Grasslands and Grassland Sciences in Northern China

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Xilingele

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The Xilingele steppe (Map 1-3) is one of the few well-preserved areas of the Inner Mongolia grassland region. Although several surveys of this area carried out during the 1950s to 1970s emphasized vegetation and geographical aspects, relatively systematic and intensive studies did not begin until the late 1970s. The founding of the Inner Mongolia Grassland Ecosystem Research Station of the Academia Sinica (commonly called the Xilingele station) in 1979 was a landmark in the history of grassland research in this region. However, previous research work had been carried out in the Xilin River Basin area, which is the site of the research station and of China's first grassland nature reserve.

The research staff of the Xilingele station is composed of scientists from the Institutes of Botany and Zoology of the Academia Sinica, Inner Mongolia University in Hohhot, and several other institutions. The major lines of research pursued by these scholars include vegetation analysis and mapping, soil typology and its relationship to land use, structure and function of plant communities, plant population distribution patterns, primary productivity and dynamics, characteristics and roles of grassland rodents and acridoids in steppe communities, soil microorganism ecology, and the creation of artificial grassland.

Dr. Wu Jianguo and Professor Orie Loucks describe the natural conditions and human impacts on the typical grasslands of Xilingele League in Inner Mongolia. Research on the flora of this region has established baseline data on species composition, population distribution and community structure, vegetation dynamics, and biomass productivity, while research on fauna has focused on rodents, game animals, acridoids, and microorganisms. The authors also describe work on the utilization and conservation of grassland resources.

THE XILINGELE GRASSLAND

The Xilingele grassland is the most typical of the Mongolian grasslands in terms of dominant species and major community characteristics such as cover, density, and primary productivity (Liu et al., 1987). Xilingele is a Mongolian word, meaning river [*gele*] on a ridge [*xilin*]. The Xilingele grassland covers a lava tableland and has a relatively flat topography. The slightly wavy terrain, dotted by bare rock outcrops, forms a distinct steppe landscape. Without major rivers, the surface water system is poorly developed. Most of the few lakes and ponds are salty or alkaline. The groundwater table is usually deep, but may be as shallow as 3–5 m below the surface in localized depressions and interhill lowlands, where most herdsmen's yurts are found. Wells are a major water source for people and domestic animals.

The Xilingele grassland is located in the temperate semiarid climatic region. The climate is characterized by the alternation of dry summers and cold winters. The mean annual temperature is around 0°C, with an annual range of about 40°C (Figure 4-1). The frost-free season lasts from 120 to 140 days. The mean annual precipitation is between 250 and 350 mm, with a very uneven distribution over the year. In most years, up to 80% of the total precipitation falls from May to September, coinciding with the peak temperatures (Figure 4-1). This coincidence of high moisture and high temperature favors the growth of plants.

Spring is usually dry and windy, with high evaporation and low relative humidity. Although only 6–9% of the annual precipitation falls in winter

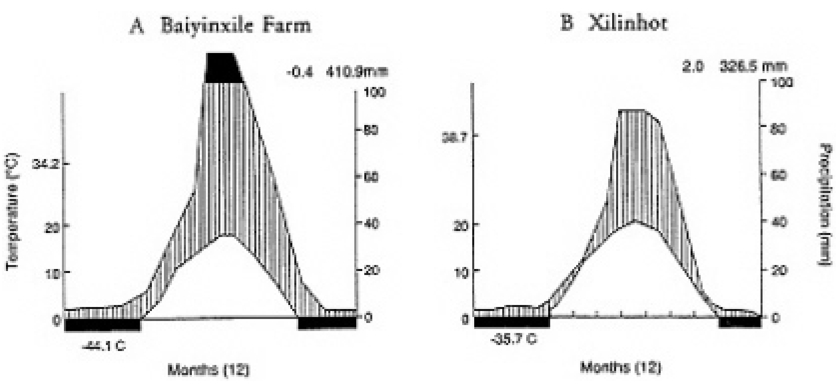

Figure 4-1 Klimadiagrams, Xilingele League, Inner Mongolia Autonomous Region: (A) Baiyinxile Livestock State Farm (1220 m), (B) Xilinhot (993 m).
NOTE: For explanation of terms, see Figure 3-1, p. 56.
SOURCE: Zhao et al. (1990).

(October to March), accumulated snow is important for winter water use and for regrowth of plants in spring. The year-to-year change in precipitation is as high as 30% in this region.

