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Mongolian rangelands in transition

Abstract

Mongolia has a rich history and diverse, expansive rangelands. Mongolia's rangelands have always been publicly owned, but their management has changed with the Country's governing structure. In its transition from a centrally controlled economy to a market economy since 1990, livestock production has undergone marked changes that have affected the management and ecological condition of Mongolia's rangelands. A combination of increased livestock numbers, diminished spatial distribution of livestock, collapse of many grazing management systems, severe winter storms, and a series of drought years have affected the ecological condition and stability of rangeland resources across much of the country, especially in the desert-steppe and desert ecological zones. An infrastructure for effective grazing regulation, support services, and marketing needs to be established to allow Mongolians to compete in a global market economy and ensure sustainable use of their unique rangeland resources.

Key words: Mongolia, Central Asia, pastoralism, animal production, arid zone, rangelands.

Résumé

Parcours de Mongolie en transition

La Mongolie possède une riche histoire et des parcours étendus et divers. Les parcours mongols ont toujours appartenu au domaine public mais leur gestion a varié en fonction des structures gouvernementales du pays. Dans leur transition d'une économie centralement planifiée vers une économie de marché depuis 1990, la production animale a subi de grands changements qui ont affecté la gestion et les conditions écologiques des parcours. L'effet conjoint de l'accroissement des effectifs et de la répartition du bétail sur un espace réduit a provoqué l'effondrement de nombreux systèmes de gestion. De sévères tempêtes hivernales et une série d'années sèches ont affecté les conditions écologiques et la stabilité des ressources pastorales dans de nombreuses zones du pays, particulièrement dans la zone steppique-désertique et la zone proprement désertique. Une infrastructure capable d'instaurer des règlements efficaces d'utilisation des parcours, des services d'assistance et l'organisation du marché sont devenus nécessaires pour permettre aux Mongols de devenir compétitifs dans le cadre d'une économie de marché global et pour garantir une utilisation durable des ressources pastorales uniques du pays.

Mots clés : Mongolie, Asie centrale, pastoralisme, production animale, zone aride, parcours.

When Westerners hear the name Mongolia, they typically think of Genghis Khan (Chinggis Khaan in Mongolian) and broad expansive grasslands or rangelands. Prior to the time of Genghis Khan, the area we know as Mongolia today, was little more than a

territory consisting of a loose assemblage of various warring clans. Genghis Khan managed to unite the warring Mongol tribes in 1206 and for the next 21 years guided the country in becoming a major power in Asia. Genghis extended the boundaries of his empire from Beijing to

the Caspian Sea. His son (Ogedi) and grandson (Kublai) further expanded Genghis' Empire from Korea to Hungary to Vietnam, making it the largest Empire the world has ever seen. After the death of Kublai in 1294, the Empire began to disintegrate and eventually reverted to a collection of warring clans.

Westerners also associate extensive rangelands with Mongolia. It is a land-locked country that has a population of 2.5 million people. More than half of the population of Mongolia is concentrated in Ulaanbaatar (the capital city), making Mongolia one of the least densely populated countries in the world. Of Mongolia's land area that is used for agricultural purposes, 98% is used as grazing land. Private ownership of rangelands has apparently never existed in Mongolian history and traditions [1], and rangelands have always been state-owned property used in common by herders or herder groups. With only about 1% (1.35 million hectares) of the land area suitable for cropland, livestock grazing has been and is currently the main use of the landscape. As a result, nomadic pastoralism continues to be a dominant aspect of Mongolia's economy and culture. There are now an estimated 26 million head of livestock in the country, and animal husbandry accounts for about 35% of agricultural gross production and 30% of the country's exports. About half of the population depends directly or indirectly on the livestock sector.

Mongolian herders are exposed to considerable risks that affect their livestock production systems and their livelihoods. These risks include: drought, snowstorms, livestock disease epidemics, grasshopper and rodent infestations, wolf predation, market access, and livestock prices. Natural disasters in the form of droughts and severe winter snowstorms pose a high risk. These can cause large livestock losses and human suffering, and impoverish large numbers of herding households. Through the centuries Mongolian herders have learned to manage these risks, employing various strategies for managing livestock in an inherently risky environment. However, with the change to a market economy in 1990, herders have become more vulnerable to risks because of the collapse of the Socialist support system that was in place under their centrally-planned economy. Reducing the vulnerability of herders to these many risks is a critical challenge in Mongolia [2].

Mongolian rangelands are in a critical state of transition today. Nomadic pastoralism as a viable and productive form of land use in Mongolia is being questioned. During the last decade, a combination of increased livestock numbers, diminished

spatial distribution of livestock because of broken wells, collapse of many grazing management systems, severe winter storms, and a series of drought years have significantly affected rangeland ecological condition and long-term ecological stability of rangeland resources across much of the country, especially in the desert-steppe and desert ecological zones. This situation has implications for the long-term sustainability of livelihoods among many herding households. It is the objective of this paper to describe the expansive rangelands of Mongolia, characterize their past and present patterns of use, and describe the challenges Mongolians face in ensuring their unique rangeland resources do not undergo irreversible degradation.

