The search for sustainable stocking rates on Chinese desert steppe

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Abstract
Grassland degradation is a serious global problem. In China, 90% of the 400 M ha of grasslands are degraded to varying degrees posing threats to livelihoods and the environment, particularly to water resources, biodiversity and the frequency of dust storms across north Asia. Studies over recent years on the desert steppe in Inner Mongolia have shown that under current conditions stocking rates can be reduced by 50% and with better feeding of livestock through the nine months when it is too cold for plant growth, household incomes, animal production and biodiversity can be increased. This provides the opportunity for grasslands to recover. At present almost all of the forage available is being utilised by livestock, which is arguably higher than you would expect these semi-arid systems to sustain. A 50% reduction in stocking rates is though still twice the estimated stocking rates in 1950 when grasslands were regarded as being in reasonable condition. To achieve additional reductions in stocking rates beyond that achieved through market based solutions it would be important to consider implementing an integrated scheme for payments for environmental services.

Key Words
Grassland management, sustainable stocking rates, ecosystem services

Introduction
Grasslands are the world's largest terrestrial ecosystem resource, are key to global sustainability through provision of a range of ecosystem services and support the livelihood of >1 billion people. However these systems are often degraded, primarily from over-grazing by livestock, resulting in hydrological disturbances, more frequent dust storms, food security issues and social consequences of uprooted people. Throughout the vast grasslands of China, which also extend from eastern China to Europe, over-grazing has caused shifts in botanical composition to less desirable species, degradation of ecosystem services and severe environmental problems. Traditional herders have found it increasingly difficult to achieve the incomes required to survive within the rapidly developing Chinese economy; they are among the poorest people in China. Dust storms have increased in frequency and siltation of river systems is a continuing problem. Ninety percent of the 400 M ha of Chinese grasslands are regarded as being degraded to varying degrees. Directly and indirectly some 40 M people depend upon these grasslands for their livelihoods. Traditionally common grazing had been practised (Kemp and Michalk 2011).

During 1950-60's there were major increases in stocking rates and people across the region, often four-fold. The number of cattle, yaks, sheep and goats all increased. By the 1980's the available forage had declined, and partly in response, the Chinese Government extended the 'responsibility' system to grasslands, which resulted in allocation of land to households and the wider use of fencing to mark boundaries since 2000. Ownership of land remains with the State. Since the 1980's stocking rates had stabilised, though within those limits sheep and goats have often replaced cattle, as they were better able to consume the short grass now available.

Chinese Authorities have been concerned with the condition of grasslands and the livelihoods of herders for some time. The Australian Centre for International Agricultural Research (ACIAR) established a large project in the early 2000's to research solutions for these grassland problems (Kemp and Michalk 2011). That project engaged three Australian and six Chinese organisations working across the Inner Mongolian Autonomous Region (IMAR) and Gansu, supported by groups in Beijing. Initially plans were discussed for grassland management research, but it became evident that the important first step was to investigate the grassland/livestock production system using simple models to identify potential solutions that could be adopted at the household level. On-going Chinese research and farm surveys provided the data for these investigations. The broad aims of this work were to improve the livelihoods of herders and to do that in ways where grasslands could be rehabilitated. This paper discusses one of the case studies investigated and then extends the analyses done to date to consider the role for Payments for Environmental Services (PES) as part of the overall strategy to rehabilitate grasslands.

Case study: Siziwang IMAR

The data presented here are from a large ACIAR project; see Kemp and Michalk (2011) for more detail on the methods used for data collection and for the models used. In this paper the emphasis is on the case study site at Siziwang in IMAR (Han et al. 2011; Wang et al. 2011). This desert steppe site is located approximately 150 km due north of Hohhot, the capital of IMAR. The altitude is 1000-1500 m, winds (especially in spring) are a common feature, average monthly temperatures vary from -15°C in January to 20°C in July (frost-free period is 70-120 days) and rainfall is summer dominant (100-300 mm; 140 mm average during this study). Vegetation is sparse (<20% cover), the dominant grasses are *Stipa* species; with overgrazing the C4 grass species *Cleistogenes* increases, as does the sub-shrub *Artemisia frigida.* Annual net primary production (ANPP) from grasslands is typically < 1 t DM/ha. Data presented here come from farm surveys and grazing experiments done in the region.

Farm survey

Surveys of 15 farms in the study village showed that the typical household had 268 adult sheep and goats on 520 ha of degraded grassland. Taking the lambs and kids into account meant the average stocking rate was ~0.8 adult ewe equivalents/ha. Livestock are managed for meat production; fibre yields and quality are very poor. Modelling showed that the energy balance of livestock was only above maintenance requirements for the summer period. Through autumn, winter and spring livestock would typically lose 20-30% of their bodyweight, depending upon what meagre supplements were fed. Over summer animals gain weight, a large part of which is compensatory gain. Lambing occurs in winter. Traditionally livestock are taken out to graze every day of the year and housed in shelters at night. Management practices have been developed to enable livestock to survive, rather than for production.