The major soil type in this region is chestnut, an alkaline soil with low organic matter content (less than 4%), poor fertility, and a marked calcic horizon. Other soils include chernozem, meadow, and saline types. The vegetation of the Xilingele grassland is typical steppe (dominated by *Stipa grandis, Aneurolepidium chinense, Agropyron michnoi*) and dry steppe (dominated by *Stipa krylovii, Cleistogenes spuarrosa*, and other bunchgrasses). Besides having distinct dominant species, other important differences between these two vegetational groups include the following: (1) forbs and rhizome grasses that are frequent in the typical steppe are poorly represented in the dry steppe; (2) the typical steppe develops in dark chestnut soils, the dry steppe in light chestnut soils; and (3) local climatic conditions are slightly drier and warmer in dry steppe than typical steppe (Li et al., 1988). With the increase in gravel and sand content of the soil, short semishrubs (e.g., *Artemisia frigida*) and shrubs (e.g., *Caragana microphylla* and other species of *Caragana*) become more important in species composition. The conspicuous *Caragana* gives the steppe a special physiognomy.

One of the most representative and best-preserved areas of the Xilingele grassland and of the whole Inner Mongolian Steppe is found in the Xilin River Basin (Li et al., 1988). This is also one of the best-studied grassland regions in China, with much background information having been accumulated during the past three decades. The Inner Mongolia Grassland Ecosystem Research Station, which includes the first grassland nature reserve in China, is located here. Several important projects related to UNESCO and the Man-and-the-Biosphere program have being carried out in this area. The Xilin River Basin extends from 43°26' to 44°39'N latitude, and from 115°32' to 117°12'E longitude, covering a total area of 10,786 km^2 (1,078,600 hectares). The elevation of the region decreases from 1505.6 m atop the Daxinganling Mountains in the east to 902 m in the lower reaches of the Xilin River in the northwest. The growing season in the basin area is 150–160 days. Plants turn green in early or mid-April, enter their most active growing period in mid-to late May, and cease growing in middle or late September (see Figure 4-1). According to one recent survey, this region has 625 seed plants, belonging to 74 families and 291 genera.

Steppe communities are composed mainly of xeric, perennial herbaceous plants, occupying about 85% of the vegetated area of the Xilin River Basin. According to Li Bo et al. (1988), there are three natural steppe zones in the basin—meadow steppe, typical steppe, and dry steppe—although some researchers argue that the whole area is typical steppe. In the upper reaches of the Xilin River, meadow steppe, rich in both xeric grasses and mesic forbs, has developed on the fertile chernozem. In the middle reaches, with a decrease in elevation and precipitation, mesoxeric or xeric forbs and xeric bunchgrasses replace the mesic forbs, forming the typical steppe. Dry steppe, lacking in forbs and abundant in xeric bunch-grasses and short semishrubs, occupies the lower reaches where topography and precipitation are even lower and temperature is higher. The major formations in this area include *Filifolium sibiricum, Stipa baicalensis, Festuca dahurica, Aneurolepidium chinense, S. grandis, S. krylovii*, and *Artemisia frigida*. In addition to the zonal steppe vegetation, some nonzonal plant communities, including sandy vegetation (sandy sparse woods, sandy shrublands, and sandy semishrublands) and wet lowland vegetation, are also found here.

HUMAN IMPACT

Since 1949, the Inner Mongolia grasslands have gone through five periods of human utilization and resource management (Yong, 1984). Although there are few reliable statistics for livestock during the pre-1949 era, Yong (1984) indicates that from 1949 to 1958, animal husbandry developed rapidly, and grassland resources were effectively utilized. Domestic livestock, although still small in number, may have increased by 10% per year. During the second period, 1959–1962, because of severe economic difficulties and food shortages, vast areas of the grasslands were put under cultivation. In the economic recovery and readjustment of 1963–1965, animal husbandry in Inner Mongolia developed further. The total livestock in this area increased to a historic peak of nearly 12 million head. As the problem of overgrazing emerged, government agencies began to recognize the need for research into and reconstruction of the grasslands. It was at this time that China's first grassland research center was established in Inner Mongolia. Meanwhile, the Academia Sinica's Integrated Expedition in Inner Mongolia and Ningxia carried out extensive field investigation on regional vegetation, which laid the foundation for subsequent grassland research.

