leymus paboanus
Leymus secalinus
Lilium martagon (3)
Lilium tenuifolium (6)
Linaria buriatica
Linum baicalense (5)
Lotus corniculatus
Malba trionum
Medicago falcata (41)
Medicago lupulina (5)
Medicago platycarpos (6)
Medicago ruthenica (9)
Medicago sativa
Medicago varia (3)
Melandrium brachypetalum (2)
Melica turczaninowiana (2)
Melica virgata (6)
Melilotus alba (1)
Melilotus dentata (18)
Nitraria sibirica (4)
Olgaea lomonossowii
Onobrychis sibirica (7)
Orobanche cumana
Oxytropis ambigua
Oxytropis ampullata
Oxytropis deflexa (2)
Oxytropis eriocarpa
Oxytropis microphylla (4)
Oxytropis nitens
Oxytropis oxyphylla
Oxytropis prostrata
Oxytropis pseudoglandulosa
Oxytropis spp. (2)
Oxytropis strobilacea (2)
Oxytropis tragacanthoides
Papaver nudicaule (4)
Parnassia palustris
Patrinia dahurica
Patrinia rupestris (5)
Pedicularis flava (3)
Pedicularis microphylla
Pedicularis resupinata
Pedicularis uliginosa (2)
Peganum harmala (2)
Peganum nigellastrum
Peucedanum baicalense
Phalaris arundinacea (2)
Phaseolus vulgaris
Phleum phleoides (10)
Phlomis tuberosa (4)
Phragmites communis (3)
Plantago depressa (2)
Plantago major
Plantago salsa
Pleurospermum altaica
Pleurospermum uralense
Poa argunensis (3)
Poa attenuata (4)
Poa botryoides (10)
Poa nemoralis
Poa palustris
Poa pratensis (25)
Poa sibirica
Poa stepposa (4)
Poa subfastigiata (7)
Polygonatum odoratum (2)
Polygonum aviculare
Polygonum divaricatum (5)
Polygonum lapathifolium
Polygonum viviparum (2)
Potentilla fragarioides
Potentilla gelida
Potentilla multifida (2)
Potentilla strigosa
Potentilla tanacetifolia (5)
Potentilla viscosa
Psathyrostachys juncea (7)
Ptilagrostis mongholica (5)
Ptilotrichum canescens
Puccinellia tenuiflora (7)
Pulsatilla bungeana (2)
Pulsatilla dahurica
Reaumuria soongarica (4)
Rhaponticum uniflorum (2)
Rhinanthus songaricus (2)
Rhodiola rosea
Ribes pulchellum (3)
Ricinus spp.
Rosa acicularis (2)
Rosa dahurica (2)
Rosa laxa (2)
Rubia cordifolia (2)
Rumex acetosella (3)
Rumex gmelinii
Rumex thyrsiflorus (4)
Salsola collina (3)
Salsola ruthenica
Sanguisorba officinalis (12)
Saposhnikovia divaricata (2)
Saussurea salicifolia (2)
Scabiosa comosa
Schizonepeta annua (2)
Schizonepeta multifida (3)
Scirpus orientalis (2)
Scorzonera divaricata
Scutellaria baicalensis
Sedum aizoon (3)
Serratula centauroides (3)
Serratula marginata
Setaria viridis (4)
Silene jenisseensis
Silene parviflora
Siliena crissentis
Solanum depilatum
Spaeropyra salsola
Spiraea flexuosa
Spiraea rubescens
Spiraea salicifolia
Stellaria dichotoma
Stipa baicalensis (5)
Stipa capillata (12)
Stipa glareosa (4)
Stipa grandis
Stipa krylovii (3)
Stipa sibirica (17)
Stipa spp.
Suaeda corniculata
Tamarix gracilis
Taraxacum collinum
Taraxacum officinale (2)
Thalictrum minus (2)
Thalictrum petaloideum (2)
Thalictrum simplex (4)
Thermopsis dahurica (4)
Thermopsis lanceolata (2)
Thermopsis schischkinii (4)
Thymus mongolicus
Trifolium lupinaster (15)
Trifolium repens (2)
Triglochin maritima
Triglochin palustris (2)
Tripogon pupurscens
Trisetum sibircum (12)
Trisetum spicatum
Urtica cannabina (2)
Valeriana officinalis
Veronica incana (3)
Veronica longifolia (2)
Vicia amoena (18)
Vicia baicalensis
Vicia costata (3)
Vicia cracca (17)
Vicia multicaulis (2)
Vicia nervata (2)
Vicia unijuga (5)
Vincetoxicum sibiricum (2)
Zea mays
Zygophyllum potanini
Zygophyllum xanthoxylum

Total = 1,373

1994 Germplasm Collection (21 Aug. to 26 Sept. 1994)

Two collection teams were organized with one going east and south to the Eastern Steppe and Gobi Desert Regions of Mongolia, and the other team going to the north and west to the Selenge-Onon and Hungai Regions (fig. 1). The two teams traveled more than 5,500 km (3,300 miles) and made a total of 412 collections, which represented 97 genera and 152 species. Mongolian scientists indicated this was the best year for seed availability in the last 20 years.

Collections were made in the mountain steppe region located in the Hentii Mountains north of Ulaanbaatar, an area of gently rolling hills dominated by grasslands interspersed with patchy woodlands occurring mainly on north-facing slopes. This mountain steppe area is picturesque and is valued for its wildlife habitat and livestock grazing (mainly sheep and horses with a few cattle). The major grass genera included: *Stipa, Poa, Festuca, Koeleria, and Trisetum,* whereas the dominant tree genera included: *Pinus, Larix, Picea, Abies, Betula,* and *Populus*. The lush, productive grasslands had a wide diversity of legumes including *Vicia amoena*, *Thermompsis lanceolata*, *Melilotus dentatus*, and *Medicago falcata*. Some of the broader, flatter areas were being cut for hay for winter feeding of livestock.

Near Bayangol the elevation drops into a broad, flat area along the Haraa River and north of Darhan along the Orhon River, where herders graze their animals in rangeland areas surrounding the grain fields. The Selenge River is one of the largest rivers in Mongolia and carries a large flow of water. The Selenge-Onon Region is a broad, flat basin area draining to the north and is the principal cropping region in Mongolia. Cattle and sheep grazed extensively in the Selenge and Hentei Mountain forest and steppe areas as well as the Onon and Ulz-Tuul steppe and arid-steppe areas. Collections were made along the broad, flat valley bottom of the Selenge River, and in moist meadow and riparian areas located along creek tributaries of the Selenge River. Main genera collected in this area included *Elymus, Leymus, Agropyron, Calamagrostis, Melilotus,* and *Medicago*. As the team proceeded up in elevation from the moist meadow areas in the broad valley along the Selenge River into mountain steppe areas, promising collections were made of *Onobrychis sibirica* and *Medicago falcata*. Large areas of abandoned croplands infested with annual weeds were noted in this area. As is typical near population centers throughout Mongolia, overgrazing became a prominent feature of the landscape near Bulgan.

As the team proceeded up in elevation into the Hangai Mountains, yak and yak-cattle hybrids became the dominant grazing animals. A diversity of important forage grass genera including *Poa, Elymus, Festuca, Bromus, Koeleria,* and *Helictotrichon* were collected in the high alpine areas of the Hangai Mountains. Lower elevation areas in the Hangai Mountains are used for overwintering sheep herds with stone and wood shelters on south-facing slopes used to protect livestock from severe winter weather. Many of the more productive meadow areas were cut for hay and stored in piles on top of the shelters for winter forage. Promising collections of *Astragalus adsurgens* and *Onobrychis sibirica* were made in these lower elevation areas.

The team traveled south of Arvayheer and descended in elevation (with associated declines in precipitation) into the expansive grass steppe area of Mongolia. This flat, treeless area had reduced species diversity (dominants included *Stipa capillata, Cleistogenes songorica, Agropyron cristatum*, and numerous *Allium* species) compared to the mountain steppe region.

As the team proceeded further south, the areas became gradually more arid and eventually graded into the northern reaches of the Gobi Desert. The dominant vegetation in this desert steppe area included low caespitose grasses (*Stipa gobica* and *Cleistogenes songorica*) and shrub species (*Anabasis, Artemisia, Eurotia, Kochia,* and *Salsola). Allium* species were abundant in the desert steppe and provide an abundant, reliable forage for sheep, goats, and camels. From Erdenedalay towards Ulaanbaatar the plant community changed to grass steppe where collections were made of *Medicago ruthenica*, a procumbent perennial legume that is closely related to alfalfa and has potential for a leguminous forage in semiarid areas.

The other team initiated germplasm collections in Hentii Aimag along the Herlen River, which is the major river in eastern Mongolia and the only river in Mongolia that drains into the Pacific Ocean. Collections were made in the typical grass steppe as well as marsh and meadow communities along the main channel of the Herlen River and associated tributaries. Livestock use was most heavily associated with riparian zones along river and stream tributaries and adjacent to villages. From Onderkhan City, germplasm collections followed the general ecological transition from typical grass steppe to desert steppe. Collection sites were located in increasingly drier grass steppe in Hentii Aimag and the northern portion of Dorngov Aimag. Collections were made in the northern portion of Sukhbaatar Aimag and through Dornod Aimag to the Mongolian border with Inner Mongolia in the People's Republic of China. This area is a vast, treeless plain in the grass steppe with generally low human and animal populations, except for areas adjacent to the Herlen River and Khalka River in extreme eastern Mongolia. The typical grass steppe is uniform in its limited plant species diversity. Soils are brown chestnut soils developed under grass steppe conditions and have not been cultivated. Collections were made in a moderate elevation hill range that parallels and is located south of the Herlen River between Choibalson and Onderkhan cities. Both human and livestock populations were high in this area because of summer grazing areas, water, and meadow/marshland associated with the Herlen River. Meadows and marshlands are used extensively as summer grazing land for livestock, whereas the higher elevation hills are used for winter grazing. Collections were made in the area north of the Herlen River between Onderkhan City and the Tariat Research Station, which was in the transition zone between the mountain steppe of the Hentii Mountains and the grass steppe of eastern Mongolia. This higher rainfall area yielded a large diversity of species, and elk and wolves were observed in the area.

1996 Germplasm Collection (13 Aug. to 18 Sept. 1996)

The two collection teams in 1996 (fig. 1) traveled about 10,000 km (6,000 miles) and made a total of 387 collections, which represented 94 genera and 176 species. Collections were made in the Gobi, Altai, and Hangai-Hovsgol Ecological Regions of Mongolia.

The Gobi Region includes the semi-arid, southern portion of Mongolia. In this region, moisture availability and arable soils are the major limiting factors to agricultural production. Except in irrigated oases suitable for the production of vegetables and melons, agriculture is limited primarily to the grazing of sheep, goats, and camels. The Gobi Region is the center of a cashmere goat industry. A major limiting factor to livestock production in the Gobi Region is the need for winter supplemental feed for livestock, which this region has little inherent capability to produce. Aimags forming the Gobi Region include Gobi-Altai, Bayanhongor, Oborhangai, Dundgov, Omnogov, and Dorngov. General climatic and physical factors of the Gobi Region include: elevations ranging from 700 to 1,400 m; mean annual temperatures ranging from 0.0 °C to >2.5 °C with a low temperature of –20 °C in January and a high temperature of 23 °C in July; mean wind velocity of 2 to 8 m/sec; from 90 to >130 frost-free days; and precipitation of about 100 mm. Lack of snow, which is used as a water source by grazing animals, limits livestock production in the Gobi Region.

The Altai Region is the high mountain region in western Mongolia. Agricultural production in the northern and central part of the region is limited to using cattle, sheep, goats and yaks to harvest grazing land forage with pastoral grazing management strategies. In the southern Altai Region irrigated fruits, berries, and melons are produced and limited fodder production is possible. Aimags forming the Altai Region include Ubs, Bayan-Olgii, Hovd, Zavhan, and Gobi-Altai. Climatic and physical factors influencing biological systems in the Altai Region include elevations between 1,500 and 4,000 m; mean annual temperature between –2.5 °C and 5.0 °C with a low temperature of –24 °C in January and a high temperature of 22 °C in July; 60 to 120 frost-free days; between 400 to 500 mm of annual precipitation; snow depths that range between 5 to >15 mm; and an average wind speed of between 2 to 6 m/sec.

The Hangai-Hovsgol Region is located in northwest Mongolia. This mountainous region has a high elevation and deep valleys with some forest and arid steppe, which limits agricultural production to the grazing of animals including yaks, cattle, sheep, and reindeer. Agricultural activities other than pastoral grazing include a limited amount of fodder harvest and grain production in the steppe areas of the region. Aimags in this region include Arhangai, Hovsgol, Bulgan, and Zavhan. Climatic and physical factors influencing biological systems in the Hangai-Hovsgol Region include elevations between 2,000 and 3,000 m; mean annual temperatures between –2.5 °C and 7.5 °C with a low temperature of –24 °C in January and a high temperature of 19 °C in July; from 60 to 100 frost-free days; and an annual precipitation of 200 to >400 mm; wind speed that averages from 2 to 4 m/sec; and snow cover that often exceeds 15 mm in depth.

1998 Germplasm Collection (21 Aug. to 20 Sept. 1998)

The 1998 germplasm collection in Mongolia was centered in north-central Mongolia, primarily in the Hovsgol and Hentii Aimags, with additional collections made in the Selenge and Bulgan Aimags (fig. 1). Specific areas within these regions include the Hovsgul and Mongolian-Daguur forest steppe areas within the Hangai-Hovsgul Region and the Hentei Mountain area within the Selenge-Onon Region. These collection areas are floristically representative of the Inner Baikal Province of Russia. In 1998, the two collection teams traveled about 5,000 km (3,000 miles) and made a total of 574 collections, which represented 132 genera and 253 species.

The Hangai-Hovsgol Region was described in the previous section. The Selenge-Onon Region is located in north-central Mongolia and includes the principle cropping area for Mongolia as well as the extensive Hentii Mountains located in Selenge, Tov, and Hentii Aimags. Although considerable cropping is done in this region, livestock grazing is still the main agricultural activity. Native or hybrid cattle and sheep are the primary grazing animals as well as large wild herbivores such as elk, deer, and moose. The mountain portion of this region is comprised of relatively low mountain ranges with *Larix* forests typically occurring on north slopes. The Onon River Basin, which enters Mongolia from Siberia and loops back to Siberia in the eastern portion of Hentii Aimag, drains the northwestern portion of Hentii Aimag. Although climatic and physical factors limit crop and livestock production, conditions are less severe than those in the Hovsgol-Hangai Ecological Region. Average elevation in this region is between 1,500 and 2,000 m. Mean annual temperature is between 0.0 °C and 2.5 °C with cold temperature in January to –20 °C and warm temperature in July to 19 °C. The region averages between 70 and 120 frost-free days and has annual precipitation between 250 and 400 mm. Snow cover averages between 5 to 10 mm in depth, except in the center of this region, which includes the Hentii Mountains. Average wind speed is between 4 to 6 m/sec.

Both the Hentii Mountains and Hovsgol areas are protected as national parks because of the unique composition of their flora and fauna and their scenic beauty. Both collection areas can be generally categorized as cold temperate. The most common vegetation type encountered during the 1998 collection was forest steppe. Many of the forests had been burned by wildfires during the previous one to three years, creating many early successional communities. High mountain and swamp steppe were encountered in the upper reaches of streams and passes both in the Hovsgol and Hentii Mountain areas. Other communities encountered were birch, river and stream riparian, and pine forest. The steppe vegetation type was also present in these areas as ecotonal communities intergrading with forest steppe vegetation. Overall, human population in both the Hentii

Mountain and Hovsgol collection areas is low. The northern boundary of Hentii Aimag with Siberia, Russia has mainly Buriat Mongols, who are few in number and primarily live in log cabins rather than the Mongolian ger (yurt). Because the human population is low, livestock numbers are also low, creating large areas of almost unused vegetation. Except for areas adjacent to villages and along main roads, most plant communities appear to be in almost pristine ecological condition, except where disturbed by fire or other natural forces.

Hovsgul Lake, which is the main physiognomic feature of the Hovsgul area, is famous as one of the largest, cleanest freshwater sources in the world. The lake is located at an elevation of 1,624 m and is 238 m deep. To the west of Hovsgul Lake is Darkhand in Hotgor Valley, which was originally the old lakebed of a large prehistoric lake. The mountains in this area have permanent snowfields, and there are active glaciers in the area. This unique area represents about 5 percent of the total area of Mongolia. Of the 768 plant species in the flora of this area, 118 are forest species, 205 are stone-rock species, and 242 are cold-resistant plants. This area has 11 endemic plant species including *Equisetum variegatum, Ptilagrostis junatovii, Poa trivialis, Festuca huvsgulica, Festuca komarovii, Elymus excelsus, Elymus kronokensis, Elymus praecaespitosus, Elymus sajanensis, Allium victorialis,* and *Lathyrus gmelinii*.

The Mongolian-Daguur Forest Steppe area represents 6.6 percent of the total area of Mongolia. It has an average elevation of 800 to 1,500 m with a maximum elevation of 1,800 m. This area contains mainly graminaceous species. Endemic plant species in this region include *Stipa pennata, Koeleria glauca, Poa supina, Elytrigia geniculatum, Elymus brachypodiodes, Allium nerinifolium, Allium victorialis, Trigonella canceolata, Melilotus albus, Trifolium pratense, Astragalus chinensis, Astragalus membranaceus, Astragalus uliginosus, Onobrychis arenaria,* and *Vicia trydenii*.

The Hentei Mountain area is the longest province in Mongolia being 250 km long. This region has an average elevation of 1,600 to 2,000 m. The Hentei Mountains are located on the continental divide and represent the main water source for Mongolia and a substantial part of Russia. This area is the headwaters for the Herlen, Onan, and Ulz Rivers (which flow to the Pacific Ocean) and the Tuul Haraa, Eroo and Minj Rivers (which flow to the north). This particular region represents about 3 percent of the total area of Mongolia. There are 844 graminaceous species and 132 forest species in this region. The flora of the region is dominated by the east Siberian flora and has a number of endemic species including *Equisetum sylvaticum, Stipa confusa, Calamagrostis turczaninovii, Poa kenteica, Poa nemoralis, Festuca komarovii, Allium maximowiozii, Thermopsis alpina, Trifloium repens,* and *Pedicularis sceptrum-carolinum*.

Forage Evaluation Trials in Mongolia

A forage germplasm evaluation project was initiated to evaluate the Mongolian seed collections made during 1994, 1996, and 1998. Funding for this effort was provided through the Food For Progress (PL-480) Program and an associated grant from the USDA's Foreign Agricultural Service during 2000-2003. The field evaluations were designed to identify promising forage collections for improving degraded rangelands in Mongolia. Three sites were selected to represent the major vegetation zones of Mongolia (fig. 1). These included: (1) forest steppe zone–located at the experimental plots of the Research Institute of Animal Husbandry in Batsumber Sum, Tuv Aimag, (2) steppe zone–located in the Turgen Gol area, near the city of Ulaanbaatar, and (3) semi-desert zone–located at the experimental plots of the Agricultural Department in Buyant Sum, Khovd Aimag. The general features of the three sites are as follows:

Batsumber Site (Forest Steppe Zone)

This site is located in Batsumber Sum in Tuv Aimag about 80 km from Ulaanbaatar, near the railway station "Mandal." The site is in an open, long valley and has an elevation of 1,100 m above sea level. Soils at the site are dark brown, and the soil texture is light sandy. The A soil horizon ranges from 0 to 40 cm. The B soil horizon ranges from 40 to 80 cm and is light dark brown with a light soil texture with few plant roots. The C soil horizon ranges from 15 to 20 cm, is gray with yellowish color, and is light sandy. The organic matter content of the top soil layer is 1.7 to 3.2 percent. The sum of absorbed alkaline per 100 g of soils is 17 to 25 g-equivalent, and for K is 4 to 9 mg with a pH of 7.1 to 7.5. Salinity increases with soil depth.

The main climatic characteristics of the Batsumber site are presented in table 2. Mean annual air temperature at the site is 1.2 °C with a mean January temperature of –21.8 °C and mean July temperature of 17.0 °C. Daily average temperature reaches 0 °C on about 13 April in the spring and 11 October

Table 2—Long-term climatic data for the Batsumber site.

Climate Variable	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Mean
Air temp, °C	–21.8	–18.2	–9.4	0.6	9.8	14.8	17.0	15.0	8.5	–0.3	–11.4	–19.0	–1.2
Soil temp, °C	–23.7	–18.8	–7.9	5.5	14.7	19.7	21.3	17.9	11	1.0	–12.6	–21.1	0.6
Rainfall, mm	22	1.6	3.8	8.0	14.9	54.8	59.4	80.8	22.3	10.2	3.6	2.7	264.0
Humidity, %	78	75	64	52	48	58	62	64	61	63	72	77	64

in the autumn. There are about 180 days with temperatures above 0 °C. Latest spring frost occurs near 20 June, and the earliest autumn frost occurs near 30 August. There are usually 130 to 140 days above 5 °C and 70 to 80 days with temperatures above 10 °C.

Mean annual precipitation is 264 mm, and 81 to 93 percent of this amount is received during June to October. There are 31 to 48 days of rain and 20 days of snow, and continuous snow cover occurs during 136 to 157 days. The depth of permanent snow cover usually does not exceed 10 cm. Mean maximum wind speed occurs in April and May with a mean of 4.1 to 4.4 m per sec. The driest period of the year occurs during April to May.

Turgen Site (Steppe Zone)

The Turgen site is located in Tuv Aimag near Ulaanbaatar in the Turgen Gol River Basin. The site is a Dauhur Mongolian type of hill and hillock steppe, lying along a widely open hollow with no permanent water flows. The soils in this area have a sandy texture, medium fertility, and light brown soil color. Organic matter content for the 0 to 30 cm depth is 1.07 to 1.36 percent. Content of P in 100 g of soil is 2.9 to 4.2 mg, and K is 2.6 mg. Soil pH is 6.3 to 6.7.

There is no meteorological station at the site, but six months of data are available from a station in Ulziit District, located about 6 km from the site (table 3). Mean annual temperature at this site is –0.9 °C. Mean annual precipitation is 200 to 230 mm, and mean wind speed is 3.5 m per sec with the spring season being the most windy. The active vegetation period is about 110 to 120 days. Mean snow cover of 4 to 9 cm lasts for 120 to 150 days from November to mid-April.

Buyant Site (Semi-desert Ecological Zone)

The Buyant site is located in Buyant Sum in Khovd Aimag in far western Mongolia, and the area is classified as a semi-desert in the Great Lake Depression. The site has light, sandy Gobi brown soils. The depth of the plow layer is 18 to 20 cm, and the soil is poorly textured with an organic matter content of 0.9 percent. The soil at the test site is rich in Ca and poor in P and N. This area is characterized by hot summers, a small amount of snow, and cold winters. Temperature and precipitation characteristics of the Buyant site are presented in table 4. Annual precipitation in this area is 120 to 130 mm with nearly all of the precipitation coming during the summer months (79 percent of total rainfall comes from July to early September).

Results of Field Evaluation Studies

A large number of seed collections of various forage species were planted at the three study sites (table 5). The largest number of collections was evaluated at the Turgen site where experiments were conducted under both rainfed and irrigated conditions with direct seeding as well as transplants started in a greenhouse. Plots were established using randomized complete block designs with three or four replications. Characteristics evaluated included seedling vigor, seedling establishment, biomass production, crude energy, and digestible protein. Based on data collected during three years of study at the three Mongolian study sites, the following species appear to hold the most promise for seed production and subsequent use in reseeding efforts in Mongolia: *Agropyron cristatum,*

Table 3—Long-term meteorological data for Ulziit Station near the Turgen site.

	Month						
Climate Variable	**April**	**May**	**June**	**July**	**August**	**September**	**October**
Air temperature, °C	5.8	12.9	21.6	20.7	17.6	11.7	–2.2
Rainfall, mm	14.0	12.2	14.2	35.3	104.4	3.2	14.5

Table 4—Long-term monthly mean temperature, °C and rainfall, mm for the Buyant site.

	Month											
Climate Variable	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Temperature (°C)	–24.5	–20.3	–7.6	3.5	12.0	17.3	18.6	16.9	10.7	1.6	–9.9	–20.1
Rainfall (mm)	1.5	0.9	2.4	6.1	10.0	26.6	38.0	23.1	10.8	4.7	1.8	1.8

Table 5—Number of seed collections tested at each of the evaluation sites.

Study sites	Collections tested
1. Batsumber site (forest steppe)	773
2. Turgen site (steppe)	
Rainfed	742
Irrigated	733
Transplants	758
3. Buyant site (semi-desert)	555
TOTAL	3,561

Allium species, *Astragalus adsurgens*, *Bromus inermis, Elymus dahuricus, Elymus gmelini, Elymus sibiricus, Festuca lenensis, Hordeum bogdanii, Medicago falcata*, *Poa pratensis, Polygonum divaricatum, Psathyrostachys juncea, Puccinellia macranthera, Puccinellia tenuiflora, Stipa capillata,* and *Stipa krylovii*.

Publication of Book "Forage Plants in Mongolia"

Based on results from the forage evaluation project, a 563-page book entitled "Forage Plants in Mongolia" was prepared and published that describes the botanical features of more than 300 forage species from the rich, diverse flora of Mongolia (Jigjidsuren and Johnson 2003). The text of the book is written in both English and Mongolian languages. The book contains plant species names in Latin and Mongolian, local Mongolian names, botanical and vegetation characteristics of each species, area of distribution within Mongolia, palatability and nutritional information, and their economic importance. Color photographs and/or line drawings for most of the forage species are included in the book and make it a resource for identifying Mongolia's main forage species. The inclusion of local Mongolian plant names in the book preserves traditional knowledge of Mongolian plants. This book will benefit a wide range of readers including amateur and professional botanists, scientists, students, tourists, and livestock herders. The book can be purchased by email (extension.publications@usu.edu) or phone (435-797-2251) at a cost of $15 plus shipping.

Project to Increase Seed of Most Promising Forage Species

A proposal for increasing seed of the most promising forage species was selected for funding through the U.S. Embassy in Mongolia. The seed increase project will be conducted at Bornuur Sum in Tuv Aimag, which is located about 110 km north of Ulaanbaatar (fig. 1). Prior to 1990, the area around Bornuur was known for its dairy production. Bornuur is recognized as one of the best areas in Mongolia for growing irrigated vegetables, grain and forage crops, sunflower, oats, and corn. Mongolian State University of Agriculture has an experimental station about 12 km from the center of Bornuur for testing of crop and forage varieties and seed multiplication. The Bornuur Experimental Station is located in the forest zone and has an annual precipitation of 300 to 350 mm. The minimum air temperature in January is –30 °C, maximum air temperature in July is 35°C, and annual mean temperature is about 1.2 °C. Soils at the Station are a sandy loam, and the elevation is about 1,200 m above sea level. The Bornuur Experimental Station has a dormitory for both students and researchers that can accommodate about 100 people. The Station is equipped with permanent electricity and water, and encompasses an area of 178 ha^2. A series of water reservoirs, canals, pumps, sprinklers, and drip irrigation facilities on about 34 ha will be used to provide supplemental irrigation to maximize seed production of the most promising forage collections.

Summary

Three joint U.S./Mongolia germplasm collection expeditions were conducted in 1994, 1996, and 1998 to collect seed of important forage species in Mongolia. These expeditions resulted in the collection of a wide diversity of forage species from the major vegetation zones of Mongolia. These collections were equally shared between both countries, and the U.S. share of the seed was added to the U.S. National Plant Germplasm System where it is stored for use by scientists around the world. In subsequent years, collections from these expeditions were evaluated at three sites in Mongolia for forage production and conservation uses, and the most promising collections were identified. Results from these evaluation trials were used as a basis to publish a book describing the major forage plants of Mongolia. A project recently funded through the U.S. Embassy in Mongolia will provide funds to increase seed of the most promising forage species for use by herders and land managers in Mongolia.

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Rangeland, Livestock and Herders Revisited in the Northern Pastoral Region of China

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Abstract—*Rangelands, which comprise more than 40 percent of China's land surface area, are an important natural resource that provides a direct livelihood for at least 39 million people. Although the importance of rangelands has been recognized for millennia, during the latter part of the 20th Century China's rangelands have been subject to over-use by a growing population that is dependent on this natural resource for their livelihood and land-use changes that have diminished productivity and promoted degradation. The first internationally funded agricultural project was initiated in the Inner Mongolian Autonomous Region in 1981. In 1985, the Yihenoer Pilot Demonstration Area was established to demonstrate methods of rangeland management and livestock production facilitating sustainable use of rangelands. An ecological inventory of rangeland vegetation compiled over three years from ecological monitoring points indicated that rangeland condition was degrading. The primary reasons for deteriorating rangeland condition were overstocking and conversion of rangeland to rainfed cropland. In 2003, the Yihenoer Pilot Demonstration Area was revisited by Canadian and American range scientists. Evaluation and comparison with information obtained in 1987 indicated that rangelands of the Yihenoer Pilot Demonstration Area had continued to degrade, grass steppe rangelands were less productive, and that conversion of rangelands to rainfed cropland was continuing. The authors recommend that a "bottom-up" rangeland management planning program designed to integrate actual land users with well defined and rational "top-down" government agricultural policies be implemented in the northern pastoral region of China or degradation and loss of rangelands will continue.*

Keywords: *resource planning, rangeland degradation, overgrazing, conservation planning, rangeland rehabilitation.*

Bedunah, Donald J., McArthur, E. Durant, and Fernandez-Gimenez, Maria, comps. 2006. Rangelands of Central Asia: Proceedings of the Conference on Transformations, Issues, and Future Challenges. 2004 January 27; Salt Lake City, UT. Proceeding RMRS-P-39. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Introduction

In this paper we present an overview of China's rangelands, including changes in livestock numbers, rangeland conditions, and recent policy affecting rangelands and the people dependent on rangelands to sustain their livelihoods. We describe a rangeland development project initiated in 1987 in the Inner Mongolian Autonomous Region and revisited in 2003 to show the change in rangeland conditions. Using this project as a case study, but also including other experiences in China and literature, we end with our recommendations for future management of China's rangelands. We stress resource management planning with household livestock producers as a fundamental approach to developing sustainable use of rangelands. Although this concept is not new in North America, it has not been applied in China using a "bottom-up" approach. As competition for land and vegetation resources become more acute, and as external forces rather than environmental conditions increasingly affect agricultural and livestock production, developing "bottom-up" resource management and production strategies that directly involve the immediate rangeland user is an important and fundamental step to sustainable use of rangelands and to sustaining household livelihoods.

Rangelands throughout China are an important and irreplaceable natural resource. Developing sustainable use of rangelands is important to the well being of current and future generations of Chinese as degraded rangelands are already causing serious environmental problems and retarding development. Over the past several years, degraded natural rangeland and rangeland converted to cropland in the northern and western regions have contributed to dust storms affecting urban and agricultural regions of China. Erosion and sedimentation arising from inappropriate rangeland use is affecting water flow and watershed stability of major rivers. Degradation is affecting the livelihood of people there and is a cause of worsening socio-economic conditions of peoples dependent on rangeland resources to support livelihoods.

Rangelands cover approximately 40 percent (400 million ha) of China's total land area and constitute an important renewable natural resource supporting rural populations engaged in various forms of livestock production. Approximately 75 percent of rangelands occur in semi-arid and arid pastoral regions of northern and western China (table 1). Rangeland dominates in the autonomous regions of Tibet, Inner Mongolia, and Xinjiang and the province of Qinghai. The remaining 25 percent of rangelands (100 million ha) occur intermixed with agricultural areas throughout China (TWB 2000). Approximately 80 percent of the total rangeland area is considered suitable for livestock grazing (Li 1998).

China has three major pastoral rangeland areas: (1) the Qinghai-Tibetan Plateau which encompasses 138 million ha, (2) the arid and semi-arid steppes of northern China which encompasses 92 million ha including Inner Mongolia, and (3) arid steppes and mountain rangelands of northwestern China which encompasses 70 million ha. Provinces in the northeast, central and southern regions of China are located in the agricultural zone. Although rangeland may have been a major natural resource of these provinces in the past, conversion of native rangeland to agricultural cropland has been long-standing and very inclusive. Most remaining native rangeland is found in areas with characteristics not conducive to development as agricultural cropland. Rangeland in the agricultural zone is divided into two parts: (1) the northern region which includes the Songliao plain, Huang-Huai-Hai plain, and Loess Plateau, and encompasses 25 million ha, and (2) rangeland in the southern region which is scattered among various provinces and encompass 75 million ha.

Rangeland Utilization

Two predominant uses of rangeland occur in China. Forage produced annually on rangelands supports livestock production throughout China but is an especially critical livestock feed resource in the northern and western pastoral areas of China. The other major use of rangeland historically and presently is conversion (some refer to it as reclamation) of natural rangeland ecosystems to cropland to produce food and, increasingly, commercial crops. Although both uses are historical, and have been occurring since the development of crop agriculture in China, conversion of rangeland ecosystems to marginal agroecosystems during the 20th Century has been widespread and irrational in its' application, especially in regions with few or no alternatives available to rangeland based livestock production to sustain human livelihoods.

Between 1949 and 1989, numbers of livestock grazing rangeland tripled in China (table 2). Livestock are estimated to contribute 30 percent of the total gross value of China's agricultural output (Nyberg and Rozelle 1999). In 1990, the total number of livestock being grazed on China's rangelands was estimated to be 521 million sheep equivalents (Yu and Li 2000). Kind of livestock included large livestock (cattle, buffalo, yak, horses, mules, donkeys, and camels) and small livestock (sheep and goats, and in some locations, waterfowl and chickens). Although there is some evidence that numbers of livestock utilizing rangeland vegetation as their only or primary source of feed is stabilizing or even declining in some areas, the increase in numbers of livestock has been significant in the northern and western pastoral regions of China.