Geographical and topographical characteristics of Mongolia

General features

Mongolia is situated in the centre of Central Asia, and its territory comprises 1.56 million km² of which 75.8% is considered having potential for agricultural production [3], primarily extensive pastoral livestock production. Mongolia stretches 1,259 km from north to south and 2,392 km from east to west [4]. The country is located between 87°41" and 119°56" east longitude, and 41°35" and 52°09" north latitude [5]. The majority of Mongolia lies at elevations above 1,500m with even Mongolian plains having elevations between 800 to 1,500m [6]. Mountain peaks > 4,000m are concentrated in the Mongolian Altai (Mt. Huiten-Uul at 4,374m) and Hangai Mountains (Mt. Otgon-Tenger at 4,031 m [7]. Mongolia has numerous mountain ranges throughout the country including the Great Sayan, Buteel, and Hentei Mountains in the north; Great Hingan highlands in the east; Mongolian Altai and Gobi-Altai ranges in the southeast and south; and Han-hohii and Hangai Mountains in the west [5, 6]. The Gobi Desert traverses the country along its southern border with China.

Water resources

Mongolia is situated between the basins of the Arctic and Pacific Oceans and the closed depressions of Central Asia [6]. Lakes, streams, and rivers are abundant in the northern portion of the country. Major rivers originating from the Altai, Hangai, Hentei, and Hovsgul Mountains drain into the Pacific Ocean Basin, while small rivers and streams flow into small lakes. Of the 3,811 streams and rivers that total > 67,000 km in length across Mongolia

[8], the Selenge River is the largest river with a total length of 600 km [9]. The Haraa and Eroo Rivers converge with the Toul River, which originates on the southern slopes of the Hentei Mountains [5]. The longest river draining into the Pacific Ocean is the Herlen River, of which 1,090 km flows through Mongolia. The deepest rivers draining into the Pacific Ocean are the Onon and Ulz Rivers. There are several large rivers with no access to the sea, including the Tes, Hovd, Zavhan, Baidrag, Tuin, Ongi, and Bulgan Rivers [9]. Mongolia has more than 3,000 lakes and ponds, of which 80% are saline. The largest lake is Huvsgul Lake, which is 134 km long and 35 km wide. Almost 65% of Mongolia has no open water sources, so livestock production in these areas critically depends on wells for watering livestock [5]. About 35% of exploitable underground water sources are found in the Dornod Plain, 25% in the Hangai-Hentei Mountains, 32% in the Gobi Desert, and 8% in the Altai Mountains. This means that 70% of underground water resources in Mongolia occur in the Gobi Desert and steppe zones. During the past several decades, water use for irrigation, mining, and other human activities has increased, and deforestation and climate change have purportedly resulted in substantial reductions in river flows, flow regimes, and water levels, or in some cases complete drying of lakes and the lowering of groundwater tables [10, 11].

Climate

With its central continental position in Asia and its long distance from oceans, Mongolia's climate is largely defined by its proximity to major mountain systems. Mountain ranges in the west and northwest portion of Mongolia intercept atmospheric flows carrying moisture from the Atlantic Ocean. Monsoonal storms from the Pacific Ocean fade rapidly and their influence is generally considered to be between 110 to 120° east latitude [4, 6, 12]. This exposes Mongolia to the dry Central Asian desert winds from the south. As a result, Mongolia has an extremely cold, dry winter; dry, cold, and windy conditions in the spring; and the occurrence of most precipitation during mid-June to the end of August [12-14]. Mean annual precipitation decreases from north to south [12]. During the last 60 years, mean annual air temperature has increased by 1.6°C. If this pattern of change continues, by 2040 mean summer temperatures are predicted to increase by 1.0°C to 3.0°C, mean winter temperatures by 1.4°C to 3.6°C, and mean annual temperatures by 1.8°C to 2.8°C [15].

Major agro-ecological regions of Mongolia

Mongolia can be divided into several major agro-ecological regions and sub-regions with distinct climatic and geophysical characteristics [4], which dictates their potential for agricultural and livestock production. Critical climatic and geophysical factors include: amount and timing of precipitation, temperature extremes, elevation, frost-free days, and soil type. Both extended droughts and winter snow/ice storms can commonly occur in any region. The major agro-ecological regions in Mongolia are described below.

• Hangai-Hovsgul Region

The Hangai-Hovsgul Region is situated in the northwest portion of Mongolia. This is a mountainous region of high elevation (2,000 to 3,000m) and deep valleys with some forest and arid steppe [4, 6]; mean annual temperature is -2.5°C to 7.5°C with the lowest temperature in January (-24°C) and warmest temperature in July (19°C); 60 to 100 frost-free days; and an annual precipitation of 200 to > 400mm [12]. Wind speed averages between 2 to 4 m/sec, and snow cover is often > 15 mm in depth [4].

• Selenge-Onon Region

The Selenge-Onon Region consists of broad valleys and plains with elevations between 1,500 to 2,000m [4], mean annual temperature of 0.0°C to 2.5°C with the coldest temperature in January (-20°C) and warmest temperature in July (19°C); 70 to 120 frost-free days; and an annual precipitation of 250 to 400mm [12]. Snow cover averages 5 to 10mm in depth, and wind speed averages 4 to 6 m/sec [4].

• Mongolian Altai Region

The Altai Region is located in western Mongolia and has two distinct districts. The first district is the Mongolian Altai, which stretches from the northwest to the southeast for more than 1,500 km. The second district is the Turgen Mountains and Lake Ureg-Nur. These districts have elevations ranging from 1,500 to 4,000m [4]; mean annual temperatures of -2.5°C to 5.0°C with the coldest temperature (-24°C) in January and warmest temperature (22°C) in July; 60 to 120 frost-free days; and an annual precipitation of 400 to 500mm [12]. Snow depth ranges between 5 to > 15mm, and wind speed averages 2 to 6 m/sec [4].