During the Cultural Revolution, from 1966 to 1976, the animal husbandry and environment of the Inner Mongolian grasslands were seriously damaged. This period was marked by the second major expansion of agriculture into the grasslands. Under the pressure of policies to "make grain production the key link," some herdsmen turned from animal husbandry to farming. The large-scale transformation of grasslands into farmlands devastated steppe vegetation and caused large-scale desertification and salinization. The grasslands were degraded, and grassland research and technology were retarded. After the end of the Cultural Revolution in 1976, new policies were announced to protect grasslands and promote animal husbandry. As a result, livestock raising again rapidly advanced. By 1980 the total number of livestock in the Inner Mongolia Autonomous Region reached 40 million.

Prior to the 1950s, agriculture had never been practiced in the Xilin River Basin (Li et al., 1988). Farming on the Baiyinxile State Farm began in 1956, when 9.33 km^2 were put under cultivation. The sown area increased to 24.67

km^2 by 1959 and 94.67 km^2 by 1968. In 1969, when urban students were "sent down" to the countryside for reeducation, increasing both the local demand for food and the labor to produce it, the area under cultivation was expanded to 141.34 km^2, or 4% of the total territory of the farm. Since a cutback in 1975, the Bayinxile State Farm cultivates about 133.34 km^2.

As a result of excessive cultivation, overgrazing, and mismanagement, degradation and desertification of the grasslands have increased. According to one recent survey, 2,133,700 km^2, or 35.57% of the available grasslands (excluding farmland), of Inner Mongolia have been degraded; within Xilingele League alone, 71,587.90 km^2 of the grasslands have been degraded, of which 33,312.50 km^2 are severely degraded (Li and Chen, 1987). Since 1949, desertification of the steppe region has increased by more than 33,000 km^2 (Li et al., 1985).

Although the scope of agriculture has increased, animal husbandry continues to dominate the economy of Xilingele League and Inner Mongolia as a whole. The principal pattern of livestock raising has been extensive seminomadism based on seasonal migration. Catastrophic winter storms historically have caused drastic drops in the number of livestock in Inner Mongolia (Figure 4-2).

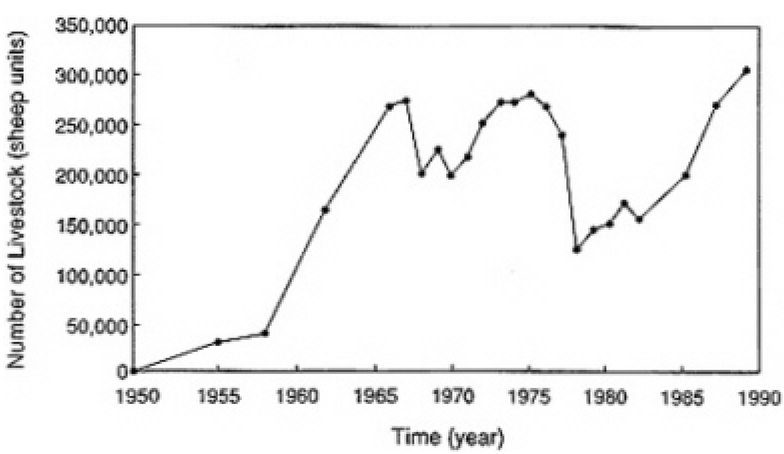

Figure 4-2 Livestock population, Baiyinxile State Farm, 1950–1989.
NOTE: The Baiyinxile Livestock State Farm was established in 1950 and enlarged in 1960, so that the increase in livestock numbers, from 1959 to 1962, represents in part an increase in area covered. The two sharp declines, in 1968 and 1977, coincide with severe storms.
SOURCE: Liu (1989).

The carrying capacity, expressed in sheep units per unit area and averaged for the entire natural grassland of Inner Mongolia, declined from 8700 in the 1950s, to 8500 in the 1960s, 6500 in the 1970s, and 5800 in the 1980s (Liu, 1989). With the reduction in area of available grassland and the increase in animal numbers, the grassland area per sheep unit in Xilingele League has declined exponentially (Figure 4-3). This does not mean, however, that the carrying capacity of this region has been exceeded. In fact, the stocking rate on the Baiyinxile State Farm has been low, currently only 0.75 sheep unit per hectare (Li, 1990).