Table 1—Rangeland Areas in Different Provinces and Regions of China.[1]

Province/Region	Total Area (million ha)	Rangeland Area (million ha)	Rangeland Area (Percent Total Area)
Tibet	122.84	82.05	66.80
Inner Mongolia	118.30	78.80	66.61
Xinjiang	166.00	57.26	34.49
Qinghai	72.12	36.37	50.43
Sichuan	45.83	21.00	43.00
Gansu	45.39	17.90	39.45
Yunnan	38.20	15.31	40.07
Guangxi	23.76	8.70	36.61
Heilongjiang	45.45	7.53	16.57
Hunan	21.13	6.37	30.16
Hubei	18.94	6.35	33.54
Jilin	18.06	5.84	32.34
Shaanxi	20.69	5.21	25.16
Others[2]	200.56	44.14	22.01
Total	960.27	392.83	40.91

[1]This table does not include rangeland in Taiwan Province.
[2]Includes provinces and regions with rangeland area less than 5 million ha.
Source: Ministry of Agriculture, National Eco-environment Construction Plan for Rangeland of China, 1999.

Table 2—Increase in Grazing Livestock Numbers (million SU[1]) in Northern and Western Pastoral Regions Between 1949 and 1988.

Province/Region	1949	1952	1965	1978	1988
Heilongjiang	1.7	2.7	3.5	5.1	5.6
Jilin	1.7	2.4	3.0	3.5	4.7
Liaoning	—	3.8	—	4.3	5.9
Inner Mongolia	—	13.3	—	30.4	36.3
Ningxia	1.2	2.2	3.9	3.5	4.6
Gansu	6.6	8.6	12.2	14.1	16.7
Qinghai	12.5	15.7	26.4	38.5	35.9
Xinjiang	10.4	12.7	26.5	23.8	32.6
China[2]	102.4	138.3	223.2	263.8	326.9

[1]Sheep Units (SU) equivalency, which is based on animal body size and feed requirements, provides a comparison between different kinds of livestock species as follows: 1 mature cow = 5 mature ewes, 1 mature horse = 7 mature ewes, etc.

[2]This table does not include animal numbers in Taiwan Province.

Source: The Rangelands of Northern China. National Research Council/Academy of Sciences (USA).

The importance of rangeland in supporting rural communities is undeniable. There are 260 counties in China in which livestock production is the primary or second most important agricultural production activity (TWB 2000). Livestock production dependent solely or partially on forage produced from rangelands is the primary source of livelihood for about 39 million people.

Rangeland Policies

Policies of the Chinese government during the previous 50 years reflects three different, changing perceptions about the role and contribution of rangelands to national development. The three perceptions are: (1) rangelands are a reclaimable resource for crop production, especially grain production; (2) rangelands are a base for increasing livestock production; and (3) rangelands are a base for livestock production and an ecological resource.

Conversion of natural rangeland to cropland has occurred with regularity and on a large scale in China since 1949. Between 1950 and the early 1980s, the commonly cited amount of rangeland converted to cropland nationwide is 6.7 million ha (Yu 1999; Yu and Li 2000). Much of the conversion occurred on state farms in the northern and western pastoral areas of China. Often, converted land provided only short-term benefits before salinity or loss of soil fertility led to reduced yields or abandonment.

Although current figures are not available, conversion of rangeland to annual cropland for short-term economic gain has continued through the 1990s. For example, large areas of relatively good condition rangeland in Keshiketeng Banner of Inner Mongolia were converted to rainfed cropland to grow rapeseed (*Brassica sp.*) as a cash crop as late as 1997 (Consortium for International Development 1997). Around Qinghai Lake in Qinghai Province, farmers from eastern Qinghai leased critical winter rangeland from Tibetan herders for the purpose of plowing, cultivating and planting rapeseed as late as 2000 (Sheehy 2000).

The Ministry of Agriculture, which administers rangeland resources in China, is primarily focused on improving agricultural productivity. Previous agricultural policy was based on the premise that increases in productivity were attainable through: (1) increasing livestock numbers and/or introducing improved breeds with higher offtake potential; (2) converting rangeland to rainfed cropland; and (3) increasing crop yields by applying higher rates of fertilizer and developing irrigated cropland (Consortium for International Development 1997). Despite regulations to the contrary (such as the 1985 Rangeland Law and the "New Rangeland Law"), these policies continue to influence agricultural and land use decisions throughout China and especially in the northern and western pastoral rangeland regions.

Rangeland Degradation

Rangeland degradation is influenced by the interaction of climate, geology, vegetation type, and disturbances caused by humans and animals. The degradation process reduces vegetation cover, yield, and usefulness for animal production and exposes soils to wind and water erosion. Allowed to proceed unchecked, degradation decreases stability of agro and natural ecosystems and impoverishes people dependent upon rangeland for agricultural and livestock production.

Key indicators of rangeland degradation on a national/regional level are: (1) the decrease in total rangeland area; (2) the increase in degraded, desertified, and salinized area; and (3) the increase in degraded rangeland as a percentage of total rangeland area. Key indicators of rangeland degradation on an ecosystem level are: (1) a decline in yield per rangeland unit; (2) a decrease in vegetation cover and height; (3) an increase in the percentage of weeds and noxious plants in species composition; and (4) a change in structure of grass species (Yu and Li 2000). Although unverified, it is estimated that millions of hectares of rangeland in Northern China are in a degraded condition. In 1997, the amount of moderately and seriously degraded rangeland nationwide in China was reported to be 133.34 million ha (table 3). Six provinces and regions contain nearly 90 percent of the total degraded rangeland in China. Inner Mongolia has over 34 percent of the degraded rangeland in China and over 58 percent of the rangeland in Inner Mongolia is degraded. Throughout China, two million hectares of rangeland are reportedly deteriorating each year (SEPA 1998).

The rate at which rangeland is degrading appears to have substantially increased during the 1990s (fig. 1). In the 10 years between 1989 and 1999, the amount of degraded rangeland in China increased by 100 percent. Highest rate of increased rangeland degradation occurred between 1992 and 1997 when 57 million ha of rangeland were degraded. Although the rate of rangeland degradation decreased between 1997 and 1999, the amount of rangeland degraded continued to be substantial.

The cause of rangeland degradation is complex, as a number of interrelated factors can be involved. Human induced disturbance, which is often induced by farmers and pastoralists responding to "top-down" social and economic policies, is a major cause of rangeland degradation. A recent review (Sheehy 1998) of rangeland ecosystems in northern China identified the following factors as major causes of rangeland degradation: (1) a higher and increasing population density with an increasing demand for meat and grain; (2) large areas of relatively fragile rangeland ecosystems with limited production capacity; (3) government policies that encourage increased livestock and grain production in marginal agricultural areas; (4) policies encouraging sedentary livestock production over mobile traditional pastoral livestock production systems, which cause an imbalance in the distribution of rangeland resources and livestock production; (5) previous large scale immigration of farmers to pastoral rangeland areas; (6) conversion of arid and semi-arid rangelands to rainfed croplands producing annual rather than perennial crops; (7) livestock overstocking leading to overgrazing, especially early and intense spring grazing; (8) lack of applied regulations concerning use of rangeland; (9) inappropriate allocation of resources needed to support household livestock production; (10) traditional methods of risk management unresponsive to resource scarcity; and (11) an underdeveloped production support and marketing infrastructure. Although causes of rangeland degradation and linkages between stresses causing degradation may vary in other provinces and regions of China, generally the underlying principles are similar in all provinces and regions of China. Natural factors such as resilience of vegetation to grazing, soil texture, prevailing climatic conditions, etc. may influence the rate of degradation and the capacity of the rangeland ecosystem to maintain long-term stability while subject to factors inducing degradation.

In rangeland areas previously degraded, increases in livestock numbers and/or conversion of rangeland to cropland were usually directly or indirectly associated with degradation. Overgrazing and overstocking alone can cause rangeland degradation; in combination with adverse climatic and geologic factors in areas having vegetation susceptible to herbivore disturbance, rangeland degradation can occur in short time frames and quickly progress from light to moderate to severe. This is especially true of rangelands formed on sandlands occurring in the northern and western pastoral regions. These rangelands are especially susceptible to degradation because of lower precipitation, light, sandy and low fertility soils, and the severe environment characteristic of these regions.

Table 3—Provinces and Regions of China Most Severely Affected by Rangeland Degradation.

Province/Region	Degraded Rangeland (Million ha)	Degraded Rangeland (Percent Total Area)	Portion of National Degraded Rangeland (Percent)
Tibet	21.00	25.59	15.75
Inner Mongolia	45.92	58.27	34.44
Xinjiang	26.58	46.42	19.93
Qinghai	10.90	29.97	8.17
Sichuan	6.12	29.15	4.59
Gansu	8.57	47.87	6.43
Yunnan	0.52	3.40	0.39
Other Provinces	13.73	16.32	10.30
Total[1]	133.34	33.94	100.00

[1]This figure does not include degraded rangeland in Taiwan Province.
Source: Ministry of Agriculture 1999.

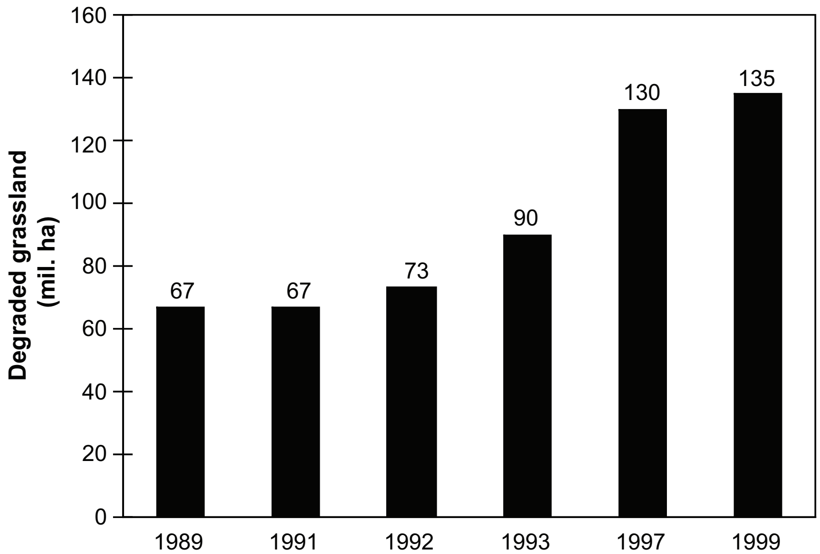

Figure 1—The Trend of Rangeland Degradation in China. Data Source: State Environment Protection Agency, China Eco-environment Condition Report (1990-2000).

Rangeland Conversion

Conversion of rangelands to cropland destroys natural vegetation and exposes soil to wind and water erosion. Wind erosion of exposed soils during the spring season can be severe because the spring season is naturally cold, windy, and droughty. Water erosion of degraded or reclaimed rangeland during the summer season can also be severe because most precipitation occurs from convection storms. These storms can release heavy rainfall over small areas in a very short time period. Water erosion of degraded rangeland or exposed soils of reclaimed rangeland in the agricultural region can also be severe because of the greater amount of precipitation, especially on sloped cultivated land.

A major portion of rangeland converted to cropland occurs in the 200 to 500 mm precipitation zone of (fig. 2). Most precipitation in this zone, which extends from the northeast in Hulunbaer League of Inner Mongolia to eastern Qinghai Province and southeastern Tibet, occurs during the summer as convection storms. The combination of maximum moisture with high ambient temperature during the summer growing season, creates a generally favorable environment for rain-fed crop production in most years. In years with normal precipitation, production of annual crops is possible. This provides the incentive, which has been fostered in the past by higher echelons of government administrators and the Ministry of Agriculture, to convert natural rangeland ecosystems to more short-term and economically profitable rain-fed cropland.

Even though crop production is possible in the zone, the entire area is subject to severe limitations imposed by climate. Summer drought is relatively common, and spring is cold, windy, and dry. During the summer cropping season, convection storms cause water erosion of annual cropland. During the spring, windstorms can severely erode plowed, fallow fields and degraded rangelands with disturbed vegetation cover. Severe dust storms affecting the global environment arise in this zone. In both pastoral and agricultural rangeland regions, use of rangelands as building sites for business enterprises, homes, roads, pipelines, and other commercial activities is increasingly becoming a factor determining utilization of rangelands.

Rangeland degradation in China is recognized as a severe and on-going problem. Even national and local environmental stabilization programs, such as building the "Great Green Wall" to reduce dust storms, shelterbelts to prevent wind erosion of cropland, or eco-environmental programs designed to improve both local economies and environmental conditions at the same time can be detrimental to maintaining or restoring rangeland ecosystems. Programs such as these, although not without merit, are often not successful when applied over large spatial scales because of the inherent variability encountered across a landscape and because factors causing degradation are not mitigated.

An indirect associated cause of rangeland degradation is the high population of pest species in some areas of the northern and western pastoral rangeland regions. At present, the rangeland area annually infested with pest species is reported to be 40 million ha. Rodents and rabbits infest 30 million ha and insect pest species infest 10 million ha. These small herbivores not only consume substantial forage in competition with livestock herbivores but, as ground burrowing animals, induce loss of soil structure and facilitate soil erosion in areas with high-density populations.

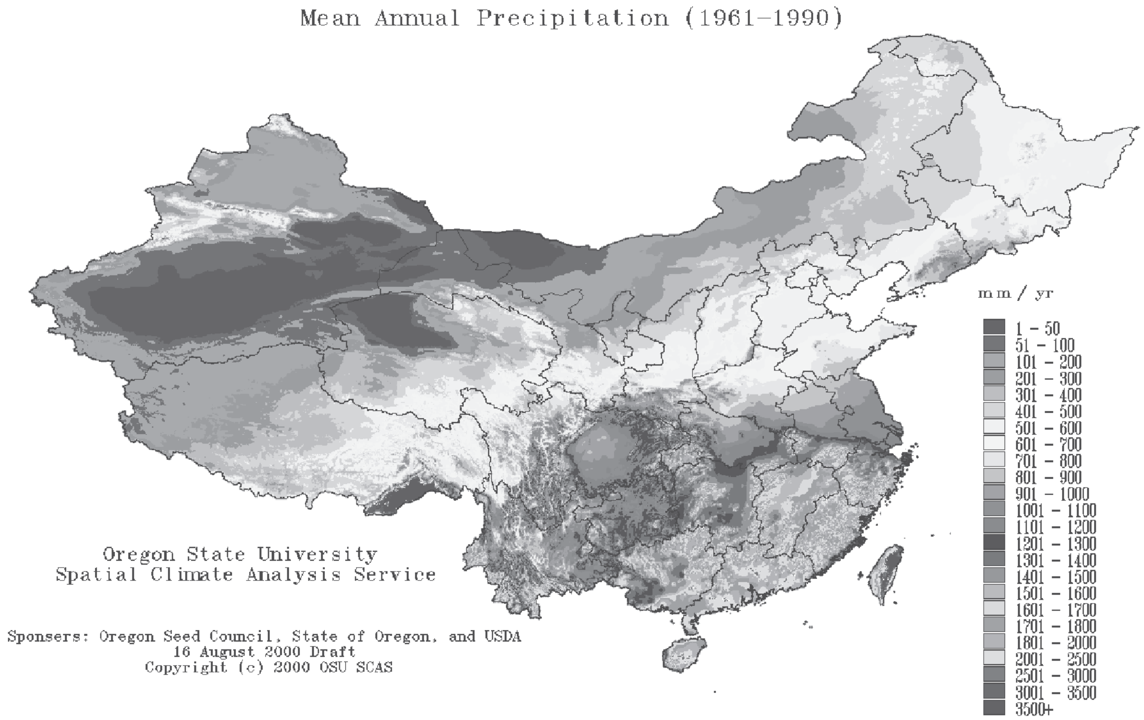

Figure 2—Precipitation Zones of China.

Adverse impacts on soil and vegetation stability are especially apparent in *Kobresia* turf communities of the Qinghai-Tibetan Plateau. Destruction of *Kobresia* turf communities not only creates barren lands commonly referred to as "black beach" but also causes an irreplaceable nutrient loss in Alpine Meadow rangelands (Sheehy 2000).

Inner Mongolian Rangeland Degradation

Grass and shrub steppe rangelands are extensive in the Inner Mongolian Autonomous Region (IMAR). Although forest steppe exists in northern Inner Mongolia, and desert steppe and desert, including sand desert and gobi exist, especially in southern (Kerqin Sandlands) and western Inner Mongolia, grass steppe vegetation ideal for supporting extensively managed livestock production predominates. Highly productive rangelands, which formed the basis of traditional pastoral livestock production systems, were comprised of temperate and warm temperate typical steppe, desert steppe, and steppe desert grasslands.

Inner Mongolia has traditionally been considered China's primary pastoral area for livestock production. As noted in table 1, Inner Mongolia is large spatially, encompassing more than 118 million hectares of land, of which more than 78 million ha is considered rangeland. The scale of rangeland degradation is also large, with more than 58.0 percent of rangeland considered degraded (table 3). As noted in table 3, degraded rangeland in Inner Mongolia comprises more than 34.0 percent of the total degraded rangeland in China. According to Fan (1998), most of the rangeland in these areas is being used for crop and livestock production and/or is severely degraded by livestock overgrazing, unsuitable use, and inclement weather conditions.

Eastern Inner Mongolia has been a major focus of rangeland conversion during the previous 50 years. A major portion of the rangeland area of Inner Mongolia receives precipitation between 200 and 500 mm. The occurrence of favorable precipitation with relatively high summer temperatures has fostered conversion of rangelands with high vegetation production potential as annual cropland. Much of the remaining rangeland, which is too marginal to be converted to cropland, has been significantly overstocked during the previous 50 years. Between 1986 and 1996, at least 970,000 ha in 34 counties were converted to predominantly rainfed cropland (Agriculture Department 1998). During the period, converted rangeland was primarily temperate meadow with access to irrigation water or typical steppe with 400-500 mm of annual precipitation. Rangeland conversion was enacted under the auspices of state-owned farms, state-owned forestry farms, government-owned enterprises, joint ventures, waste land auction, and by individual agriculture households, often with duplicitous intent (Yu and Li 2000).

Chifeng City Municipality, Inner Mongolia, is typical of a former pastoral rangeland area in eastern Inner Mongolia that has been transformed from a traditional pastoral livestock production system to a predominantly extensively managed livestock production system to a mixed farming-livestock production or intensively managed agricultural crop pro and livestock "banners" (a Mongolian banner is equivalent to a county). Counties and banners have further separated into livestock production or farming townships, with Han dominant in agriculture townships and Mongolians dominant in livestock townships. Beginning in the 1950s, rangeland with highest natural productivity (meadows and deeper soil grasslands) was converted to marginal rainfed cropping areas in which livestock production was a secondary production activity. In livestock townships, expansion of livestock numbers was encouraged under the Household Responsibility System.

Both policies have significantly increased the stocking rate of animals and fostered degradation of cropland and natural rangeland (fig. 3). In the 1990s, various schemes to exploit remaining natural rangelands for economic gain were promoted by or with the concurrence of the local government. For example, large areas of degraded rangeland in livestock townships were cultivated and used to grow rapeseed or other cash crops. The rationale used to justify growing rapeseed was that rapeseed, if seeded with alfalfa, would cover the costs of the alfalfa seeding. This practice often resulted in stand failure, exposure of soils to wind and water erosion, and abandonment of the cultivated area.

Throughout the region, inappropriate land conversion and subsequent abandonment, overgrazing of remaining natural rangeland, and the agricultural focus on annual crops has seriously decreased sustainability of land use and livelihoods. Although techniques for rangeland rehabilitation exist and have proven to be effective, there is little interest in applying these techniques because of the high cost-to-benefit ratio characteristic of rangeland rehabilitation projects.

Rangelands, livestock and herders in Inner Mongolia have been the focus of national and international attention for years. The first international agricultural development project (1981-1989) was located in several Mongolian Banners of Chifeng City, Inner Mongolia and focused on modernizing the livestock production system and improving rangelands. Since that initial project, most of the international development agencies have had one or more large-scale projects addressing directly or indirectly the same set of problems in the region. A number of bi-lateral projects, including the Canadian Sustainable Agricultural Development Project, have project sites in banners within the Chifeng City administrative area.

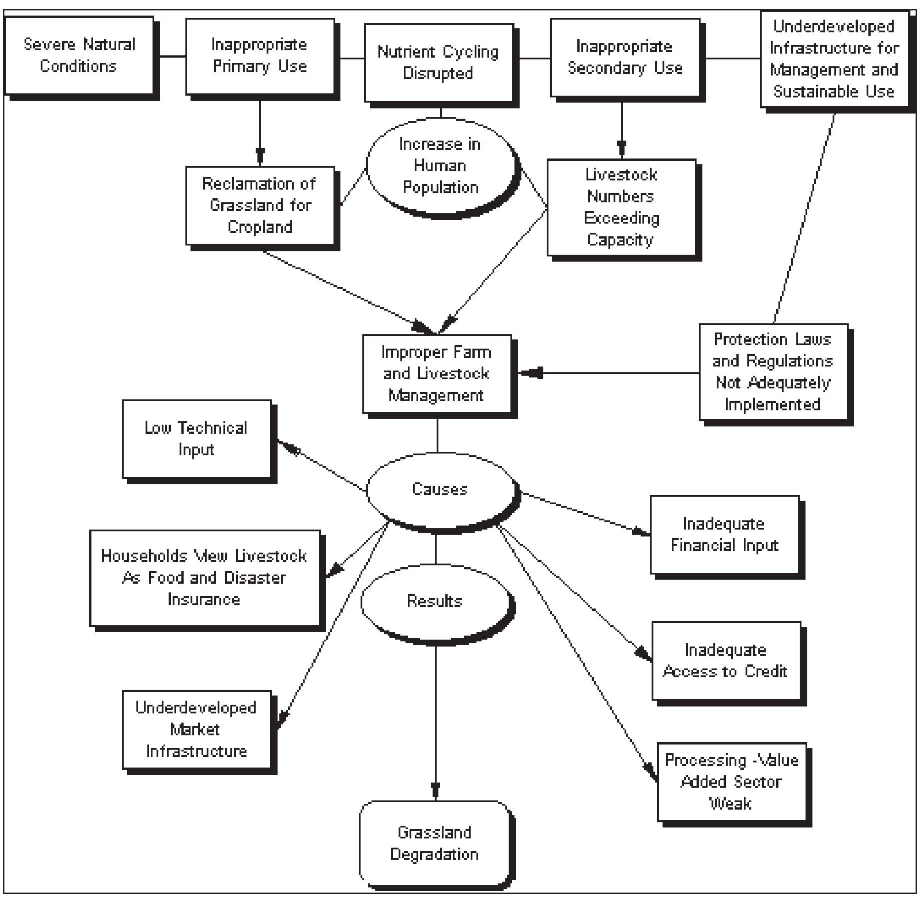

Figure 3—Factors Influencing Rangeland Degradation in One Livestock Banner of Chifeng City, Inner Mongolia (1997). Source: Adapted from "Improvement of Northern Rangeland Ecosystems," Consortium for International Development/ Ministry of Agriculture, 1997.

Yihenoer Pilot Demonstration Area

Yihenoer Sumu is a Mongolian livestock township in Balin Right Banner of Chifeng City. The senior author worked in Yihenoer from 1985 to 1987, studying the grazing resources of the area and developing a range management plan for the Yihenoer Pilot Demonstration Area (YPDA) The YPDA included herders and land area of three livestock production teams. It was established in 1985 by the International Fund for Agricultural Development (IFAD) Northern Pasture Project, which was an on-going project in Inner Mongolia between 1981 and 1989, to demonstrate modern principles and techniques of rangeland and livestock management. This project was co-administered by IFAD and the Chinese Ministry of Agriculture.

The primary goal of the YPDA was demonstrating that balanced use of the YPDA's natural resources could be achieved and that herder livelihoods would benefit as a result. Subsequent to this work, development of irrigation systems in the region led to conversion of a significant portion of the rangeland to annual cultivation. There had also been extensive block-planting of poplar trees, supported by national programs aimed at soil conservation.

Mongolian herding families of the YPDA were organized into three village production teams: Maodu, Aoboa, and Hailijin. By 1987, village production teams were making the transition from organization as rural livestock collectives to Household Management Units operating under the "Self Responsibility System." Livestock were being privatized by household, and the household had greater control of production resources. Most rangeland utilization continued as "common use" but with access limited to members of the village production team. Households were allocated meadow-land to harvest hay for winter livestock feed. A major portion of the irrigated cropping area being developed by the Bureau of Water Conservancy of Balin Right Banner was allocated to Maodu herder households.

The YPDA was subject to major climatic influences typical of east-central Inner Mongolia. Winter and spring winds, which originate in Siberia and Mongolia, bring cold and dust and little moisture to Inner Mongolia until the summer season begins. Consequently, the spring season is almost always droughty. In May and June, a major shift in wind patterns occurs and continental winds are replaced by monsoon winds from the Pacific Ocean. Wind amount and speed is from the northeast during the winter and spring and from the southeast during summer and fall seasons. Approximately two-thirds of precipitation occurred during the May to September season, which also coincides with maximum temperature. Average annual temperature of the YPDA was 6.3 °C with a range of temperature between 29.8 °C in July and –27.2 °C in January. Annual average precipitation averaged 344 mm/year with most occurring as rain during the summer. Total evaporation averaged 1200 mm/year. Frost-free days ranged between 130 and 150 days/year.

The overall increase in livestock numbers experienced throughout Inner Mongolia after 1949 also occurred on the YPDA. Total Yihenoer Sumu livestock numbers in 1987 reflected the high stocking rate that increasingly placed greater demand on rangeland standing crop throughout the year. Between 1985 and 1987, when application of the Household Responsibility System privatized livestock, sumu livestock numbers in terms of Sheep Equivalent Units increased 5.7 percent. Comprising the 14,355 SEU on the YPDA were 1,617 cattle, 337 horses, 2505 sheep, 853 goats, and 103 mules and donkeys. The local BAH was introducing Frisian dairy cattle, Simmental beef cattle, and Merino sheep breeds. By 1987, the animal stocking rate was 0.41 ha/SEU.

Vegetation of the YPDA was typical of the Mongolian Floristic Province and northeastern steppe region. Both grass steppe and shrub steppe vegetation types are found on the YPDA. Temperate and warm temperate typical steppe vegetation dominated by needlegrass (*Stipa* sp.) dominated grass steppe vegetation and *Ceratoides arborescens* and *Atraphaxis manshurica* shrubs dominated shrub steppe vegetation.

Rangeland Ecological Relationships 1987

Six vegetation types comprised rangeland of the YPDA (fig. 4). A moist meadow type occurred on low lying areas that received seepage from irrigation canals. Three shrub types were sandland shrub, Manchurian goatwheat shrub, and Sibirian elm trees with a shrub understory. Lovely Achnatherum was common on clay soils with a high water table. The two dominant types were Typical Steppe on sandy-clay loam soils and Manchurian Goatwheat Shrub on sandy soils. Except for small protected areas, goatwheat and the highly palatable winterfat (*Ceratoides arborescens*) had almost been eliminated from sandland vegetation stands. Plant taxa comprising Typical Steppe rangeland vegetation of the YPDA were similar to taxa found throughout Inner Mongolia and northeastern China. Perennial grasses and forbs dominated over annual species and most species that had increasing presence as a result of disturbance were perennial species. Vegetation on ecologically stable Typical Steppe rangeland was dominated by *Stipa grandis*. Dominant grass species were warm season species that began growth in late spring-early summer, matured in the latter stages of the growing season, and entered senescence in late September. Cool season grasses that were present were dominated by *Aneurolepidium chinense*, *Agropyron cristatum*, and occasionally *Poa* sp. that initiated growth in late March, matured by late June, and entered senescence by late July.

Grazing impacted all vegetation types and communities; Typical Steppe communities and the Manchurian goatwheat communities were least disturbed. Sandy shrub communities in shrub steppe and the Mongolian thyme communities in Typical Steppe were most disturbed communities. In the former community, only remnant shrubs were present while in the latter, upper soil horizons had been eroded away by wind and water.

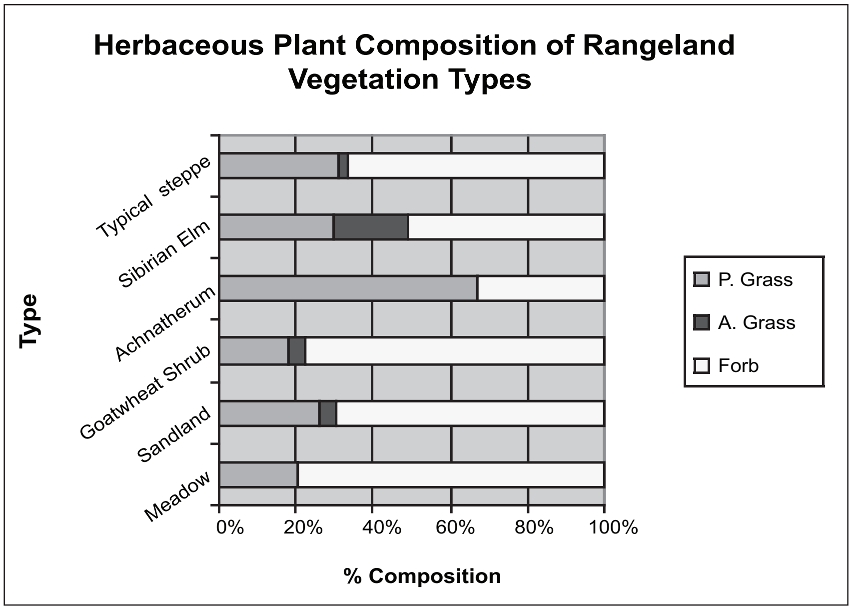

Figure 4—Dominant Vegetation Types of the Yihenoer PDA. Source: Non-published reports compiled by the senior author for the International Fund for Agricultural Development and the Ministry of Agriculture between 1985 and 1987.

Rangeland Condition—An important activity of the YPDA technical support group between 1985 and 1987 was evaluation of rangeland condition and trend. By the late 1970s, there was already recognition by government rangeland technicians and livestock herders that rangelands were declining in productivity and degradation was occurring. A primary objective of the IFAD project and rationale for forming the YPDA was to determine causes and suggest potential solutions to the problem. Typical steppe rangeland of the YPDA, although obviously stressed by 1985, did retain considerable potential to respond to improved management and balanced utilization.

Typical steppe successional communities in the *Stipa grandis* association were Ural licorice, jointfir ephedra, Chinese stellera, and Mongolian thyme communities, which were successional communities formed relative to amount of soil erosion, sand deposition, or disturbance from grazing (fig. 5). Although the four plant communities inhabited sites with similar soil characteristics, disturbance to the original soils appeared to be the primary factor separating the *Stipa grandis* association into different successional communities. The difference in relative proportion of plant growth forms was a primary factor separating successional communities in the *Stipa grandis* Association.

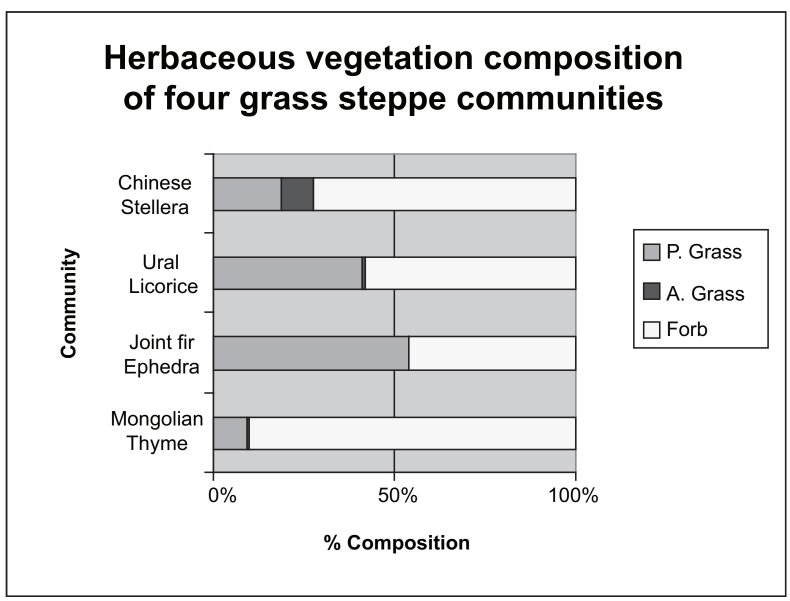

Figure 5—Successional Communities in the *Stipa grandis* Association. (P. Grass represents perennial grass and A. Grass represents annual grass). Source: Non-published reports compiled by the senior author for the International Fund for Agricultural Development and the Ministry of Agriculture between 1985 and 1987.

The Mongolian thyme community had been severely eroded by both wind and water events. Vegetation cover was also low on sites of the community; often the presence of vegetation created "mounds" which retained a portion of the upper soil horizons. Ecological condition of the Mongolian thyme community was rated as poor with declining trend. Although less eroded, the Chinese stellera community had a compacted surface layer caused by animal hoof action during twice-daily movement of animals and frequent grazing. The community had higher presence of grasses than the Mongolian thyme community. Ecological condition of the Chinese stellera community was rated as poor/fair with declining trend. Both the Ural licorice and Jointfir ephedra communities were not obviously being eroded, rather, deposition of wind-blown materials was affecting community stability. The higher ecological condition of both communities is reflected in the higher proportion of grasses occurring in the communities. Ecological condition of both the Ural licorice and jointfir ephedra communities was rated as good.

Chinese Stellera (*Stellera chamajasmae*) Community—Soils of the Chinese stellera community were sandy-clay loam. Soil surface was compacted by high intensity livestock hoof action and a calcium layer occurred between 12 and 36 cm depth in the soil profile. The impenetrable calcium layer defined the effective moisture penetration into the soil, increased moisture run-off during precipitation events, and limited seedling establishment. Graminoid plants were present but had low frequency and cover. Palatable grasses such as needlegrass appeared to adapt to high intensity grazing by growing through the crown of the poisonous Chinese stellera. Crested wheatgrass had low vigor as indicated by a prostrate growth form, low leaf development and low development of seed stalks. Increaser grasses such as scabrous clistogenes had high frequency of occurrence but less than one percent cover. Decreaser forbs such as sickle alfalfa had low frequency while increaser forbs such as fringed sagebrush, Prezwalskii skullcap and Mongolian thyme were the dominant herbaceous plants. Chinese stellera visually dominated the site even though the plant had low frequency. Chinese stellera was highly competitive with other plants in the community. It was observed to flower and mature seeds twice during the growing season, in early June and again in late August.