• Central and Eastern Steppe Region

The Central and Eastern Steppe Region is the broad, essentially treeless region in central and eastern Mongolia [16], which

is characterized by low knolls, hills, and high plains. This region has elevations ranging from 900 to 2,000m [4]; mean annual temperature of 0.0°C to 2.5°C with the coldest temperature in January (-20°C) and warmest temperature (22°C) in July; 110 to 140 frost-free days; and an annual precipitation of 150 to 250mm [12]. Snow depth ranges between 5 to 10 mm, and wind speed averages 4 to 8 m/sec [4].

• Gobi Desert Region

The Gobi Desert Region includes the semiarid and arid southern portion of Mongolia. This region has elevations ranging between 700 and 1,400m [4]; mean annual temperature of 0.0°C to >2.5°C with the coldest temperature in January (-20°C) and warmest temperature (23°C) in July; 90 to >130 frost-free days; and an annual precipitation of 100mm [12]. Lack of snow as a water source is a major factor limiting livestock production in the Gobi Desert Region. Wind speed averages 2 to 8 m/sec [4].

Major rangeland ecosystems of Mongolia

Gubanov [17] reported 2,823 species of vascular plants in Mongolia's flora including 662 genera and 128 families. The growing season in Mongolia is generally

short (60 to 120 days) so that livestock and wild herbivores rely mainly on senescent vegetation for > 200 days of the year [18, 19]. About 80% of Mongolia's total land area (128.9 million hectares) can be considered rangeland and has been subjected to grazing for more than 4,000 years [20]. Mongolia has six major rangeland ecosystems, each having different topography, elevation, temperature, rainfall distribution, soils, and vegetation [10]. Mongolia's major vegetation zones (figure 1) and the percentages of land area occupied by each are: alpine tundra (3.0%), mountain taiga (4.1%), mountain steppe and forest steppe (25.1%), grass steppe (26.1%), desert steppe (27.2%), and desert (14.5%).

Alpine tundra has an annual standing crop yield (dry weight) that ranges between 1,050 to 1,500 kg/ha [21]. Lichen-dominated areas at the highest elevations are used for summer grazing of reindeer. Lichen-*Carex* areas of alpine tundra are used for summer grazing of yak. *Caligonum* shrubs and *Kobresia* meadows are used for summer and autumn grazing of yak and cattle. Alpine shrub and meadow areas are used for summer and autumn grazing of yak and cattle, whereas swamp areas are used for summer grazing of cattle. *Poa* grazing land is used yearlong by all livestock.

Forest steppes, swamp steppes, and grass steppes predominate in Mongolia and exhibit high forage yields. Forest steppes

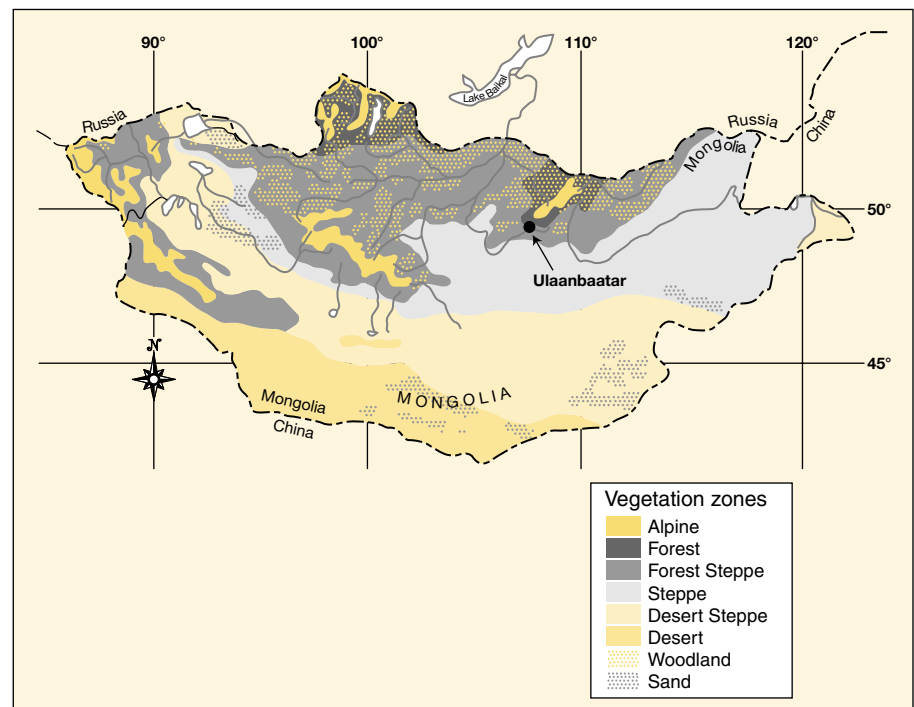


Figure 1. Major vegetation zones in Mongolia.

have annual standing crop yields ranging from 1,150 to 1,940 kg/ha [21]. *Betula-Pinus* forest, *Larix* forest, and *Betula-Populus* forest areas are used primarily for summer grazing by horses, cattle, and large wild herbivores. Forests with an extensive shrub understory are grazed during the summer by all livestock except camels. Swamp steppe areas are dominated by grasses (*Koeleria*, *Carex*, *Poa*, *Agropyron*, and *Puccinellia*), *Carex* species, and forbs. Swamp steppes are grazed throughout the year and are generally most suited for grazing by horses and cattle.