HISTORY OF SCIENTIFIC RESEARCH

According to Li (1964), the first report on the vegetation of Inner Mongolia was by J.F. Gerbillon, a European missionary, in the late seventeenth century. In 1724, the German scholar D.G. Messerschmidt made the first collection of plants in eastern Inner Mongolia. Such collecting activities were continued by the Belgian Artselaer (1854), the Frenchman P.A. David (1866), and a number of Russians (1831 and later). The systematic scientific study of this region began under the central Asian surveys conducted by the Geographical Society

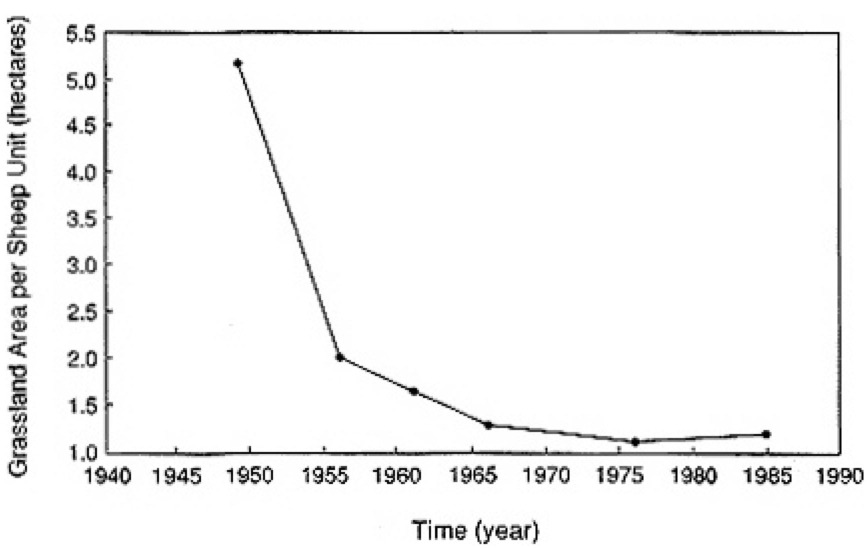

Figure 4-3 Grassland area (hectares) per sheep unit (S.U), Xilingele League, 1950–1985.
SOURCES: Jiang (1988); Li (1990).

of Russia (1870–1885). From that time on, Russian studies of the vegetation of Inner Mongolia made important contributions to grassland research and grassland science in China. In the early twentieth century, Japanese scholars carried out extensive surveys of Inner Mongolian plant life.

European and American scientists have done less work in this area. An extensive survey by Europeans, conducted between 1927 and 1935, produced more than 50 volumes on various biological subjects. From 1913 to 1915, A. Sowervy, from the Natural History Museum of New York, surveyed the fauna of eastern Inner Mongolia. A paleontological expedition, led by Roy Andrews and representing the same museum, visited north China, Inner Mongolia, and southern Mongolia in 1918 and 1919. In 1923, the American R. Wulsin organized a scientific expedition to survey the people, plants and animals of Gansu and Inner Mongolia. In 1935, the U.S. Department of Agriculture sent a work team to Inner Mongolia to collect seeds of drought-resistant grasses that might be adaptable on the prairies of the southwestern United States. In recent years, several cooperative projects between Chinese and Western scholars have focused on the Inner Mongolia grasslands. The American rangeland ecologist George Van Dyne visited Inner Mongolia in 1980. Other ecologists from Europe, Australia, New Zealand, and Japan have visited or worked on the Xilingele grasslands since the late 1970s.

In the 1930s, Chinese scholars began to study the flora and fauna of Inner Mongolia. Several surveys, organized by government agencies, scientific associations, and universities, have been conducted since the early 1950s. After the founding of Inner Mongolia University in 1957, the university's department of biology selected the Baiyinxile State Farm as the site of its field experimental station. In 1963, the State Science and Technology Commission decided to set up the Experimental Research Center for Modern Grassland Husbandry in Xilingele. From 1964 to 1965, 70 scholars from Inner Mongolia University, Inner Mongolia College of Agriculture and Animal Husbandry, Nanjing University, the Institute of Botany, the Experimental Research Center for Modern Grassland Husbandry, and other work units carried out a large-scale, integrated survey of this area. Based on this survey, Li Bo and others compiled the report "Vegetation and Grassland Resources of Xilingele Farm Region," one of the most comprehensive and detailed studies of its kind. Because of disruptions caused by the Cultural Revolution, this report was not distributed until 1975 and then only for internal reference. In 1977, Inner Mongolia University established the first plant ecology major offered by a Chinese university since the 1960s, and 24 students were enrolled. These students and their professors have played an important role in China's grassland research. In 1979 the Baiyinxile State Farm was chosen as the site of the Inner Mongolia Grassland Ecosystem Research Station. Shortly thereafter, China's first grassland nature reserve was set up in the same area.