Stocking rate experiment

The effect of stocking rates on livestock production and grassland condition was examined in a series of experiments (Han et al. 2011). Data presented here are for the summer periods of 2004-8 (Figure 1) when grass was green and livestock were growing. Once frosts occur animals consistently lose weight. These results show an average response in per head production that was relatively constant (~110 g/d) at stocking rates below ~1.5 dry sheep equivalent (DSE)/ha, then a relatively rapid decline at higher stocking rates. The derived production per ha showed the steep decline in production between 2-3 DSE/ha. The district stocking rate over summer, of 0.8 breeding ewes/ha plus lambs, is equivalent to ~2 DSE/ha. This is close to where production per ha is maximised, though this means the production per head is only 50-60% of that achieved at lower stocking rates. In practice, this doubles the time required to reach target sale weights. Given that animals lose weight for the nine months of the year when grass is frosted, it is important to maximise growth rates over summer. Animal growth rates above 100 g/d occurred when the herbage available per DSE exceeded 450 kg DM over summer (Figure 2). At this site the herbage mass produced each year did vary with rainfall (100-250 mm), but was not affected by stocking rate (Wang et al. 2011).

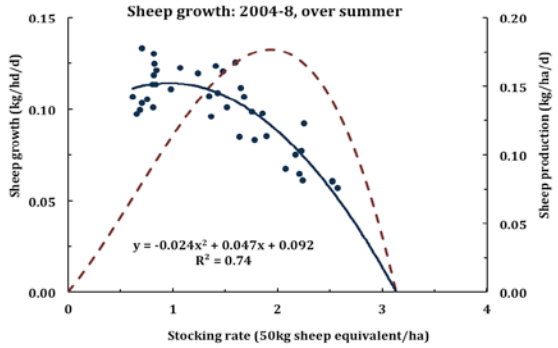

Figure 1. The effect of stocking rate (50 kg DSE/ha) on sheep growth per head and per ha on the desert steppe. Data for five consecutive summers from three stocking rates (2004-8). Experiment at Siziwang IMAR China.

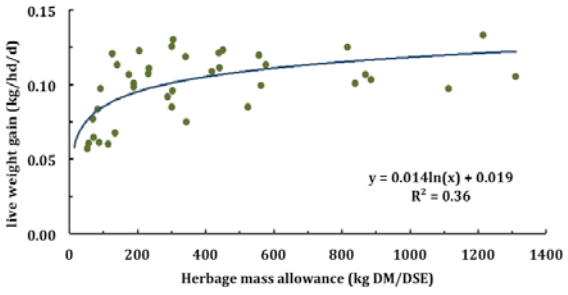

Figure 2. The effect of herbage allowance per DSE on liveweight gain per animal over summer on the desert steppe. Data for five summers (2004-8) at Siziwang IMAR China.

Consumption and utilisation rates

The consumption rates at the biologically optimal stocking rates help illustrate the grazing pressures on the desert steppe. At stocking rates (1 DSE/ha) where liveweight gain over summer exceeded 100 g/hd/d, the

average ANPP from the grassland was ~460 kg DM/ha/yr and at the end of summer the residual herbage mass was ~150 kg DM/ha indicating that ~300 kg DM/ha had 'disappeared'. Of this 300 kg DM, ~150 kg would have been consumed by a DSE and the remainder lost through other processes i.e. 50% 'wastage'. The consumption rate of ANPP is then 33%, but as 'wastage' is often related to grazing, the overall utilisation rate could approach 66%. At current district stocking rates (2 DSE/ha) the consumption rate would double to 66% and utilisation rates would approach the maximum forage available as observations show very little residual forage in winter. This would limit the plant reserves available for their survival through the harsh winter.

These livestock growth, consumption and utilisation, rates for the whole 120 d growing season seem exceptional in comparison to experience in Australia. Estimates for the Central Tablelands of NSW (Kemp, unpublished) suggest on intensively grazed phalaris (*Phalaris aquatica*) pastures the sustainable utilisation rate is only 40-50% of ANPP. To sustain low productive native grasslands in Central NSW, a utilisation rate of 20% is arguably more appropriate as higher utilisation commonly leads to weed invasion with species such as *Nassella trichotoma* becoming a major problem.

The higher animal growth rates than one might expect, are due to animals undergoing compensatory gain through summer. After losing weight for nine months through autumn, winter and spring, they regain that lost weight each summer. A small amount of 'real' gain also occurs. Livestock take nearly twice as long to reach maximum adult weights as generally occurs in Australia.