Grass steppe has annual standing crop yields ranging from 650 to 1,300 kg/ha [21]. These areas are dominated by grasses including *Cleistogenes*, *Stipa*, *Aneurolepidium*, *Elytrigia*, *Festuca*, *Helictotrichon*, and *Koeleria*; various *Carex* species; and forbs including *Artemisia*, *Filifolium*, and *Allium*. The shrub *Caragana* is often present in the community as a codominant. Awns on *Stipa* species limit livestock use of some grass steppe areas by livestock to certain seasons. Most grass steppe is grazed throughout the year by all livestock except camels. Gazelles are the most common wild herbivore grazers in grass steppe areas.

Desert steppes and deserts generally exhibit standing crop yields between 290-380 kg/ha [21] and a high diversity of vegetation communities, soils, and land forms, which create "patch" grazing for livestock and wild herbivores. Desert steppe is dominated by grasses, herbs, and shrubs. Desert steppe formerly was the habitat of the Mongolian wild horse (*Equus ferus*). Deserts are especially suited to grazing by camels, sheep, and goats and provide habitat for a number of wild herbivores.

History of Mongolia and its relation to rangeland use

Pre-Socialist Period

There is general consensus that pastoralism originated as a result of a Neolithic revolution that produced a complex agricultural-herding society [22]. The question remains as to whether farmer-herders evolved into nomadic pastoralists, or whether the appearance of nomadic herders was connected with immigrants coming into contact with established farmer-herder societies. Possible reasons for a transition from a complex farmer-herder society to a narrowly specialized herding economy include: i) increase in livestock numbers and the accumulation of experience in migratory herding that

made nomadic pastoralism the most effective option under these conditions; ii) periodic changes in landscape and climate, especially long-term droughts, which forced previously settled farmer-herders to turn to nomadic pastoralism; iii) overpopulation in complex-settled societies driving individual clans already inclined towards nomadic pastoralism into a migratory way of life; iv) migratory hunting tribes obtaining transport animals and domesticated livestock from settled farmer-herder societies and the subsequent gradual development of nomadic pastoralism, which did not require a major change in the hunters' migratory lifestyle; or v) some combination of all four.

Many scholars refer to members of pastoral herding societies as "nomadic pastoralists." However, in the true sense of the word, pastoralists in Mongolia are not nomads and have not been for millennia. Jaqchid and Hyer [23] stated that "Although in pre-modern times, there was competition for grazing and gaming areas, the use of areas usually became set, and in normal circumstances trouble was avoided because seasonal migration is not haphazard or chaotic, but rather quite carefully defined. Individual household possession of land is not the most important driving force of a society engaged in pastoral livestock production. It is the use of land resources in a migrating, transhumant society that is of greatest concern, not the possession of land." Realizing that true pastoralists are not usually nomadic, but rather employ transhumant strategies within natural and administratively defined resource boundaries, is an important factor.

During the pre-revolutionary period before 1921, Mongolia was divided into administrative areas called banners or "hoshuu," each ruled by a hereditary secular prince or high-ranking religious leader in Buddhist monasteries [1, 24-26]. These areas were further subdivided into smaller administrative districts called sums or bags. Rangelands were under the control of feudal officials, clans, and tribal groups [1]. According to Fernandez-Gimenez [27], pasture allocation and use were also governed in many areas by informal norms and customs described by herders as "unwritten law." Herders were allowed to graze specific rangeland areas through rights offered by the hoshuu leader. Boundaries between the herding groups were quite inexact and subject to interpretation [26]. Herder use of rangelands at that time typically involved wide ranging seasonal migration of herds and herder families. According to Ykhanbai [1], specific groups of herders were explicitly linked with geographically defined territories,

and nomadic movements were coordinated by designated leaders. The pastoral resources associated with the rights to graze included seasonally used rangelands, natural and human-made water sources, campsites, animal shelters, corals, haylands, salt licks and stock rights-of-way [28]. Murphey [29] believes that most intratribal conflicts among nomadic groups during the pre-revolutionary period may have resulted from herder groups thinking that neighbouring groups may have encroached on their grazing areas. Forage was, and is, the basic and indispensable (as well as finite) resource for pastoralists, which sustains their livestock and their own livelihood.

Socialist Period

Between 1921 to 1990, Mongolia had a Communist Socialist Government with a centrally-planned economy. Mongolians could not individually own croplands or livestock, and they herded state-owned animals on state-owned rangelands for a salary [1]. The administration of the collective or "negdel" allocated rangeland usage and controlled seasonal grazing movements.

Although nomadic movements were restricted during the Socialist period, collectives allowed seasonal movements and regulated rangeland use. The collectives provided an infrastructure that supplied subsidized transportation, water developments, and veterinary services. In addition, the collectives coordinated haymaking activities to provide winter forage during the critical winter period and provided markets for livestock.

Free-market Period (1992-Present)

In 1992, the collectives that allocated rangeland and campsite use and controlled seasonal movement of livestock during the Socialist era were dissolved, and livestock were privatized. During this difficult period, when Mongolia's controlled economy was changed to a market economy and a democratic political system was established, private ownership of animals was again allowed and rangeland use was not formally controlled [28]. With the dismantling of the collectives, grazing became unregulated, and herders became responsible for their own management decisions and assumed all the production risks. In addition, all the services provided by the collectives were eliminated. Between 1992 and 2000, the number of herder families increased more than twofold and livestock numbers increased by about 18%. For example, herding households rose steadily from 1990 (with 17% of total household being herders) to 35% by 1998. In 2000, there were 268,732 households with live-

stock, of which 191,526 households were totally dependent on animal husbandry for their livelihood.