GRASSLAND RESEARCH

Species Composition, Distribution, and Community Structure The distribution and community structure of the Xilingele grasslands have been well documented. Li et al. (1988) cover a variety of topics on the vegetation of the Xilin River Basin, including the history of vegetation formation, flora, classification and mapping of vegetation, structure and function of different steppe communities, sandy land vegetation, dynamics of vegetation, grassland productivity, and regionalization and utilization of vegetation. This is a well-integrated summary of previous scholarship on the vegetation of the Xilingele region. Liu et al. (1987) analyze the characteristics of grassland resources using vegetation as an integrative indicator, in order to provide guidelines for proper use of the grasslands. Xilingele is one of the several regions of Inner Mongolia covered in their article. Yong (1982) explains and discusses the objectives and significance of mapping, the techniques and rules of mapping, the types and distribution of natural vegetation—and the ecological regionalization of vegetation—all in connection with the mapping of the Xilin River Basin, carried out between 1979 and 1981. Wang et al. (1979) divide Inner Mongolia into vegetation zones: the cold-temperate bright coniferous forest zone, moderate-temperate deciduous forest zone, moderate-temperate steppe zone, warm-temperate steppe zone, and warm-temperate desert zone. The Xilingele grasslands are located in the moderate-temperate steppe zone. Liu (1963) recognizes seven types of Stipa steppes in Inner Mongolia, belonging to three vegetation subtypes: meadow steppe, typical steppe, and desert steppe. Li (1962) presents a classification system of zonal vegetation in Inner Mongolia, including forest, steppe, and desert regions, and describes relationships between vegetation and its physical environment on a regional scale. This paper is one of the classics on Inner Mongolian vegetation and laid the foundation for subsequent research. Liu (1960) describes the environmental conditions, floristic characteristics, classification, regionalization, and utilization and improvement of grassland vegetation in Inner Mongolia. This paper was one of the most important early contributions to the knowledge of Inner Mongolia grasslands and, along with other work done in the 1960s by Li Bo, Yong Shipeng, and Liu Zhongling, reflected the viewpoint of the Russian geobotany school.

Vegetation Dynamics The steppe communities of Xilingele are believed to have existed in a climax stage or stable state sometime before the recent array of perturbations. The dynamics of these grasslands are now influenced by grazing, mowing, and fallow-land succession (Yong, 1984). Although a reasonable and comprehensive understanding of vegetation dynamics is crucial for the wise utilization and management of natural resources, there have been few systematic studies of grassland succession in Xilingele. Yong (1984) and Li et al. (1988) have summarized most of the research on this subject.

Overgrazing and overtreading have caused a decrease in the diversity of species and community structure and a degradation of the soil in many places, especially near human habitation. For example, vegetation within 10 km of the Baiyinxile State Farm has severely deteriorated. With increasing grazing intensity, the average height, cover, and density of the dominant species *Stipa grandis* and *Aneurolepidium chinense* decrease sharply, whereas undesirable plants of the *Artemisia frigida* and *Potentilla* species, increase. Five distinctive stages in grazing succession have been identified: slightly grazed, moderately grazed, slightly overgrazed, overgrazed, and severely overgrazed. General trends in community dynamics caused by increased grazing have also been described. First, community productivity declines, with a decrease in plant height, cover, and density. Second, changes in species composition, including a decline in the number of palatable grasses and an increase of unpalatable species, also occur. Although changes in water content, structure, and organic matter of soil, as well as selective browsing, are believed responsible for changes in vegetation, the mechanisms behind this phenomenon remain poorly understood.

The major types of mown grasslands in Xilingele are *Aneurolepidium chinense* steppe and *Bromus inermis* meadow. Increased mowing produces effects similar to those caused by overgrazing: decrease in plant height, undesirable changes in species composition, and decline in productivity (Li et al., 1988). Both empirical and experimental data on mowing succession have accumulated in the last several years (e.g., Zhong et al., 1987, 1988; Zhong and Piao 1988). Yong (1984) and Li et al. (1988) found that left untended, abandoned agricultural lands may return to their precultivation state, although research on this phenomenon has been limited. In general, fallow-land succession passes through four stages: from fallow land to tall annual and biennial forbs (1–2 years after abandonment), to rhizome grass (2–3 years), to rhizome bunchgrass (5–10 years), and finally to bunchgrass (15–20 years). Detailed information on changes in community structure and function during old-field succession has been reported by Li et al. (1988).

Biomass Production Since the 1950s, several studies have been done on community production in the Xilin River Basin. During a survey of natural vegetation in the 1960s, the productivity of different vegetation types was measured, and based on these measurements, estimates were made of standing crops and animal carrying capacities (Li et al., 1988). The productivity of major vegetation types found on the Xilingele Station has been monitored, and some general characteristics of biomass production have begun to emerge.