Biodiversity

Additional studies have investigated the relationship between plant species diversity and mean herbage mass (Figure 3). Species diversity under current conditions was maximised when the annual net primary productivity was 500 kg DM/ha or more. That was approximately the average annual rates of production, occurring when rainfall was at or above average and when the stocking rate was 1 DSE/ha or less.

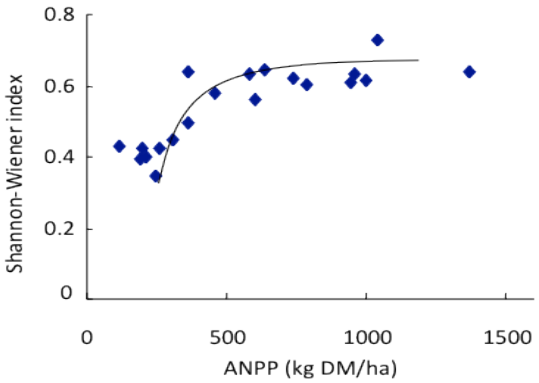

Figure 3. Annual net primary production (ANPP) and Shannon-Wiener diversity index for plant species under three stocking rates and for five summers on the desert steppe.

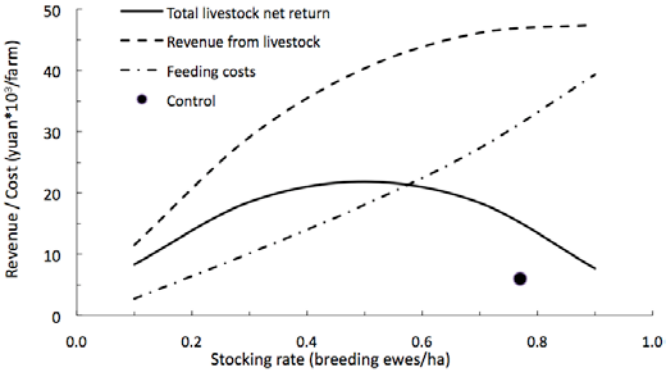

Figure 4. Livestock production revenue and feed costs for the current meat production system in Siziwang Banner, Inner Mongolia Autonomous Region. The 'Control' data point is an estimate of current net income from livestock on farms in same area, for which case animals graze outside all year, are not fed to maintenance requirements, and revenue and feed costs are less than apply in other calculations.

Financial returns

The data from farm surveys and the grazing experiments were used to construct a linear programming model to investigate the financial returns from different stocking rates, using current feed sources, but maintaining animal liveweights through the year (necessary for a production oriented system) and kept through winter in a warm shed (Han et al. 2011). Warm sheds minimise weight loss when nutrition is poor and improve net household financial returns. Net returns were optimal at a stocking rate that was approximately half that of present practice (Figure 4). That is ~1 DSE/ha in the stocking rate experiment considered above. In the Siziwang district 500 households have now reduced their stocking rates by 40% and when combined with better advice on animal nutrition and the creation of a better market system for lambs, household incomes have increased. Other changes in management are possible that would further increase incomes.

Grassland rehabilitation and PES

The above analyses support the view that under current grassland conditions on the desert steppe stocking rates can be reduced by 50% and at the same time substantially increase net financial returns to households. Just as importantly, this reduction in grazing pressure provides a window of opportunity for the rehabilitation of grasslands. Limited data are currently available on how the process of grassland rehabilitation would respond. On the meadow steppe (where rainfall is 250 mm/yr or more; 500 km east of Siziwang) grazing exclosures (data of Liu Zhongling, Inner Mongolia University, Kemp et al. 2001, Kemp and Michalk 2011) showed that depending on the level of degradation, it took 3-10 years for annual forbs to be replaced by perennial grasses and then another 3-5 years before ANPP had doubled to the level that was expected for these grasslands. However, on the desert steppe it is then likely that considerably more than 20 years rest from grazing may be required to restore species composition and production to desirable levels. Some grassland areas will only be rehabilitated through complete grazing bans, but most of the grasslands can still support some livestock.

A 50% reduction in stocking rates would improve current household incomes and would place less pressure on the grasslands but depending on the current condition that may not be enough to restore grasslands to previous levels of composition and productivity. A 50% stocking rate reduction would still be twice the estimated stocking rate that applied in 1950. One way of achieving this additional 25% reduction is to develop systems of payments for environmental services. The need to reduce dust storms across northern China provides a clear incentive for Chinese policy makers. The Chinese Government is currently spending $2 billion/yr on better grassland management and to support herder household incomes. It would be worthwhile to integrate the market-based solutions discussed here with a payments for environmental services scheme to achieve the desired outcomes.

Acknowledgments

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