With the change from a centrally-planned to free-market economy, authority for rangeland management in Mongolia was given to the local governments and herder groups. However, because of a lack of capacity to deal with rangeland management issues, confusion and conflicts frequently occurred between herders and herder groups [1]. With increasing herd sizes and number of herder families and no regulation of grazing, there was an increase in the uncontrolled concentration of animals near water sources, roads, population centres, haylands, and seasonal camps [1, 30]. Although recent legislation in Mongolia allows for the transfer of urban and arable land to private ownership, rangelands were defined in the Land Law of 2002 as common-use public property, with rangeland privatization specifically prohibited.

Under the current Land Law and the absence of strong formal or informal institutions to allocate rangeland use and regulate grazing, the current rangeland situation in some parts of Mongolia can be characterized as a downward spiral of decreasing mobility and increasing out-of-season grazing [30]. Conversely, some rangeland areas in Mongolia away from population centres and roads are being depopulated with very little grazing activity. However, herders in Mongolia increasingly perceive that localized overstocking and especially lack of mobility are causing significant declines in the ecological condition and forage production of Mongolian rangelands [28]. This agrees with the assessment of Gunin *et al.* [6] who provided detailed descriptions of the vegetation dynamics of Mongolia based on field studies conducted throughout the country during a 10-year period. Gunin *et al.* stated that almost all of Mongolia now shows widespread regressive vegetation changes associated with increasing anthropogenic activities, even in years with favourable precipitation.

Livestock production in Mongolia

General aspects

Mongolia has had a nomadic pastoral production system for at least 1,000 years and possibly as long as 4,000 years. During this period, herders developed a sophisticated system of extensive livestock production that enabled them to make efficient use of the diverse rangeland landscapes and their varied resources. By grazing a mix of different livestock spe-

cies, by using their indigenous knowledge of rangeland ecology, climate, and animal behaviour, and by making use of a mobile and flexible extensive herding strategy, Mongolian herders were able to exploit patches of rangeland to obtain a reliable output of goods and services from their livestock with few, if any, external inputs [27]. Herders depend on their livestock for subsistence, obtaining much of their food from meat and dairy products; using wool, hair, and hides for domestic purposes; burning dung for fuel; selling or bartering livestock and livestock products for cash or goods; and using camels, horses, and cattle for transportation and draft purposes. Mongolia's pastoral livestock production has been the country's main safety net for social and economic problems associated with the transition of the country from a centrally-controlled economy to a market-based economy. More people are engaged in livestock production and are dependent on livestock as a source of livelihood compared to the Socialist era.

Livestock producers in Mongolia and around the world must have: i) access to animal feed on a daily basis and at critical time periods; ii) animals that are adapted to their environment and able to overcome weather extremes; iii) animal off-take products that ensure the livelihood of their dependent human population; iv) an ability for flexible decision-making that allows livestock producers to respond to immediate needs in a continually changing environment, while at the same time keeping a long-term decision-making perspective that ensures response options to both foreseen and unforeseen events affecting livestock production and personal livelihoods; and v) a support infrastructure that allows producers access to necessary inputs and that promotes competitive pricing and the sale of surplus animal off-take products.

The pastoral livestock producer must retain mobility in livestock production and be flexible in decision-making in an environment that varies through time and space. Without mobility and flexibility, environmental risk increases the probability that a catastrophic event will significantly reduce production capability (*i.e.*, either by increasing mortality or by reducing reproductive efficiencies to levels that directly affect livelihood potential of the livestock producer). The producer must have the ability to move livestock away from a severe weather event (such as severe winter storms, summer drought, and pest infestations) to an area where livestock have improved probabilities of survival. The producer must also have the type and kind of livestock that can utilize available pastor-

al resources effectively during different seasons and challenging environmental conditions. Reduced or limited livestock mobility, whether arising from internal or external sources, can destabilize or even destroy pastoral production systems. If a support infrastructure exists, the livestock producer can exchange mobility of livestock for mobility of inputs, especially nutrients to support livestock during critical times of the production cycle.

Herders in Mongolia must deal with highly variable arid and semiarid environments. The extreme variability of environments that herders inhabit, combined with the always shifting political-economic backdrop they live in, require herders to maintain freedom to move opportunistically and draw on social networks to access all types of resources including labour, transportation, state bureaucracy, markets, rangelands, and water [30]. Because of all these interacting factors, pastoralists around the world often exhibit great flexibility in social organization as well as temporal and spatial patterns of resource use [30-36]. The critical aspects of pastoral land use and strategies of resource use in variable environments are diversity of livestock species, mobility, flexibility, and reciprocity [30, 37, 38]. Mobility and flexibility allow herders to utilize a broad range of resources during the year and to exploit patchy and temporally variable environments [30]. Social reciprocity at the household, local, and regional levels in turn supports mobility and flexibility in resource use by facilitating access to reserve pastures, transportation, or other critical resources [30].

Three basic grazing management strategies are used in livestock production in Mongolia: i) extensive, which formed the basis of the traditional Mongolian nomadic pastoral system; ii) semi-extensive, which was practised in the collective system and provided energy inputs to increase livestock production; and iii) an intensive strategy, which was used by State Farms and around sedentary agricultural production areas [39]. Today, livestock production in Mongolia is still dominated by an extensive pastoral livestock system involving the mobile herding of livestock on rangelands. While some hay and fodder is prepared for winter, most of the nutrition for livestock is obtained from grazing on native forage (grasses, forbs, and shrubs). Small amounts of hay are made in the more productive forest-steppe areas, but most livestock rely on standing cured forage during the winter and spring. This requires that herders defer grazing on winter and spring "reserve" pastures during the growing season.