Yield of forage standing crop in the community was moderate to low (table 4). After three years protection from grazing, total standing crop averaged 1544 kg/ha. Standing crop was comprised of perennial grasses (18.6 percent), annual grasses (9.0 percent), and forbs (72.4 percent). Both soils and vegetation reflected the high intensity grazing by livestock of rangeland near villages.

Jointfir Ephedra (*Ephedra distachya*) Community—Soils of the jointfir ephedra communities had relatively undisturbed profiles. The soil surface was friable and had a relatively high vegetation litter surface component. Cover of perennial grasses and forbs was high and ranged between 54.0 percent and 45.9 percent, respectively, while cover of annual grasses was low. Scabrous cleistogenes was the dominant grass and appeared to increase under high intensity animal grazing. Decreaser grasses such as needlegrass and Chinese aneurolepidium and decreaser forbs such as sickle alfalfa had low cover and frequency. The jointfir ephedra community had live aboveground standing crop throughout the year. Fringed sagebrush formed mat-like growth on heavily grazed areas of the community.

After three years protection from grazing, total standing crop was 2546 kg/ha (table 4). Standing crop was comprised of perennial grasses (9.5 percent), annual grasses (0.5 percent), and forbs (90.0 percent). Forbs classified as unpalatable to livestock comprised 81.2 percent of forb standing crop.

Ural Licorice (*Glycyrrhiza uralensis*) Community—The Ural licorice community was highly impacted by livestock grazing. Increaser plant species dominated composition and soil surface compaction by animal hoof action was evident. Soil condition was deteriorating because of overgrazing and the effect of wind erosion. Vegetation composition of this community was similar to the jointfir ephedra community but without the presence of jointfir ephedra. The community also appeared to be less stable ecologically. The location of the Ural licorice community is close to Maodu village and consequently subject to more intensive grazing and hoof action. Cover of grasses averaged 1.7 percent. Dominant grass species were scabrous cliestogenes and crested wheatgrass. Fringed sagebrush and shrub lespedeza dominated forb cover. Total forb cover was 3.1 percent. Bare soil dominated the community and litter had minimal occurrence.

Table 4—Productivity of Successional Communities Forming Typical Steppe Vegetation.

Community	Yield (Air Dried, kg/ha)	Standing Crop (Percent) Perennial Grass	Standing Crop (Percent) Annual Grass	Standing Crop (Percent) Forbs
Chinese stellera	1544.4	18.6	9.0	72.4
Jointfir ephedra	2545.9	9.5	<1.0	90.0
Ural licorice	1684.2	54.0	<1.0	45.9
Mongolian thyme	1256.6	29.6	19.7	50.7

After three years of protection from livestock grazing, total standing crop averaged 1684 kg/ha (table 4). Perennial grasses comprised 54.0 percent, annual grasses less than one percent, and forbs comprised 45.9 percent of total standing crop.

Mongolian Thyme (*Thymus mongolicus*) Community—The Mongolian thyme community was the most degraded community on the YPDA. The community occurred on sandy-clay loam soils adjacent to herder villages. Destruction of vegetation cover had caused severe wind and water erosion of upper soil horizons, often to the hard infertile calcareous pan underlying Typical Steppe communities. High soil temperature at the soil surface and the calcareous pan limited success vegetation reestablishment. The Mongolian thyme community was nearly devoid of forage species. Mongolian thyme was itself the dominant plant in the community and was recognized as an indicator of poor ecological condition. Fringed sagebrush dominated less deteriorated sites of the community. Vigor of scabrous cliestogenes and green bristlegrass (*Seteria viridula*) was low. Cover of grasses was 1.1 percent. Crested wheatgrass had highest cover among grass species. Cover of forbs was 2.8 percent with highest cover provided by fringed sagebrush and Mongolian thyme.

Standing crop was the lowest, averaging 1256.6 kg/ha after protection from grazing during two growing seasons (table 4). Perennial grasses comprised 29.6 percent, annual grasses 19.7 percent, and forbs 50.7 percent of total standing crop.

A series of small exclosures were established throughout the YPDA in 1985 to evaluate plant response to protection from livestock grazing. Vegetation yield was harvested from the exclosures each year at the end of the growing season (table 5).

The response of vegetation to protection from grazing by livestock was considerable. Many species that appeared to be eliminated from the community were actually present and responded to the removal of grazing-induced stress. This response was especially relevant to grasses considered to be decreaser species. Among the seven perennial grasses commonly encountered on the YPDA, five had a positive response to protection from grazing. The only perennial grass which had an apparent negative response to protection from grazing was scabrous cliestogens, which although relatively palatable to livestock, is considered to be an increaser species. Over 50 percent of the most commonly encountered forbs appeared to respond favorably to protection from grazing, especially species considered palatable to livestock.

The response of Typical Steppe vegetation to protection from grazing by domestic livestock was encouraging and indicated that improved livestock management and balanced utilization could potentially enhance rangeland condition and mitigate rangeland degradation. At the conclusion of the YPDA project in 1987, the senior author had recommended a number of livestock management and rangeland improvement measures to the IFAD Northern Pasture Improvement Project that, if employed on the YPDA and throughout east-central Inner Mongolia, would have substantially reduced the rate of induced rangeland degradation. The foremost recommendation was development of a resource management program which included a balanced animal stocking rate, winter and spring full ration feeding of livestock, deferred rotation grazing systems, and various rangeland improvements including inter-seeding and reseeding of degraded rangeland.

Rangeland Ecological Relationships (2003)

During 1987, the senior author obtained quantitative species composition data from a number of representative areas of different rangeland types at the YPDA. In 2003, a visit to the area under the Canada-China Sustainable Agriculture Development Project allowed the authors to relocate and remeasure about half of the areas sampled in 1987 (others having been destroyed by cultivation or village construction). This provided an opportunity to measure the ecological results of recent land use changes at Yihenoer.

Analysis of the Yihenoer data made use of a draft *Range Condition and Stocking Rate Guide for Inner Mongolia*, which is being developed under the Canada-China project (Houston and others 2004). This is a demonstration of a North American tool for range assessment and planning, adapted to Chinese concepts and using Chinese information and expert knowledge to develop the content. The Guide divides Inner Mongolian grasslands according to ecological regions and ecological sites. The YPDA falls within the moister part of the Typical Steppe Ecological Region. The grazing land of the YPDA is on two main ecological sites. The core area of the township is a level plain with coarse-textured soils (Sand Plain Ecological Site). Much of this land has been converted to irrigated cropland and tree plantations.

The potential vegetation, observed by the senior author in the 1980s in a protected area, is Shrub Steppe dominated by *Ceratoides arborescens, Atraphaxis mandshurica* and *Ulmus pumila*. Surrounding this sand plain are moderate slopes with sandy loam soils supporting Grass Steppe. These areas fall into the *Stipa grandis*/Well-drained Loamy Ecological Site, although degradation through overgrazing has removed most of the *Stipa grandis,* which is interpreted to be the potential dominant species on this type of land. In the range inventory in the 1980s, most of this area was placed in *Glycyrrhiza*/*Ephedra* and *Stellera* community types, which are interpreted to be degradation stages of the *Stipa grandis* type. There are also small areas of Sand Dunes, Meadow, and Marsh Ecological Sites.

In each sample area, 10 Daubenmire frames (20 cm by 50 cm) were systematically placed along a line transect. Percent cover was estimated in cover-classes for all plant species as well as litter, cryptogams, rocks, and bare soil. For the *Stipa grandis*/Well-drained Loamy Ecological Site, transects were averaged and a range condition score was calculated using reference data from the draft Guide. No reference data were available for the Shrub Steppe found on the Sand Plain Ecological Site.

Table 5—Change in Typical Steppe Composition and Yield (kg/ha) After Three Years Protection from Grazing.

Plant Species	Typical Steppe 1985 (kg/ha)	Typical Steppe 1987 (kg/ha)	Change (Percent)
Perennial Grasses			
Agropyron cristatum (D)	63.8	147.2	+83.4
Aneurolepidium chinense (D)	10.1	9.9	-0.2
Cliestogenes squarrosa (I)	317.4	242.7	-74.7
Clinelymus dahuricus (I)	0.2	242.7	+242.5
Pennisetum flaecidium (I)	31.5	32.1	+0.6
Puccinellia tenuiflora (D)	0.0	1.9	+1.9
Stipa grandis (D)	40.8	84.5	+43.7
Annual Grasses			
Seteria viridulus	145.4	224.1	+78.7
Grasslike			
Carex aridula (D)	0.0	2.8	+2.8
Forbs			
Allium odorum (D)	0.0	1.6	+1.6
Anemarrhena asphodeloids	0.0	2.0	+2.0
Artemisia frigida (I)	64.7	72.4	+7.7
Artemisia scoparia (I)	6.8	2.5	-4.3
Artemisia compestris	384.9	393.6	+8.7
Artemisia siversiana	0.0	0.4	+0.4
Artemisia tripolium	28.0	9.3	-18.7
Chenopodium album	2.2	11.4	+9.2
Convoluvus ammanii (I)	21.4	24.5	+3.1
Cynanchum stenophyllum	0.0	3.2	+3.2
Ephedra sinica	92.7	130.6	+37.9
Erodium stephanimum	9.8	13.9	+4.1
Euphorbia fischeriana	1.8	1.1	-0.7
Euphorbia humifusa	3.0	0.0	-3.0
Glycyrrhiza uralensis	14.1	18.0	+3.9
Heteropappus altaicus	0.0	31.7	+31.7
Iris tenuifolia (I)	1.6	3.4	+1.8
Ixeris chinensis	1.8	1.2	-0.6
Lespedeza bicolor	447.3	388.7	-58.6
Medicago falcata (D)	26.5	49.2	+22.7
Messerschmidia sibirica	0.0	2.4	+2.4
Oxytropis psammocharis	0.3	24.5	+24.2
Polygala tennuifolia	0.2	0.0	-0.2
Salsola collina	196.9	160.6	-36.3
Scutelleria przewalski	23.4	20.2	-3.2
Serratula cornata	8.3	2.8	-5.5
Stellera chamajasmae	84.0	9.9	-74.1
Stenoselenium saxatile	7.3	0.0	-7.3
Thymus mongolicus	1.5	24.0	+22.5
Tribulus terrestris	0.4	0.4	nc

The average results for the Grass Steppe were summarized (table 6). There was a general increase from 1987 to 2003 in plant and litter cover and decrease in bare soil cover. However, most of the increase was related to the spread of annual grasses, especially *Enneapogon borealis*, while cover of perennial grasses was low in both years. A number of forb increasers and invaders, both perennials and annuals, also increased substantially. The shift towards a higher proportion of annuals as well as perennial increasers resulted in a decrease in range condition from 48 to 32. The draft *Range Condition and Stocking Rate Guide* interprets range condition scores in terms of the "degradation-state" terminology that is familiar to Chinese rangeland specialists. According to this terminology, the Grass Steppe has shifted from medium degradation to heavy degradation.

Also shown in Table 6 are results for an area of Grass Steppe on Hailijin Mountain, an isolated hilltop that received relatively little grazing in 1987. At that time, it was in much better condition than the surrounding Grass Steppe, with dominance by *Stipa grandis*. By 2003, most of the *Stipa grandis* had disappeared, and *Carex* sp., *Artemisia frigida*, *Lespedeza dahurica*, and *Enneapogon borealis* had increased substantially. Range condition decreased from 93 to 38, a shift from the potential state to heavy degradation.

Table 6—Changes in Vegetation from 1987 to 2003 on Grass Steppe (*Stipa grandis*/Well-drained Loamy Ecological Site) at Yihenoer, Inner Mongolia.

	Average of grazed areas		Hailijin Mountain		
Year	**1987**	**2003**	**1987**	**2003**	
Number of transects	**19**	**13**	**1**	**1**	
COVER (Percent)					
Plants	5.1	35.5	16.6	18.2	
Litter	4.7	24.6	1.8	17.0	
Rock		0.5		18.5	
Bare soil	90.4	75.4	82.0	64.5	
Decreaser Perennial Graminoids					
Stipa grandis	0.2	0.1	10.1	0.1	
Increaser Perennial Graminoids					
Carex spp.	0.0		0.2	1.7	
Cleistogenes squarrosa	0.6	1.8	2.8	1.8	
Trisetum sibiricum		0.6			
Increaser Perennial Forbs					
Allium mongolicum			0.5		
Artemisia frigida	0.5	0.5	1.7	8.4	
Astragalus galactites		0.5			
Ephedra sinica	0.3	1.0	0.0		
Glycyrrhiza uralensis	0.1	1.1			
Lespedeza dahurica	0.4	3.3	0.1	1.2	
Scutellaria przewalskii	0.2	4.5	0.0		
Thymus mongolica	0.2	0.7			
Annual Graminoids					
Chloris virgata	0.1	3.7		0.1	
Digitaria ischaema		1.2			
Enneapogon borealis		9.8		3.5	
Setaria viridis		0.8			
Annual Forbs					
Euphorbia humifusa	0.1	0.6		0.4	
Salsola collina	0.1	1.3	0.1	0.2	
Tribulus terestris		1.9		0.3	
RELATIVE COVER (%)					**Reference**
Decreaser perennial graminoids	10.0	0.5	61.5	0.3	57.7
Increaser perennial graminoids	13.4	7.0	18.2	19.0	12.8
Increaser perennial forbs	57.6	36.6	17.3	56.2	24.0
Annual graminoids	2.1	43.6	0.5	19.6	0.0
Annual forbs	17.0	12.3	2.5	5.0	0.9
RANGE CONDITION	47.7	32.4	92.5	38.0	
DEGRADATION STATE	medium	heavy	potential	heavy	

Upland steppe dominated by *Stipa* sp. accounts for a large part of the grazing land in Inner Mongolia. At the YPDA, this grassland appears to have been substantially impacted by overgrazing, as indicated by low abundance of the most productive decreaser grasses and replacement by increasers. Grazing impact appears to have increased over the years from 1987 to 2003, resulting in further shifts in species composition and loss of range condition. The increase in grazing impact is probably related to the increase in the human population coupled with a shrinking area of grazing land in the township. Overgrazing in the areas close to habitation is a principal cause of land degradation in Inner Mongolia, although the impact at Yihenoer is unusually severe. Over much of the Typical Steppe region, areas that are considered to show medium to heavy degradation are dominated by perennial increasers such as *Artemisia frigida*, *Cleistogenes squarrosa*, *Carex duriuscula*, and a variety of forbs. At Yihenoer, this stage of degradation is found in the least impacted areas, such as Hailijin Mountain, while most of the Grass Steppe shows a more advanced state of degradation in which the perennials have been replaced by annual invaders.

Results for three areas of Shrub Steppe/Sand Plain were summarized (table 7). Changes in the proportions of species varied among sites, with no apparent explanation. However, the most notable trend was a very large increase in plant and litter cover at all sites. Cover of the shrub *Atraphaxis mandshurica* also increased substantially at two of the three areas. These areas were almost bare in 1987, with wind erosion leading to incipient dune formation. The increase in cover, while mostly attributable to annual grasses, has improved soil protection as well as forage production. It is possible that grazing impact has actually declined in the Shrub Steppe because of the conversion of some of it into cultivated fields. Because these fields are not fenced out, herders would be prevented from turning livestock into the adjacent rangeland during the growing season (this may have contributed to the increased pressure on the Grass Steppe, which is more remote from the cropland).

Table 7—Changes in Vegetation from 1987 to 2003 on shrub steppe (Sand Plain Ecological Site) at Yihenoer, Inner Mongolia.

	Grassland Station		Aoboa Grazed Area		Maodu Grazed Area	
Year	**1987**	**2003**	**1987**	**2003**	**1987**	**2003**
Number of transects	**1**	**1**	**3**	**1**	**1**	**1**
COVER (Percent)						
Plants	3.7	56.9	18.7	44.4	6.7	79.8
Litter	6.4	31.0	0.3	30.0	0.4	22.5
Bare soil	93.6	69.0	99.7	70.0	99.6	77.5
Decreaser shrubs						
Ceratoides arborescens		0.5				
Increaser shrubs						
Atraphaxis manshurica		7.6	1.5	1.1	2.7	14.4
Urmus pumila			1.0	0.1		
Decreaser perennial graminoids						
Agropyron cristatum	0.3		0.5	0.3	0.0	0.3
Increaser perennial graminoids						
Cleistogenes squarrosa	1.0	0.1	0.4	5.0	0.5	15.3
Increaser perennial Forbs						
Allium mongolicum	0.1	0.0			0.1	5.1
Artemisia halodendron						4.0
Ephedra sinica						1.4
Euphorbia fischeriana	2.5					
Lespedeza dahurica	0.4	0.7	0.2	3.2	0.0	11.3
Annual graminoids						
Chloris virgata	0.2	37.8	13.8	14.2	0.1	0.6
Enneapogon borealis		2.7		18.4		14.1
Setaria viridis		0.7		1.9		6.6
Annual forbs						
Artemisia scoparia	0.0	2.5	0.1		0.2	
Chenopodium acuminatum		0.1				4.4
Chenopodium album	0.2		0.1		2.5	
Coripermum spp.	0.2	0.3	0.1		0.1	1.2
Salsola collina	0.2	0.9	0.3		0.3	1.2
Tribulus terrestris	0.2	0.7	0.1		0.0	

Deferral of grazing on Shrub Steppe until fall (after harvest of the cultivated crops) would be expected to promote recovery of the rangeland. Many of these areas probably also receive a shelter benefit from the new tree plantations, which would reduce evaporation and wind erosion. The changes in Shrub Steppe illustrate the complexity of the land degradation issue. While there has been a loss of rangeland, increased protection of the remaining rangeland appears to have been an accidental result in this particular area.

By 1987, considerable change had occurred to the YPDA. Agriculture production changes, which were on-going, included: (1) privatization of livestock, (2) physical improvements to degraded rangeland by reseeding and developing rotation grazing systems, (3) development of irrigated land to produce winter livestock feed, (4) introduction of potentially higher producing livestock, (5) diversification of agricultural production activities, and (6) access to agriculture extension technicians providing advice to agricultural production activities. Social-economic improvements included: (1) improved education of children, (2) improved individual household living conditions through government assisted construction of new houses with electricity and running water, and (3) improved market access provided by roads linking the YPDA with population centers of the Banner.

Revisiting the YPDA in 2003 indicated that, while socio-economic development continued to alter herders lives, ecological stability of rangeland had continued to be negatively affected by conversion and overgrazing. There was no evidence that any of the rangeland or livestock management practices initiated or recommended by the senior author in 1987 had been followed, either on the YPDA or the IFAD Northern Pasture project areas. In fact, there was very little evidence that the IFAD Northern Pasture Development project had even existed, other than that herding families were still paying off the loan. It was also obvious that conversion of rangeland was continuing, even though both the 1985 and "new" Rangeland Law prohibits such activities.

The major change in composition of livestock of the YPDA that occurred between 1985 and 2003 indicates the influence of government agricultural policies and the socialist market economy (table 8). Between 1985 and 1987, IFAD project and local government policies promoted development of introduced cattle breeds, especially Friesen dairy cattle and Simmental dual-purpose cattle, and Merino sheep breeds. These breeds were replacing native Mongolian cattle, fat-tailed sheep, and meat goats. During the three years of the YPDA existence, meat goat numbers declined over 55 percent. However by 2003, the herd structure of Maodu Village of the former YPDA was dominated by Cashmere goats, while number of cattle and sheep of both local and introduced breeds were substantially reduced. A major impetus for the high relative number of Cashmere goats was the higher value of Cashmere wool relative to other animal products and the adaptability of goats to degraded rangeland conditions.

Comparison of rangeland ecological condition between 1987 and 2003 also indicated that rangeland degradation had continued after 1987. Key indicators of rangeland degradation on an ecosystem level are: (1) a decline in yield per rangeland unit; (2) a decrease in vegetation cover and height; (3) an increase in the percentage of weeds and noxious plants in species composition; and (4) a change in structure of grass species (Yu and Li 2000). With some exceptions, rangeland of the YPDA in 1987 reflected declining condition. In 2003, key indicators indicated that rangeland condition was continuing to decline, and generally throughout the former YPDA, was in very poor ecological condition relative to the potential natural community that existed as late as the 1960's (Chang, Personal Communication 1987).

Discussion

Current rangeland ecological condition on the YPDA substantiates the growing consensus among government agencies, researchers, and herders that environmental problems and land degradation in IMAR and the northern pastoral regions of China is worsening, and that previous policies and programs have either made the problem worse or have been ineffectual. Livestock production, despite policies promoting intensification, is less efficient, rural poverty is increasing, and the environment is becoming ecologically less stable.

Table 8—Changes in livestock numbers of YPDA livestock between 1985 and 2003.

Type of Livestock	Yihenoer 1985	Yihenoer 1987	Maodu 2003
Cattle	1526	1824	<<<Cattle
Sheep	3370	4609	<<Sheep
Goat	2065	950	>>>>> Goat
Horse	375	375	<Horse
Donkey	101	101	<Donkey
Camel	28	28	<<<<Camel
Mule	2	2	Mule

Although exact livestock numbers were not available, "<" or ">" indicates substantial downward or upward trend in relative numbers.

In Inner Mongolia, the previous 50 years of policies, programs and projects has not led to sustainable use of rangeland resources. These policies, which have affected the Household as the basic production unit, include:

- State Farm/collective/commune production systems which intensified livestock production under socialist conditions,
- Self-Responsibility System which succeeded the livestock collective and privatized livestock by households but continued common use of land,
- Land conversion policies which focused on converting natural rangeland to rain-fed cropland,
- The Great Green Wall environmental program designed to mitigate impacts of rangeland degradation on China south of the wall,
- The Environmental-Economic program which increased the rate of land conversion in farming and livestock counties by promoting conversion of rangeland to three or four-species (1 grass species and 1 legume forb to feed livestock on a "cut & carry" basis, 1 fruit bearing shrub, and 1 tree species for future wood harvest) monocultures,
- Infusion of funds from international and national sources through "quick-fix" projects which are repaid whether successful or not by the rural agriculture household,
- The contract land program, which is on-going and, while a form of household land-privatization, is partially a "top-down" policy response promoting intensification of agricultural production as a solution to rangeland degradation in pastoral areas.
- The *Caokulun* and 4-way programs that promoted higher agricultural production through household land conservation and quasi-commercialization.

Short-Term Solutions

In the past 50 years, scientists and organizations entrusted with finding solutions to rangeland problems have developed an extensive knowledge/information base relating to proper management and maintenance of rangelands. Rangeland improvement techniques exist and have proven to be effective in restoring degraded natural rangelands to a higher ecological condition. Techniques are also available to reduce wind and water erosion of soils on both natural and converted rangelands. Between 1995 and 1997, many of the rangeland improvement techniques applicable to northern and western pastoral rangelands were tested and evaluated in Keshiketeng Banner of Chifeng City, IMAR (Appendix 1).

Although these techniques were tested and evaluated at only two locations, most techniques have had widespread application throughout the northern and western pastoral regions and, with modification depending on local conditions, rangelands in the agricultural region. Common rangeland improvement projects using variations of the above techniques include:

- Livestock feed improvement used in conjunction with seeding forage plants on abandoned or slope cultivated land,
- Construction of artificial rangelands,
- Fencing to protect rangeland from grazing livestock,
- Shelterbelt construction to stabilize moving sand or reduce soil erosion.

Although rangeland improvement techniques generally improve rangeland productivity, other associated factors are often not favorable. Livestock feed production had highest yields but also had high capital requirements and high or moderate financial and environmental risks. Using livestock grazing management to improve rangeland had low capital and financial and environmental risks but a long payback period. Dune stabilization, which involved establishing vegetation cover and protection from livestock grazing, required that no livestock use be allowed in the future. Although not tested in the above trials, "minimum tillage" techniques have been tested by the Sustainable Agricultural Development Project (SADP) and the Agricultural Bureau of the Ministry of Agriculture. These techniques have proved to be effective in reducing wind and water erosion of rangeland converted to rainfed cropland.

These, and other tests of rangeland improvement techniques, illustrate a number of important constraints relative to improving pastoral and agricultural rangelands. Constraints include:

- Restoration of rangelands is costly,
- Rangeland restoration has to be regarded as a continuous, long-term process,
- Rangeland improvements not accompanied by changes in management and administration are usually not sustainable,
- Improving rangeland is difficult or impossible without mitigation of the stresses causing degradation,
- Restoring rangeland stability will require a national program that systematically addresses the problem across provincial and regional boundaries and addresses the needs and desires of the rangeland user.

Changing Production Paradigms

Agriculture production in China is now experiencing a paradigm shift. Traditionally, crop agriculture for food security has been the focus of historical and modern agricultural and social policies. Although food security remains a rationale and major focus of agricultural activities throughout China, other concerns at the national level are beginning to influence agricultural decision-making. Especially important are the national poverty alleviation and environmental programs. Both of these national programs focus on improving environmental and economic conditions in "marginal agricultural areas."

The Ministry of Agriculture (1999), in a document entitled "China National Ecological Environment Program: Contributions of the Agriculture Sector," has developed an approach to restoring degraded rangeland. The ministry's intention as stated is:

> "During the ninth five-year plan period and before the year 2003, for the rangeland construction, based on the effective execution of the Rangeland Law and the long-term paid contracting responsibility system, more

> aggressive efforts will be made for the protection, development and construction of the rangeland. Compatible efforts will be made especially for the grass-feeding animal products processing. The advanced but practical grazing technology will be extended and "*Caokulun* (local Mongolian word, referring to enclosed rangelands for grazing and management) "will be established to accelerate the transformation to intensive management. Enclosed grazing, closure for rehabilitation and rotating grazing will be carried out to increase the animal husbandry production level and ecological environment to realize sustainable development for the rangeland and animal husbandry."
>
> "The priority projects include: (1) degraded, desertified and salinization rangeland control project, (2) the rangeland ecological system assurance project, (3) rangeland pest control project, and (4) rangeland type natural reserve establishment project. From now to year 2003, 4.3 million ha of rangeland will be established, 6 million ha of rangeland will be upgraded, high standard enclosed rangeland of 3 million ha will be established, and pest control will cover 25.3 million ha. In addition, 19 rangeland type nature reserves, 300 rangeland monitoring stations, 20 ongoing monitoring stations and 200 pest monitoring stations will be established."

Although implementation of the priority projects described above indicates an awareness by the central government and the Ministry of Agriculture of rangeland problems and a desire to address problems, the activities involved in the priority projects are not new in their approach. Rehabilitation of rangelands, fencing, construction of artificial rangelands, control of pest species, and development of livestock grazing management strategies have been applied in the northern and western pastoral rangelands for at least 20 years (Consortium for International Development 1998). Yet, the rate of rangeland degradation continues to be higher than the rate of rangeland improvement (Yu and Li 2000). Possible reasons for previous lack of success in controlling rangeland degradation include:

- Failure to control rangeland conversion activities at the county level,
- Failure to follow and enforce provisions of the 1985 Rangeland Law,
- Application of improvement treatments at too small a scale as a result of insufficient funding and/or commitment,
- Addressing symptoms of problems rather than the cause,
- Failure to include a "bottom up" approach that includes the land user in the rangeland solution with the customary "top-down" approach to solving rangeland problems.

It is apparent that "top-down" policies emanating from agencies and bureaus have failed to create a sustaining environment for rangeland use and household based livestock production in the northern pastoral region. It is also apparent that the livestock production system in both pastoral and agricultural regions of China is gradually assuming traits more characteristic of livestock production in an industrial economy rather than livestock production as part of a natural economy (Lickatowich 1999). These traits include:

- Large increases in livestock numbers in certain regions and by individual or commercialized producers,
- Focusing production on what sells in the market place rather than environmentally adapted livestock,
- Changes in herd structure to favor animals and animal products (such as cashmere goats or cash crops produced on reclaimed rangeland) for which a cash market exists,
- Control of large numbers of livestock by a few producers while many producers have access to only a few or, increasingly, no animals,
- Increasing conflict between individual producers and between producers and external economically driven entities over control and access to critical resources,
- Less mobility in the production system as producers gain "de facto" control of critical resources through "right of possession (privatization through household land contracts),"
- Less flexibility in production decision-making as the collective infrastructure and co-resource use agreements made between producer groups to reduce environmental risk (such as storing standing crop forage on set-aside winter range to allow use during severe weather related events) fail.

As agricultural and livestock production becomes increasingly industrialized, herders in the northern pastoral region are being forced by both internal and external factors to adapt to a new version of an industrial economy driven by socialist market economics (as opposed to an industrial economy driven by "command" economics). However, the means and techniques of production available to the household livestock producer have remained relatively consistent with livestock production techniques developed during the previous command-economy industrialization. The infrastructure built during the collective era to support livestock production in a socialist industrial economy is rapidly disintegrating. A new support infrastructure and policies assisting adaptation of the livestock production system to new social and economic realities does not as yet exist.

Actual livestock production continues to use production practices characteristic of a natural economy, but forces that are external to actual livestock production, especially commercial aspects, are forcing the production system to behave as it would in an industrial economy. The large increase in livestock numbers and changing demographics of the livestock population are causing animal density-dependent relationships to become major influences affecting sustainable use of natural resources. Conflict over access to resources is increasing as more and more people either want to obtain a share of a finite set of resources or those who have access to the finite set of resources try to maintain their advantage.

With the introduction of the Household Responsibility Program in the 1980s and Household Land Contract Program in the 1990s, the land user is gradually gaining greater control of resources needed for agricultural production. However, increased control by individuals or group organizations also means greater responsibility must be assumed by the user organization to ensure rangeland use is sustainable. As competition for land and vegetation resources becomes more acute, and as external forces rather than environmental conditions increasingly affect agricultural and livestock production, the need to develop "bottom-up" resource management strategies that directly involve the immediate rangeland user is becoming acute.

Successfully implementing producer oriented resource management strategies requires involvement of several critical participants: (1) government at various administrative levels, (2) technically capable staff to develop and implement resource management strategies imparting sustainability to livestock production, and (3) livestock producers and farmers willing and able to use innovative management and production strategies. Without the active involvement and interest of the three components described above, development and implementation of rangeland management strategies leading to sustainable rangeland use will invariably fail.

A logical sequence of program development is needed to develop a sustainable resource use program applicable to different rangeland regions. Although training of some staff in rangeland management may be needed, technically capable staff is generally available within prefecture and county government agricultural staff. Research institutions with staff capable of providing applied research support to a natural resource management (NRM) program are available from university and research oriented institutions of the province. The most important liability to forming and applying a program of this nature is financial support and government and rangeland user commitment to such an activity.

Long-Term Solutions

The most important "bottom-up" strategy is facilitating development of practical resource management plans that involve collaboration among land users and between land users and government resource administrators. Natural resource management plans are an important tool to develop sustainable use of rangeland resources while improving the livestock production and livelihood potential of livestock producers. Although the livestock producer often views livestock as the most important component of extensively managed livestock production units, in reality the availability and quality of feed resources are the most basic and important components of the livestock production system.

As competition for land and vegetation resources becomes more acute, and as external forces rather than environmental conditions increasingly affect livestock production, the need to develop resource management strategies is also acute. However, successfully implementing a resource management plan requires involvement of several critical participants: (i) government at various administrative levels, (ii) technically capable staff to develop and implement resource management strategies imparting sustainability to livestock production, and livestock producers willing and able to use innovative management and livestock production strategies. Without the active involvement and interest of the three components described above, development and implementation of resource management strategies for sustainable livestock production will fail.

Developing systems at the administrative level where government control and funding intersect with the agricultural producer is a key element for sustainable development and improvement of both pastoral and agricultural rangelands. A sequence of phased steps should be followed:

- Commitment to the systematic rangeland improvement program from government rangeland and livestock management organizations is needed. Research institutes and university departments involved in adaptive research should be included to obtain specific information. Support from local government to implement rangeland improvement projects at township and village levels will be needed. The most important stakeholder will be households and/or groups of households directly involved in livestock production.
- A multidisciplinary team recruited from among the stakeholders will need to be formed to develop and implement the rangeland improvement program. Teams should have links with universities/institutes to provide technical assistance as required to augment local capacity.
- Field staff should be trained to address problem solving using multidisciplinary and participatory approaches. Technical training in database management, application of improvement techniques, and rangeland inventory and monitoring should be provided as necessary.
- Locations to initiate rangeland improvement programs should be selected based on discussions with local officials, farmer-herder and village leaders. Selecting the locations should take into consideration the socio-economic situation, rangeland condition and potential for improvement, and land tenure arrangements. The improvement program should be applied at the smallest administrative unit where government administrative actions interact with agricultural production activities (such as individual livestock production households, producer associations, or groups of producers with access to a common rangeland resource).
- A rangeland improvement program advisory group consisting of county and township government officials, technical staff, and representatives from farm and livestock producer organizations should be established to guide project implementation.
- A formal agreement between rangeland users and agencies implementing the project that defines responsibilities and obligations of all participants is a critical element of the improvement program.
- Preparation and implementation of rangeland improvements requires that resources, including rangeland, water, livestock, financial and human resources, be inventoried. Plans may be made for individuals, groups or associations, and for villages or watersheds with scale of the plan dependent on local situations. A planning process should be adopted before rangeland improvements or developments are initiated.

- Implementing the rangeland improvement project requires: (1) initiating sequences of rangeland development and improvements indicated by the inventory as having highest potential for longevity, yield and being economically beneficial; (2) conducting applied research to institutionalize new knowledge gained at the local level during preparation and implementation of the plan, such as using new tillage methods to reduce cropland soil erosion; and (3) monitoring of rangeland soils, vegetation and use.
- The rangeland improvement program can be used as the basis for developing extension programs with land users. Training field teams can be viewed as extension program for technical information. The rangeland improvement program can also be the mechanism to extend rangeland and animal husbandry improvements and new technologies to herders and herders' associations.

