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.*

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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 agro-ecosystems 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.

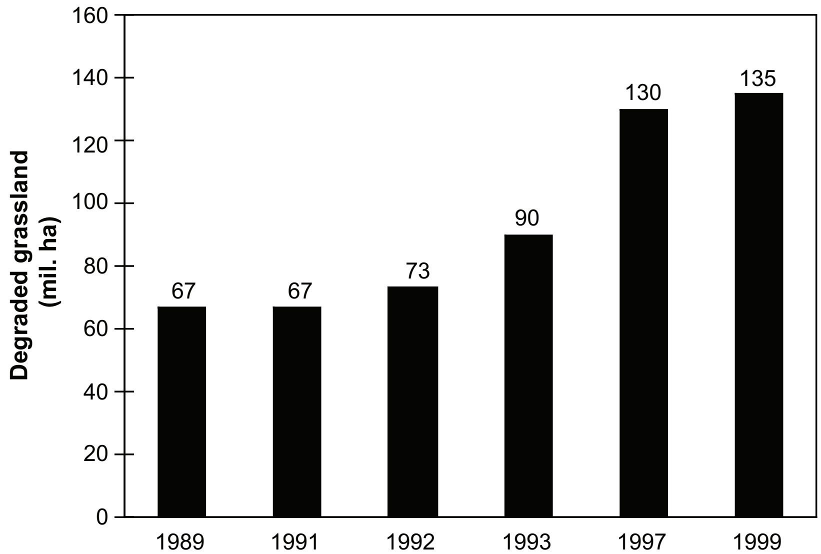

Figure 1—The Trend of Rangeland Degradation in China. Data Source: State Environment Protection Agency, China Eco-environment Condition Report (1990-2000).

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.

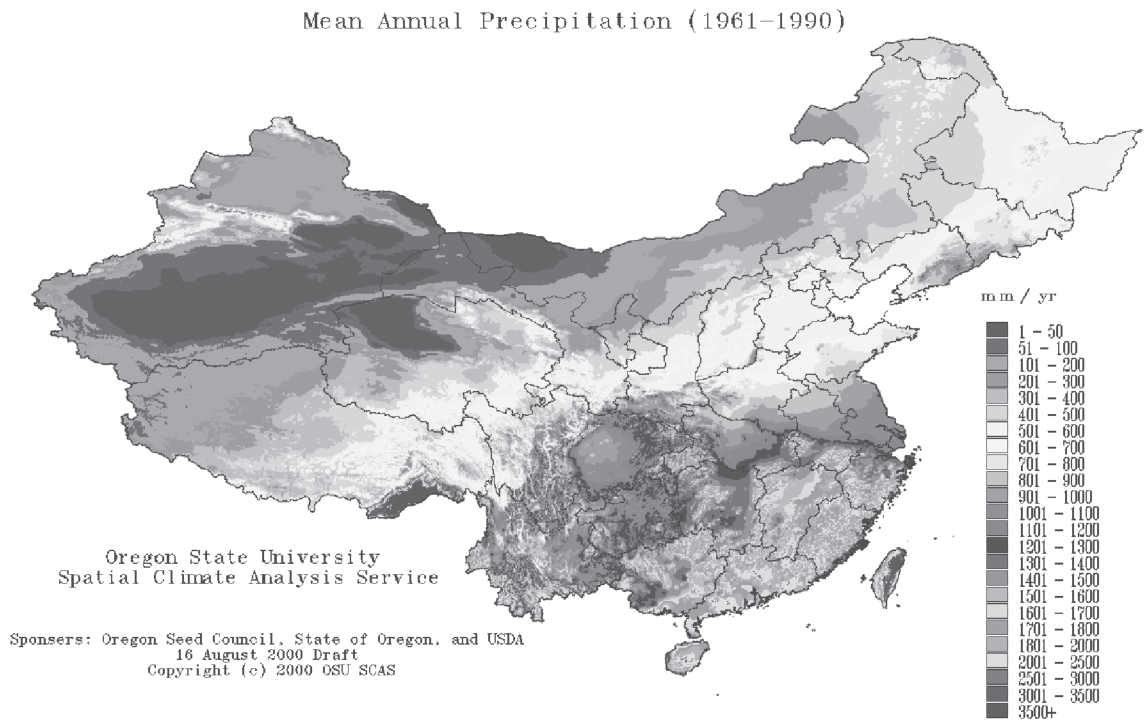

Figure 2—Precipitation Zones of China.

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.