Most work on community productivity has been done by researchers from the Institute of Botany and Inner Mongolia University and published in *Research on Grassland Ecosystem* [*Caoyuan shengtai xitong yanjiu*], which is edited by the Inner Mongolia Grassland Ecosystem Research Station. Research on biomass production has included studies of qualitative and quantitative rela tions between community productivity and environmental factors such as water and minerals (e.g., Li, 1963; Li, 1985; Yang et at., 1985; Chen Zuozhong et al., 1988); photosynthetic efficiency, dynamics, and other characteristics of dominant grass species (e.g., Du and Yang, 1983, 1988; Qi et al., 1983); and community structure-phytomass relations and dynamics of above-and below-ground biomass (e.g., Qi et al., 1985; Wang, 1985; Gao, 1987; Chen and Huang, 1988; Huang et al., 1988; Li et al., 1988).

According to data obtained from the Baiyinxile State Farm, the aboveground biomass production of different steppe communities ranges from 350 to 850 g/m^2 (fresh weight), with large yearly variations caused primarily by differences in precipitation. In general, the productivity of meadow steppe is higher than that of typical steppe, while within the latter, *Aneurolepidium chinense* steppe, has higher production than *Stipa grandis* steppe. The below-ground biomass ranges between 860 and 1700 g/m^2 (fresh weight), which is about twice that of aboveground. The total amount of solar radiation energy is 5,756,850 kJ/m^2 per year (137.5 kcal/cm^2 per year) in the Xilingele Basin, of which about half is effective radiation (i.e., the portion available for photosynthesis). The plant growth season in the basin lasts about 140 days (early May to late September) during which time 1,582,610 kJ/m^2 (37.8 kcal/cm^2) of effective radiation are received. The light use efficiency (biomass/effective radiation) of the Xilingele Basin grasslands (including meadows, swamps, and sandy land vegetation) ranges from 0.49 to 1.5% (Li et al., 1988), with an average of 0.7% for steppe vegetation and 1.4% for meadows and semiartificial grasslands. The spatial distribution of vegetation productivity is heterogeneous: highest (1500–3000 kg per hectare) in the upper reaches of the Xilin River, moderate (1000–1500 kg per hectare) in the middle and parts of the lower reaches, and lowest in the lower reaches and the vicinity of Xilinhot City, which are much drier, more heavily populated, and thus more susceptible to human perturbation.

Population Distribution and Community Structure Researchers from Inner Mongolia University have carried out studies on the structure of plant communities in Xilingele, including detection of population distribution patterns and analysis of community structure (Yang, 1983; Yang et al., 1984); determination of species correlations and pattern analysis of species association (Yang and Hou, 1985); development of a new approach to pattern analysis (Yang et al., 1983); and optimal sampling areas (Yang and Bao, 1986; Yang et al., 1984).

Ecological Regionalization Ecological regionalization provides a scientific basis for the utilization and management of natural resources in different geographical regions. In contrast to European and American ecologists, who have based classification of ecological regions on the spatial arrangement of geo graphical factors, Li Bo and other Chinese ecologists emphasize the integrative function and potential productivity of regional ecosystems, a perspective that is more closely related to land use planning and resource management. The work on ecological regionalization in Inner Mongolia has been summarized by Liu et al. (1987) and Li et al. (1987).

There are three basic levels in the classification of ecological regions: ecoregion, subecoregion, and ecodistrict. An ecoregion is an area with similar biotic climate, potential productivity, and dominant vegetation type. A subecoregion is characterized by a greater homogeneity or similarity in biotic climate, land-form, and soil conditions, and in potential for utilization and management. Ecodistricts are distinguished by the specific features and local variations of their ecosystems. Inner Mongolia is divided into seven ecoregions: coniferous forest, deciduous forest, forest steppe, steppe, desert steppe, steppe desert, and desert. The steppe ecoregion, which covers the largest area, is divided into 10 subecoregions. The Xilingele grasslands fall into the *Stipa grandis-Aneurolepidium chinense* steppe ecodistrict, one of the two ecodistricts within the *Stipa grandis-Aneurolepidium chinense* steppe subecoregion. It has been recommended that this area be used primarily for animal husbandry and that large-scale farming be prohibited.