Conclusions

Continued development of rangelands for livestock production and other economic uses in China may be warranted and even necessary to support economic development and improve the livelihood of rural populations. However, to do so without consideration of ecological consequences and application of adequate safeguards is not in the best interests of the rangelands or the people of China. Ongoing and unsustainable management of the northern and western pastoral rangeland regions has caused serious ecological and socio-economic imbalances in those regions. Seriously addressing and resolving these problems will require application of costly remedial measures over a long period of time. Even if mitigation efforts are successful, rangeland stability and productivity potential will be less than existed prior to exploitation.

A majority of China's rural poor live in areas that are now both ecologically and economically marginal for either crop or livestock agriculture (Sheehy 1998). Although current agriculture development programs continue to focus on altering natural rangeland ecosystems or improving existing crop based production systems (such as the intensification of agriculture production), the environmental and economic costs associated with this effort are high and increasing. Also, these programs in the long term may not be in accord with the new national focus on poverty alleviation and environmental improvement. Exchanging environmental risk for both higher environmental risk and economic risk is not conducive to either environmental stability or decreasing rural poverty.

A new approach to rangeland sustainability that integrates scientific assessment, greater and more responsible support from government entities involved in crop and livestock agriculture, and develops suitable alternatives able to meet the needs of farm and livestock production units is needed. A national program that integrates sustainable rangeland use at the household/village level with government administration and scientific institutions engaged in adaptive research is an example of the institution needed if rangeland problems in both pastoral and agricultural regions are to be resolved.

Successfully implementing ecologically sustainable rangeland development, improvement and rehabilitation strategies requires an acknowledgement by all participants that not all problems can be immediately resolved. The major reasons for taking a long term approach include: (1) there are not enough financial resources available to address all problems at once, (2) the problem of high human population density in rural areas relative to ecological carrying capacity can not be easily resolved, (3) ecological improvements are "time intensive," and (4) other important and critical needs in the development of China exist.

While farm and livestock households make management decisions daily, seasonally, and even annually about use of rangelands as a feed resource for livestock, decisions to convert rangeland to other uses, enforce regulations pertaining to use, fund and implement rangeland improvement and rehabilitation programs are the prerogative of government. Government still bears the responsibility to ensure that rangeland use is sustainable and does not promote rangeland ecological degradation.

Many of the same factors affecting resource use are common throughout Inner Mongolia and on the Yihenoer Pilot Demonstration Area. Solutions, especially developing and implementing new approaches to maintaining or restoring rangeland ecological condition under the constraint of continuous utilization, will also be similar. This is especially relevant for the Inner Mongolian Autonomous Region. Insights gained from reevaluating the Yihenoer Pilot Demonstration Area emphasize that herder households in Inner Mongolia and throughout China are in transition to an unknown future. Change that has occurred at Yihenoer in the last 50 years, especially in the last 20 years and that is presently occurring is obvious. Political, economic, and social institutions have obviously undergone radical change since 1987. Change will continue to affect rangeland, livestock, and herders in the northern pastoral region of China, but lessons learned at Yihenoer and other areas can be used to ensure that change is directed towards improving sustainability of rangeland use and the livelihood of farmers and herders.

The most realistic approach to changing rangeland exploitation to sustainable use is selecting small but representative areas to demonstrate how sustainable rangeland use can be achieved. These areas are where government policy, funding, regulation, and support intersect with livestock and farm production units, which are actual users of rangeland resources (such as rural people that form natural resource dependent communities). In both pastoral and agricultural rangeland areas, extensively and semi-extensively managed livestock production or mixed farming-livestock households are hierarchically organized into larger administrative units (village, township, county, and so forth). National rangeland restoration and protection programs, while administered using "top-down" strategies, need to be implemented using "bottom-up" strategies. Developing and then using resource management plans to guide decisions concerning household rangeland use and livestock production can be the key element needed to reverse the trend of rangeland degradation in the northern pastoral region of China.

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Appendix I. Evaluation of Rangeland Improvement Techniques

Rangeland Improvement	Yield (kg/ha)	Net Present Value (12 percent)	Internal Rate of Return (percent)	Capital Required	Payback Period (years)	Financial Risk	Environmental Risk
Livestock Feed Production							
Cultivate/Seed cover crop with *Astragalus*	907	158	79	High	2	High	High
Cultivate/Seed cover crop with Alfalfa	459	143	65	High	2	High	High
Cultivate/Seed wheatgrass	941	213	>100	High	<1	Moderate	Moderate
Cultivate/Seed wheatgrass w/alfalfa	685	286	>100	High	<1	Moderate	Moderate
Cultivate/Seed alfalfa	636	281	>100	High	<1	Moderate	Moderate
Cultivate/Seed silage corn	357						
Pasture Improvement							
Disk Surface /Seed wheatgrass	271	63	73	Moderate	2	Moderate	Low
Disk Surface /Seed alfalfa	279	58	73	Moderate	3	Moderate	Low
Sandland Improvement							
Dune stabilization	-	-	-	High	-	Moderate	Low
Sandland Stabilization	164	267	>100	Moderate	<1	Moderate	Low
Livestock Grazing Management							
Protection from grazing w/Fencing	-55	(21)	<0	Moderate	>5	Moderate	Low
Deferred grazing w/fencing	124	(10)	<0	Moderate	>5	Moderate	Low
Reduced stocking rate w/fencing	127	(5)	<0	Moderate	>5	Moderate	Low

Payback Period — Time required for additional proceeds generated by the improvement treatment to pay back costs of the improvement treatment.

Source: A full description of trial results is available in report form (Chinese and English) from the Ministry of Agriculture/Consortium for International Development. 1997. Improvement of Northern Rangeland Ecosystems. Vol. 1, Final Report. Asian Development Bank TA No. 2156-PRC. 89 p.

The Paradox of the Individual Household Responsibility System in the Grasslands of the Tibetan Plateau, China

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Abstract—*Grasslands of the Tibetan plateau are commonly believed to be degrading as a result of unsustainable grazing practices. In response, the Grassland Law attempts to allocate grasslands based on the Individual Household Responsibility System model that has worked in the agricultural areas of China. However, the actual tenure scenario in the rangelands of Tibet is not as open access as is commonly implied. Communal forms of pasture tenure and management (including village level and kin-group arrangements) are advantageous given the socio-economic and ecological context. This paper will review the inherent logic of opportunistic movement in these high altitude rangelands, the "rationale" for existing grassland policies, and the impacts of these policies in the Tibetan Plateau. It will then discuss models for policy implementation that allow flexibility in legal tenure contract and management arrangements that better reflect the de facto common property situation in these areas. These models reflect local interpretations of policy that promote more equitable resource rights within a common property regime rather than individual "usufruct" property rights as proposed in more strict interpretations of law.*

Keywords: *grassland tenure, individual household responsibility, collective management, grassland policy*

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Introduction

Grasslands of the Tibetan plateau are extensive, covering an expanse of over 2.5 million km^2 (Miller 1997). These cold alpine rangelands extend from the moist sub-humid grasslands of the eastern plateau to the semi-arid alpine desert steppe in the west. These rangelands display a diverse array of plant and wildlife species, and support a large livestock population (over 40 million head) central to the livelihoods of people on the Tibetan Plateau. These ecosystems are extremely resilient, as evidenced by the rapid response of "degraded" rangelands to rainfall and fencing of wetland areas (Banks and others 2003, Miller in press).

Many claims have been made regarding overgrazing and degradation particularly the perceived link between upper basin degradation and lower basin flooding, leading to a number of policy initiatives in recent years, notably a timber ban through the upper Yangtse and Yellow river basins of China (Xie and others 2002) and enactment of environmental legislation that relocates pastoral populations out of upper watershed areas (Richard and Benjiao 2004).

Several causes of degradation have been proposed, including: (1) a drying climate (Miehe 1988); (2) in-migration and population increase (Miller in press); (3) increase in burrowing mammal populations due to ineffective control and rampant hunting of predators (Smith and Foggin 2000); (4) increasing concentration of livestock near winter settlements (Wu 1997);

(5) reduced mobility due to restrictive pasture tenure (Richard 2002, Yeh 2003); (6) breakdown of traditional regulatory mechanisms (Richard 2002); and; (7) lack of government investment in rangeland and livestock marketing infrastructure (Miller 1997). All but the first are strongly influenced by policies.

Pastoralists of China have experienced a number of policy changes affecting how livestock were managed and marketed, and how pastures were distributed, although there were strong continuities in land management systems and herding techniques. (Miller in press, Williams 1996, Wu and Richard 1999). With the advent of a new socialist regime in the early 1950's, livestock were redistributed among households to decrease the disparity between rich and poor. By the end of the 1950's, the commune system was in place in the eastern plateau, although started later in the west. Livestock became the property of the collectives and remained this way until the early 1980's, when economic reforms swept the nation. At this time, livestock were again redistributed to individual households but rangelands were still used communally. Over time, increasing human and livestock populations and redistributions of communal land holdings due to administrative boundaries have led to conflicts over resource use (Yeh 2003) and to subsequent overgrazing, a result of restricting movements as more and more households have settled (Miller in press, Richard 2002).

To address perceived issues of rangeland degradation, the government of China, citing the success of reforms in the early 1980's (specifically the Individual Household Responsibility System in cropping areas), formulated the Grassland Law in the mid-1980's and has been implementing it throughout western China (Banks and others 2003, Thwaites and others 1998, Williams 1996, Wu 1997). Land contracts are granted to individual households as a long-term lease (50 years), renewable provided that land management is satisfactory, while ownership of the land remains government property. The Chinese government justifies its policies due to the difficulty in providing nomads with social services like education and health care, and in responding to heavy snowfalls that have historically led to livestock losses (Wu and Richard 1999).

However, implementation of the law is proving to be difficult in non-arable lands (Schwarzwalder and others 2004), particularly in remote landscapes such as the Tibetan Plateau that are socially and environmentally marginal. Tibetan rangelands are heterogeneous in terms of water and forage availability, and display typically non-equilibrium patterns (Miller in press), even in the more sub-humid alpine grasslands of the eastern Tibetan plateau. The majority of locals depend on diverse livelihood practices besides animal husbandry, such as seasonal cropping, trade, migratory labor, and crafts. Given this reality, the allocation of grasslands to individual families (and its concomitant settlement) may not be the most efficacious means of ensuring access to pasture resources. Given the lack of information on the impacts of grassland policy implementation in China, the International Center for Integrated Mountain Development initiated a series of case studies to understand the actual realities of grassland allocation on the Tibetan plateau.

Study Sites

Figure 1 shows the main counties in the Tibetan plateau of China where research studies have been conducted. Most of the sites are in the more humid eastern plateau of Sichuan, Gansu, Yunnan and Qinghai provinces, situated at an average elevation of approximately 3600 m, where carrying capacity is higher than the more arid western plateau and where implementation of the Grassland Law is further along. Dominated by alpine meadow species from the genera *Elymus, Deschampsia* and *Kobresia,* these grasslands are quite productive and may have the highest stocking densities of any natural grassland in the world, even though they are periodically subject to drought and heavy winter snow falls.

We also include a case study from Naqu Prefecture, in the northern Tibetan Autonomous Region. Here much of the grassland is situated at extremely high elevations (greater than 4500 m), yet receives sufficient moisture to support an alpine meadow community.

Grassland Tenure and Management Arrangements

Table 1 provides a typology of tenure and management arrangements that currently and potentially exist on the Tibetan plateau. Tenure is distinguished from management as the right to claim benefits from a particular resource or set of resources. Management refers to the ways a particular resource is maintained. For example, each household may hold individual plots of land for hay but choose to share labor to plant and plow, yet harvest their own hay crops (individual tenure – collective management). This type of arrangement exists in an agro-pastoral village in Zhongdian County in northwest Yunnan (Xie and others 2002).

Arrangements range from individual household contracts, where land is individually managed (the upper left-hand corner of the matrix in table 1), to large-scale collective arrangements among contract holders across a landscape (bottom right). The former is more suited to crop lands, small winter and spring pastures, and hay fields. Large scale collective arrangements facilitate more effective protection and management of landscape amenities such as biodiversity or hydrological functions. An example of such an initiative would involve agreements whereby downstream users compensate upstream residents for protecting their landscapes to reduce flooding incidences. Such approaches have been tried elsewhere (Koch-Weser and Kahlenborn 2002), but not in China to date.

Figure 2 shows three simplified models of land allocation and management to illustrate how the Grassland Law has been implemented to date. These examples reflect real situations, based on data collected from Hongyuan County, Sichuan Province, and Maqu County, Gansu Province. These models represent the following situations: strict enforcement of the Individual Household Responsibility model (household tenure - household management); customary communal tenure and management

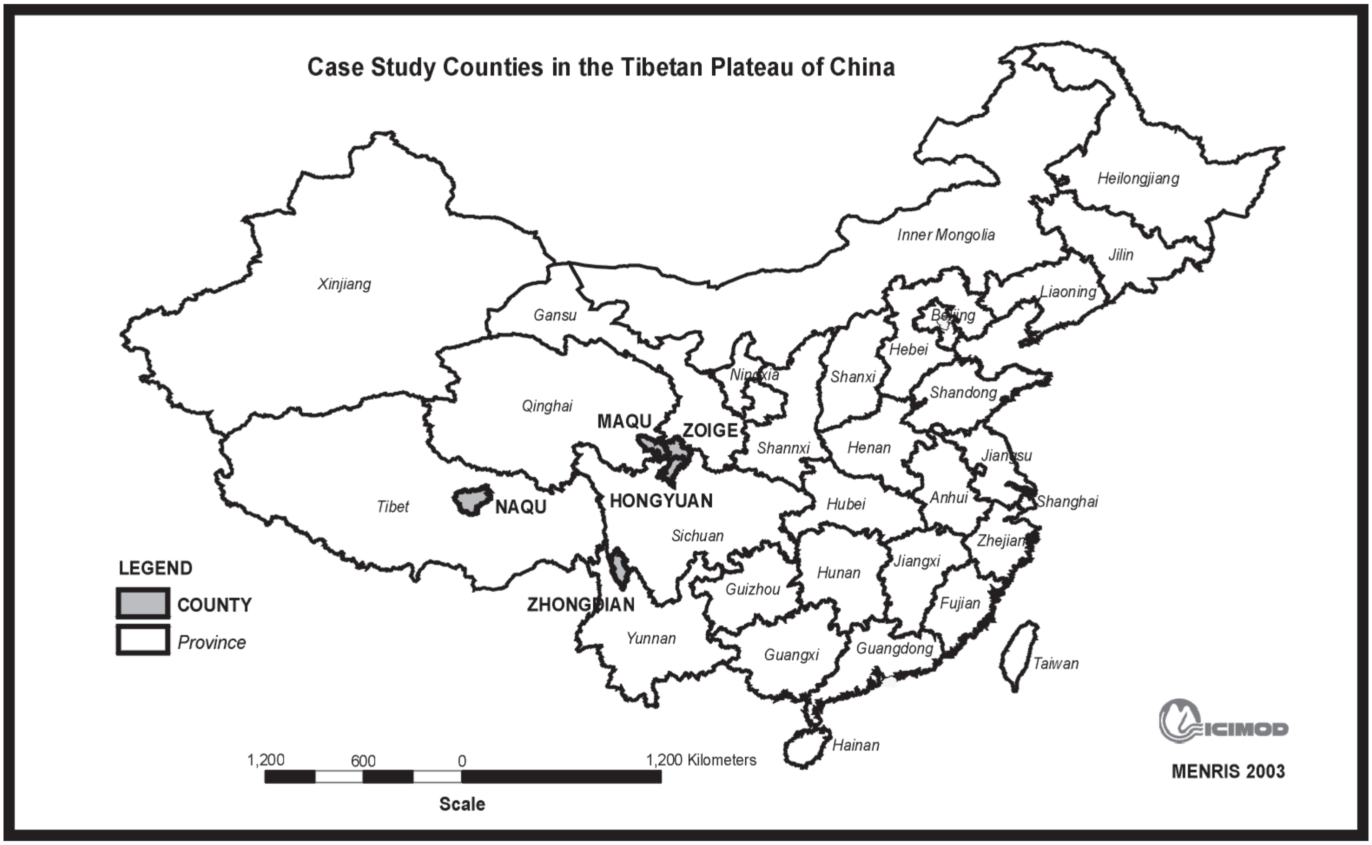

Figure 1—Map of China showing provinces and the main case study counties located in the Tibetan plateau.

Table 1—A typology of potential tenure and management arrangements for rangeland landscapes in the Tibetan plateau. Adapted from Richard (2003).

		MANAGEMENT ARRANGEMENTS		
		Household	**Household group**	**Village collective**
TENURE (legal contracts)	**Household**	➤ Grassland contract with individual household ➤ Management by individual household ➤ Each household derives benefits from their own land *Example: Hongyuan County, Sichuan – see fig. 2 (Yan and others 2002)*	➤ Grassland contract with individual household ➤ Management by household group ➤ Resources shared communally based on household and livestock population *Example: Maqu County, Gansu – see fig. 2 (Du and Zhang 2000)*	➤ Grassland contract with individual household ➤ Cooperative of individual contract holders for pasture or landscape management ➤ Each household derives benefits from their own land *Example: Zhongdian County, Yunnan (Xie and others 2002)*
	Household group	-	➤ Grassland contract with household group ➤ Management by group ➤ Resources shared communally based on household and livestock population	➤ Grassland contract with household group ➤ Pasture or landscape management by cooperative of household groups ➤ Resources shared communally based on household and livestock population
	Collective (village level or larger)	-	-	➤ Grassland contract with village (no internal land division) ➤ Management by village or collective of villages ➤ Resources shared communally based on household and livestock population *Example: Naqu County, TAR (Banks and others 2003, Richard and Tan 2004)*

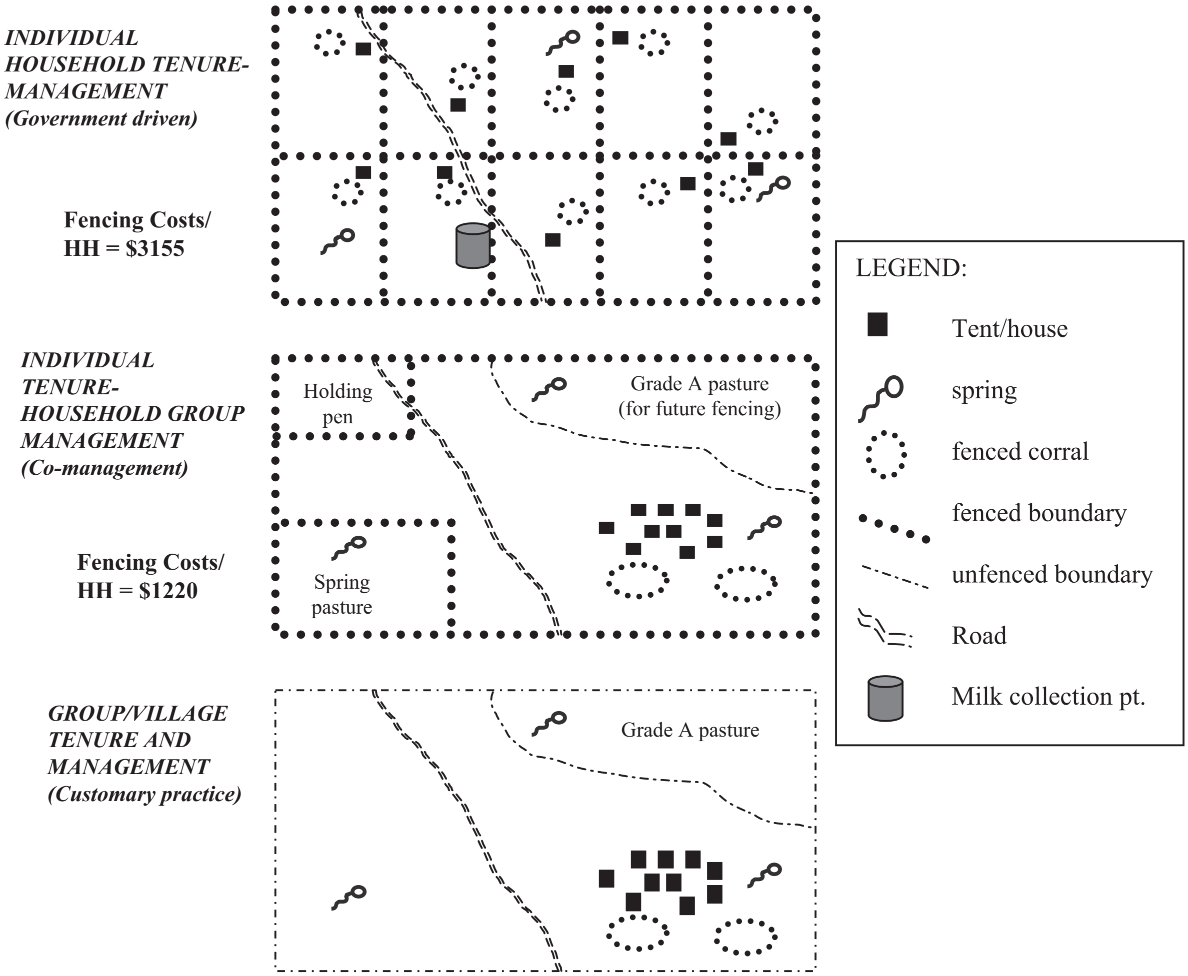

Figure 2—Comparisons of tenure and management arrangements for the eastern Tibetan plateau. The area of each large box represents the total pasture area (ha) required for ten households (HH), each with 300 sheep equivalency units (1 adult sheep or goat = 1 SEU; 6 sheep = 1 horse; 5 sheep = 1 yak), on a total of 1,600 ha of land. Fencing costs are calculated based on the price of 7 RMB/meter (approximately US$1) for fence (Adapted from Richard 2003).

(no enforcement of the Grassland law); and a co-management model that brings together indigenous and scientific strategies, allowing for more flexible policy interpretations and locally appropriate adjustments.

Government driven model—strict interpretation of law

A pilot program has been established by the Sichuan Animal Husbandry Bureau in Hongyuan County, Sichuan Province as a demonstration site for livestock and pasture development programs. Here, families have been settled on individual allotments for year-round use and household management (Yan and others 2002). Although some positive outcomes have arisen from this strict implementation of the Grassland Law (where contracts are allocated to individual households and management is conducted by the household), such as reduced overall labor demand for households and increased survival of herds in the winter, researchers have noted several disadvantages to such an approach. One is that fencing costs per household are often prohibitive without heavy government subsidies. As an example, each household would pay US$3,155 to fence their 160 allotted hectares. Individual allotments also restrict access to water for many households, forcing them to travel long distances to riparian areas (Du and Zhang 2000, Richard and Tan 2004, Yan and others, in preparation). This has lead to increased bank erosion along water courses due to concentration of livestock at watering sites. In addition, Hongyuan County has been designated a milk production zone, which has dramatically impacted herd distribution. Most families want to keep their lactating herds near the road and milk collection points, renting tent sites and pastures from those families who were allocated roadside allotments. The impacts of overgrazing have become quite severe along roadsides near collection points.

These studies have also noted significant social impacts of the individual tenure, individual management model, such as increasing conflicts due to poor allocation of pastures, and widening gender gaps. Although reducing household labor overall, fencing has drastically reduced men's grazing responsibilities, in fact, transferring them to women and children, and reducing the opportunity for children to attend school. The impacts of the individual tenure, individual management model, both positive and negative, are summarized in Table 2.

Allocation of pastures and management responsibilities to the household level appear to be more successful where environmental conditions are more amenable to the cultivation of hay, or where moisture is high enough to ensure relatively good grass growth, such as the eastern plateau. In areas of higher carrying capacity (for example, 0.5 ha/SEU[1] in Maqu County), individual households may be able to obtain enough pasture to maintain small but viable herds. Another important factor is the proximity of county or township government offices, which provide important subsidies for large-scale fencing. In most sites where the government has imposed individual tenure-management, people fence as they can afford it, meaning that wealthier families fence first and continue to graze outside their fence on other's "property" (Williams 1996). Unfenced

[1] sheep equivalency unit is defined locally as one yak equals five sheep and one horse equals six sheep.

Table 2—The impacts of the individual tenure, individual management model, in case study sites of the eastern Tibetan plateau (Du and Zhang 2000, Ma and others 2000, Richard 2002, Yan and others 2002).

	Positive	Negative
Allocation process	On paper the allocation is perceived to be fair and equitable	In reality, poor allocation of pastures in many areas: some receive good quality lands and others poor land
Size of pastures	Has required herders to fix number of livestock	Individual pastures often too small; herders liquidate herds/ rent pasture from those with excess land. Flexibility reduced during drought
Water availability	None documented	Lack of water on individual pastures and lack of access to neighbor's water sources; high cost of water development
Risk management	Livestock mortality reduced through use of reserve pastures	Costs per household high for improvements—require significant subsidies by the government
Social services	Better access to veterinary care and government services where holding pens constructed	Greater isolation of individual households in remote areas
Household labor distribution	Reduced labor for overall household	Gaps between men's and women's labor increased as men spend less time herding; increased labor for children reducing opportunities for schooling
Social conflicts	If boundaries clearly demarcated - reduced conflicts	Increased conflicts over water and pasture resources
Market access	Increased access to markets with use of holding pens, feedlots, settlement	None documented
Eco-system protection	Improved productivity within the fence due to protection during growing season	Degradation of surrounding "commons"; no responsibility for landscape amenities, such as riparian areas which are heavily grazed "outside the fence"

areas experience more grazing pressure as a consequence, resulting in increased weed invasion outside fences.

Inevitably, conflicts arise. However, there are a few examples of government sponsored "demonstration areas" where heavy subsidies have ensured that most households concurrently fence their pastures, such as in Heibei, northern Qinghai (Wu and Richard 1999). In these cases, most households receive fencing and technical oversight so that conflicts are minimized and, for the most part, people stay within their allotted boundaries.

Customary communal tenure and management

Many pastoral communities throughout the Tibetan plateau currently manage pastures communally—with legal rights given to 'administrative villages', government units comprised of smaller 'natural villages' or herding groups that are not officially contracted under current law. Until now, 'natural villages' and herding groups have retained autonomy and set their own rules for pasture access and management, using collective herding and border patrols to enforce boundaries. Some county governments, such as Maqu, refuse to provide government subsidies to such groups if they fail to allocate grasslands according to the strict interpretation of the Individual Household Responsibility policy (Richard and Tan 2004), thus these communities lack government inputs such as fencing and pest control. The obvious advantage to this approach is that fencing costs are nil (see customary model, fig. 2). However, disadvantages include higher labor requirements and greater potential for encroachment by outside communities without effective legal recourse.

Co-management model—flexible interpretation of law

In Maqu County, southwestern Gansu Province, many families have also been legally allocated individual winter pastures and manage at an individual level. They express varying degrees of satisfaction with the allocation process and outcomes (Du and Zhang 2000, Yan and others in preparation, Zhao and others 2004). This county has adopted an approach that allows groups (up to ten households) to pool their pastures for use as a collective, although usufruct rights are held legally at the household level (fig. 2: individual tenure, household group management arrangement). Locally perceived benefits include lower fencing costs, estimated to be only $1,220 per household.

In addition, herders share labor. The number of livestock a household can graze depends primarily on the number of people per household and secondarily on the number of livestock the household possesses. Households that graze fewer livestock than the hypothetical carrying capacities of their share of the joint pasture are compensated by those households that graze more animals. Poor households are ensured access to the forage equivalent produced by their share of pasture, and they can earn supplementary income in the form of rents (Banks and others 2003).

The county government has declared Maqu a meat and butter producing zone, and has established marketing facilities. Consequently, herds are more evenly distributed across the landscape than those in Hongyuan County because these more durable products can be carried to market instead of being collected near the site of production, such as for milk (Richard and Tan 2004). With this type of policy, incentives are in place to ensure that the rangeland areas are more effectively utilized.

Table 3 summarizes the strengths and weaknesses of the three land management models presented. The co-management approach better bridges local knowledge with government support and gives greater legitimacy to practices local communities are already enacting. This is an effective option given the complex nature of rangeland ecosystems and the realities of poverty and subsistence still prevalent on the plateau.

The Paradox of Policy Implementation

An obvious paradox lies in the fact that a strict interpretation of the law, which favors individual usufruct rights and true "individual household responsibility," simply does not match Tibetan cultural or rangeland characteristics. As it is, the vast majority of areas in western China are still managed by common property regimes, despite government claims of over 90% allocation to the household level (Banks and others 2003, Schwarzwalder and others 2004, Sheehy 2001). The *de facto* situation reflects traditional norms and the persistence of village and kinship commons. These groups exclude others at the village level, with varying degrees of exclusion at the group boundary level, and possess informal mechanisms to arbitrate grassland disputes (Banks and others 2003). However, many of these groups lack internal regulation of pasture use leading to unequal appropriation among rich and poor households.

Local county and township governments are increasingly recognizing that pasture boundaries at the household level are not effective beyond smaller winter pastures and hay fields. They have thus been issuing group- and village-level contracts for fall and summer pastures which are typically in more remote areas (Richard and Benjiao 2004). As these groups mature, poorer members with fewer livestock are starting to demand greater benefits from their resource rights, forcing negotiations at the township or county level. They are working out arrangements *within* groups so that poorer households receive compensation for their "rights to grass." In this way, individual rights are ensured within the group, without the ineffective parceling of pastures across the landscape. The paradox is that local interpretation and implementation of "individual household responsibility" is actually providing each household access to grazing resources that are still perceived as common property.

Naqu County in the northern Tibetan Autonomous Region (TAR) is an example of a co-management approach in which resource rights are allocated at the village level and management is collective, but resource rights are fairly accrued to individual

Table 3—A comparison of policy implementation models for resource tenure-management arrangements and their relative strengths and weaknesses.

Government Driven	Co-Management	Customary Practice
Easier to provide services such as credit and veterinary care	Lower risks/costs per household	Lack financial resources and technical inputs
Tenure more secure under situations of conflict and instability	Legal rights ensured per household	Individual households lack equitable rights
Ignores community strengths	Subsidies and technical inputs provided	High (but shared) labor to protect traditional pastures
Creates higher costs/risks	Decisions regarding management made by community	Increasing external encroachment
Creates unintended conflicts due to poor allocation process	Communities' skills are strengthened (social capital)	Greater mobility for grazing
Does not protect large landscape amenities	More facilitation required, especially with larger population	
Reduced flexibility during dry years	Greater mobility for grazing	

households through benefit sharing arrangements (Richard and Tan 2004). Here the government, with assistance from an international non-governmental organization, has established a number of fattening pastures that have been, or will be, formally contracted to a group or village (either administrative or natural). Locations for these improved pastures were selected through consultation with beneficiary communities, and fences were constructed where they serve to protect wetland functions and facilitate rapid growth response. Each beneficiary group has developed rules for pasture use, including stocking rates and timing of grazing, which vary from site to site.

Households are not required to join a group contract. Once the formal grassland contracting process begins, households may choose to take individual winter allotments or to combine land access rights at the group or natural village levels, provided that they decide to do this prior to the land division process. Use rights per family—be they individual or collective contracts—are calculated based on household population (70%) and livestock number (30%). For collective contracts, the county has established a use tax of 0.05 RMB[2]/day for each SEU, so that those that graze more animals pay more. This "grazing fee" is then collected by the village or group leader and redistributed among member households within the village or group, based on the formula above.

[2] At time of publication, one US dollar was equivalent to 8.26 Chinese RMB.

Opportunities and Constraints for Future Policy Implementation

A number of factors currently favor a more community-centered approach to rangeland management on the Tibetan plateau in China. For one, customary practice and native perception of resource rights favors communal arrangements. Historically nomadic populations worked in groups to achieve economies of scale for livestock management in this harsh environment. These customary norms build community cohesion and can facilitate the shift for poorer households toward increasingly market-oriented production practices, provided that individual rights are protected within groups.

There is a growing awareness among policy makers that tenure policies for non-arable rangeland areas require different strategies than those for agricultural lands (Schwarzwalder and others 2004). Since rangelands are not homogenous landscapes, local communities and governments should have the flexibility to create tenure regimes that match local cultural and ecological characteristics. Fortunately, current laws allow site-specific interpretation while simultaneously protecting rights of poorer households. The revised Rural Land Contracting Law (2002), while still maintaining emphasis on contracting rural land to the household, allows joint management where individual households can invest their individually allotted rights in a common pool. The revised Grassland Law states that pastures may be contracted to individual households or groups of households acting as a collective entity.

In addition to these laws, the central government is currently drafting a new rural cooperatives policy (Li Ping pers. comm.). Promotion of local marketing cooperatives in the region can indirectly enhance collective efforts for grassland management as groups that herd together typically market together. Organized group marketing at the township level is a growing trend across the plateau (Richard and Benjiao 2004). A rural cooperatives policy, combined with flexible interpretations of land contracting laws, will grant these fledgling groups more legitimacy.

A constraint to community-based rangeland management is that the new grassland law vests greater power in county, prefecture and provincial governments to regulate land contracting, which could undermine local efforts to influence land use planning and the allocation process. Those mandated to implement these policies often do not understand the laws' inherent flexibility. They often are at the mercy of higher-level decision-makers, and thus there is poor local representation in the grassland allocation process (Yan and others 2004).

A key strategy in promoting community-centered approaches will be to develop implementation guidelines, based on co-management principals, which enable local governments and communities to jointly define and adopt appropriate land management models that accommodate site-specific conditions and aspirations. This will require government officials and technicians to re-orient toward co-management approaches, both through formal training and through involvement in a participatory planning and implementation process at the local level. This can be combined with development interventions that strengthen rural marketing cooperatives and increase access to rural credit for both individuals and groups, which will in the long run reduce vulnerabilities and give pastoralists tools to deal with the risk inherent to the nomadic way of life on the Tibetan plateau.

