The State of Grasslands across Inner Mongolia and Mongolia

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Abstract

Grasslands across Inner Mongolia and Mongolia, with their long history of nomadic livestock grazing, are very important natural resources for animal husbandry and environmental services. The main types of grasslands are meadow steppe (forest steppe), typical steppe (steppe) and desert steppe. Most of the grasslands are degraded due to over-grazing, which reduces animal production and the values of environmental services. Overgrazing decreases plant production, species biodiversity, ecosystem stability, soil fertility & structure, and lowers animal productivity leading to reduced household incomes. In pastoral areas across Inner Mongolia and Mongolia, degraded grasslands can be rehabilitated by better managing stocking rates. Our surveys, experiments and farm demonstrations have found that, in degraded grasslands, lower stocking rates had benefits for animal production, net incomes and environmental services. To implement these improvements across Inner Mongolia and Mongolia will be challenging to avoid deleterious trade-offs with livelihoods as it will require changes in herder practices. Further research and demonstration are required to develop locally relevant systems.

Introduction

Grasslands are 54% of the world's total terrestrial lands providing major food sources, other goods and environmental services for pastoral areas and the wider community (Estell *et al*. 2012). In Inner Mongolia and Mongolia, grasslands are the major natural resource occupying 70%, and 72% respectively, of the total land. Livestock grazing on grasslands has a long history in Inner Mongolia and Mongolia, where many people depend on grasslands for their livelihoods. Traditional nomadic grazing of livestock did maintain the grassland in a sustainable condition, but since 1950 the livestock numbers (as sheep equivalents) have increased 4x in China and since 1990 by 2x in Mongolia, resulting in overgrazing and grassland deterioration (Kemp 2020, Brown 2020). Today, the main question is, what is the trade-off between grassland rehabilitation and herder livelihoods in Inner Mongolia and Mongolia. In order to answer this question, we review a series of studies done in Inner Mongolia and Mongolia, involving; field surveys, grazing experiments, stimulation modelling and farm demonstrations. Other papers in this panel session deal with additional issues influencing grasslands.

Climate and grassland types

The climate of Inner Mongolia and Mongolia, across the Mongolian Plateau and neighbouring areas, is continental and harsh with low precipitation from 50 to 500mm (mostly in summer), and cold and windy in winter. Plants start to grow when the daily mean air temperature is above 5 ℃ in spring and cease when air temperatures decline below 5 ℃ in autumn (Zhao *et al*. 2008; Jamsran *et al*. 2018).

In Inner Mongolia, from northeast to southwest annual precipitation decreases resulting in a gradual shift of vegetation from forest in the east to desert in the west. The grasslands range from meadow to typical to desert steppe. The meadow steppe is a humid type in the east with 320-380mm annual precipitation and black chestnut soil. The main plant species are the grasses *Leymus chinensis*, *Stipa baicalensis*, and the forb *Filiforlium sibiricum*. The typical steppe grows on a chestnut soil, is the largest grassland type and covers much of the middle of Inner Mongolia. The annual precipitation is 310-350mm. The main species are the grasses *Stipa krylovii*, *Stipa grandis*, *Cleistogenes squarrosa* (C4) and the semi-shrub *Artemisia frigida*. The desert steppe, on brown chernozem soils, is close to desert in the west with 150-280mm annual precipitation. The main grass species are *Stipa klemenzii, Stipa gobica*, *Stipa breviflora*, *Cleistogenes songorica* (Zhao *et al*. 2008).

In Mongolia, a cold and humid climate and high mountain belt in the north gradually shifts to a warmer (in summer) drier climate and desert in the south. Zonal grasslands in Mongolia include mountain forest steppe,

steppe, and desert steppe. The forest steppe is of 200-300mm annual precipitation and 130-150 days growing season. The main plant species are the grasses *Festuca lenensis*, *Koeleria macrantha* and *Poa allenuata*. The steppe is the largest grassland type in Mongolia with 200-250mm annual precipitation and 150-170 days growing season. The main plant species are the grasses *Stipa krylovii*, *Stipa grandis*, *Cleistogenes squarrosa*, and *Leymus chinensis*. The desert steppe is a unique type between steppe and desert with 100-125mm annual precipitation and 170-190 days growing season. The main plant species are *Stipa gobica*, *Stipa glareosa*, *Cleistogenes songorica* and *Allium polyrrhizum*, (Jamsran *et al*. 2018).

