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Chinese degraded grasslands – pathways for sustainability

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Abstract. The 400 m ha of grazing lands in China, mainly across the north and west of the country, have similar problems to those throughout the steppe of Mongolia, Central Asia and neighbouring countries. The grasslands are in drier regions (50–500 mm) across mainly Inner Mongolia, Xinjiang, Tibet, Qinghai, Gansu and Sichuan, often at higher altitudes on the Tibetan, Mongolian and Loess Plateaus, and have for millennia supported the livelihoods of millions of herders. By 2002, surveys were classifying 90% of the grasslands as degraded. Less than 10% were considered desertified to the extent that replanting was the only option to restore some plant cover. The majority of the grasslands were considered capable of being rehabilitated to some degree through changing management practices. In the 1980s the first Grassland Laws were promulgated, initiating a series of programs aimed at rehabilitating the grasslands. These programs included the establishment of individual ‘user rights’ to herders to use a defined area of grassland and the imposition of grazing bans, often for five years, to rehabilitate degraded areas. These were often applied at a regional level. At the same time, herders were encouraged to have more livestock as that was seen as a pathway to lift them from poverty. The sheep equivalent of grazing animals for the whole of China, has increased 4-fold since 1949, often by greater amounts in some regions. But there was very limited work done on how best to manage grazing livestock in ways that could aid grassland rehabilitation. In the early 2000s a collaborative program was started between several Australian and Chinese Institutes, to investigate better ways of rehabilitating the grasslands and to improve herder incomes from livestock. This work involved the development of four models that could use the limited data available, to help guide a series of research programs. These models indicated that halving stocking rates could maintain or increase herder net incomes. Farm demonstrations showed this result applied in practice and grasslands did improve. A series of grazing experiments found that halving the current stocking rates was needed to enable the survival of the better plant species within the grassland. A model that estimated the net value of each animal indicated that often half the animals were generating marginal or negative incomes, and could be culled without affecting the household income, again substantiated in farm demonstrations. In this paper, the causes of degradation, which can be traced back to the progressive changes that have occurred in China since 1949, are discussed together with the practice changes that have come from a large collaborative research program between Australia and China. Efficient markets and land tenure reform are needed to help create the incentives for herders to change in sustainable ways.

Keywords: China, degradation, grasslands, herders, Mongolia, overgrazing, rehabilitation, solutions, steppe.

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Introduction

China has 400 m ha of grasslands that have sustained the livelihoods of herders for millennia, but since the 1990s there has been considerable concern about their degrading condition and

ability to sustain herder households (Li 1999; Ren *et al.* 2001; Lu Fan and Liu 2002; Lu *et al.* 2005; Hong 2006; Hong 2011; Kemp and Michalk 2011a). In 2002, the State of Environment Report (SOE 2002) estimated that grassland degradation in China was

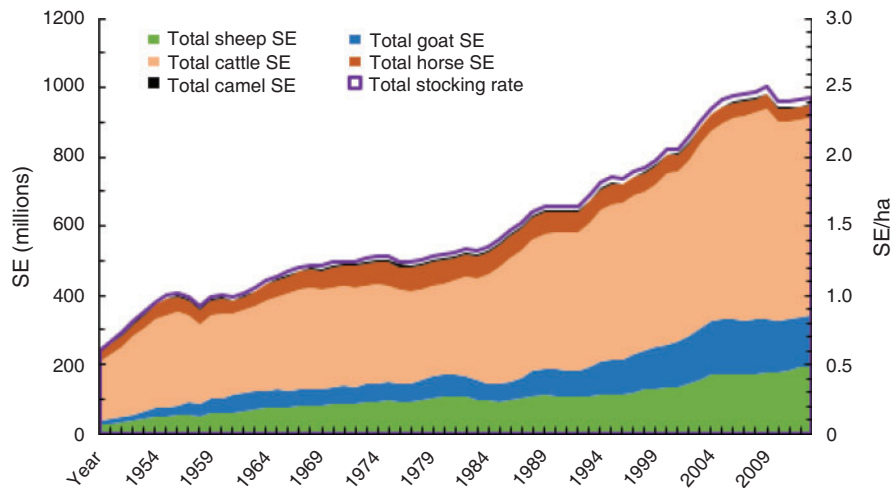


Fig. 1. Cumulative livestock numbers, as sheep equivalents (SE), and average stocking rate (SE/ha) 1950–2014 (Kemp 2020)