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Providing Winter Bases for Transhumant Herders in Altai, Xinjiang China: Some Consequences and Lessons Learned

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Abstract—*This case study from Altai in Xinjiang, N.W. China looks at a traditional transhumant system where for centuries Kazakh herders have moved with their livestock from low desert areas, where they winter, to high pastures for rich summer grazing. A project (from 1988 to 1997) introduced winter bases with permanent housing and irrigated forages and cash crops. A 1999/2000 study compared the socio-economic conditions of a group with winter bases and another of nomads. Families with bases had far higher incomes, increasing herds, lower risks and good access to social services. Although alfalfa yields are still far below their potential, winter weight loss in sheep has been converted to weight gain; flocks are mated earlier and lambs ready to slaughter in their first year. Nomadic families had lower incomes, little access to services and own what they carry in their baggage train; their sheep still lose weight in winter and lamb late, so they are kept through a second summer. Because more animals are now carried through the winter there is additional pressure on spring and autumn pastures as well as summer grazing lands. Although there are some changes in the social structures, the project has successfully demonstrated the complementarity of mobile pastoralism and sedentary agro-pastoral development. However, signs of increasing pressure on the grasslands require careful monitoring to determine long-term change in rangeland conditions.*

Keywords: *Xinjiang China, transhumant system, winter bases, irrigated fodder.*

Introduction

In China grasslands cover more than 40 percent of the total land area with 84 percent of them being in western China (Fuzeng Hong and Ren Jizhou 2001), much is semi-arid and high plateau pastoral land. As with other major grassland areas, China's grasslands are being subjected to many negative forces and to rapid change. According to Miller (2001) estimates suggest that about 34 percent of all rangelands in China are moderately to severely degraded and about 90 percent are degraded to some degree. The future of China's grasslands is of increasing concern for the livelihood of many people; the grasslands are important areas for the conservation of biodiversity, with their many distinctive species; the headwaters for many of Asia's major rivers are found in these areas so what happens in these grassland areas will have important implications for millions of people downstream. In spite of their extent and importance, China's grasslands are being subject to the many forces of degradation and difficult decisions will have to be made to reduce the extent of land degradation and loss of biodiversity and to safeguard this vital resource for China's future generations. Miller (2001) suggests that managers will face difficult challenges and decisions in order to ensure the sustainable development of the grasslands.

With rising population the present pressure on the grasslands can only increase. We are aware of what is happening at a global level, but what is happening within some of the areas that make up these large global ecosystems? Are management systems being developed that will not only provide the offtake needed now (in terms of meat, milk and fiber and so forth), but also ensure that in the longer term there is no degradation and loss of the resource? Are we certain that our management systems will ensure the sustainability of the grassland and of the way of life of herders and farmers? Are we making good use of the grass and water and will the same resources be available for future generations?

This paper focuses on a case study from Altai in Xinjiang, N.W. China and looks at an ancient transhumant system where for centuries Kazakh herders have moved with their livestock from the low desert areas, where they winter, to the higher summer pastures for rich summer grazing, moving back down again as the days become shorter and colder (fig. 1). A project to introduce winter bases with permanent housing and irrigated

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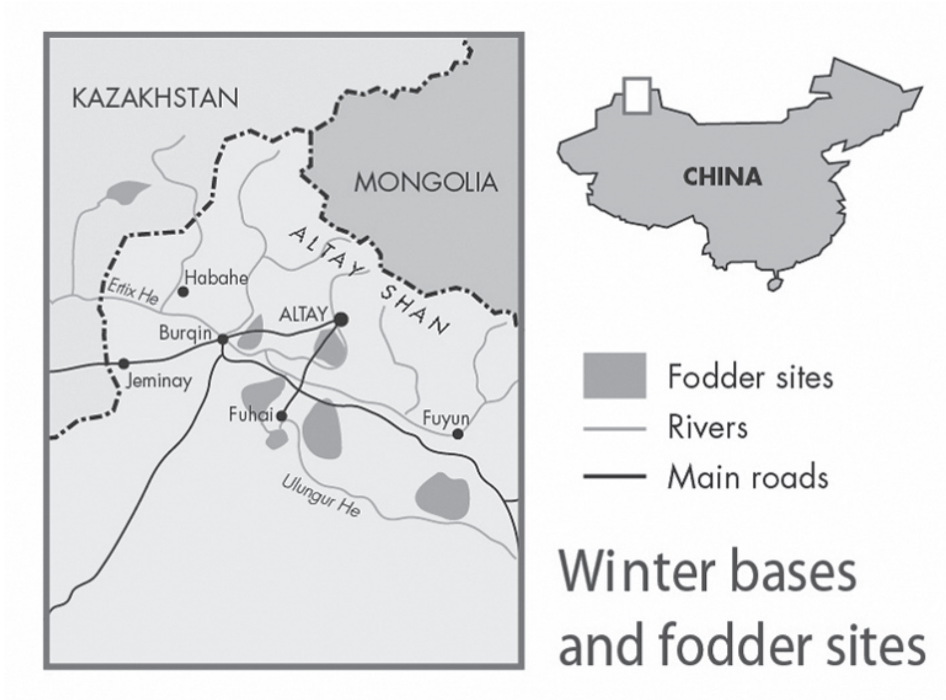

Figure 1—Study area location in China and winter bases and fodder sites.

land for forages and cash crops has had a significant impact on their way of life. What have been the consequences of the changes introduced? How does the socio-economic status of these herders compare with that of traditional nomadic herders who still follow the "old ways"? Are the systems of management and development that have been adopted sustainable in the longer term or is the development leading to instability and seriously degrading the grassland resource?

The Case Study in Altai Prefecture, Xinjiang, China

The rearing of livestock using transhumant production systems is the main land use and livelihood in large areas of the arid and semi-arid temperate zones of Asia. One of the major constraints to improving livestock production and family incomes (Li-Menglin and others 1996) is the lack of feed during winter and early spring which reduces the number of animals that can be carried through the winter and also means that pregnant breeding stock may be at their most vulnerable in the period of lowest feed availability. Attempts have been made in a number of countries to settle nomadic people permanently, often with less than desirable social consequences. This project attempted to provide settled bases for herders, where fodder for the winter period is produced and where education and social facilities for the herders' households are provided, but where, for the major part of the year, the traditional transhumant system is followed. This paper looks not only at the effects of providing settled bases, but also compares two transhumant groups: one provided with irrigated land for hay and crop production and permanent housing in settled winter bases and the other traditional nomads with no settled base who spend their winters in the low desert areas.

The context—Altai Prefecture is located in the northern part of Xinjiang Uygur Autonomous Region in China near its border with Kazakhstan and Mongolia. Bounded on the north by high mountains and cut off from southern Xinjiang by a large expanse of desert and semi-desert, this is an area with a markedly continental climate, hot summers, very cold winters, snow and low rainfall. The mean minimum temperature for January is –26 °C and the mean maximum for July is 30 °C. Precipitation, which mainly falls as snow, ranges from less than 100 mm per annum on the plains to more than 600 mm per annum on the high pastures, where the problem of high winds, snow and spells of extreme cold, with temperatures of less than –40 °C, means that many areas of high pasture are open for less than 3 months each year. Of the total area of 11.8 M ha, more than 9.8 M ha are pastoral and over half of the population is engaged in livestock farming (dominated by transhumant systems) which contributes nearly 60 percent of the value of agricultural production in Altai.

The main livestock are cattle, sheep, goats, horses and camels, with sheep and cattle being the most important. Most Kazakh herders follow a transhumant way of life with good summer grazing for their stock on lands above 1,300 m limited to only 2.5 to 3 months per year (late June to late September). In spring (April to late June) and autumn (mid-September to end November), the herds feed on the heavily grazed transition routes and in winter (December to end March) they feed on the desert plains. The transhumance route is long, 180 to 200 km one-way from the desert plains to the high summer pastures.

The project—A number of rivers and areas of relatively flat land provided the base for an irrigation-based solution to the winter feed problem. From 1988 to 1997, a development program was implemented to produce and conserve fodder by cultivating over 20,000 ha of irrigated land for hay. The production of alfalfa (*Medicago sativa*) in rotation with crops on the irrigated land was assisted by the World Food Programme (WFP) and the United Nations Development Programme/Food and Agriculture Organization of the United Nations (UNDP/FAO). Starting in 1988, work was begun at Burjin, Fuhai and Altai to produce "through irrigation by gravity of 34,425 ha of land, large quantities of hay, expected to reach 130,000 tons per year at full development, and to settle 8,650 families through the allocation of irrigated land" (Li-Menglin and others 1996). By 1997, some 6,100 Kazakh households had been settled, and 32,000 ha had been developed, providing 20,000 ha of alfalfa (*Medicago sativa*) pasture. The average farm size is 3.7 to 4.3 ha, producing annually about 18,000 kg of hay from 3 ha (with the remaining land utilized for wheat, maize, beet or sunflower) with a house for winter quarters for the family and for those who remain on the plains for haymaking in summer while the livestock are away on the summer pastures. Usually a proportion of the wheat, soybean and sometimes alfalfa are sold. Some farmers grow maize solely for making into silage. With 26,700 ha of existing alfalfa land and the newly established 20,000 ha, the present area in Altai Prefecture is some 46,700 ha and there are plans to establish another 20,000 ha under the Ninth Five Year Plan.

Results

Visitors to the area can quickly appreciate the degree of success of the project in transforming former (Gobi) desert areas into productive irrigated farms, and herders into herder/farmers. The project has had a very big impact in Altai and is accepted as a model for further Kazakh herder resettlement schemes (Anon 1992). The findings of the 1995 evaluation mission were that "the project has attained its ambitious targets. An area of 30,218 ha is under irrigation and settlement of 7,550 Kazakh herdsmen is proceeding on schedule. Food security for the region as well as household food security of the target population has been dramatically increased without dismantling the traditional socio-economic system upon which livestock transhumance is based. The project's beneficial impact on living conditions is evident and has resulted in a steady increase in family incomes and access to education and health facilities. However, the future of pastoral farming in the region is ecologically fragile because of the constant threat of the "salting-up" phenomenon. Proper drainage maintenance and efficient water management are crucial. Livestock pressure on transitional pastures will also need to be monitored carefully. Therefore sustainability is heavily dependent on a continuous and scrupulous management of the environmentally sensitive components of the project" (Reynolds 1998).

Comparison of Project Herders with Traditional Herders

In 1999 and 2000 I examined the transhumance patterns and socio-economic conditions of two groups: (1) the project herders with irrigated land for hay and crop production and permanent housing, and; (2) the other traditional nomads still following the "old ways." In each group 9 households (in 3 sub-groups of 3) were selected and studied and data collected. The project Group was referred to as the Treatment Group (64 people, 30 males and 34 females) and the traditional group was the Control Group (61 people, 31 males and 30 females). Data were collected throughout the year from the households both in the winter and summer areas as well as on transitional spring and autumn pasture transhumant routes. Only a part of those data is presented here; for further details see Wan Lin Wang (2003).

A comparison of livestock numbers—Tables 1 to 4 demonstrate the differences in livestock numbers between the control and treatment groups in years 1999 and 2000 with the settled bases and fodder crops for winter feed enabling many more animals to be carried through the winter and for higher numbers to be sold.

Table 1—Livestock of the control group in 1999 (head).

	Number at start of year			Fate		Total number
Species	Total	Females	Weaned offspring	Killed for home use	Sold	at year end
Cattle	121	57	51	8	20	144
Horses	74	19	11	5	4	76
Camels	26	12	7	–	1	32
Sheep	670	459	452	64	269	789
Goats	108	66	64	27	16	129
Total	999	613	585	104	310	1170

Table 2—Livestock of the control group in 2000 (head).

Species	Number at start of year Total	Females	Weaned offspring	Fate Killed for home use	Sold	Total number at year end
Cattle	144	49	46	7	32	153
Horses	76	12	12	4	3	70
Camels	32	1	1	–	–	24
Sheep	789	501	494	90	346	735
Goats	129	90	94	28	37	155
Total	1170	653	647	129	418	1127

Table 3—Livestock of the treatment group in 1999 (head).

Species	Number at start of year Total	Females	Weaned offspring	Fate Killed for home use	Sold	Total number at year end
Cattle	126	61	34	14	25	121
Horses	68	19	11	3	2	74
Camels	24	10	1	–	–	25
Sheep	834	714	667	89	460	952
Goats	62	29	27	5	1	83
Total	1114	836	740	111	488	1255

Table 4—Livestock of the treatment group in 2000 (head).

Species	Number at start of year Total	Females	Weaned offspring	Fate Killed for home use	Sold	Total number at year end
Cattle	121	47	45	11	34	136
Horses	74	13	10	2	12	74
Camels	25	4	4	–	1	24
Sheep	952	637	634	119	408	1055
Goats	83	37	40	14	13	99
Total	1255	736	733	146	468	1388

Economic Comparison—Tables 5 to 8 show the differences between the two groups in terms of agricultural income, production expenses, household expenses and per capita income. Thus, families in the project treatment group with irrigated land and hay had far higher incomes. Their herds are increasing and risks are much lower. They also have good access to medical, educational and other facilities, and are investing in production equipment and household goods, although alfalfa yields are far below their potential, largely because herders are unwilling to provide inputs. Winter weight loss in sheep has been converted to weight gain through shelter and feeding hay; such flocks can be mated earlier and the lambs brought to slaughter weight in their first year. Nomadic families (the control group) had lower incomes, little access to services and own what they can carry in their baggage train; their sheep still lose weight through winter and lamb late, so that many have to be kept through a second summer.

Consequences and Lessons Learned

- For the project herders incomes have increased, risk has been reduced;
- Undoubtedly the project has had a dramatic impact on most of the herders involved. During interviews herder/farmers visited expressed satisfaction with the new way of life;
- In interviews with traditional (non-settled) herders it was noted that they also were hoping to be selected for participation in future schemes;
- For the settled families, the big change in their lives is that, with the farm base, life has become easier, especially for the women upon whom many of the hard tasks fall in the traditional transhumant way of life. There is better access to medical facilities, the children can attend school, entertainment such as television is available and family incomes have increased. Of the families interviewed, it

Table 5—Agricultural income of both stury groups (RMB)[1].

	Control Group		Treatment Group	
	1999	2000	1999	2000
Livestock Sales	98,642	133,680	126,150	170,950
Milk	1,900	33,800	22,176	23,260
Skins	–	6,340	620	3,050
Wool	–	10,155	11,778	3,250
Subtotal Livestock	100,542	183,975	160,724	200,510
Other	57,058	10,950	9,900	33,180
Crop sales	–	–	61,584	126,464
Fodder	–	–	47,860	129,469
Straw	–	–	29,059	–
Machinery hire	–	–	45,200	10,500
Total	157,600	194,925	354,327	500,123
Per household	17,511	21,658	39,370	55,569

[1] In 1999 and 2000 1US$ was equivalent to about. 8.28 RMB (Yuan Renminbi)

Table 6—Production expenses of both study groups (RMB).

	Control Group		Treatment Group	
Item	1999	2000	1999	2000
Moving and Transport	2,120	7,850	3,700	700
Herding by others	970	5,000	11,868	17,228
Animal health	5,420	5,338	4,024	7,851
Salt	980	870	1,276	2,730
Pasture fee	1,358	1,564	631	1,030
Fodder	2,860	10,500	71,887	86,202
Other	3,320	16,740	100	370
Water and electricity	2,799	2,144	19,668	14,780
Construction	1,650		7,130	3,000
Machinery and tools		2,180	2,200	1,060
Subtotal livestock and general	21,477	52,186	122,484	134,951
Ploughing and harvesting			22,197	22,040
Fertilizer and pesticides			27,349	21,997
Seed			21,193	12,969
Total	21,477	52,186	193,223	191,957

Table 7—Per capita income of both study groups (RMB).

	Control Group		Treatment Group	
	1999	2000	1999	2000
Total income	157,600	194,925	354,327	500,123
Population no.	61	59	59	61
Per capita income	2,583	3,303	6,005	8,198
Income per household	17,511	21,658	39,369	55,569

Table 8—Household expenses of both study groups (RMB).

Item	Control Group 1999	Control Group 2000	Treatment Group 1999	Treatment Group 2000
Food and basic commodities	52,183	51,468	89,299	133,510
Clothing	17,900	17,000	29,500	28,040
Marriages and funerals	14,000	11,200	15,100	26,250
Tuition	15,496	8,440	26,650	20,300
Medical	5,630	9,650	17,270	4,460
Various fees	–	8,036	–	5,860
Fuel	–	–	–	6,570
Building and repair	13,060	–	18,580	–
Other	10,200	5,986	1,052	2,240
Total	128,469	111,780	197,451	227,230
Expenses per household	14,274	12,420	21,939	25,248
Expenses as percent of net income	67	43	35	32

was significant that most of the sons preferred to become farmers rather than herders; in one family, the young son wanted to be a tractor driver/farmer and the daughter a teacher;

- While good crop yields are, in many cases, being obtained by project herders and rotational systems (alfalfa, wheat, soybean, maize, sunflower and so forth) are being introduced, there remain many problems such as the low use of fertilizers, poor crop management, low crop productivity, diseases of alfalfa such as anthracnose, lack of good quality/certified alfalfa seed, the considerable problem of dodder (*Cuscuta* sp.) in alfalfa, the need for good management of the irrigation system to prevent vegetation growth in drainage channels and to prevent salinization and the need for continued herder/farmer training;
- Early trials have demonstrated the need for phosphate fertilizer both at establishment and for maintenance;
- Well-managed alfalfa fields have remained in good condition for about four to six years and thereafter one cereal or cash crop is taken before resowing to alfalfa, generally under a nurse crop of wheat, sunflower or beet;
- Although there is increased focus on crop growing, maize and alfalfa are grown mainly to feed the animals and the income from livestock remains for most families the major source of income;
- Because more animals are carried through the winter there is additional pressure on spring and autumn pastures (in particular), as well as summer grazing lands;
- Most herder/farmers have more than doubled their numbers of livestock owned since settling on their farms; the number of sheep and goats owned per family unit ranges from 50 to 130 (mean of 85) and the number of cattle and horses ranges from 5 to 30 (with a mean of 16). The increase in numbers of livestock per farmer has come about largely because of the ability to overwinter many more animals (because of feed, shelter and no predators like wolves), and by lambing in January instead of March/April, the liveweights had been increased by sale time in October;
- Already there is a tendency for some families to become sedentary farmers by contracting relatives, or even hired herders, to take their flocks to summer grazing. This results in some changes in the social structures, however, food security and the overall quality of life has been dramatically increased without dismantling the basic traditional socio-economic system upon which livestock transhumance is based.

Is the system sustainable?

At the present moment in time the (transhumant) system that has evolved over many centuries and been modified with the recent introduction of irrigated lands (for haymaking and the growing of winter feed) and winter bases, appears to be approximately in balance, with fluctuations due to wetter or drier years; certainly the lot of the Kazakh herders involved has improved, but even so there are worrying signs:

- Herders on the high summer pastures speak of many more families visiting the area than previously with larger herds (Reynolds 1998); increased livestock numbers and more herders needing more wood, water and grass are placing additional pressure on the summer pastures;
- While herders have increased incomes by being able to carry more animals through the winters and lambing earlier, these additional numbers are leading to additional pressure on the already heavily grazed intermediate grasslands in spring and autumn. Is there sufficient control of livestock numbers in terms of the carrying capacity of the grasslands?
- Problems on the irrigated areas include the whole process

of training herders to become farmer-herders, poor irrigation techniques, build up of saline areas due to poor water management, dodder development in alfalfa, low crop yields, low fertilizer use, lack of experimental work to study rotations etc.

Overall Conclusions

Although the system presently appears to be approximately in balance there are signs of increasing pressure on the grasslands and both these and the irrigated crop and fodder areas require careful monitoring, not for short-term fluctuations but for longer-term change.

- Government focus on the issues associated with grazing rights, access to grazing lands, and the effects of any changes to traditional systems is needed;
- To varying degrees the problem of animal numbers has to be addressed. The provision of winter feed to enable more animals to be carried through the winter will place greater pressure on spring, summer and autumn pastures and the situation needs to be closely monitored. Uncontrolled stock numbers is a key issue both for sustainable grassland systems and for improved incomes;
- Long-term success in terms of sustainable grassland systems depends on full people's participation, and taking note of the aspirations of the local population;
- It is possible to settle pastoralists successfully, without destroying their pattern of life, as long as it is recognised that their survival depends upon maintaining their overall mobility for a portion of the year so that the flexibility remains in their system to sustainably exploit natural resources;
- The concept of a settled base for transhumant herders can work well by providing extra feed for feed shortage periods (from intensively managed fodder production areas) and increasing incomes, as well as providing a base for the provision of services (such as education and health). The concept is particularly favourable for families, women and children;
- Changes in systems may be slow and long-term and even may not be apparent in the short-term. Government resources are needed over the long-term with a willingness of responsible parties to take appropriate political and economic decisions that may be required for the sustainability of rangelands and for the long-term benefit of the peoples dependent on these areas;
- Changing institutional, economic and marketing conditions - nationally, regionally and globally - will have a significant effect on rangeland use in the coming decades. With globalisation, decentralisation and liberalisation, the focus on technological development will have to be in parallel with social, environmental and ecological considerations.

This paper has looked at only one case study which appears to be fairly resilient and sustainable at the moment, but perhaps we need to bear in mind the words of Miller (2001) who noted that in general: "…current livestock production systems in many of the pastoral areas of China now appear to be unsustainable and development of intensive livestock production systems as a means to increase production of livestock products and alleviate poverty in pastoral areas will place additional pressure on rangeland ecosystems."

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Fragmenting Pastoral Mobility: Changing Grazing Patterns in Post-Soviet Kazakhstan

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Abstract—*Kazak nomads were seasonally mobile in the pre-Soviet period, in response to climate variability and landscape heterogeneity. The scale of these movements was interrupted during the Soviet period, but some degree of mobility remained. Mobility virtually ceased in the post-Soviet 1990s, but is re-emerging as flock numbers rebound from the mid 1990s population crash.*

The paper presents results from a three-year multidisciplinary study in southeast Kazakstan, from 2000 to 2004. The study areas cover ecological transects of up to 600 km in length, which in some cases are still traversed by pastoral flocks. The transects cover desert, semi-desert, riverine, semi-steppe, foothill and sub-alpine pastures, with precipitation ranging from 150 mm to 650 mm.

Results show the proportions of livestock grazed around villages and those which are seasonally mobile. Animal nutrition and economic factors associated with livestock mobility are presented. Forage assessments indicate discrepancies between available resources and their exploitation, due to decreasing mobility.

Under the current grazing systems, pastures distant from settlement are now mainly unused and former integral grazing circuits have therefore become fragmented. Non-mobile livestock have lowered productivity compared to mobile livestock.

Keywords*: Kazakstan, pastoralists, seasonal mobility, economic change*

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Introduction

Rangelands in Kazakstan occupy nearly 70 percent of the country, covering over 180 million hectares, most of which is semi-arid with less than 300 mm annual precipitation.

The rangeland ecology is heterogeneous at a large regional scale (Asanov et al. 2003). Climatic variability in precipitation and temperature occurs spatially and temporally across latitudes and altitudes. Four major rangeland vegetation types are associated with these major transitions in climate and topography: grassland steppe in the north, giving way to semi-steppe and semi-desert in the center, with deserts in the southern regions and alpine meadows in the mountains rimming the plains to south and east. Each of these broad zones contains myriad smaller-scale soil and vegetation complexes (Rachkovskaya et al. 2003). There is a complicated pattern of productivity between intrazonal ecosystems as well as considerable seasonal and interannual fluctuation in biomass (Gilmanov 1995).

Traditional Kazak nomadism knit these distinct zones together through seasonal migration to different pastures (Fedorovich 1973; Zhambakin 1995). There were two characteristic annual cycles, with many variations; latitudinal from south-north-south starting in spring and traversing distances from 200 to 2,000 km, and secondly, vertical, from plains in winter, spring and autumn to mountains in summer, of much shorter distances. Two principals underlay these nomadic movements; firstly that livestock should only stay for short periods in a single place in order not to graze regrowth, and secondly, that tracts of pasture were grazed only at the onset of maturity or at their seasonal productivity peak (Alimaev et al. 1986). In addition to meeting livestock feed requirements, other crucial factors underlying nomadism were avoidance of deep snow and severe cold in winter, and providing access to water (Khazanov 1984).

In the last two centuries, the extent of flock mobility has expanded and contracted in response to fundamental changes in national political and economic systems (Alimaev and Behnke 2003; Alimaev and Temirbekov 2003). These changes are first recorded in the period of Russian imperial expansion into Kazak tribal lands during the 19th Century. Changes in the 20th Century were initiated with the Communist revolution and subsequent collectivization of Kazak livestock into state-managed farms (1920-1935). Further changes encompassed the post-Stalinist state farm expansion and emphasis on high livestock output (up to the end of the USSR in 1991). In the last decade, the pastoral Kazaks had to cope with the immediate post-Soviet economic crisis, dissolution of state farms and loss of 70% of the national flock (1992-1999). The current period is one of rebuilding private livestock holdings starting in 2000.

Seasonal livestock mobility by Kazak pastoralists allowed the efficient exploitation of natural pasture variability (Alimaev 2003). Contraction of mobility leads to ecosystem fragmentation, which has been recently summarized as:

> "a diminished ability of large herbivores to access natural heterogeneity in vegetation and topography. As fragmentation occurs, ecosystems are simplified by breaking up interdependent spatial units into separate entities… the result of this simplification is a reduction in the scale over which complex interactions among environment, large herbivores and human management takes place" (Hobbs and Galvin 2003).

This paper examines the processes and consequences of fragmentation in several study sites in southeastern Kazakstan.

For livestock to make use of large-scale landscape heterogeneity requires a relatively large human scale of social and economic production units. In contrast to wild large herbivores such as the migratory saiga antelope in Kazakstan, domestic livestock must be accompanied by their human managers, who need to protect, nurture and live off their livestock property.

Historically, Kazak livestock have been shepherded between seasonal pastures under several types of production unit, each considerably larger than the individual family unit. Under the pre-Soviet traditional system, Kazak nomadism was organized around sub-clans, the aul group of up to 100 families who traveled together to share herding and defense, while higher tribal and judicial authorities coordinated inter-clan movements. Clan organization was mostly destroyed under collectivization in the early 1930s, as pastoralists were forced into state-run farms. By the 1940s large groups of animals were once again being herded to remote pastures, this time supplied with technical inputs by the state collective farms. By the end of the Soviet period, state farms with up to 60,000 head of small stock orchestrated a regimented system of seasonal movement, dividing labor into brigades separately responsible for shepherding and other tasks such as harvesting hay, veterinary inputs, transport, marketing and social infrastructure for the state farm workers.

The immediate aftermath of decollectivisation in the 1990s left most formerly employed pastoralists atomized into nuclear family units, and having obtained very few livestock or capital assets from the privatization of state farms. With neither sub-clans nor state farms to provide support, individual families with their small flocks could not cope with the scale of investment and effort required for long distance migration.

Currently, there is an emergence of large-scale extended family units who can and do undertake longer distance seasonal movements. They were either fortunate enough to have acquired key assets such as vehicles from the disbanded state farms, or have accumulated enough livestock to invest in necessary technical equipment. They are able to operate at a greater social and economic scale through hiring shepherds, deploying dependent family members, and drawing upon kin networks for investment and co-management.

The Kazak government is defining new policies towards livestock and rangeland management, as revenues from the booming mineral economy are released for rural reconstruction and agricultural research. Entirely new systems of private livestock and rangeland management have developed in the past decade, about which there is little information. Urgent and controversial questions about the rangelands have arisen in Kazakstan including: whether to encourage private rangeland ownership, how to prevent overgrazing on common land, whether to charge fees for grazing on state land, how to prevent livestock mortality during drought and blizzards, what scale of private farm operation is viable and should be given state support. There is a need for contemporary and relevant data to guide policies on extensive livestock management.

Study Areas

The areas were selected to represent the major ecological zones of the Kazak rangelands. Six sample villages were selected within two *rayons* (districts) of two *oblasts* (provinces) in the southeast part of the country.

The desert zone selected is the Moinkum district of Jambul province in southern Kazakstan. Average annual precipitation is 170 mm (highly interannual variability from 20 to 325 mm) and temperatures are extreme, falling to –45 °C in winter with a maximum of 46 °C in summer. Villages are located along the Chu River that runs through the desert, and the reeds around the Chu flood plain are a crucial livestock feed in an otherwise semi-arid environment. The vegetation of the district varies. The area of sand dunes is dominated by perennial *Agropyron* grass species and by suffrutescent *Artemisia* species and by shrubs (*Calligonum*, *Artemisia* and other species). The riverine area contains reeds (*Phragmites*) and *Tamarix* while the plain north of the river has mainly *Artemisia* and *Salsola*.

Three small villages (Sary Uzek, Ulan Bel and Male Kamkale) were selected in this desert zone. A defining feature of the desert villages is their remoteness; these villages are up to 300 km from the nearest urban market, about a seven hour drive on very poor roads.

The semi-desert area is in the northern part of Jambul district of Almaty province, in the south east of the country. The semi-desert covers a precipitation and vegetation gradient ranging from 230 mm in the northern section to 350 mm in the southern section, the latter, which supports rainfed wheat cultivation. Temperatures range from a minimum –35 °C in January to a maximum of 45 °C in July. Vegetation is mainly composed of *Artemesia* species, small shrubs of *Salsola* and *Kochia*, and in spring, ephemeral grasses and grass-like plants of which *Carex* is the most important.

One sample village of Ul Gule is 100 km and the other village, Ay Darly, is 200 km from the nearest urban centre, respectively 2 to 4 hours driving on good roads.

The foothills zone lies to the north of the Tien Shan mountain range (called Ala Tau). The study village of Shien lies in the southern part of Jambul District of Almaty province. Precipitation is considerably higher than in the other two study areas, averaging 450 mm, and even more on the grazed slopes above the village. Temperatures are moderated by the mountains and are less extreme than the desert and semi-desert zones. Cereal farming is carried out and crop residues provide an important source of winter fodder for livestock. Vegetation composition varies by altitude, with meadow grasses and forbs in the higher slopes and steppe species (*Artemisia*, *Stipa* and *Ceratocarpus*) in the drier lower plain. The sample village is one hour from the nearest urban centre.

Methods

A sample of 46 households and their associated flocks were selected from local government records of village livestock, to create a sample representing the distribution of smallstock ownership by households within each survey village.

Surveys were conducted on the households every three months starting in August 2001, for a total of eight rounds. An economic questionnaire was administered to the head of household or flock manager, to obtain data on the costs and returns of livestock owned by the households. Data gathered included: assets owned; type of winter feed given to the flock; amount of labor used for flock management; costs of livestock transport, feed, veterinary inputs and marketing; income from sales of live animals, wool and fibre, and dairy products. In each household up to 30 sheep and goats were ear-tagged and several thousand animals were weighed every 3 months. In a separate survey, the same flock managers were interviewed concerning the breeds, reproduction and winter supplementary feeding of their livestock. In spring 2004, a small follow-up survey was conducted to weigh some 400 sheep and goats in 12 flocks at two of the study villages.

A census of livestock numbers and seasonal movement over an entire year was carried out in autumn 2003, in the same six villages. The census accounted for 40,000 head of sheep and goats, and over 8,000 cattle, horses or camels. Owners or flock managers were asked where their flocks were grazed in each of the previous four seasons (2002 to 2003).

Study methods included a series of in-depth informal interviews with householders, traders in livestock products, officials in villages and district centres, and sellers at livestock markets. Participant observation methods were used for the interviews, entailing periods of temporary residence by the researchers in the sample villages or rangeland grazing areas between 2000 and 2003.

Rangeland sites grazed by livestock from the sampled village were monitored every three months (spring, summer, autumn and winter) from 2001 to 2003. Using methods of line intercept and metre quadrant, vegetation data were obtained at 11 grazing sites in the Moinkum district and 13 in Jambul district. These sites were located at intervals of 1, 2 and 5 km from the village centres, and at remote points grazed by livestock of some households belonging to the sampled villages. The following vegetation characteristics were obtained: plant cover, height, weight, palatable and unpalatable ratios; biomass per hectare and chemical composition of forage plant nutrients was also measured.

Results

Current Grazing Patterns

There are four principal grazing management systems (fig. 1). Over a third of livestock owners do not move their animals away from their villages throughout the year. These owners graze their animals within a radius of 5 km around the villages. In winter periods, their animals are stall-fed in barns for several days up to several months, depending on the availability of pasture around the village and the severity of winter conditions, including temperature, wind and depth

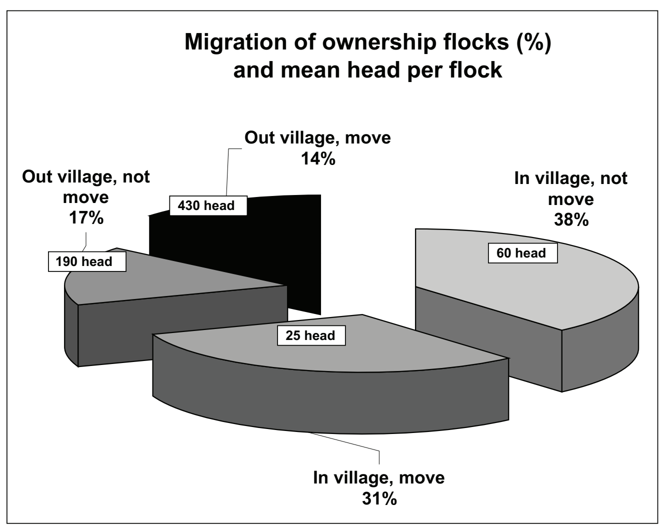


Figure 1—Migration of livestock among 6 sampled villages, 40 thousand sheep equivalent units in 448 flocks, southeast Kazakstan 2003.

of snow. Smallstock are continuously shepherded due to the risk of predators (wolves) and thieves. Shepherding is carried out either by the owners or through collective neighbourhood groups that rotate shepherding duties between the group members. The individual holdings of sedentary village flocks are relatively small, with an average of 60 smallstock.