The climate and grassland types are very similar between Inner Mongolia and Mongolia. The grasslands in both countries have suffered from over grazing. Livestock numbers have quadrupled since the 1950's in China and since 1990 doubled in Mongolia (Kemp, Han *et al*. 2020). With over-grazing, there is an initial shift from palatable to less-palatable plant species then a decline in productivity and in some areas to eventual desertification (Kemp, Li *et al*. 2020). With more people and more animals on the grassland, the challenge is to reduce stocking rates to sustainable levels where the grasslands can recover to more productive states and then be maintained at those better states. We need to understand the grassland livestock system to solve the problem of grassland degradation in terms of environmental and economic considerations.

Grassland health

From 2005 to 2007, sites were monitored in each of the meadow steppe, typical steppe, and desert steppe grasslands of Inner Mongolia. Vegetation, soil, hydrological properties, and methane emission of soil were measured to understand the grassland degradation stages every 2m along 3 * 50m transects from a watering point or stock yard within each grassland type. The grasslands were classified in four seral stages from early to late, applying the ecological concept of plant community succession; the reverse of succession then being degradation. The typical and desert steppe sites studied were in a lightly degraded stage, while the meadow steppe was heavily degraded (Zhao *et al*. 2008). This study showed that key indicator species such as the grasses: *Leymus chinensis* declined with degradation, *Cleistogenes songorica* was more frequent at intermediate stages, while *Stipa grandis* was more frequent in heavily degraded sites.

A survey of livestock grazing intensities across the meadow steppe, typical steppe, and desert steppe indicated that heavy grazing reduced plant community production, species richness and species asynchrony, which reduced temporal stability of plant community (Qin *et al*. 2019). Consequently, the total value of ecosystem services declined with increasing grazing intensity (Figure 1).

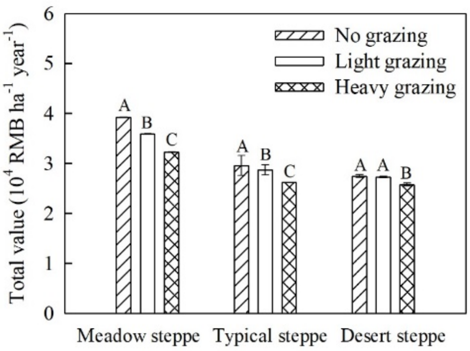

Figure 1. Total values of ecosystem services under different grazing intensities in the three types of steppes. Different uppercase letters indicate significant differences among grazing intensities in the same steppe

One of the more important environmental services from grassland is as a methane sink throughout the growing season. Nil or light grazing on the desert steppe, resulted in more methane uptake into the soil than moderate or heavy grazing. Differences were less for the typical and meadow steppe, though the trends were similar (Tang *et al*. 2013). A further study on the typical steppe found that light to moderate grazing was optimal for methane uptake and for managing the plant species composition (Zhang *et al*. 2015). The biomass of *Leymus chinensis* was maintained above 70% and the less desirable *Artemisia frigida* below 10% when the stocking rate was half the district average.

Extensive surveys were done in 2014 and 2016 across all Mongolian grasslands to define their current *health* using 1450 survey sites (Densambuu *et al*., 2018). The grasslands in 2016 were: Class I, non-degraded state (42%); Class II, slightly degraded and may be recovered quickly (14%); Class III, moderately degraded and would take 5-10 years to recover (21%); Class IV, heavily degraded with local loss of key desirable plant species (13%); and Class V, fully degraded with extensive soil loss leading to desertification (10%). These results found that degradation had increased since 2014, with 10% less land in Class I and 5% more in Class V. Clearly there is a significant decline in grassland condition, though about half the grasslands were judged to achieve a sustainable state in ten years with better management. These overall averages suggest the grasslands are in better condition than in Inner Mongolia, but the distribution of results showed that in central Mongolia, the steppe near the capital Ulaanbaatar and other major towns, was in a poor condition. Mongolia allows common grazing anywhere in the country, which has meant more herders have moved closer to urban areas so that family members can receive better education and health services and/ or find supplementary income. The higher density of herder households has reduced their ability to move to new grazing areas every few months. Herders used to move up to six times a year, now some do not move at all, or only twice a year.

Desert steppe grazing management

A long-term sheep grazing (only in summer) experiment (2004-15) with 4 stocking rates and 3 replicates, was done on a desert steppe site of Inner Mongolia to investigate the productivity and plant species diversity responses to grazing and climate variability. The high, district average, stocking rate decreased species richness, diversity, net primary productivity and per head animal production (Zhang *et al*. 2019, Wang *et al*. 2020). The grassland methane sink was reduced under moderate or high stocking rates in summer, but there was no treatment effect in winter (Wang *et al*. 2012). The light stocking rate that optimised environmental services was half the district average.