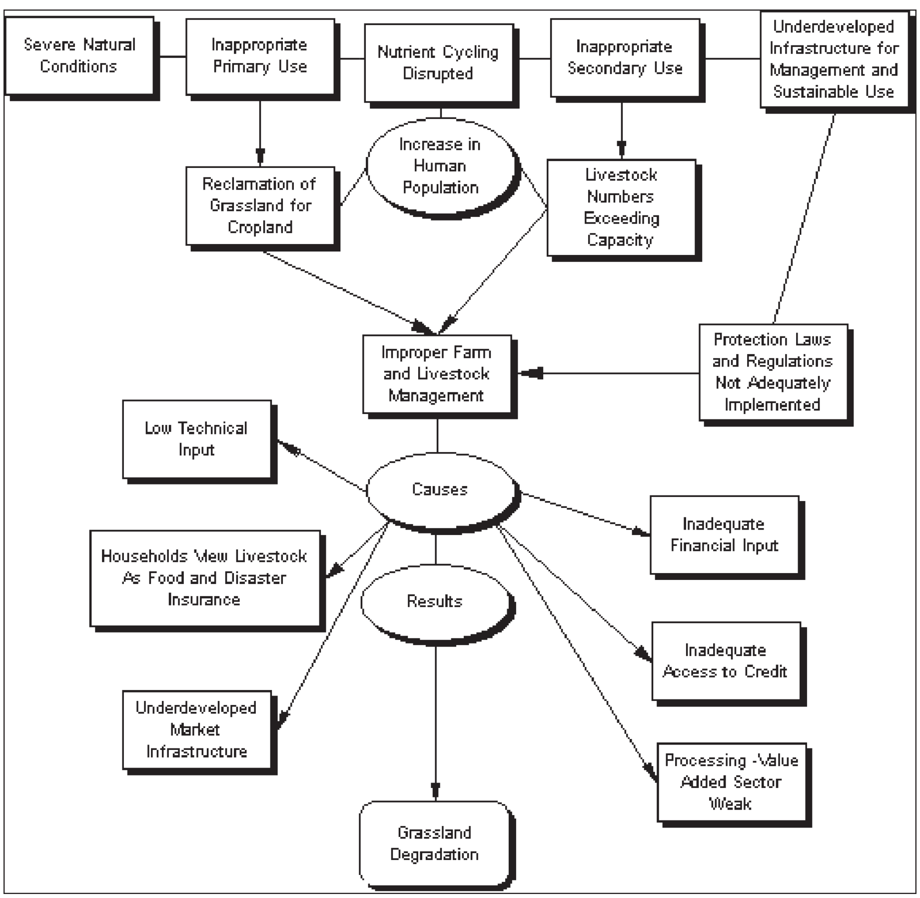

Figure 3—Factors Influencing Rangeland Degradation in One Livestock Banner of Chifeng City, Inner Mongolia (1997). Source: Adapted from "Improvement of Northern Rangeland Ecosystems," Consortium for International Development/ Ministry of Agriculture, 1997.

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.

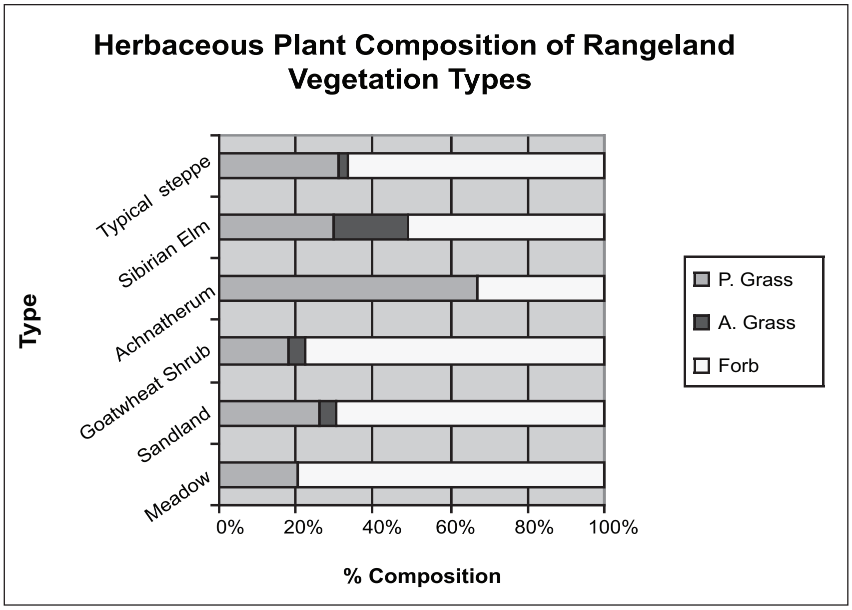

Figure 4—Dominant Vegetation Types of the Yihenoer PDA. Source: Non-published reports compiled by the senior author for the International Fund for Agricultural Development and the Ministry of Agriculture between 1985 and 1987.

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.

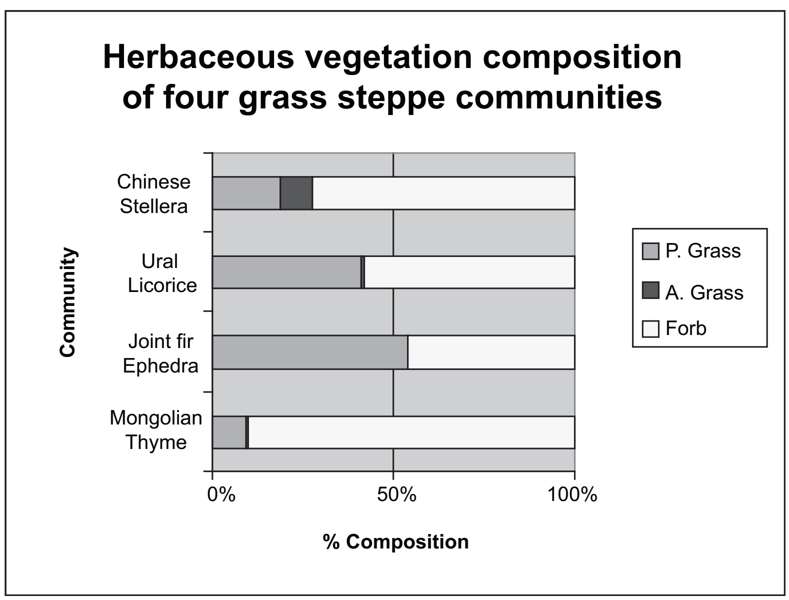

Figure 5—Successional Communities in the *Stipa grandis* Association. (P. Grass represents perennial grass and A. Grass represents annual grass). Source: Non-published reports compiled by the senior author for the International Fund for Agricultural Development and the Ministry of Agriculture between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