A further third of village residents, however, place their livestock into larger flocks that are taken to different and distant pastures at least once a year. There are several types of arrangements. Some villagers entrust their livestock to larger-scale mobile livestock owners who are often relatives; others pay a monthly rate per head of animal herded, while another arrangement is to group village animals and collectively hire shepherds to manage the animals for one or more seasons. Villagers who practice these forms of management tend to have very small flocks, with a mean of 25 head.

Another group of livestock owners (17 percent) have settled outside of the villages, occupying buildings formerly used by the Soviet state farms. These sites include winter barns, wells, shearing and lambing stations and temporary shepherd houses which were either abandoned, sold off or leased after the state farms were dissolved in the mid 1990s (Behnke 2003). These sites are from 5 to 60 km distant from the villages and always include at least one water point. Owners' families or hired workers stay year-round with the animals, which have less competition for pasture compared to those permanently grazed around the villages. Flock sizes in this group are larger, with an average of 190 smallstock.

The last group of owners (14 percent) are those with the largest flocks (mean 430 head) whose animals are moved to different pastures from three to ten times a year. Moves between pastures can be quite short, of about 10 km for some flocks. A few other large owners with several thousand head move their animals a total of more than 150 km between winter and summer pastures, with a number of temporary stops between grazing sites. These very large flock owners have hired shepherds and some owners do not themselves stay with their flocks, depending on younger relatives to supervise their animals.

Overall, 45 percent of owners do now have their animals in flocks that move away from settled areas for some portion of the year. This is a change from the period immediately following the break-up of the state livestock farms in 1996. A study of the same areas in Jambul district in 1998 to 1999 found that all small flocks (less than 40 head) were managed on a sedentary basis (Behnke 2003). Another study in 1997 to 1998 of a region north of the Moinkum district also found that only the few large-scale livestock owners with more than 200 head were still migrating seasonally (Robinson and Milner-Gulland 2003).

Currently, though seasonal mobility is highly correlated with flock size – bigger flocks are mobile (fig. 1), not all small flocks are managed on a sedentary basis. This is a major positive trend in accessing distant pastures that had been unused for at least five years after the end of the state farms in 1995/96. Keeping animals away from the village areas for some seasons is also alleviating grazing pressure and degradation in these areas.

Grazing pressure around villages

The intensity of grazing around villages is highly variable between different ecological locations. Depending on the village, figure 2 shows that between a low of 6 percent and a high of 55 percent of annual grazing occurs within a 5 km radius of villages throughout the year. This variability is partly due to the differences in quantity of available forage around villages (fig. 3). Thus, villages in the foothills with higher precipitation have higher available forage and a greater concentration of animals grazing around the village.

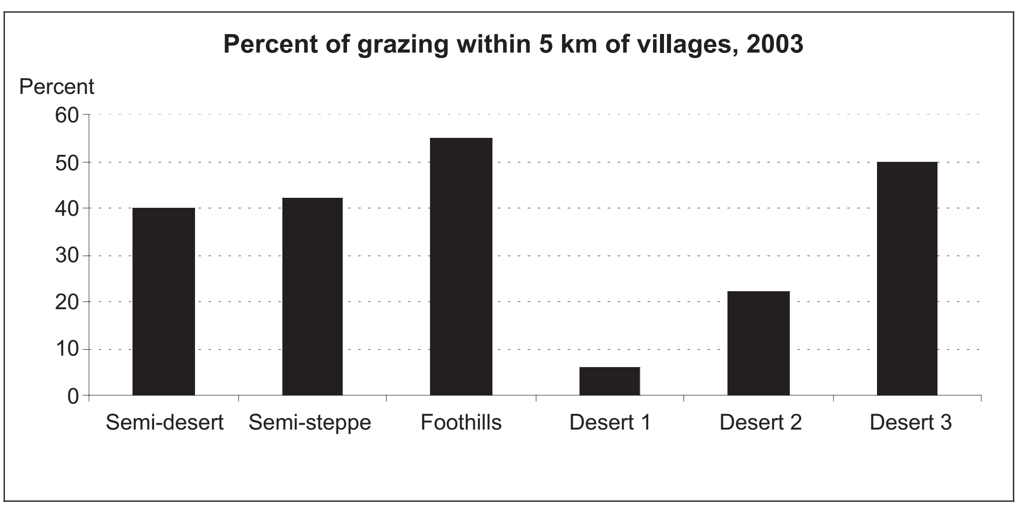
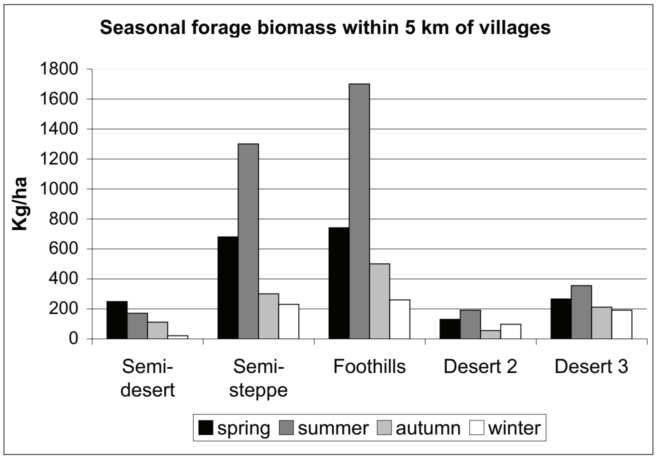


Figure 2—Annual grazing pressure around 6 sampled villages, 448 flocks in southeast Kazakstan 2003



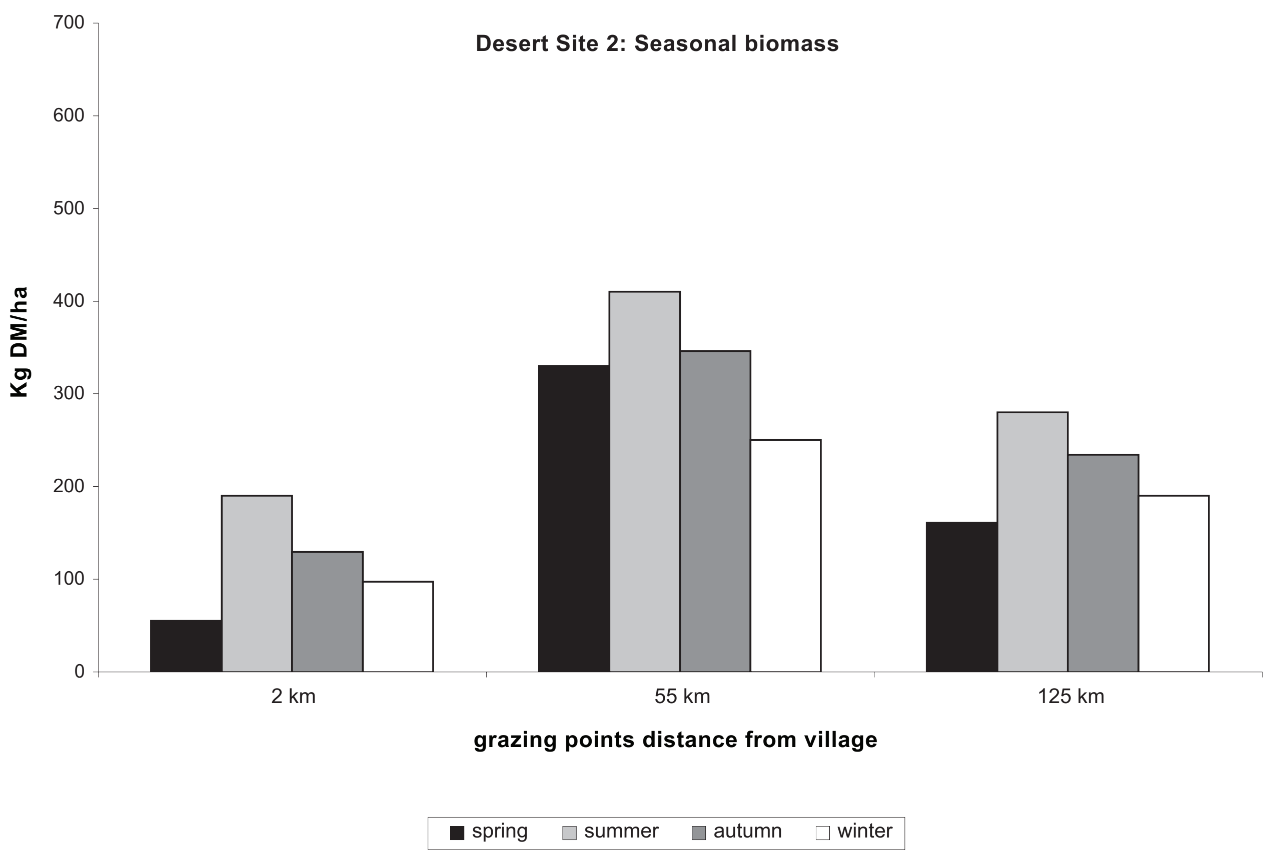
Note: data on biomass is not available for Desert Village 1.

Figure 3—Forage biomass available seasonally around 5 sample villages, spring 2002 to autumn 2003.

The source of circum-village grazing pressure is likewise not uniform. Since migratory flocks also return to their owners' villages for some period of time each year, typically for lambing, shearing and mating, up to 40 percent of grazing around villages can be caused by temporarily stationed migratory flocks. Facilities required for these tasks (e.g. electricity to run shearing machines) may only be available in villages, where extra labour can also be obtained to manage animals during peak periods of lambing and shearing. In other cases, permanently resident livestock in the villages causes all the circum-village grazing.

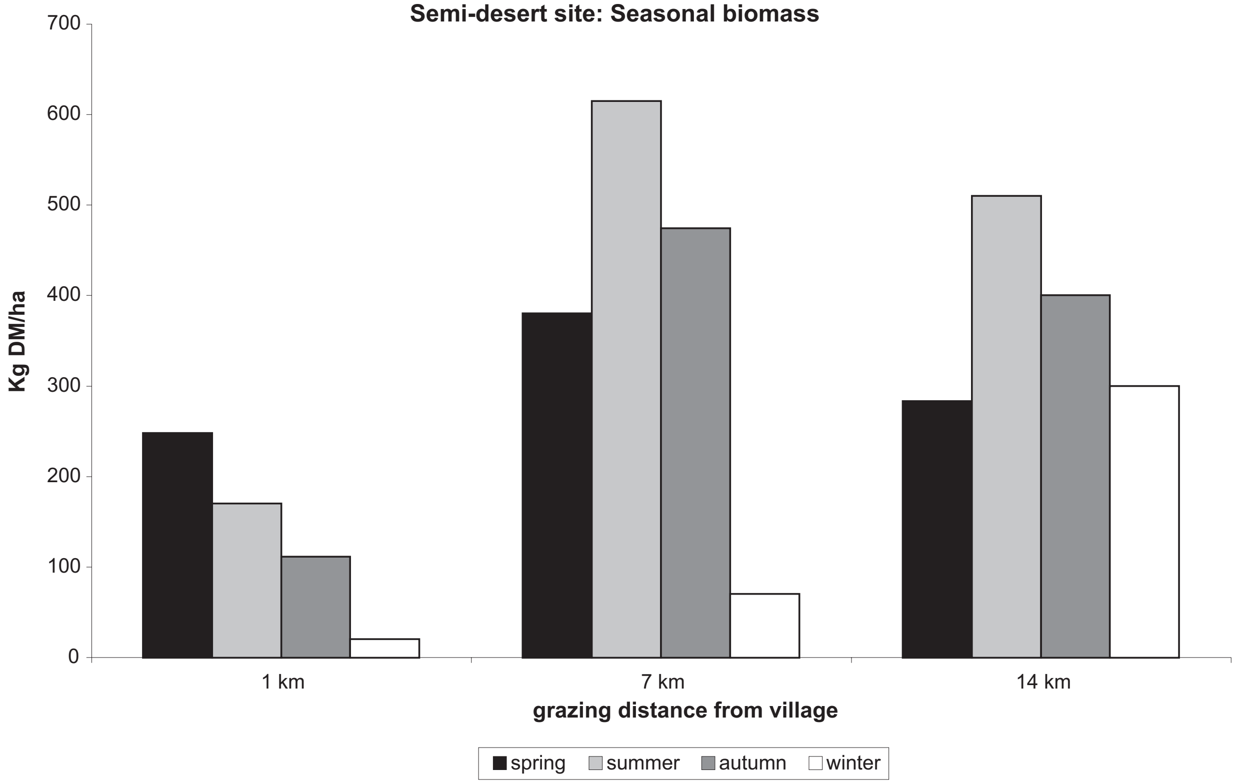
Degradation and Unused Pasture Resources

The present decline in seasonal mobility has two consequences: overgrazing around villages and under-grazing on remote seasonal pastures. Comparison of vegetation at grazing points around villages and at remote areas still grazed by migratory flocks indicates that livestock at remote pastures have access to higher biomass and more nutritious forage (figs. 4, 5 and 6).



Note: Winter data not available

Figure 4—Desert Site 2: Seasonal biomass and crude protein at grazing points around villages and distant areas.



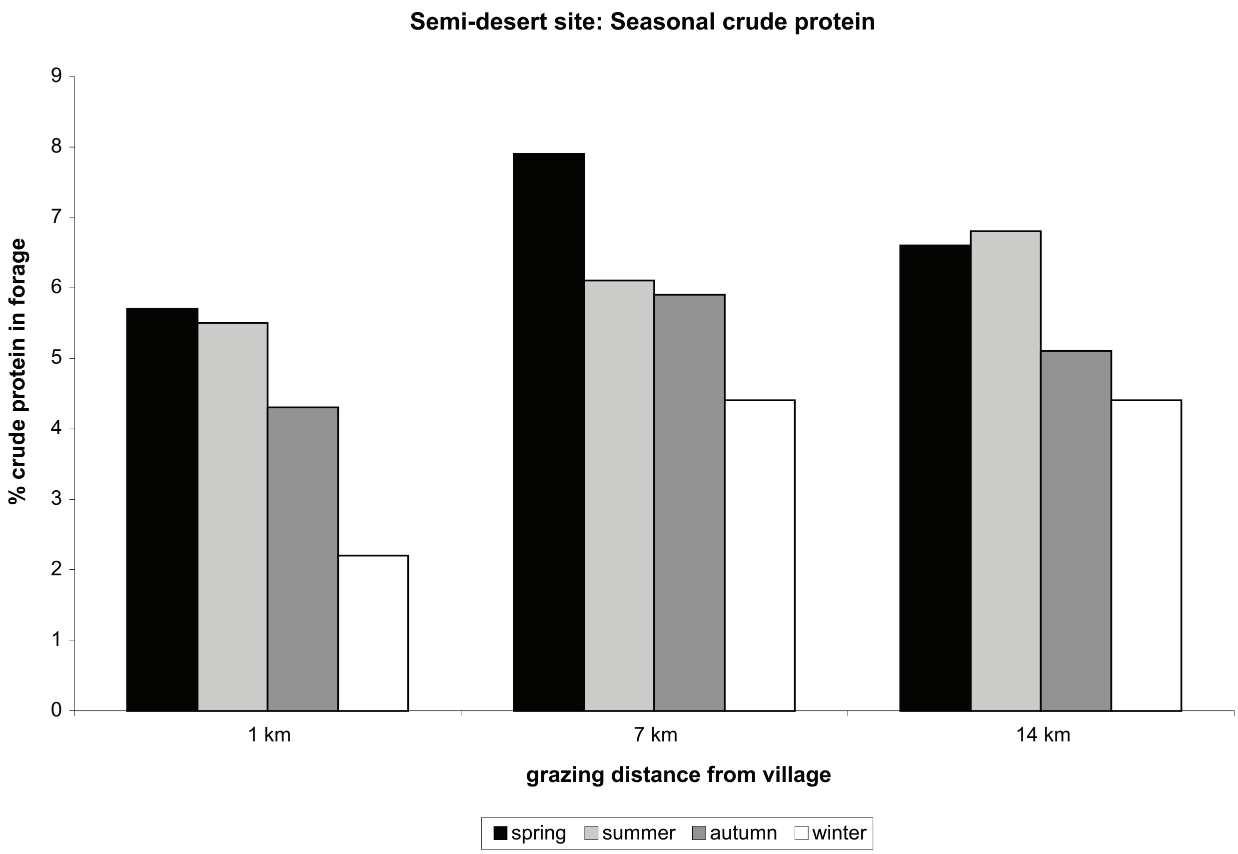
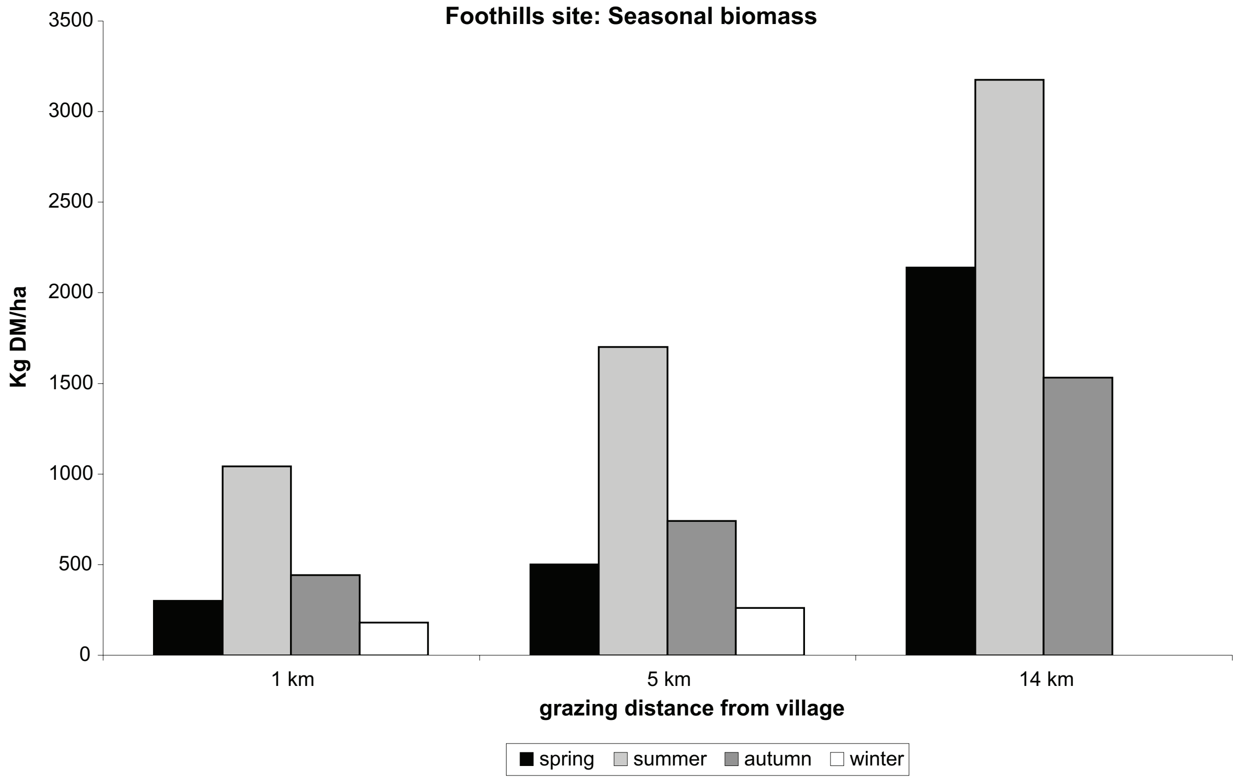


Figure 5—Semi-desert site: Seasonal biomass and crude protein at grazing points around villages and distant areas.



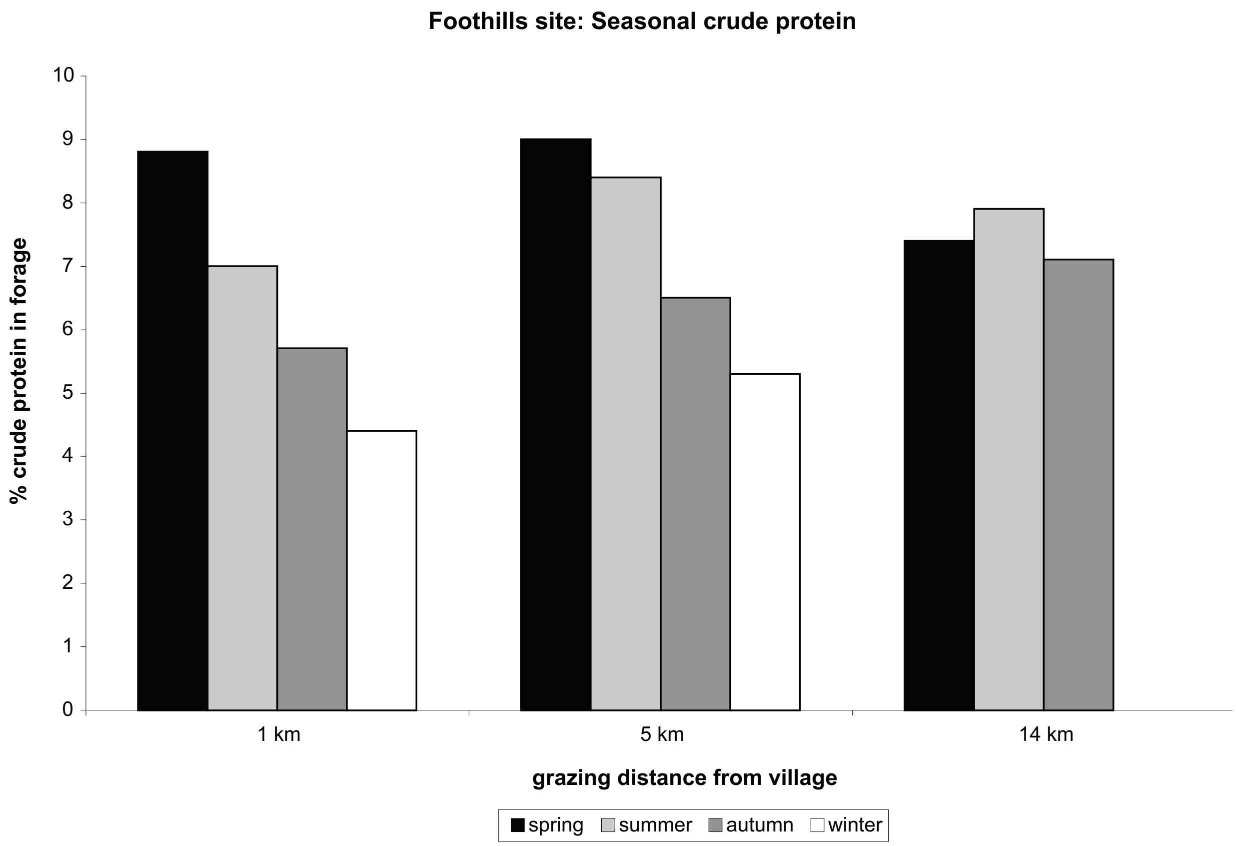


Figure 6—Foothills site: Seasonal biomass and crude protein at grazing points around villages and distant areas.

At the desert site 2, most animals are kept away from the village due to a very low amount of forage around the village (fig. 3). At one currently used grazing outpost located 55 km from this village, biomass is greater than around the village in all seasons (fig. 4). At a temporary grazing area some 125 km distant, biomass is lower but levels of crude protein are much higher. However, these very remote grazing points are only used by a few flock-owners at the present time.

Village animals considerably overgraze the peri-village area around the semi-desert site (fig. 2), where the percentage of ground covered by vegetation is measured at 10 to 15 percent. Both biomass and crude protein levels improve at 7 and 14 km distant (fig. 5) where some owners now keep their livestock seasonally. Ground cover at these areas is 50 to 60 percent. The higher level of biomass at a temporary grazing point 14 km from the village is particularly noteworthy in winter when there is almost nothing available to graze around the village and animals remaining in the village must be stall-fed.

The foothills with their higher precipitation offer a higher amount of forage year-round, resulting in a relatively high amount of circum-village grazing pressure (fig. 2). But there is still a crucial difference in spring and summer between biomass around the foothills village and at further points 5 km and 14 km distant (fig. 6). In winter the area located 14 km distant cannot be grazed at all, because being in the mountains it is covered with snow.

Not only is biomass lower around villages due to a more sedentary grazing management, but the ratio of palatable to unpalatable plant species has also been affected by overgrazing around villages. This is shown in figure 7 in the case of the semi-desert site 2. The more nutritious and preferred species of *Artemisia* and *Salsola* are in greater abundance at 10 km distance from the village compared to 3 km, while the unpalatable species of *Peganum* and *Ceratocarpus* are much more prevalent closer to the village.

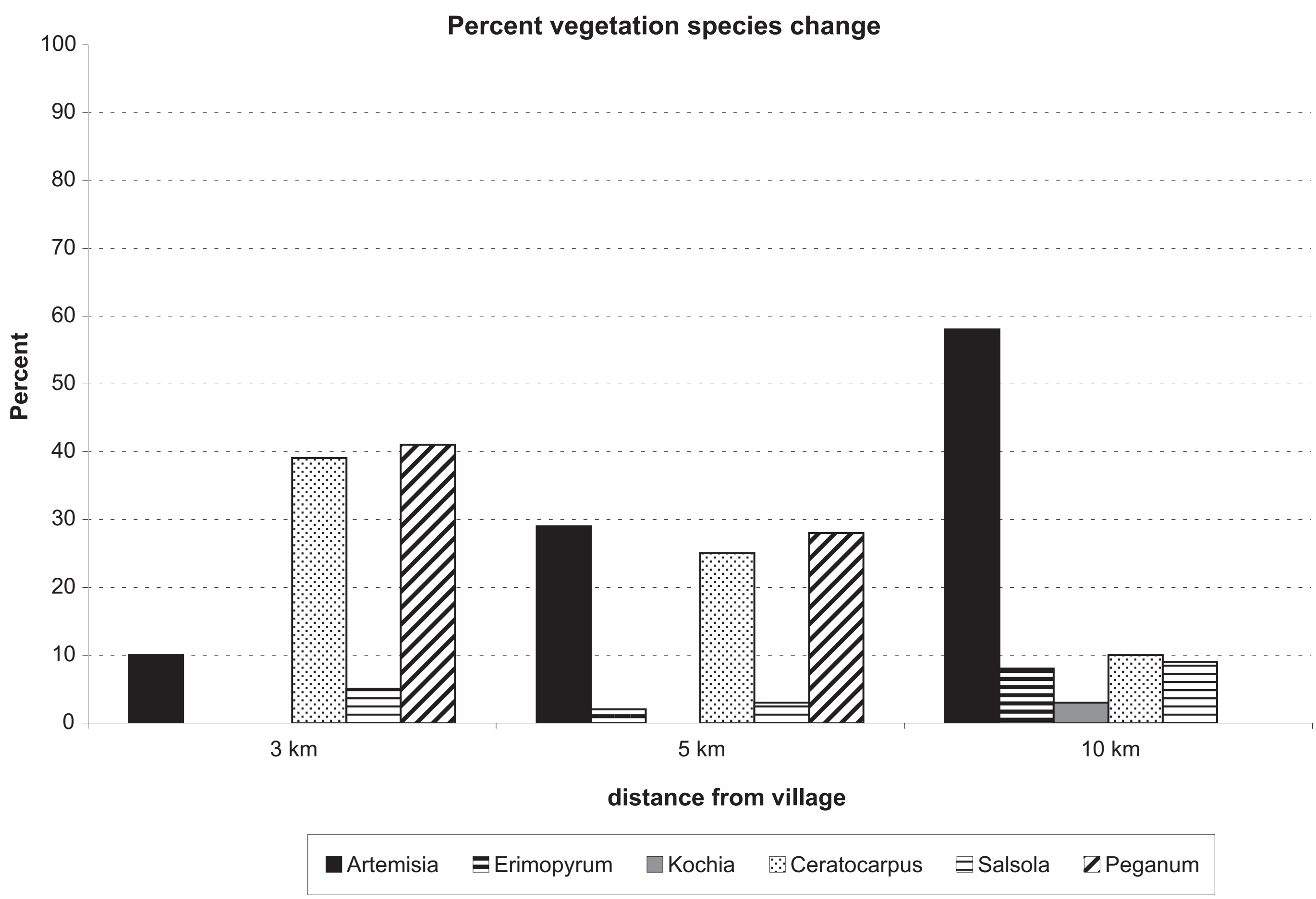


Figure 7—Changes in vegetation species composition with distance from semi-desert village.

Mobility and Livestock Weight

Livestock productivity is directly affected by whether animals are moved to seasonal pastures or are grazed all year around settlements. Figure 8 shows the effect of seasonal movement on sheep weights. Sheep that were moved in each of the previous four seasons gained on average 5 kg weight over winter, compared to village-based sheep that lost on average 8 kg, being stall-fed or foraging on over-grazed ranges within 5 km of villages over winter.

In the following year (2003/2004), sheep in flocks that were moved to different seasonal pastures as compared to being grazed around villages weighed on average 7.7 kg more in spring, as shown in table 1. Sheep kept at stationery grazing sites outside of villages did not weigh more. The effect of seasonal movement on goat weights is less significant.

Seasonal Mobility Requires Capital Assets

Moving animals to seasonal grazing areas requires capital equipment and recurrent expenditure, mainly on hired labour but also on vehicles (fuel, spare parts). Only larger flock owners tend to own the equipment necessary for seasonal movement (fig. 9). The chief item of equipment needed is motorised transport – trucks and/or tractors – not to move animals as they are herded on foot to the different grazing areas, but to bring supplies of fuel, food and fodder to the remote grazing sites. Some form of shelter is also required for mobile shepherds, which includes wagons, yurts (traditional nomadic felt tents) and small permanent winter houses. Due to the extreme cold climate, livestock grazed at remote winter sites also require shelter in the form of barns. Lastly, distant grazing areas are dependent on water from wells, which often require motorised pumps.

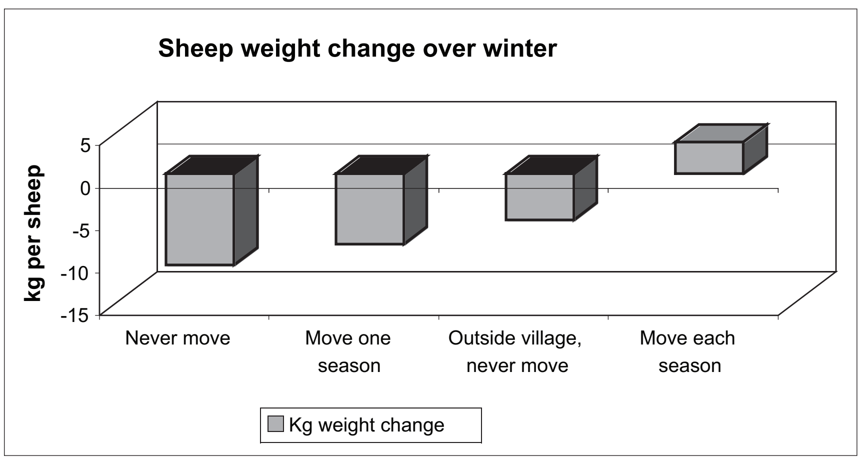


Figure 8—Changes in live weight of sheep kept under four different grazing systems 2001-2002.

Table 1—Mean live weights of sheep and goats in flocks according to seasonal movement, May 2004.

Species	In village, never move	Out of village, never move	Move each season
Sheep	49.5 kg	48 kg	57.2 kg
n	50	71	80
Goats	37.7 kg	41.4 kg	40.1 kg
n	63	59	83

Standard error of a difference ($p \leq 0.01$) = 1.34.

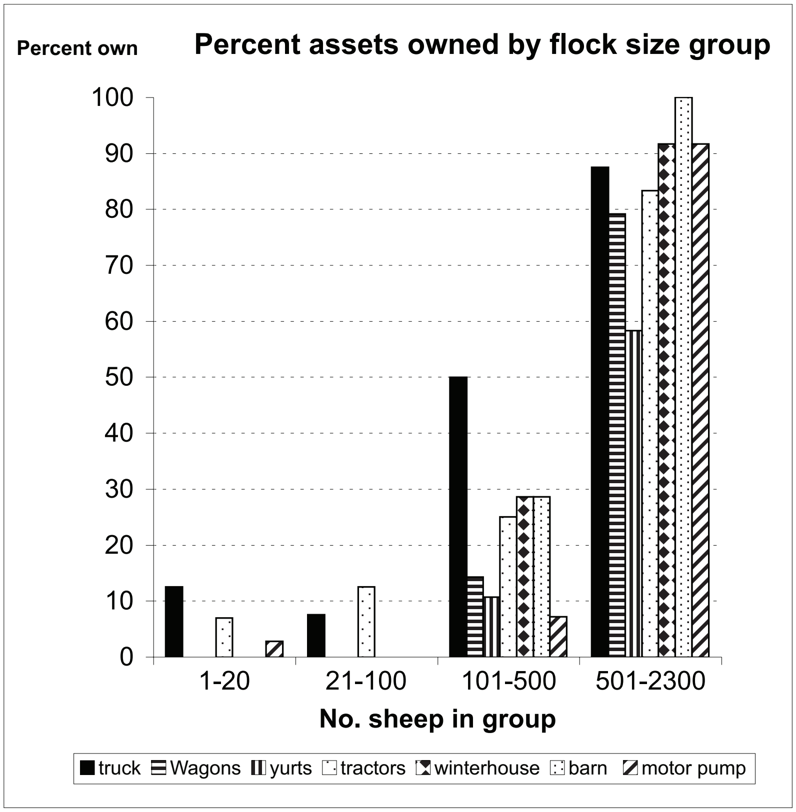


Figure 9—Capital assets required for livestock migration by household flock size.