Artificial Grasslands Both small and large areas are being seeded manually to create artificial grasslands that are important to the sustained utilization and management of the Xilingele steppe. Since 1981, large-scale experimental studies on artificial grassland have been conducted at the Xilingele Station by a group of researchers from Inner Mongolia University. Results of these studies have been reported by Chen and Bao (1985, 1988), Chen and Wang (1985), and Chen Min et al. (1988). A fine native forage grass, *Aneurolepidium chinense*, and a few leguminous plants were chosen as the experimental species. Researchers have carried out field studies on the ecophysiology, reproduction, and other biological characteristics of these forage plants. Techniques have also been developed for cultivating grasses on the steppe. By 1987, more than 40 hectares of artificial grassland had been successfully established in this way. This work has laid a theoretical and practical foundation for developing large-scale artificial grasslands in semiarid regions without the use of irrigation.

Remote Sensing From 1983 to 1987, a team from Beijing and Inner Mongolia Universities, carried out a project entitled "Applying Remote Sensing in the Survey of Inner Mongolia Grassland Resources" (Li and Chen, 1987). This was the first large-scale grassland research project in China that made use of remote sensing. It relied primarily on data from a Multispectral Scanner (MSS), although images from a Thematic Mapper (TM) and other sources were also employed. Although visual interpretation was the fundamental method, comprehensive biogeographic analysis of image information and image en hancement were also used. This project resulted in the compilation of thematic maps of grassland resources at 1:1,000,000 for the IMAR and 1:500,000 for each league, including maps for vegetation, rangeland type, land use, climate (surface moisture and temperature), geomorphology, water resources, soil, and ecoregionalization. These achievements have provided valuable information for agricultural regionalization, grassland management, land use, environmental conservation, and monitoring of resource dynamics at various scales. The results of this project have been published in the book *Survey of Inner Mongolia Grassland Resources Using Remote Sensing*, edited by the Inner Mongolia Grassland Resources Remote Sensing Expedition (Chen and Li, 1987).

Animals and Animal Ecology Animal ecology has received less attention than vegetation or plant ecology in the Xilingele steppe region. A survey of mammalian fauna was carried out from 1979 to 1987 by a group of scientists from the Institute of Zoology. The first systematic report on the mammals of Xilingele (Zhou et al., 1988) found 32 species, belonging to 15 families and 6 orders. These include several species that are representative of the Mongolia-Xinjiang region and the East Steppe subregion: *Microtus brandti, Citellus dauricus, Ochotona daurica, Phodopus sungorus, Meriones unguiculatus, Allactaga sibirica, Procapra gutturosa, Vulpes corsac*, and *Felis manul*. The activities of herbivorous rodents such as *Microtus brandti, Ochotona daurica*, and *Citellus dauricus* damage the grassland, whereas seed-feeding rodents such as *Cricetulus barabensis* and *Meriones unguiculatus* do harm to farmlands. Game animals in this area include the herbivores *Lepus capensis, Capreolus*, and *Procapra gutturosa*. Several carnivores, such as *Mustela nivalis, M. altaica, M. sibirica, M. eversmanni, Felis manul, Vulpes corsac*, and *V. vulpes*, are fur-bearing animals and predators of grassland rodents.

Animal studies have focused primarily on two groups: grassland rodents and acridoids. Rodents are among the most diverse and abundant of the grassland mammals. Studies of the species composition, spatial patterns, food preferences and consumption, behavioral characteristics, and community structure and function of steppe rodents have been carried out continuously since 1979 (Zhong et al., 1981, 1982, 1983, 1985a,b; Zhou et al., 1982, 1985; Agren et al. 1989a,b).

Since 1980, researchers at the Institute of Zoology have also studied the acridoids of the Xilin River Basin (Li et al., 1983; Li and Chen, 1985, 1988). Specimens collected during the periods 1963–1964 and 1980–1986 include 33 species of acridoids, belonging to 4 families and 24 genera, in the Xilingele typical steppe area (Li and Chen, 1988). Among geofauna, palaearctic species are dominant, with 29 species accounting for 87.8% of the total. The steppe acridoids may be divided by habitat into three major groups: xerophilous, mesophilous, and hydrophilous. *Pararcyptera microptera meridionalis, Myrmeleotettix palpalis*, and *Chorthippus dubius* are important pests during outbreak periods, and *Dasyhippus barbipes, Chorthippus fallax, Angaracris rhodopa*, and *A. barabensis* also destroy steppe vegetation when their populations are high. Food selection by the dominant species *Dasyhippus barbipes, Myrmeleotettix palpalis*, and *Chorthippus dubius* have been studied in both artificial and natural conditions (Li et al., 1983; Li and Chen, 1985). The dominant acridoids prefer *Aneurolepidium chinense* but will also feed on other plants.