The total grassland growth on desert steppe is only 1-1.5 t DM/ha/year. The optimal light stocking rate meant that the estimated consumption by sheep was only 10% of that herbage and the standing herbage mass over summer was above 0.5 t DM/ha. Studies on the typical steppe had shown the optimal consumption was 20%, but the minimal herbage mass that should be maintained was also 0.5 t DM/ha over summer (Zhang *et al*. 2015).

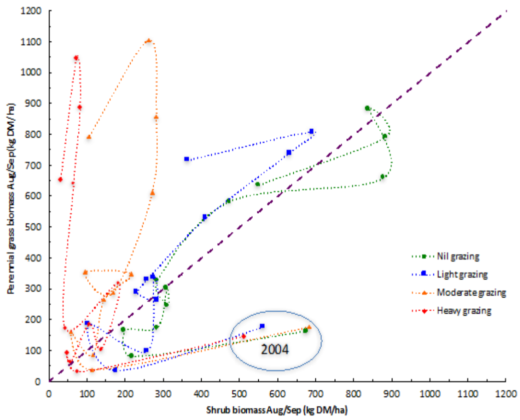

Figure 2. Trends in the interaction between shrub and perennial grass herbage mass in the desert steppe from 2004 to 2015 in response to grazing treatments. The starting point for all treatments in 2004 is identified with an oval. The dashed line indicates the 1:1 ratio of these two plant groups (from Wang et al., 2019).

The dominant species in the desert steppe experiment were the low palatability grass, *Stipa breviflora* and the semi-shrub *Artemisia frigida,* indicating that the site was over-grazed and degraded. In general, the stocking rate treatments did not change the biomass of *Stipa breviflora* within each year, but did affect *Artemisia frigida*, indicating that the animal growth rates were dependent upon the shrub, not the grass (Wang *et al.* 2020). When the annual trends in biomass between these two species are compared (Figure 2) it is evident that the grass and shrub maintained close to a 1:1 ratio under light grazing for most years, whereas the moderate and high stocking rates had much higher proportions of unpalatable grass and little shrub. This experiment showed that it took eight years before the treatments differentiated significantly and the light grazing treatment had the same results as no grazing. Grazing bans have typically been for five years. Financial analyses showed that the light stocking rate had the highest net income per hectare.

Modelling and farm demonstrations

A series of models were developed (Kemp & Michalk 2011, Kemp 2020) in order to understand the grassland livestock system, including feed (energy) balance analyser (StageONE), linear program optimiser (StageTWO), dynamic sustainability (StageTHREE) and precision livestock management (PhaseONE). In general, these models showed that halving the average stocking rates would increase herder net income and improve the grassland condition. A large farm project was then established across the grasslands of Inner Mongolia to compare demonstration farms where stocking rates were reduced, while improving supplementary feeding in winter and better use of warm, shelter sheds, against control farms. The demonstration farms had higher net incomes than the controls, even where the overall stocking rate had been reduced to nearly half the district average (Kemp 2020). This study was short-term, but visually the grasslands were reported to be in better condition on the demonstration farms.

Conclusion

Overgrazing has caused grassland degradation in both Inner Mongolia and Mongolia. This has resulted from various National and Local policies that enabled / encouraged herders to increase their animal numbers, often with the view that this would increase household incomes. However, the results of grazing experiments, modelling and farm demonstrations have all consistently shown that the highest net income results from stocking rates that are around half that which applied in the early 2000's. Net income is a better criterion than gross income as that indicates the disposable income for households.

The studies of grassland condition and environmental services show that stocking rates that are half the district averages have resulted in better outcomes for the grassland (Kemp 2020). However, herders who have used common grazing across large areas and where fences are not used, are unfamiliar with measuring and managing stocking rates. In addition, there are many aspects to environmental services and to manage each to an optimal level is effectively impossible for herders. The more important environmental services are though, all related to the herbage mass of the grassland and that is the component that herders can manage (Kemp, Li *et al.* 2020). A decline in herbage mass is often the first visible sign of degradation, less production, more soil erosion *etc.*, and can be used to manage grasslands. Herders can be taught to identify the minimum critical values of herbage mass that should be maintained. Animals should be moved to new grazing areas when that critical value is approached. The experiments on the desert and typical steppe found that critical value was 0.5 t DM/ha. By managing on herbage mass criteria this reduces the need to define optimal stocking rates.

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