As indicated in figure 9, small flock owners rarely own these capital assets, and so for them, seasonal livestock mobility is only possible if they combine their livestock into the flocks of large flock-owners or else pay hired shepherds to take their animals to distant pastures.

Small Flocks have Higher Input Costs per Head

Fodder is the principal input costs for all flocks regardless of size or seasonal movement (fig. 10). During the cold winter period from December to March, village-based flocks all require supplementary stall-feeding. The amount of feed required depends on the severity of each winter, mainly the degree of cold and the depth of snow covering the vegetation. Flock owners try to obtain as much fodder as they can afford in autumn due to the risk of a particularly bad winter when animals would die through lack of accessible pasture or exposure to cold winds. The type of fodder varies by region. In the desert area, reeds and grasses are collected from the river flood plain in autumn. In the foothills area, grain crop residues and natural mountain hay are fed to animals in winter, while in the semi-desert area, planted *Agropyron* and natural hay harvested from the rangelands are common winter feed sources. Additionally, some commercially processed bran is often purchased.

The cost of providing winter feed (whether harvested or purchased) is proportionately much higher for small flocks, which as we have seen tend to be more sedentary (fig. 1 and 10). Large flocks are usually moved to the desert for winter, where sand dunes provide shelter from the worst cold as well as accumulate less snow such that taller woody shrubs can provide browse throughout the winter. Large flock-owners who station their animals at winter grazing sites do not normally provide supplementary feed to their sheep and goats throughout the winter. Although cattle and particularly riding horses will be given some additional feed, only pregnant and lactating sheep and goats will be given feed for a few weeks at the end of winter. The result is that fodder costs per head are much lower in large and mobile flocks and conversely, quite high for small and sedentary flocks. Seasonal movement compensates for winter supplementary fodder.

Labour costs per head of livestock are not significantly linked with flock size (fig. 10). While large flock owners must usually hire labour, small flock owners devote more family labour per head of animal owned. The other main input costs – marketing, veterinary and movement to pastures – are also not closely linked to flock size. There appears to be little evidence of economies of scale in recurrent input costs, apart from fodder.

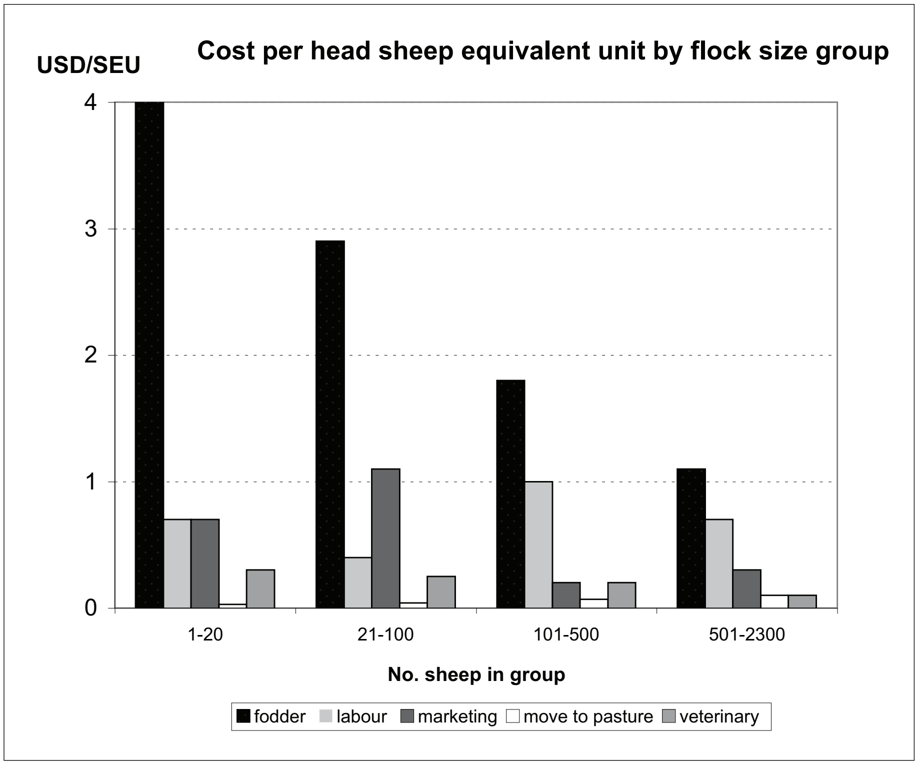


Figure 10—Input costs per sheep equivalent unit by household flock size.

Conclusions

Currently, rangeland use remains fragmented as few pastoralists can operate at a large enough economic scale to take advantage of the ecological scale in the landscape. An emerging group of wealthier pastoralists is moving their livestock seasonally again.

Smaller scale flock owners are organizing communal grazing at seasonal summer pastures where land around villages is becoming overgrazed. Smaller flock owners are also increasingly trying to place their animals into the flocks of large owners that are moved to seasonal pastures. However, many smaller flock owners will need external assistance or credit if they are to undertake seasonal migrations on their own, as they lack capital equipment needed for movement.

An outstanding issue is whether small, non-mobile flocks can be as productive as large, mobile flocks. Moving animals to temporary seasonal pastures may produce heavier animals, but at what cost to their owners? Are heavier animals more financially rewarding to their owners over the longer term?

Livestock owners must calculate the costs and benefits of having their animals move away seasonally from their settlements to graze on distant pastures. Our results suggest some of the factors that villagers have to consider. Sheep grazed on distant pastures over winter actually gained weight, while sheep kept in the village sheds for at least part of winter and given fodder lost significant weight. By springtime, the loss of weight will have a negative effect on lambing rates.

A new smaller-scale study, "Biocomplexity, Spatial Scale and Fragmentation: Implications for Arid and Semi-Arid Ecosystems" beginning in 2004 will continue to measure the economic and biological impacts of livestock mobility at several of the previous study areas. This study is funded by the National Science Foundation to the Natural Resources Ecology Laboratory at Colorado State University. The Further analysis will consider whether sedentary small flocks are viable in the longer term, able to continue providing their owners with an income but not capable of expanding due to high off-take. The longer-term profitability of moving animals will be assessed by comparison.

Acknowledgments

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Scaling-up of CO_2 Fluxes to Assess Carbon Sequestration in Rangelands of Central Asia

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Abstract—*Flux towers provide temporal quantification of local carbon dynamics at specific sites. The number and distribution of flux towers, however, are generally inadequate to quantify carbon fluxes across a landscape or ecoregion. Thus, scaling up of flux tower measurements through use of algorithms developed from remote sensing and GIS data is needed for spatial extrapolation of carbon fluxes and to identify regional sinks and sources of carbon. Spatial and temporal quantification of carbon dynamics are useful in understanding the biophysical factors that cause regions to be sinks or sources of carbon. We analyzed data sets from the Northern Great Plains and the Kazakh Steppe and found similarities in latitude, precipitation, and carbon fluxes between the two regions. These similarities allowed us to pool carbon flux data, remotely sensed data, and GIS data from these two regions to map gross primary productivity (Pg), total ecosystem respiration (Re), and net ecosystem exchange (NEE) for Kazakh Steppe for 2001 using regression tree techniques. We estimated 10-day Pg and Re with mean absolute errors of 3.2 and 2.7 g CO_2/m^2/day, respectively. The NEE for grasslands in the Kazakh Steppe during the growing season (April through October 2001) was 0.79 t C/ha. Localized carbon sinks and sources were positively correlated with growing season precipitation and Pg. The regression tree technique provided an effective method for the regional mapping of carbon dynamics as seasonally quantified by flux towers in the Northern Great Plains of North America and the Kazakh Steppe of Central Asia.*

Keywords: *Kazakhstan, carbon sinks, carbon sources, carbon dynamics, Northern Great Plains.*

Introduction

Increasing levels of atmospheric carbon dioxide (CO_2), one of several "greenhouse gases" that impact global climate, have been well documented. Vegetation absorbs atmospheric carbon through photosynthesis to form biomass and ultimately soil organic matter. Increased plant primary productivity can, therefore, partially offset fossil fuel emissions of CO_2 into the atmosphere.

Although rangelands have relatively small magnitudes of net carbon fluxes compared to forests, they cover a vast area that

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represents about 30 to 40 percent of the earth's land surface area (Brown 1989, World Resources Institute 2000). As a result, rangelands could have a substantial effect on global carbon budgets. Grasslands store 90% of their carbon below ground and through time can accumulate significant soil carbon. For example, it has been estimated that grasslands contain 10 to 30% of the world's soil organic carbon (Schuman and others 2002) with temperate grasslands containing about 18% of global carbon reserves (Burke et al. 1997).

Isotopic analysis of atmospheric CO_2 suggests a significant carbon sink (removal of atmospheric carbon) in Central Asia (Miller and others 2003). This appears to be related to the abandonment of collective wheat farms in the 1990s, which were expansively established during the Kruschev era (De Beurs and Henebry 2004), although the effects of this land use change may be confounded by the impacts of global warming. Quantification of rangeland carbon fluxes may be important for possible trading of carbon credits, wherein industries with excessive point sources of carbon emissions must pay for carbon sequestration through improved vegetation production elsewhere. The USAID GL-CRSP project "Livestock Development and Rangeland Conservation Tools for Central Asia (LDRCT)" has provided a crucial database for quantifying carbon fluxes in Central Asia.

Flux towers, micrometeorological instruments that use Bowen ratio-energy balance or eddy covariance techniques, provide detailed quantification of fluxes of carbon into and out of the atmosphere at the land surface. The quantification of soil carbon stocks that include biomass and soil organic matter have large sampling errors so sampling can detect only relatively large changes in carbon pools across 5- to 10-year time-frames for most systems. Flux towers, on the other hand, are capable of quantifying daily, seasonal and annual carbon dynamics. Flux tower equipment and operation, however, can be both expensive and complex, and may result in an under-sampling of carbon fluxes across many ecosystems and land uses. Therefore, the ability to scale up localized flux tower observations is important for quantifying carbon budgets, identifying and mapping carbon sinks and sources, and understanding the dynamics and causal factors for areas being carbon sinks and sources. The scaling of flux measurements is particularly important for expansive rangeland ecosystems that have heterogeneous soils and variable precipitation.

Our study sought to quantify rangeland carbon dynamics across growing seasons for the Kazakh Steppe ecoregion in Central Asia, as defined by Olson and others (2001; fig. 1). This ecoregion is representative of vast Eurasian rangelands extending from the Ural Mountains in the west to the Altai Mountains in the east.

Based on the similar vegetation structures in the Kazakh Steppe and Northern Great Plains (fig. 1), we hypothesize that these ecoregions also have functionally similar carbon fluxes. If this is true, then rangeland flux towers from these two ecoregions can be used to develop algorithms to scale up carbon fluxes. This synergistic use of rangeland flux data from rangelands in Central Asia and North America should strengthen flux predictions in both regions and would maximize the use of flux tower data, which are currently under-sampling these extensive ecosystems and their various management scenarios.

Study Area

A Bowen ratio-energy balance (BREB) flux tower was established in 1998 on a virgin prairie site (51° 40' N, 71° 00', 367 m above sea level) near the town of Shortandy, Kazakhstan on the Baraev Research and Production Center for Grain Farming. This area is classified as a true grass and forb steppe dominated by *Stipa capillata* L., *Stipa lessingiana* S. Zalesskii, *Agropyron cristatum* L., *Kochia prostrata* L., *Medicago falcata* L., *Festuca valesiaca* Hackel, *Salvia stepposa* Schost., *Artemisia marshalliana* Spreng., and *Artemisia glauca* Pall. The long-term (1936-2001) average annual precipitation at the study site is 324 mm with a mean annual temperature of 1.6 °C. Precipitation is variable, and drought is common during June and July.

Partitioning of Carbon Fluxes

Flux towers measure net exchanges of CO_2 above the land surface (Dugas and others 1997). These carbon fluxes can be summed seasonally or annually to quantify net ecosystem exchange (NEE). However, NEE is determined by two basic ecosystem processes, gross primary productivity (Pg) and total ecosystem respiration (Re), which have opposite effects on carbon fluxes. Partitioning carbon fluxes into Pg and Re components improves the regional predictions by allowing them to be more process-based and also contributes to understanding the driving factors for carbon sinks and sources. We use detailed light curve analysis to separate daytime respiration and daytime Pg (Gilmanov and others 2003). Night-time fluxes represent only respiration fluxes so Re is the sum of daytime respiration and night-time respiration and includes both autotrophic and heterotrophic respiration.

Two light curve equations are used, one without soil temperature (*Ts*):

$$P(Q;\alpha,\beta,\gamma,\theta)=\frac{1}{2\theta}\left(\alpha Q+\beta-\sqrt{(\alpha Q+\beta)^2-4\alpha\beta\theta Q}\right)-\gamma,$$

and one with soil temperature:

$$P(Q,T_s;\beta,\gamma_0,\theta,k)=\frac{1}{2\theta}\left(\alpha Q+\beta-\sqrt{(\alpha Q+\beta)^2-4\alpha\beta\theta Q}\right)-\gamma_0 e^{kT_s},$$

where P is the theoretical magnitude of daytime CO_2 flux, Q is the incoming photosynthetically active radiation (PAR), α is an initial slope of the light response curve, β is a plateau parameter (equal to the maximum rate of gross photosynthesis), γ is the respiration term, θ is the curvature parameter that modifies the shape of the light-response curve, and k describes the strength of the hysteresis of the light-response curve (Gilmanov and others 2003).

This detailed nonlinear analysis was conducted using flux tower 20- or 30-minute time step data and allowed independent determination of night-time and daytime respiration components. Lastly, Pg and Re were summarized to match

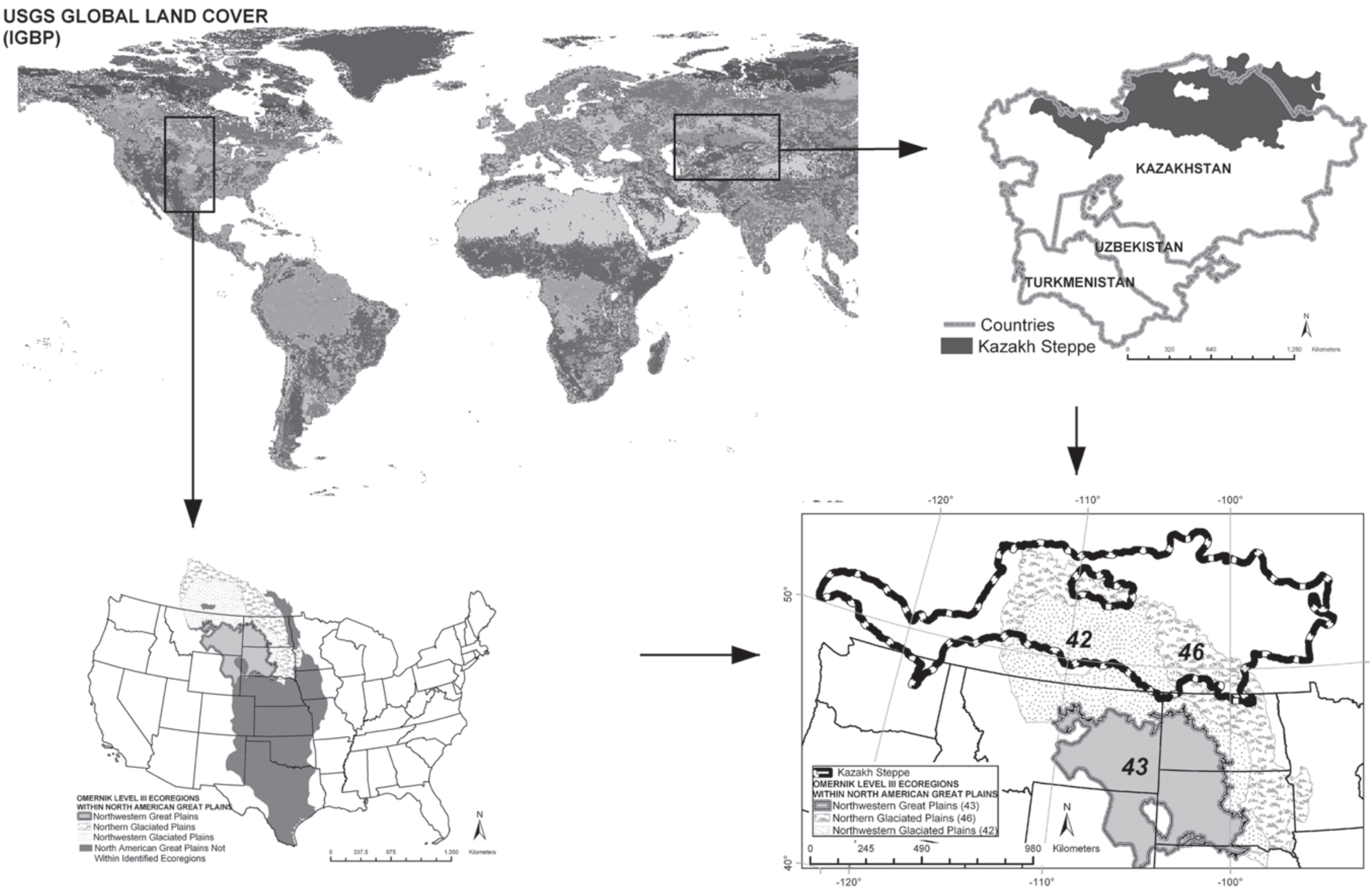

Figure 1—Latitudinal comparison of the Kazakh Steppe ecoregion (Olson and others 2001) and the Northern Great Plains ecoregions (Omernik 1987).

the 10-day time steps of SPOT VEGETATION Normalized Difference Vegetation Index (NDVI) composite periods.

Regression Tree Analysis

Biogeochemical models have been the typical approach for producing regional or global carbon fluxes. Some of these models primarily use precipitation and temperature to simulate plant growth for a theoretical ecosystem and estimate land use-specific net primary production (Liu and others 2003), while other models use the light-use-efficiency approach (Running and others 1999). However, input demands and model parameterization can be problematic for both of these approaches because they require "spin up" model runs to establish initial conditions and parameterization (Running and others 1999). For our study, we utilized a bottom up, robust, empirical approach that seeks to minimize input variables and yet maintain prediction accuracy. We used regression tree analysis to develop predictive relationships between GIS and remotely sensed data as independent variables, and flux tower observations from multiple sites and multiple years as the dependent variable. Prince and Steininger (1999) proposed the use of a regression tree technique to scale up ecosystem and meteorological parameters. De'ath and Farbricius (2000) demonstrated the robustness of the regression tree approach and its insensitivities to high-order interactions, ability to fit nonlinear trends, and ability to reveal new relationships not evident in classical regression analysis. Regression tree analysis has been used successfully to scale up flux tower data in the western United States and Central Asia (Wylie and others 2003; Wylie and others 2004). For this study, we used the regression tree software Cubists (www.rulequest.com) to identify GIS and remotely sensed variables and respective thresholds, which stratifies the data set into near-optimal linear subsets. Multiple linear regression equations were then established for each linear subset. This resulted in a series of "rules" or stratified regression equations that were used to map the predicted variable (10-day Pg or Re).

The data used to train the regression trees and develop the predictive rules consisted of flux tower, GIS, and remotely sensed data sets with a 10-day time step (table 1). Data values from each of these spatial and temporal variables were extracted at each tower location. These values were combined with the 10-day Pg and Re data from flux tower observations and then used to develop regression tree algorithms. The relative frequency of use of variables utilized to stratify the training data combined with a relevance weight (a surrogate for partial R^2 values associated with respective independent variables used in each regression model) was used to identify heavily and slightly used variables (Wylie and others 2003). The effects of ignoring slightly used variables on the accuracy of regression tree prediction were quantified by cross validation. This approach allowed selection of a minimum number of input variables required to retain model prediction accuracy.

To ensure the robustness of the regression tree algorithms, multiple flux tower sites and multi-year data sets were used to develop the regression tree algorithms. Flux tower locations used in this study were from both the Kazakh Steppe and similar ecoregions in the Northern Great Plains of North America (table 2).

Is the Kazakh Steppe Functionally Similar to the Northern Great Plains?

To establish the functional similarity between the Northern Great Plains and the Kazakh Steppe, we made regional comparisons based on latitude, precipitation, and seasonal NDVI patterns. Latitudes for the Omernik ecoregions (Omernik 1987) of the Northwestern Glaciated Plains and the Northwestern Great Plains were quite similar to those for the Kazakh Steppe (fig. 1). Because incident solar radiation is primarily determined by day of year and latitude (Charles-Edwards 1982), this suggests that PAR levels should be similar in the two ecoregions.

To compare precipitation between the two regions, 0.25 degree daily estimates of precipitation for 1998 through 2001

Table 1—GIS and remotely sensed variables used to predict and map 10-day gross primary productivity (Pg) and total ecosystem respiration (Re).

Variable	Description	Time step	Surrogate for:
NDVI	SPOT VEGETATION, 10-day composites	10 day	photosynthetic potential
Precipitation	NOAA Climate Prediction Center	10 day	
Temperature	NOAA Climate Prediction Center	10 day	
Start of season date (SOSt)	NDVI metrics algorithm	annual	DOY of beginning of growth
Solar radiance (RAD)	derived from latitude and DOY[1]	10 day	day length
Day of year (DOY)		10 day	photoperiodisum
Days since SOSt	NDVI metrics algorithm	10 day	vegetation age or phenology
Time integrated NDVI	NDVI metrics algorithm	annual	annual biomass production
Start of season NDVI	NDVI metrics algorithm	annual	soil and litter background

[1] from Charles-Edwards (1982)

Table 2—Flux tower data sets used to develop regression tree algorithms for the scaling up of carbon fluxes.

Location	Year(s)
Cheyenne, WY	1998
Fort Peck, MT	2000
Leithbridge, Canada	2000, 2001
Mandan, ND	1999, 2000, 2001
Miles City, MT	2000, 2001
Shortandy, Kazakhstan	1998, 1999, 2000

were obtained from the NOAA Climate Prediction Center. These were mapped with a one km^2 cell size and masked to remove all areas that were not comprised primarily of shrub or grass cover. For the U.S.A., this was done by using one km^2 areas that had less than 70% area of shrub and grass as determined by the USGS NLCD 1992 (Vogelmann and others 2001), and for the Kazakh Steppe by areas classified as grass in the MODIS land cover (MODIS/Terra Land Cover Type 96-day L3). Precipitation across the rangeland pixels in both the Kazakh Steppe and Northern Great Plains was summarized both for the growing season (April thru October) and annually (table 3). Mean annual precipitation was similar between the two ecoregions; however, mean precipitation for the growing season was less for the Kazakh Steppe with growing season precipitation representing a lower percentage of annual precipitation. For example, growing season precipitation for a dry year in the Northern Great Plains (2000) was similar to a wet year in the Kazakh Steppe (2001). In addition, precipitation was more variable for the Kazakh Steppe than the Northern Great Plains. Although annual precipitation amounts were similar for the two regions, seasonal proportions appeared to differ.

The temporal patterns of NDVI at the flux tower locations in the Northern Great Plains and Kazakh Steppe were used to evaluate similarity to other pixel locations using Euclidian distance criteria. Data for 10-day SPOT VEGETATION NDVI (http://free.vgt.vito.be) were temporally smoothed to remove residual clouds (Swets and others 1999). Then, pixels with NDVI patterns and magnitudes (or NDVI – time signatures) similar to various flux tower locations were mapped. Time profiles for flux tower NDVI in this analysis corresponded to the flux tower locations and years where flux data were processed to obtain Pg and Re (table 2). Results from the Euclidian distance comparisons allowed identification of pixels similar and dissimilar to the flux tower sites and year, which were used to develop the algorithms for the regression tree scaling up. Spatial estimates made in areas with similar NDVI patterns and magnitudes as the flux towers would likely be more accurate than those made in areas with dissimilar NDVI patterns. By comparing similarities in NDVI patterns for the flux towers in the Northern Great Plains and northern Kazakhstan, the utility of merging the flux data sets can be better evaluated. The flux tower located in northern Kazakhstan best represented the northern rangelands in the Kazakh Steppe; however, the drier rangelands of southern Kazakh Steppe were more similar to the flux tower located at Miles City, Montana (fig. 2). This suggests that combining the flux tower data sets from Central Asia and Northern Great Plains would yield a regression tree algorithm that would be more robust in scaling up carbon fluxes to a wider range of environmental conditions and would minimize over-extrapolation from the single flux tower in the Kazakh Steppe, thereby, improving the accuracy of regional mapping of Pg and Re.

Table 3—Comparison of regional average rangeland precipitation (mm) in the Northern Great Plains and the Kazakh Steppe.

	Year	April-Oct.	Annual	Percent of Annual
Northern	1998	311.97	383.21	0.81
Great	1999	312.83	353.49	0.88
Plains	2000	255.88	315.60	0.81
	2001	277.32	304.93	0.91
Mean		289.50	339.31	0.85
Std. Dev.		27.86	35.93	0.05
CV		0.10	0.11	0.06
Kazakh	1998	117.85	187.40	0.63
Steppe	1999	172.82	264.28	0.65
	2000	224.41	328.39	0.68
	2001	248.15	349.56	0.71
Mean		190.81	282.41	0.67
Std. Dev.		57.92	72.98	0.04
CV		0.30	0.26	0.05

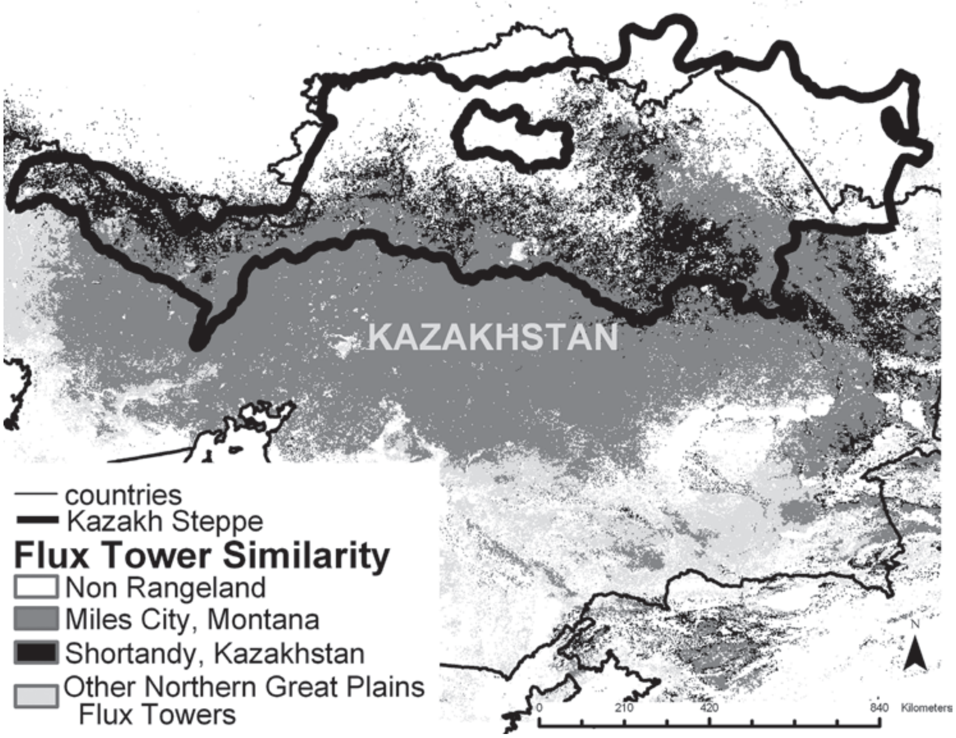

Figure 2—Flux tower similarity for Central Asia based on NDVI patterns and magnitudes from Northern Great Plains and Kazakh Steppe flux tower locations.

To assess similarities in ecosystem carbon functionality, a regression tree was developed from data from the Northern Great Plains and compared to flux measurements from the flux tower on the Kazakh Steppe. Regression for Pg from the Northern Great Plains used the following input variables to map 10-day Pg: day of year (DOY), DOY of start of growing season (SOSt, derived from NDVI seasonal patterns), NDVI, time-integrated NDVI (TiNDVI), precipitation, temperature, and radiant flux (RAD). This regression resulted in an average absolute error of 1.5 g CO_2/m^2/day and an R^2 of 0.85. We applied this regression tree model to the flux tower data from Shortandy, Kazakhstan for the 1998 to 2000 growing seasons and found that it performed remarkably well (fig. 3), accounting for 79 percent of the variation in 10-day Pg. This general agreement occurred despite a severe midsummer drought in 1998. These results suggest substantial similarity in the functionality of carbon fluxes in the Northern Great Plains and the Kazakh Steppe and considerable robustness in the regression tree algorithm. They also provided justification for pooling the flux data sets from these two distant regions.

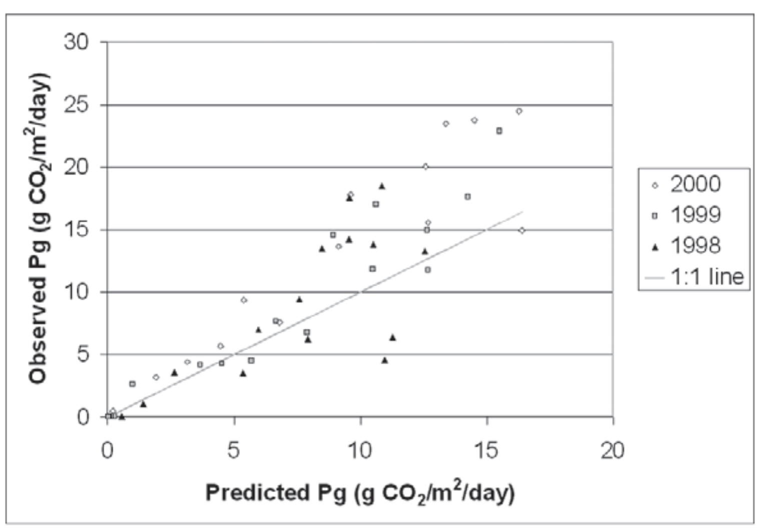

Figure 3—Application of a Northern Great Plains 10-day gross primary productivity (Pg) regression tree (predicted) to a flux tower (observed) in Northern Kazakhstan (1998-2000).

Pooled Northern Great Plains Kazakh Steppe Scaling Up

Based on the above comparative analysis, the training data sets of carbon fluxes, GIS, and remote sensing for the tower locations in the Northern Great Plains and the Kazakh Steppe were pooled, and predictive regression trees were developed for 10-day Pg and Re. After elimination of slightly-used or under-used variables, the resulting regression tree model for predicted 10-day Pg included the input variables of NDVI, SOSt, TiNDVI, days since SOSt, RAD, and precipitation. The accuracy of this regression tree was evaluated by jack-knifing each year of data at Shortandy sequentially as test data. The pooled regression of observed and predicted carbon fluxes for all three jack-knifed years yielded an R^2 of 0.81 and a standard error of 3.24 g CO_2/m^2/day. Using the same jack-knifing approach, a similar regression tree used to predict 10-day Re had an R^2 value of 0.63 and a standard error of 2.7 g CO_2/m^2/day. The regression tree for predicting Re used the input variables of precipitation, NDVI, temperature, TiNDVI, and SOSt.

We applied these regression trees to map Pg and Re every 10 days from April through October. Ten-day maps were then summed to construct maps of growing season fluxes, with non-grass and non-shrub areas removed (fig. 4). This approach identified regional carbon sinks and sources through the calculation of regional net ecosystem exchange (NEE), where NEE = Pg – Re. Localized sink and source areas for growing season NEE are evident in this map. A preliminary paired-plot analysis was conducted to assess the environmental drivers of these localized variations in carbon fluxes. Arbitrary pixel locations with high and low values of growing season NEE were selected from areas in the eastern, western, and northern areas in the Kazakh Steppe. These three pixel pairs of high and low NEE were then compared to growing season environmental variables (fig. 5). The selected paired points that represented sink and source trends in NEE were relatively consistent across the eastern, western, and northern areas. Similar and consistent trends also were observed for Pg and precipitation.

Valentini and others (2000) used a comprehensive data set from European forests and suggested that Re was the primary determinant of carbon sinks and sources, but we did not observe this based on our limited data set. The significance of Re in determining carbon sinks and sources may be important if annual fluxes are considered rather than growing season fluxes. Alternatively, the proportion of Re with respect to NEE and Pg in grasslands may be smaller than that in forests. Although small differences in growing season temperatures were observed between the carbon sink and source areas, the differences were consistent with what we would expect with more productive areas being cooler and less productive areas warmer. This analysis indicates that precipitation was apparently the primary driver of carbon sinks and sources for the Kazakh Steppe. Mapping of multi-year carbon fluxes for the Kazakh Steppe would allow an assessment of consistency of carbon sink and source locations. We expect that precipitation-related carbon dynamics would vary locally from year to year, and that carbon sources would be associated with shallow, poor, or degraded soils.

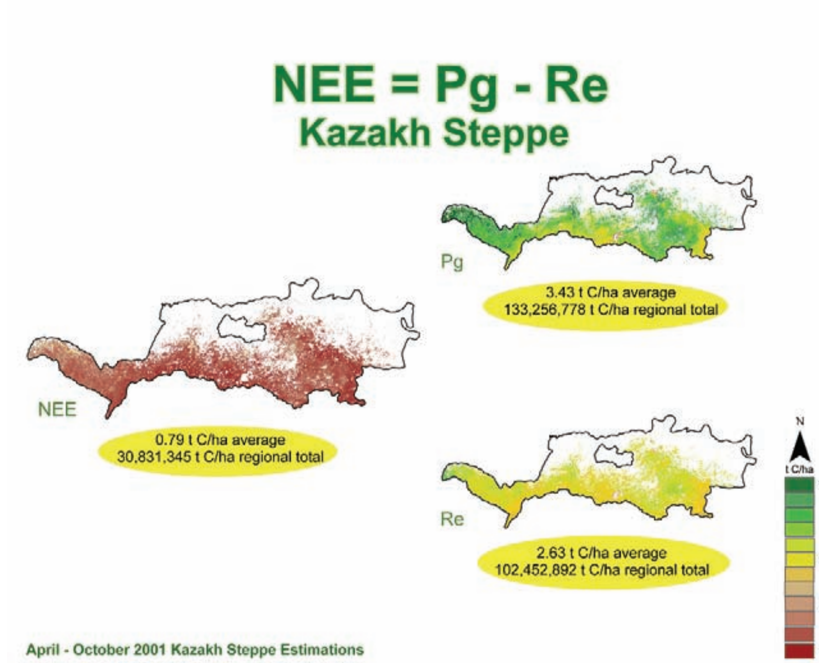

Figure 4—Growing season (April – October) 2001 regional carbon flux maps of gross primary productivity (Pg), total ecosystem respiration (Re), and resultant net ecosystem exchange (NEE = Pg – Re) for grasslands within the Kazakh Steppe.