Soil Animals and Microorganisms Researchers from Inner Mongolia University have studied soil animals and the soil microorganism ecology of the Xilingele region. He et al. (1988) identified 23 families of soil animals, belonging to 15 orders, 8 classes, and 6 phyla. Nematoda, Acarina, Coleoptera, and Formicidae of Hymenoptera were found to be dominant. The variety and number of soil animals are highest in the *Aneurolepidium chinense* steppe, lowest in *Stipa grandis* steppe, and intermediate in sandy land, meadow, retrogressive steppe, and artificial grasslands.

The study of soil microbial ecology begun in 1979 has covered seasonal changes and distribution in soil profiles (Liao et al., 1985), biomass dynamics (Liao and Zhang, 1985), and soil enzymatic activities (Liao et al., 1988; Zhang and Liao, 1990). These studies have shown that the density of microorganisms varies with the type and fertility of the soil, whereas their distribution in the soil horizon and the dominant groups alternate with the seasons. In both *Aneurolepidium chinense* and *Stipa grandis* dominant communities, the microbial biomass is highest for actinomycetes, intermediate for bacteria, and lowest for fungi.

Utilization and Conservation of Grassland Resources There have been many articles and reports on the principles of grassland utilization and conservation in Inner Mongolia (e.g., Yong, 1984; Liu et al., 1987; Jiang, 1989). Li et al. (1988) have done a thorough synthesis of work on the Xilingele steppe. All of these authors have identified existing problems in grassland utilization and made recommendations for improving the management of grassland resources. Their studies have shown that the fencing of degraded grasslands can aid restoration. For the typical steppe of Xilingele, appreciable improvement (especially the recovery of fine forage grasses such as *Aneurolepidium chinense* and *Agropyron* spp.) may occur in two to three years after fencing, and its natural ("normal") state can be approached in five years (Jiang, 1989). The cost of fencing is about 112 *Renminbi* (U.S.$24.00) per hectare (Jiang, 1989).

There have been some attempts to estimate the carrying capacity of grasslands in the Baiyinxile State Farm, based on data for forage productivity, stocking rate, and animal consumption rate (e.g., Jiang, 1988; Li, 1990). These studies have brought together quantitative data that could be used to develop systems models for grassland resource management in this area. Although still incomplete, this data set is probably better than that available for any other grassland area in China. Li (1990) has developed a simple, static model that may stimulate future work in this direction.

According to these studies, the key limiting factor for the development of animal husbandry in the Xilingele steppe has been the shortage of forage in winter and early spring. Several measures have been proposed to overcome this problem: adjust the geographical allocation of livestock; ensure adequate mowed grassland; establish artificial grasslands; establish an integrated system of agriculture and animal husbandry through an ecological engineering approach; and accelerate the livestock turnover rate (Jiang, 1988, 1989; Li, 1990).

CURRENT PROBLEMS AND FUTURE OPPORTUNITIES

Finally, while recognizing the accomplishments of Chinese grassland scientists working in Xilingele and throughout the country, it is worth noting some of the shortcomings of previous research and opportunities for future growth. First, as Chinese scholars themselves have noted (see Li et al., 1989), there has been an emphasis on basic at the expense of applied science; the results of academic research have not been converted promptly to useful methods for the management of grassland resources. It is essential to establish closer connections between these two functions of scholarship. Second, grassland research in Xilingele, as elsewhere in China, has lacked an integrated systems approach. For example, studies of the grasslands have not included livestock as an integral part of the system. There has been virtually no ecosystem level research. In the future, Chinese scholars must build on the data that have been accumulated for the Xilingele region to undertake research with a broad ecosystem perspective and an integrated approach. Third, grassland research in Xilingele and in China generally has followed a basic ecology (man-outside-nature) approach, while the human impact on the structure and function of steppe ecosystems has been largely ignored. Future studies should adopt an applied ecology (man-in-nature) approach that incorporates economics and other social factors. Fourth, there has been no landscape ecological study in the Xilingele region. Landscape ecology is relatively new in China. Still, it is important to achieve a better understanding of the geographical and functional relationships among ecosystems. Fifth, Chinese scholars have made little use of Geographical Information Systems (GIS), which could be used to promote grassland research at the landscape level and could help solve the problems of over-and underutilization of current grazinglands in a sustainable manner. Finally, previous work has not made sufficient use of ecosystem models. Computer simulation models can greatly assist and guide ecosystem level studies and help solve problems related to the long-term use of grasslands for livestock production.

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