The Mongolian pastoral livestock system consists of: camels, horses, cattle, yaks and cattle-yak hybrids, sheep, and goats. The livestock population reached a high of 33.5 million head in 1999 and declined to 30.2 million in 2000. In 2000, camels comprised 1.1% of the total herd; horses made up 8.8%; cattle 10.2%, sheep 45.9%, and goats 34%. As of the June 2001 census, the national livestock herd was estimated to be 26 million head. The decline in livestock numbers since 1999 is due to large livestock losses in the severe winters of 1999-2000 and 2000-2001. Mongolia's rangelands also support populations of wild ungulates including gazelle (*Gazella subgutturosa*, *Procarpa gutturosa*), argali (*Ovis ammon*), ibex (*Capra sibirica*), wild bactrian camel (*Camelus ferus*), wild ass (*Equus hemionus*), saiga antelope (*Saiga tatarica*), and reintroduced populations of Przewalski's horse (*Equus przewalskii*) [40].

The herd sizes for Mongolian households vary considerably from 1 to more than 2,000 animals. In 2000, 63% of households had less than 100 animals, 22% had herds of 100 to 200 animals, and only 12% had herds between 200-500 animals. This large variability is due to the unequal distribution of livestock when livestock of collectives (*negdel*) were privatized in the early 1990s. Herders who obtained a small number of livestock from the *negdel* found it difficult to increase their herd size. In addition, skills and abilities for effectively managing livestock vary greatly among herders. Herd sizes of less than 100 to 150 animals are generally considered insufficient to maintain a livelihood for a herding household, and many herders would prefer to have 250 to 400 animals with a mix of large (camel, horse, cattle) and small (sheep, goats) animals. With 85% of Mongolian households having herds of less than 200 animals, there is widespread poverty among the pastoralists, and they face considerable difficulties in sustaining an economically viable livelihood from their animals. With the limited markets for livestock and livestock products in Mongolia since the 1990s, livestock have served as the main asset for herders and provide self-sufficiency for most of the rural population.

Livestock herd composition is greatly influenced by the particular rangeland environment in which herders reside. In deserts and desert-steppe, a greater proportion of goats and camels occur, whereas in the steppe sheep and horses are more common. Although cattle are raised throughout the country, they make up a greater proportion of herds in the forest-steppe and steppe region. In the high mountains, yaks and yak-cattle hybrids

replace cattle. While the proportion of horses and cattle in Mongolia has remained relatively stable between 1989 and 2000 (about 9 and 11%, respectively), the proportion of camels and sheep has declined. From 1989 to 2000, camel proportions declined from 2.2 to 1.1% and sheep decreased from 58 to 46%, respectively. The large *negdel* camel herds, which produced conditions favourable for camel breeding, were disbursed in small numbers or given as individual animals with resulting reductions in camel numbers. During the initial years of transition, sheep often served as a means of payment for goods, which resulted in a reduction in numbers of sheep [41]. The proportion of goats in Mongolia has risen considerably since 1990. For example, in 1989 before transition began, goats comprised about 20.1% of domestic grazing animals in Mongolia. By 2000, the percentage of goats had risen to 34%, which reflects the improved market opportunities that herders have for cashmere. Cattle and horse populations represent about 9% and 8%, respectively, of the total domestic livestock population, and have been markedly affected by recent drought and severe winters.

Livestock production: natural versus industrial economies

Examining traditional Mongolian pastoral livestock production systems in the context of 'natural economies' versus 'industrial economies' as described by Lichatowich [42] is useful for relating pastoral livestock production to sustainability of livelihoods and resource use in the 21st century (table 1). Livestock production in a natural economy has many similarities with naturally occurring large wild herbivore systems. Migration occurs between seasonal rangelands during annual cycles, and environmental characteristics are the major factors that limit livestock production. The focus of livestock production in a natural economy is on obtaining an animal off-take surplus sufficient to meet consumption needs of the livestock producer. Prior to 1921, it appears reasonably certain that traditional Mongolian pastoralism operated as a natural economy. During that time, rangeland grazing areas in Mongolia were naturally defined by geographic and topographic features except for boundaries imposed by "right of possession" by local groups of herders. Administrative or political boundaries existed, but were designed to allow large-scale seasonal shifts between ecological regions to reduce environmental risk. The traditional pastoral livestock system was dependent on naturally-produced animal feedstuffs and animal medicines (*i.e.*, standing

crop of forage, hay and supplemental animal feed produced in the local area by the livestock producer) in a natural system that focused on animal reproduction, self-consumption, and recycling, which produced little if any waste in the production system. The livestock producer in this traditional system focused on using indigenous knowledge about climate and biophysical attributes of the environment gained across many generations to maintain optimal livestock production as a means to support pastoral livelihoods.

In an industrial economy, economic and sociopolitical factors replace environmental factors as the major factors that limit livestock production. Inputs obtained from the well-developed and vertically-integrated production infrastructure characteristic of an industrial economy are necessary to provide products to meet demands of consumers living external to the actual production system. Although access to external inputs is both necessary and generally guaranteed under marketplace conditions, the higher costs of production necessitate higher off-take rates to create surpluses that can be sold to enable the producer to meet costs of production and remain in business.