increasing at 2 million ha per annum. These grasslands are part of the vast Eurasian grasslands that extend from eastern China and Mongolia to eastern Europe, with many common species and characteristics throughout. Precipitation is mainly through summer (50–500 mm) with a 3–5 month growing season when temperatures are above 0°C, then genuinely cold winters that are below –20°C for extensive periods in all regions. Areas on the Mongolia Plateau are colder than Tibet. In China, 90% of the grasslands were considered to be overgrazed, though only 10% were in a state of rapidly increasing desertification and would require planting. Across the varying regions of China, it is estimated that the grasslands are over-grazed by 27–89% (Zhang *et al.* 2014). Herders in China are among the poorest people in the country, and poverty alleviation is a major ongoing government goal. Livestock are primarily used for meat and for some less-valuable fibre production. For many sheep, the cost of shearing exceeds the value of the fleece, while cashmere prices have been very volatile and goat numbers have declined. The use of large animals for draft and transport has greatly reduced over recent decades. In this paper, we discuss the causes of grassland degradation, which can be traced back to the progressive changes that have occurred in China since 1949, and then how a large collaborative research program between Australia and China (Kemp 2020) has identified practice changes to rehabilitate the grasslands and improve herder incomes.

Grassland degradation

The typical pattern in grassland degradation found in many grassland ecosystems is an initial shift from palatable to less-palatable species – a reversible change – then species loss and potentially irreversible losses in plant productivity, followed by gradually declining plant cover. In the worst cases, there is clear evidence of desertification with soil loss, chemical and hydrological changes (Fernández-Giménez *et al.* 2018; Jamsranjav *et al.* 2018). The Chinese grasslands differ from many in Australia, in that few annual species ever become a significant component and there are almost no invasive, exotic species. The

shifts are among the existing species, understandable in ecosystems where there are several thousand species. In terms of environmental services, there is an associated sequence of declining animal production from the initial decline in overall nutritive value, then declining plant growth, reduced residual herbage mass, decreasing diversity, poorer nutrient cycling, reduced water quality, lower soil carbon and soil erosion increases (Kemp Li *et al.* 2020). This list of provisioning, regulating and supporting services (Millennium Ecosystem Assessment 2005) relates to the grassland characteristics that herders identify as critical for grassland condition (Bruegger *et al.* 2014). These environmental services do not all decline at the same time and rate. From a management perspective, it is argued (Kemp Li *et al.* 2020) that more attention needs to be paid to managing the herbage mass as that is an early indicator of decline and does correlate closely with all the other key services.

Political and livestock changes

China had major political changes through the last century since the 1949 revolution, which affected the numbers of livestock and their impact on the grasslands (Fig. 1). Since 1949 when there were 250 m sheep equivalents in China, livestock numbers had risen to 1000 m by 2010. In 1949 after the Chinese Communist party took control of the country from feudal landlords, there was an initial recovery period in livestock numbers (7.5% per annum, 1950–57) then a relatively steady rise (1.2% per annum, 1958–84) during the period of collective farms. During the collective farm period cattle were primarily used for mechanical power, not consumption, and there was limited trading in livestock. Chinese scientists believe that the grasslands were in reasonable condition during this period, though some were being over-grazed. Unfortunately, there were no studies at that time to document grassland condition. Studies in more recent years have often only examined stocking rates changes since around 2000, and then argued that stocking rates have not been the cause of grassland degradation. A longer-term view is clearly needed.

The first Grassland Law in China, in 1985, was to address a range of issues, including the improvement of herder incomes and to aid rehabilitation of some degrading grassland areas. This coincided with the opening up of markets and the progressive allocation of individual user rights to specific areas of land for each herder household and a specified number of animals per household. Both land area and animal numbers varied for a range of reasons between households. Herders responded to this change by rapidly increasing their herd and flock sizes at double the rate of the previous 30 years (2.5% per annum, 1985–2008). The average stocking rate across China reached 2.5 sheep equivalent (SE)/ha around 2010, four-times the 0.6 in 1950. Since 2010 there has been a steady decline in livestock numbers, as herders, officials and researchers realised that the grassland condition could no longer support the large numbers of animals and some regulation was imposed. The State of Ecology and Environment Report in 2017 (SOEE 2017) estimated that grassland production could only sustain 250 m sheep equivalents, one-quarter of the actual (Fig. 1). In recent years there has been an increase in the use of supplements, but they are mainly fed in winter and rarely when animals are grazing, but this can encourage the keeping of more animals than the grasslands can sustain in summer.