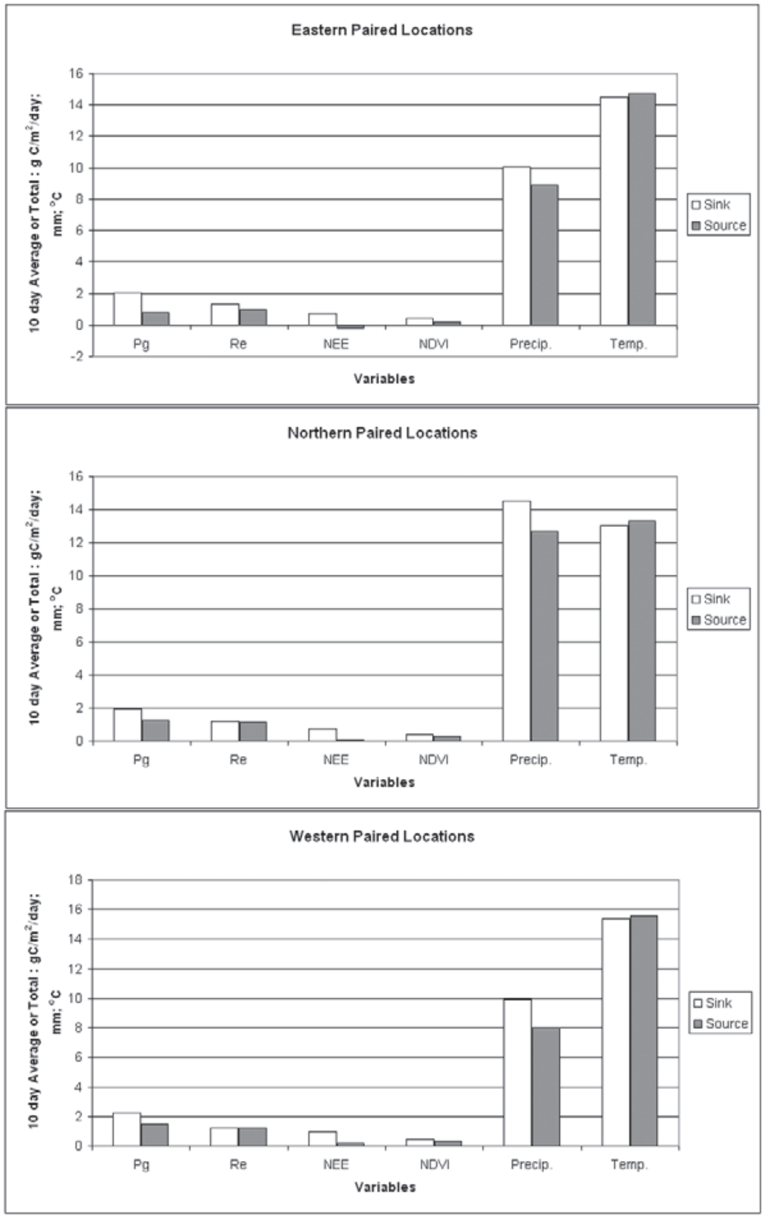

Figure 5—Comparison of selected growing season (April through October) carbon sink and source paired locations in the northern, eastern, and western Kazakh Steppe.

Although the magnitudes and dynamics of carbon fluxes during the growing season are larger and more variable than winter fluxes, quantification of annual fluxes is essential. Efforts to quantify winter fluxes in the Kazakh Steppe have been complicated by extreme winter conditions resulting in a limited number of days with reliable winter flux data. A modeling and gap-filling approach based on temperature, wind speed, and snow depth allowed preliminary quantification of annual fluxes in northern Kazakhstan. Results indicated the flux tower site in northern Kazakhstan was a weak annual carbon sink during 2001-2002 (Gilmanov 2002).

Summary

Similarities in vegetation structure, latitude, precipitation, seasonal patterns of NDVI and carbon flux responses from flux tower sites in the Northern Great Plains in western North America and the Kazakh Steppe in Central Asia indicated that data sets for carbon flux, GIS and remote sensing could be pooled from these two regions. These data were used to map 10-day and seasonal Pg, Re, and NEE for quantifying seasonal regional carbon dynamics. Pooling of data optimized the application of data sets from the Northern Great Plains and improved the robustness of regional flux mapping in the Kazakh Steppe. Carbon sink and source relationships in the Kazakh Steppe were strongly influenced by precipitation and Pg. Regression tree analysis was an effective method for scaling up localized carbon flux data to a regional scale.

This bottom-up regional scaling of flux tower information provides one km quantification of carbon dynamics at the 10-day time step that can be used for carbon monitoring, quantification of environmental drivers to carbon fluxes, and validation or training data for biogeochemical models. Future studies will assess geographic consistency of growing season carbon sinks and sources.

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A Comparison of Low Cost Satellite Imagery for Pastoral Planning Projects in Central Asia

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Abstract—*We discuss some of the advantages and disadvantages of satellite data for rangeland planning in Central Asia, with our emphasis being on sources of low cost or free data. The availability and use the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) as a base map and tool for coordinated natural resource planning in Central Asia is discussed in detail. Base maps are important in planning projects to help in identifying vegetation types, water sources, areas of concern (for example degraded sites), structures, for description of past and current uses, and the communication and development of a new plan. The ASTER data are currently free and use a non-continuous acquisition method so not all areas of the globe receive the same repeat coverage. ASTER data were found to have high coverage over Central Asia and "usable images," defined as growing season images and with ≤ 15 percent cloud cover, were found for 93 percent of points sampled in Central Asia. We compare the ASTER reflectance product with two other moderate resolution data sources, Landsat ETM+ and MODIS (250 m). This paper will benefit development agencies and natural resource managers in Central Asia that may not be aware of the advantage and disadvantages of different remote sensed data or sources of data.*

Keywords: *Landsat ETM+, MODIS, ASTER, Xinjiang, Co-management, coordinated planning, resource planning.*

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Introduction

The development of natural resource management plans, stressing multiple-uses and values and developed with herders and government officials, have been stressed in several papers in this proceedings (Fernandez-Gimenez; Reading and others; Sheehy and others; Schmidt). We certainly concur in the importance of coordinated resource planning. In China, Mongolia and Uzbekistan we initiated natural resource plans with pastoralists for development organizations as a means for helping conserve biological and cultural resources. In the development of coordinated resource plans, a base map is a necessity for communication and planning. These base maps can be as simple as a drawn map showing key resources to as detailed as Geographic Information Systems showing detailed planning information with aerial photographs as the base map. In general, resource information for natural resource planning in Central Asia is often very limited and/or not easily available, even for the development of base maps. For example, we have found that it is difficult to obtain topographic maps or aerial photographs because of cost and/or security concerns. In one instance we had security personnel confiscate topography maps and in other instances topographic maps were restricted to in country use. When topographic maps have been available, scales were usually greater than 1:100,000, a scale not conducive to effective base maps.

We have used low cost satellite images (such as Landsat ETM+) for the development of base maps for spatially locating resources, for communication of areas of concern to pastoralists and government officials, and for describing historical use. We have found that herders easily "read" moderate resolution images such as Landsat Enhanced Thematic Mapper plus (ETM+) images (fig. 1). Satellite data have been available worldwide

Figure 1—Mongolian herders identifying various resources using a Landsat ETM+ scene in Gobi Gurvan Saikhan National Park.

for several decades, but often the costs of image data at scales for development of base maps has been too costly and often difficult to obtain. For example, high-resolution satellite data such as the Systeme Pour l'Observation de la Terre (SPOT) or Ikonos may necessitate several scenes for large planning areas required for semi-nomadic groups making price prohibitive in many instances. We have also found that development agencies and natural resource managers in Central Asia are often not aware of the advantage and disadvantages of different remote sensed data or sources of data. There have been many papers reviewing or describing uses of satellite images for natural resource work (Cohen and others 2003; Nicholson and others 1998; Pickup, 1998; Zhou and others 2001) and a comparison of sensors (Chavez and Bowell, 1988; Chavez and others 1991; Cohen and others 2003; Yuhas and Goetz, 1993); however, in this paper we concentrate on the potential use, advantages and disadvantages and availability of free or low cost moderate resolution data products for pastoral planning projects in Central Asia. Our primary data analyses is an examination of the availability of a relatively new sensor, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), that provides data at a higher resolution (15 m in visible and near — IR bands) than LANDSAT and is currently free to the public.

The ASTER sensor was launched in conjunction with the Moderate Resolution Imaging Spectroradiometer (MODIS) as part of NASA's Earth Observing System (EOS) program in December 1999. While ASTER was launched primarily to obtain better understanding of the interactions between the biosphere, hydrosphere, lithosphere and atmosphere, MODIS was designed to improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere (http://modis.gsfc.nasa.gov/about/index.html). The ETM+ sensor, which is the most recent addition to the Landsat project that began in 1972, was also launched in 1999. Enhanced Thematic Mapper plus data were designed to facilitate applications in agriculture, geology, forestry, regional planning, education, mapping, and global change research (http://landsat.usgs.gov/).

We explore the availability of ASTER data for Central Asia as these data sources do not employ a continuous data acquisition strategy. We compare an ASTER NDVI to Landsat ETM+ and MODIS for an area we had developed a resource planning project in Fuyun County, Xinjiang Uygur Autonomous Region, Peoples Republic of China and discuss the uses of these three sources of information.

Methods

ASTER image availability was determined for 165 random geographic points in Central Asia by searching the EOS Data Gateway (http://edcimswww.cr.usgs.gov/pub/imswelcome/). ASTER, unlike other satellite data sources, does not employ a continuous data acquisition strategy and thus coverage in Central Asia was unknown. The 165 points included 20 points in each of Mongolia, Kazakhstan, Kyrgz Republic, Uzbekistan, Afghanistan, Turkmenistan, and Tajikistan and 25 points in western China (Xinjiang, Gansu, and Qinghai Provinces) to determine frequency of coverage and mean coverage by country. Points were selected by using a random numbers table to select latitude and longitude. Our search period was from April 1, 2000 to November 1, 2003. We also determined "usable images" as those within the growing season (April 1 to October 31) and with ≤ 15 percent cloud cover.

Spatial and temporal coverage of ASTER images was determined for the growing season (April 1 to October 31, 2000-2003) for a 26,000 km^2 project search site in Fuyun County, Xinjiang Province, China. Fuyun County varies from 600 m to 3600 m in elevation and annual precipitation averages 315 mm in the high mountains to 110 mm in desert areas. Maximum and minimum recorded temperatures are 43.5 °C and –51 °C. The vegetation varies from desert to grassland to forest as elevation increases. The vegetation of the Altai Mountains is predominately forest taiga, mountain grasslands, alpine meadows, and mountain meadows. In 2002, we used Landsat ETM+ for a pastoral planning project in this area and were aware of vegetation and topographic characteristics of this area. Any ASTER image intersecting or included within the study area was included as an available image.

We processed scenes of ASTER, MODIS, and Landsat ETM+ as a Normalized Difference Vegetation Index (NDVI) for the study area to illustrate differences and similarities. The NDVI was computed for ASTER and ETM+ data as (NIR – RED)/(NIR + RED) where RED and NIR are the spectral response in the red and near – infrared wavelengths, respectively. The ASTER Sensor is equipped with 14 spectral channels but for this study, we focused on NDVI computed from the visible and near – IR bands. For visible and NIR channels, ASTER has a spatial resolution of 15 meters while ETM+ has a resolution of 30 meters and both sensors measure radiance in the identical RED wavelength (0.63 – 0.69 µm) and nearly identical NIR bands (0.78 – 0.86 and 0.75 – 0.79 µm for ASTER and ETM+ respectively) (http://landsat.usgs.gov/). In contrast, MODIS offers 36 spectral channels ranging from visible to mid-infrared, with spatial resolutions at 250 meters (bands 1 and 2) 500 meters (bands 3 – 7) and 1000 meters (8 – 36) (Justice and others 1998). The 250 meter RED and NIR bands of MODIS are positioned between 0.62 – 0.67 and 0.84 and 0.87 μm respectively (http://modis.gsfc.nasa.gov/). Another unique feature of MODIS is the production of twelve land products grouped as radiation budget variables, ecosystem variables and land cover variables (Justice and others 1998). Fortunately, NDVI is one of the land products offered by the MODIS product suite. Though we had to compute NDVI for ASTER and ETM+, we used the standard NDVI from MODIS for comparison.

Results

We located 1419 total ASTER images and 622 "usable" images (during growing season and cloud cover ≤ 15 percent) for the 165 random geographic points (table 1). The mean number of total images/point varied from a high of 11.45 in Mongolia to a low of 7.05 for Kazakhstan (range of 2 to 19). The usable images varied from a high of 4.75/point in Uzbekistan to a low of 2.4/point in western China (range of 0 to 12). The lack of usable images was generally associated with cloud cover greater than 15 percent. Only 6.7 percent of random points had no usable images available.

Table 1—Mean number of available ASTER images and "usable" growing season images for 165 random geographic points in Central Asia.

Country or Area	Mean Available Images/Point	Growing Season Images with ≤15 Percent Cloud Cover
Mongolia[1]	11.45	3.50
Kazakhstan	7.05	3.75
Kyrgz Republic	8.65	2.65
Uzbekistan	8.80	4.75
Tajikistan	7.95	3.00
Turkmenistan	7.30	4.70
Afghanistan	7.85	5.40
Western China	9.52	2.40
Mean	8.57	3.77

[1] A point in Mongolia (106.11E and 46.15N) had 83 images available and 53 usable images (growing season and ≤15 percent cloud cover). We considered this an outlier and not included in our analyses. We believe this is a Japanese study site where researchers had requested additional coverage.

A comparison of spatial and temporal coverage of growing season ASTER images for 26,000 km^2 area in Fuyun County, China showed high temporal and spatial coverage between years (fig. 2). The number of growing season images varied from a high of 72 in 2001 to a low of four images in 2002. The number of available growing season images with low cloud cover (≤15 percent) varied from 23 images in 2001 to four images in 2002. Spatial coverage of growing season and low cloud cover images included 95 percent of the study area in 2001, but only 12 percent of the area in 2002.

An ASTER NDVI of the Fuyun area was processed and compared to Landsat ETM+ and MODIS data for the study area (fig. 3). A quantitative comparison was not appropriate because data sources are from different dates and different resolutions (table 2). However, a visual comparison illustrates similar NDVI patterns across this variable landscape (fig. 3). This is especially true for linear or contrasting features. For example, the relatively long and straight riparian areas of the Ertix River are clearly visible in all three sources of imagery. In addition, heavily vegetated areas near barren regions appear in sharp contrast regardless of the source of imagery.

Discussion

Our primary objective was to determine the potential availability of ASTER images for pastoral planning projects. We found a mean of 8.7 images available and 3.8 usable images (growing season with cloud cover <15 percent). Obviously, the number of low cloud cover images will be associated with climate and dates of ASTER data acquisition are not continuous. As ASTER data are free, and relatively easy to process, it is a ready source of information for developing base maps and for communication of information in developing natural resource plans in Central Asia.

Our secondary objective was to compare low cost moderate resolution satellite images for pastoral planning projects

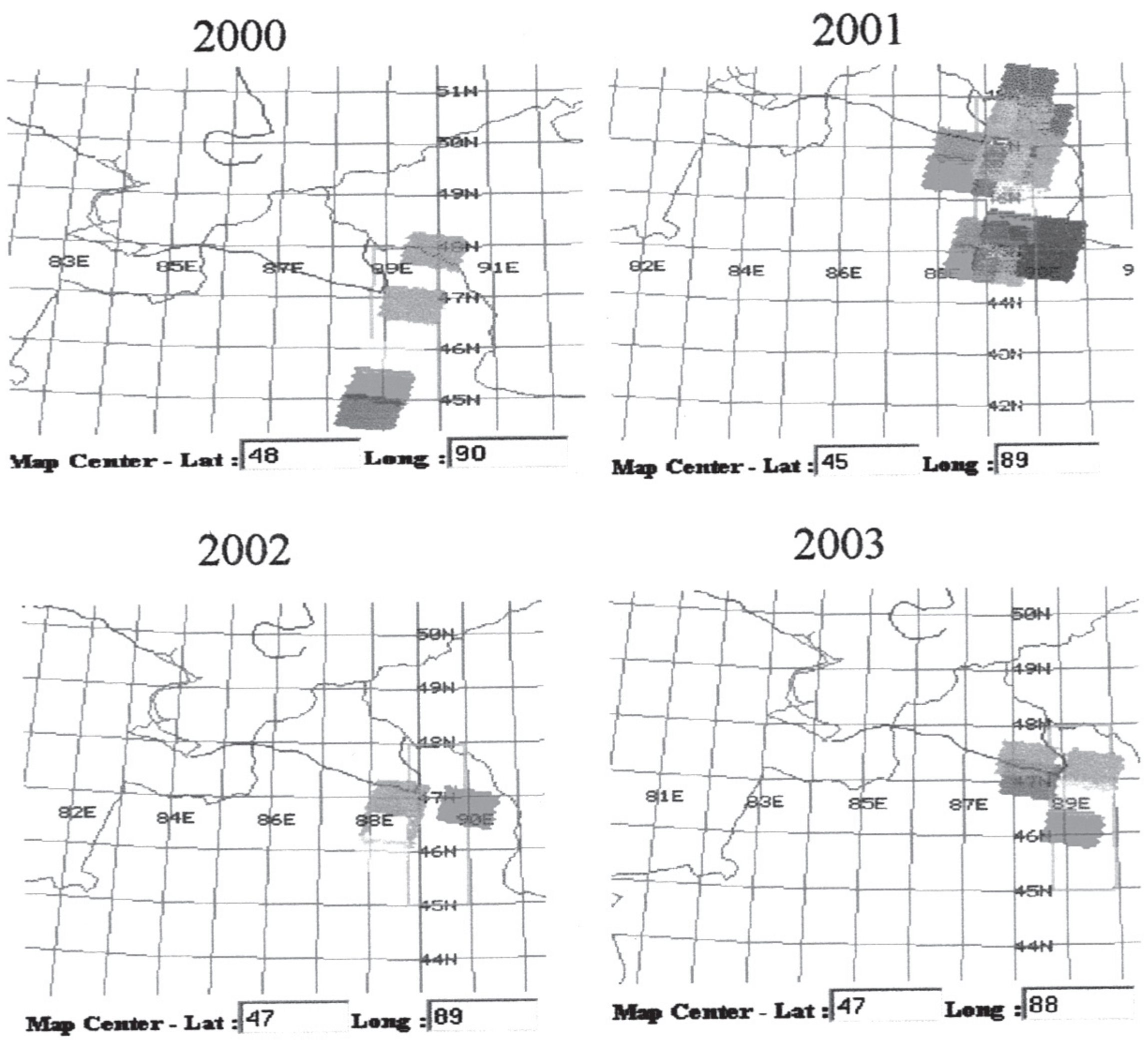

Figure 2—Temporal and spatial coverage of ASTER data (April 1 to October 31) for Fuyun project area, Xinjiang Uygur Autonomous Region, Peoples Republic of China.

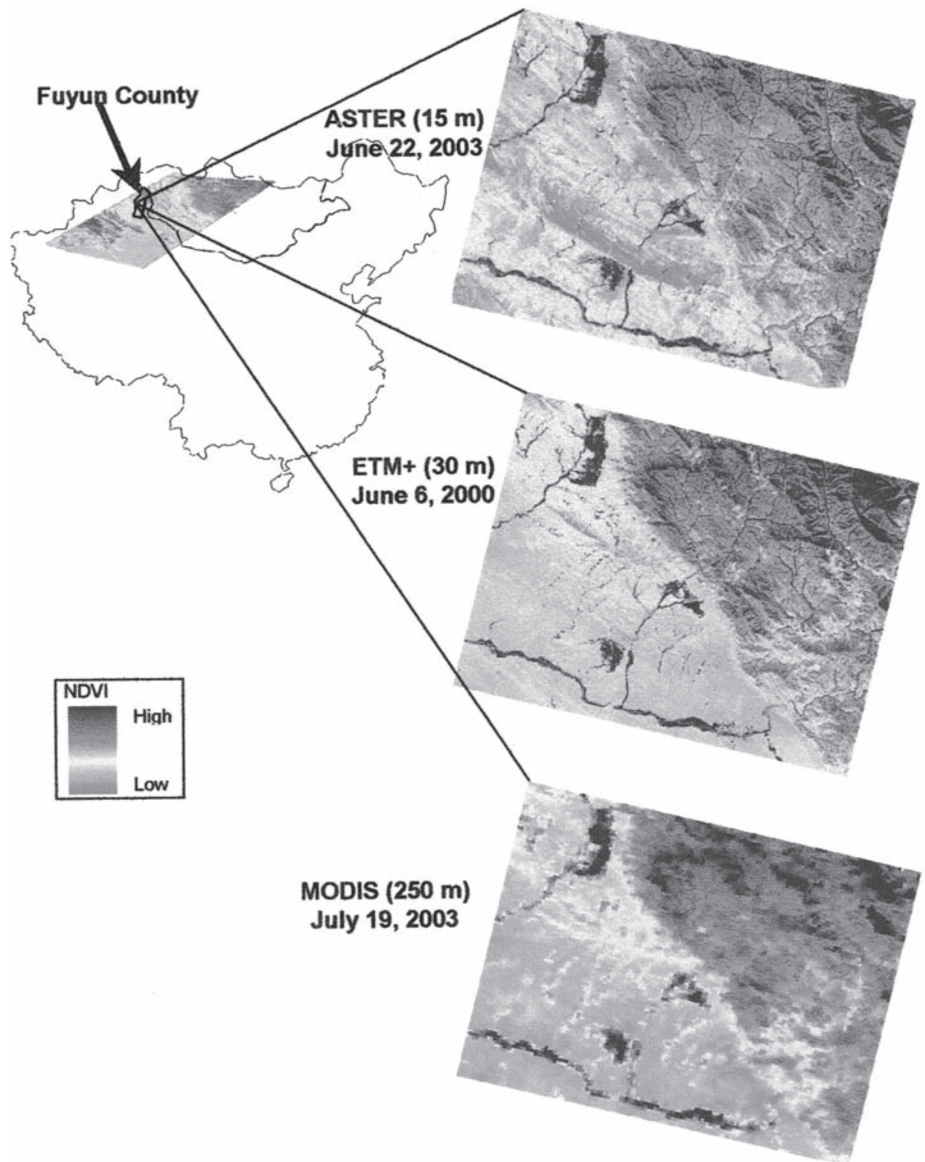

Figure 3—Study area, Fuyun County, showing MODIS scene coverage over portions of China and Mongolia. MODIS, ASTER and ETM+ NDVI's are illustrated for a subset of Fuyun County, Xinjiang Uygur Autonomous Region, Peoples Republic of China. The Normalized Difference Vegetation Index (NDVI) was computed as (NIR – RED)/(NIR + RED) where RED and NIR are the spectral response in the red and near – infrared wavelengths respectively.

Table 2—Spatial coverage of Fuyun County, Xinjiang Uighur Autonomous Region study area (88.73, 89.94E, 48.02, 45.01N) during April 1 and October 31 in 2000-2003.

Year	Total ASTER Images Available	Low Cloud Cover ASTER Images (≤15 percent cloud cover)
2000	16	5
2001	72	23
2002	4	4
2003	5	5

in Central Asia. Remote sensing instruments are necessarily designed with specific trade-offs in mind. For example, there is an inverse relationship between pixel resolution, repeat frequency and scene size. Accordingly, Landsat ETM+, ASTER and MODIS have different sensor characteristics encompassing a suite of spatial and spectral resolution, repeat frequency and cost of data (table 3). Despite these differences, the NDVI from these sensors produced remarkably similar vegetation patterns for our study area in China. This begs the question of what are appropriate uses for each different dataset? The answer depends on the intent of the analysis, the amount of data needed, the size of the study area and the operating budget. For example, we recommend use of MODIS 250-m NDVI for evaluating regional spatio/temporal patterns of vegetation. However, if the intent of the analysis is developing basemaps for identifying key landscape features and planning with herders and government workers, we recommend ASTER.

ASTER data provide sufficient resolution for identification of specific landscape features that aid in identifying vegetation types, geographic features and navigating diverse terrain. Features such as small pockets of riparian vegetation and individual agricultural fields are readily apparent in ASTER imagery (fig. 4). Other features such as roads, man-made structures and water-ways are also visible in ASTER imagery (fig. 4), which aids local navigation and communication between development specialists and pastorolists, particularly when other sources of information are lacking. Indeed, both the Ertix River and surrounding irrigated hayland are easily identified in ASTER imagery (fig. 4). The fine resolution of ASTER data also provides an ideal basemap for overlaying point data. For example, if vegetation attributes are measured in a 1-m^2 quadrat they should theoretically be more representative of a 15 meter image pixel (as in the case of ASTER) than a 30 or 250-m pixel (as in the case of ETM+ or MODIS). Thus, for spatially and temporally limited studies of vegetation patterns and for creating basemaps, ASTER data are quite useful.

The main disadvantage of ASTER data is the lack of continuous coverage for a particular area. While the results indicate that 93 percent of the study area had at least one image during the period from April 1, 2000 to October 31, 2003, the same coverage cannot be expected everywhere on earth. This is because ASTER does not employ a continuous data acquisition strategy and each acquisition must be scheduled and prioritized. Three categories of data acquisition exist: local observations, regional monitoring, and global map (Abrams and others 2004). For localized acquisition, the ASTER team designed an acquisition system that facilitates requests from authorized users. For example, a registered user can request ASTER imagery for any region in Central Asia. Currently, three groups of scientists can be registered users. These include ASTER Science Team members, Earth Observation System (EOS) principal investigators, and other approved investigators. In contrast to "local observation," "regional monitoring" occurs on a regular basis on a pre-determined set of locations around the globe including the worlds mountain glaciers, active and dormant volcanoes, and the Long-Term Ecological Research (LTER) field sites (Abrams and others 2004). Finally, "global map" acquisition is set to facilitate investigation by researchers in nearly every field. As such, each region of the earth has been prioritized by the ASTER Science Team (Abrams and others 2004). Currently, local observation, regional monitoring, and global acquisitions are allocated approximately 25, 50 and 25 percent of ASTER acquisitions, respectively.

In contrast to the ASTER system, the ETM+ sensor acquires data continuously along a set path. This means that for each area on the globe there will be coverage at an interval of approximately 16 days for every point on the globe. The ETM+ (and its predecessor Landsat 5) have been used more extensively for evaluating natural resources than either MODIS or ASTER. Thus, a wealth of information exists for processing and evaluating Landsat imagery. The 30-m resolution of ETM+ permits better visual identification of landscape features than MODIS, but not ASTER. Carefully designed plot-level analyses can also be coordinated with ETM+ in a similar fashion to ASTER. The primary disadvantages to ETM+ data are the cost ($605/scene), the lack of atmospheric correction, and since May 31, 2003 a sensor problem. The lack of atmospheric correction may not impose a problem for projects where the aim is developing base maps to aid in development of natural resource plans. Perhaps of greater concern is that the sensor anomaly, known as the scan line corrector (SLC) anomaly, produces large areas of missing data for every image. The United States Geological Survey (USGS) is currently implementing a series of improvements to remedy the problems being encountered within the ETM+ data stream, but there is no doubt that the problem greatly decreases the value of this data source and there are no known plans to replace the ETM+ sensor. Some facilities, such as the Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml)

Table 3—Selected sensor characteristics of the ASTER, ETM+, and MODIS Sensors.

Sensor Characteristics	ASTER	ETM+	MODIS
Cost (US$)	Free	$605 [2]	Free
Repeat frequency (Days)	Variable[1]	16	1 – 2 [3]
Atmospheric correction	Yes	No	Yes
Spatial resolution of VNIR (m)	15	30	250 – 1000
Spatial Coverage (ha/scene)	470,610	4,854,299	144,000,000

[1] Can be pointed off-nadir to increase repeat frequency but is typically about 16 days.
[2] Some websites now offer a limited source of free ETM+ data.
[3] Close to the equator the repeat time is approximately 1.2 days.

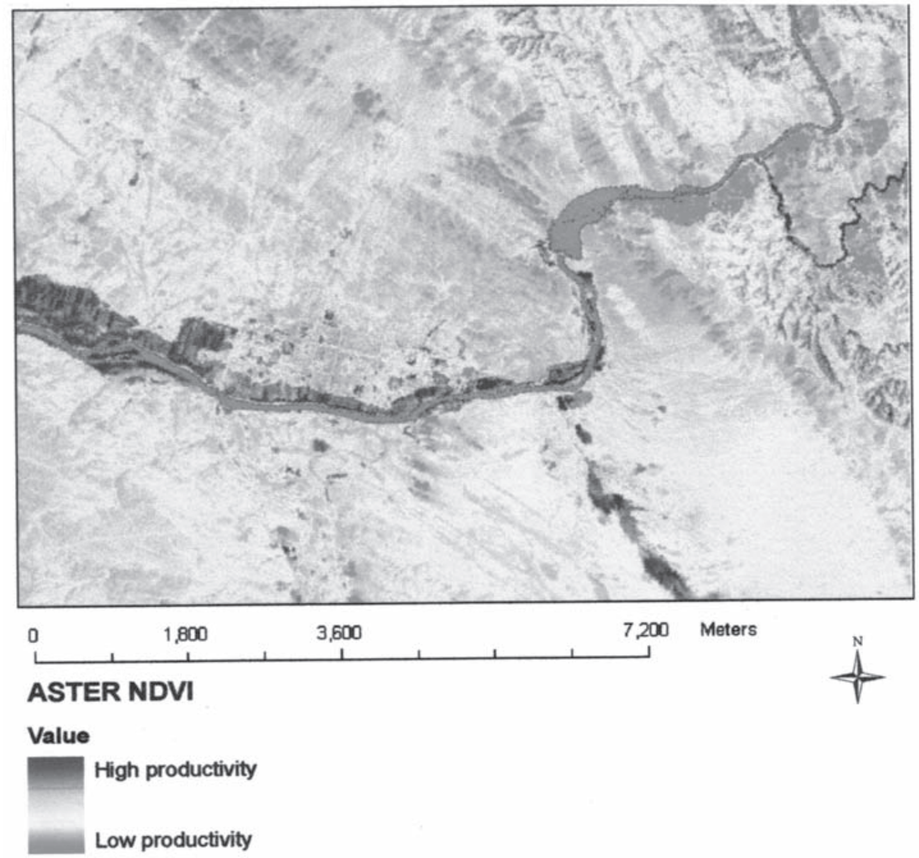

Figure 4—ASTER NDVI (1:40,000 scale) of Fuyun region, Xinjiang Uygur Autonomous Region, Peoples Republic of China.

are now offering free ETM+ data for many areas around the globe. At this time, spatial coverage, and especially temporal coverage, of free ETM+ scenes are limited.

MODIS data lack the resolution of ASTER and ETM+, but provide a logical choice for evaluating vegetation trends over a large region. For example, figure 3 indicates that it would require few MODIS images to completely cover China. In addition, MODIS data are cloud - screened which is a clear advantage compared with standard ETM+ or ASTER imagery. Since MODIS data are cloud screened and collected for the globe every 1 – 2 days, temporal composites are typically produced such that even if a pixel is cloud-covered for a given day, it can be replaced with the next un-clouded value in the temporal sequence. Such is the case with the standard MODIS NDVI product, which is a 16 – day composite.

In contrast, ASTER and ETM+ data are acquired using longer repeat cycles (table 3), hence only a few images may be acquired during the growing season, which often yields only a few useable images because of cloud cover. Another benefit of MODIS data is that it is atmospherically corrected prior to dissemination and contain a variety of quality control (QC) information permitting the user to interactively determine which pixels are suitable for analysis. In the case of the standard 250 – m NDVI MODIS product there are 13 data fields that can be accessed for each pixel that describe different aspects of the data quality (Huete, 2002; Huete and others 1999).

The primary limitation of MODIS NDVI is the relatively coarse spatial resolution (250 – m). While the MODIS 250 – m spatial resolution is superior for global and regional analyses, it is insufficient for developing the cartographic output necessary for developing base maps for pastoral planning projects showing micro-resource areas or for navigating in complex terrain.

Summary and Management Implications

Coordinated natural resource planning stressing multiple-uses is critical for conserving natural resources and pastoral livelihoods in Central Asia. We have been involved in a number of development projects where base map information for developing resource management plans have been lacking. The use of satellite imagery such as Landsat ETM+ and ASTER provide planners inexpensive sources of information for development of base maps. MODIS offers the ability to illustrate temporal changes and regional differences. We have found that pastoralists often easily "read" ASTER and Landsat ETM+ images. For example, we have had pastoralists draw in grazing areas, past land-use and past-movement of herds, current and past wildlife areas, important resources or areas of resource concerns on printed images. We have also used images for identification of monitoring sites and communication of plans with pastoralists and government officials or other pastoral groups. It is very likely that there will be greater free or inexpensive web resources of satellite images in the future, but at this time we believe that ASTER with its high degree of coverage in Central Asia, its relatively high resolution (15 m), offers a valuable resource tool for natural resource planners.

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RMRS
ROCKY MOUNTAIN RESEARCH STATION

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

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