In a natural economy, organization is by natural units of the landscape with boundaries imposed by natural constraints, the largest part of the production infrastructure is invisible, production activities are driven by solar energy and the need to reproduce, production is dispersed among small units, production activities are circular and renewable, consumptive use and recycling of production prevails, and natural resources are viewed as connected habitats for use rather than exploitation. In a true industrial economy, the natural resource base is artificially divided by political and administrative hierarchies, competition exists among the artificial divisions for purposes of economic gain, a well-developed production infrastructure exists and is driven by fossil fuels and capital inputs, large-scale and vertically-integrated production facilities favouring monoculture production exist, and spheres of competing (but independent) economic interests develop.

An important, but unresolved, question affecting sustainability of rangeland forage-based livestock production involves the question of whether prevailing rangeland ecosystems in Mongolia are in equilibrium or non-equilibrium. This question is important because the perception of how particular ecological systems function determines the approaches that are advocated in modifying or manipulating ecosystems and the rationale to change live-

Table 1. Attributes of livestock production systems in natural versus industrial economies.

Industrial Economy	Natural Economy	Change Factors
Livestock production in an industrial economy is organized into political hierarchies (countries, states, counties, cities, private homesteads)	Livestock production in a natural economy is organized into natural units (watershed, basins, mountains, and natural habitats defined by soils, vegetation, and topographic features, etc.) where use is defined by natural factors of the animal and the habitat.	Higher human population in the industrial economy causes conflict over "de facto" possession of critical natural inputs (winter shelters, hay making areas, water sources, access to markets).
Livestock production in an industrial economy has political divisions competing and often conflicting over the ownership, use, and distribution of resources. Livestock are mere tools used to exploit natural resources for economic benefit to the owner.	Livestock production in a natural economy views livestock and natural resources as part of a co-evolving relationship. Boundaries are imposed by biophysical constraints. Livestock are the basis of livelihoods.	Change to political, social and economic systems creates conflict over "ownership" of natural resources critical for livestock production. Conflicts over access to and use of natural resources increases, regulations defining livestock use of natural resources dominate over need for animal mobility and flexible decision-making by the livestock producer.
Livestock production in an industrial economy has a production infrastructure which is visible and recognizable, and its function is generally understood-animal rearing areas, feedlots, slaughterhouses, feed production, market channels, wholesale and retail chains. Livestock production depends on provision of inputs obtained externally to the local production infrastructure.	Livestock production in a natural economy has a production infrastructure, which is only partially visible, and its function, while poorly understood, is the basis of sustainable livestock production. Livestock production is low input and dependent on local resources.	Focus of production becomes introduction of higher yielding livestock breeds, increase in yields and inputs to meet international market demand, and development of marketing centres and infrastructure. Development of a more visible production infrastructure will increasingly be driven by social, environmental and economic considerations affecting the rural human population rather than livestock production considerations.
Livestock production in the industrial economy is driven by fossil fuel and the need to accumulate capital.	Livestock production in the natural economy is driven by solar energy and the need to reproduce.	The need to market products over long distances, labour shortages replaced by technological advances, the lack of local value-added processing centres and the transfer of primary off-take products to urban distribution centres and markets create a dependence on fossil fuels.
Livestock production in an industrial economy favours large centralized production facilities (single livestock type and breed, feedlots, slaughterhouses, trading centres, etc.), which lead to biological and technological monocultures.	Livestock production in the natural economy favours dispersed production among small units.	Concentration of animals introduces density-dependent feedback mechanisms. Unless more top-down interventions are added to the livestock production system, sustainability of livestock production and ecosystem stability can rapidly be negatively impacted.
Livestock production in the industrial economy is linear and extractive, emphasizing production.	Livestock production in the natural economy is circular and renewable, encouraging reproduction.	Changes to circularity of livestock production will diminish adaptability of livestock in the herd to environmental constraints. The need to support livestock with costly inputs will increase.
Livestock production in the industrial economy creates waste and fails to fully recycle resources.	Livestock production in the natural economy has no waste, everything is recycled	Waste is a characteristic of an industrial economy usually generated by supply and demand functions of a market economy.
Livestock production in the industrial economy partitions natural resources into discrete economic spheres that operate independently of each other.	Livestock production in the natural economy views natural resources as a maze of connected habitats.	Pastoral livestock production views natural resources as a "continuum" with forage and nutrients and shelter as the critical elements of livestock production. Livestock production in an industrial economy operates within artificially defined discrete units that have little relationship to the natural environment or animal behaviour.

stock production systems from extensively managed to intensively managed, industrialized agricultural production systems [32]. North American range management concepts were developed from the perspective that rangeland ecosystems generally function as equilibrium systems. Equilibrium ecosystems are regulated by animal density-dependent feedback controls that livestock producers often override to the detriment of themselves and the ecosystems in which they operate. An alternative perception, which is gaining pastoralism advocates, is that many ecosystems occupied by pastoral livestock producers are non-equilibrium systems. Non-equilibrium ecosystems are controlled by external mechanisms and are not subject to feedback control mechanisms from within the system. Available evidence suggests that Mongolian rangelands

represent a continuum from equilibrium systems in the mountain steppe to predominantly non-equilibrium systems in the desert steppe [38]. However, Fernandez-Gimenez and Swift [38] indicate that each of the rangeland ecosystems in Mongolia exhibits characteristics of both equilibrium and non-equilibrium systems. Table 2 attempts to categorize the rangeland ecosystems of Mongolia in the context of an equilibrium or non-equilibrium ecosystem.

Current transitions in livestock production systems in Mongolia

During the Socialist period, considerable emphasis was placed on the development of a cropping sector in the State Farm system. With the end of the Socialist Period, both cropping and livestock sec-

tors underwent considerable change as Mongolia began transformation to an open-market economy. The State Farm system with its orientation towards intensive livestock and crop production collapsed, and the system returned to a more extensive livestock production system.

Under the current developing market economy, Mongolia is again rapidly attempting to industrialize agriculture and livestock production. The present situation is characterized by low levels of productivity in both the livestock and cropping sectors, demographic shifts in the population because of socioeconomic reasons, subsidization of the economy by international institutions, and rising expectations from an increasingly urban population. This pattern unfolding in Mongolia is similar to that which occurred during developmental phases in Europe and North America.

Table II. Equilibrium and non-equilibrium rangeland ecosystems in Mongolia (adapted from [32]).

	Equilibrium	Non-Equilibrium	Mongolian Rangeland Ecosystems
Abiotic patterns	a. Abiotic conditions relatively constant	a. Stochastic/variable conditions	a. Varies by ecological zone
	b. Plant growing conditions relatively invariant	b. Variable plant growing conditions	b. Varies by ecological zone but more characteristics of equilibrium systems.
Plant-herbivore interactions	c. Tight coupling of interactions	c. Weak coupling of interactions	c. Traditional pastoral plant-herbivore interactions are changing in some areas to tight coupling of interactions characteristic of equilibrium systems as expansion and concentration of livestock numbers continues.
	d. Feedback control	d. Abiotic control	d. Abiotic controls continue to affect plant-herbivore interactions. In some areas, both feedback and abiotic controls are affecting plant-herbivore interactions.
	e. Herbivore control of plant biomass	e. Plant biomass abiotically controlled	e. Herbivore control of plant biomass developing in areas of livestock concentration.
Population patterns	f. Density dependence	f. Density independence	f. Density dependence developing in areas with livestock and human concentration. Density independence in areas not subject to animal concentration.
	g. Populations track carrying capacity	g. Carrying capacity too dynamic for close population tracking	g. Expanding livestock and herder populations, and concentration of livestock population, change in herd structure, and decreasing mobility in livestock management are creating situations where populations track carrying capacity.
	h. Limit cycles	h. Abiotically driven cycles	h. Expansion of animal numbers and concentration of livestock can limit population cycles within an abiotically driven vegetation cycle.
Community/ecosystem characteristics	i. Competitive structuring of communities	i. Competition not expressed	i. Competitive structuring of communities in forest and grass steppe ecosystems; competition not expressed in desert steppe and desert ecosystems.
	j. Limited spatial extent	j. Spatially extensive	j. Ecosystems are spatially extensive but mobility of animals and access to ecosystems becoming spatially limited.
	k. Self-controlled systems	k. Externalities critical to system dynamics	k. Externalities critical to system dynamics throughout the livestock production system.

Similar to North America, the market economy exerts a destabilizing influence on communities dependent on natural resources, as the mainly urbanized population loses connections to agricultural production. These changes led to shifts in legislative, legal, and economic power from rural agricultural areas to urban areas. In North America, the urbanized population depends on rural agriculture as a source of inexpensive, high quality food that is made available by well-developed production, transportation, and value-added food industries. Currently in Mongolia, non-economically viable herders are moving from rural to urban areas, and the Ministry of Food and Agriculture is planning to intensify agricultural and livestock production in the central, urbanized areas and develop regional production centres in the outlying areas, a modified State Farm approach under a market economy.

Conclusions

The location of Mongolia in the centre of the Asian Continent with dry and temperate climatic conditions has favoured the development of extensive rangelands.

Mongolia's rangelands have the capacity to support large numbers of grazing animals that includes both domestic livestock and wild herbivores. However, variations in temperature and precipitation in Mongolia create seasonally harsh conditions for livestock with long, cold, and dry winters and cold, dry, and windy spring periods. Extended drought periods and severe winter snow storms are common in Mongolia and cause major challenges for livestock production. The rangelands of Mongolia have undergone periodic changes in management and utilization throughout history coincident with changes in their governments. During the last century, Mongolia changed from a feudal system of ruling lords and religious leaders to a Socialistic country with a central-command economy to the current democratic Government with a market-driven economy. The transition of Mongolia to an open, market economy, which began in 1990 is continuing today. Building the support services and marketing infrastructure needed to allow Mongolians to compete in a global market economy is still underway.

The pastoral livestock production system in Mongolia is threatened by changes that include degradation of natural resources

needed to support livestock production and livelihoods, and the loss or failure to gain community empowerment. Pastoral communities in Mongolia are currently unable to adequately respond to new paradigms that arise from government policies, environmental activism, changing production economics, and shifting food desires of an increasingly urbanized population. These changes are affecting the social, economic, and ecological sustainability of pastoral communities that have existed for thousands of years. The key to the future lies with maintaining sustainable livestock use of Mongolia's diverse, extensive rangelands, developing an infrastructure that regulates grazing and allows livestock producers to make timely responses to internal and external factors that affect livestock production, developing an effective transportation system and regional livestock markets, and providing herders with access to information concerning production costs and potential income to make informed production decisions. Establishment of such an infrastructure will aid efforts to restore and maintain an ecological balance between livestock and forage resources used to support natural resource-based livelihoods in Mongolia. ■

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