Traditional herder practices and attitudes

Traditional herders across much of the grassland of China followed a transhumant system, often moving six or more times a year. The movements in mountainous areas were to exploit grasslands at higher altitudes in summer, whereas in other areas the summer grazing lands were often those that were less accessible in winter, but at similar altitudes. After 1949, herders were organised into large collective farms, and then after the mid-1980s were granted individual ‘user rights’ with specific areas of land and numbers of animals, allocated. Currently, in China there is limited movement of animals, the exceptions being on the Tibetan-Qinghai Plateau. Herders do rent land from neighbours and use that rented land for grazing in summer, which results in increased overgrazing of those areas, often because several herders amalgamate rented land and graze it collectively.

When herders were initially allocated user rights, they were first given an allocation of animals and then an allocation of land, although these two factors were not necessarily connected (Williams *et al.* 2009). Local officials then did not regulate stocking rates all that effectively. Herders sought to acquire more animals, as a means to improve their incomes (Fig. 1). Herder attitudes can be seen in an adaptation of the model for east-African herders of the development pathway: ‘user – keeper – producer – breeder’ (Neidhardt *et al.* 1996; Kemp Michalk 2011b). The ‘user’ is hunting and gathering and may keep some animals; no longer common in East and Central Asia. A ‘keeper’ is one who has animals, relies overwhelmingly on grasslands to feed them, with supplements only being given to obviously sick animals, minimal shelter is provided in winter, where temperatures drop below -20°C , and is very commonly observed in China, Mongolia and neighbouring countries. Traditionally only a small proportion of the flock/herd was sold each year. Households aim to be largely self-sufficient. A ‘keeper’ develops great skills for animal survival, but not

necessarily for animal production. The ‘producer’ pays more attention to managing their animals through the year and sells a higher proportion of their animals. They aim to be more efficient in animal production. The ‘breeder’ engages in more intense management of their animals and aims for a high level of efficiency. Today more herders in China are oscillating in the transition from ‘keeper’ to ‘producer’; in poor seasons they revert to a ‘keeper’ model. Arguably, that is also the position of many graziers in semiarid zones of Australia.

Surveys of herder attitudes (Hou *et al.* 2020) found that while some had higher stocking rates than they considered desirable, they wanted to increase their stocking rates further, in contrast others had fewer animals than they desired, but were intending to decrease their stocking rates. There were also intermediate positions. This raised the important issue of what underlay these views. Stocking rates are arguably an inappropriate measure for herders who traditionally could graze anywhere at any time. Until recent times, land and animals per unit area were not necessarily a constraint. An analysis of the survey data indicated herders were more focussed on the total number of animals they considered viable for sustaining their households, as insurance against adverse seasons e.g. a winter with heavy snow falls, and to maintain their status as a herder. Analysis found in some villages the optimal number of animals was ~ 400 SE, ~ 600 SE in others. Further work showed that as farm size increased, stocking rates declined, reflecting that when herders achieved their ideal animal number they did not exceed that, despite having additional land (Fig. 2; Li *et al.* 2020). This relationship was not influenced by the level of net income per farm. The more and least profitable herders had a similar relationship, and this was not influenced by the amount of supplements fed.

Grasslands only grow for 3–4 months each year, with total annual production varying from a few hundred kg dry matter (DM)/ha in the desert steppes to 4 t DM/ha in the meadow steppe. Estimates of the sustainable consumption rates for these grasslands, to maintain desirable species and other environmental services, indicate these would range from 5% in desert areas to 30% in higher rainfall regions (Kemp *et al.* 2018). Animals only grow during summer. For the remaining 8–9 cold months, there is only frosted grass, and typically by spring, no herbage is left on the grassland, although herders traditionally take their animals out to graze every day of the year. Over autumn, winter and spring, livestock lose 20–30% of their bodyweight due to the cold, the energy cost of walking and the lack of forage. Traditionally supplements were rarely fed, except to sick animals. The main supplements are often poor quality meadow hay, or whole crop stalks, loosely stacked in the open. Mature animals then regain the weight loss over summer, such that by the end of summer they are back to the weight they had a year before. Animal growth rates appear to be very good on meagre amounts of herbage mass, due to large amounts of compensatory gain and high quality of early season growth. The weight loss and gain experienced is out side the range of most experiments done in developed countries (Nicol 1987). These effects lead herders to believe their animals grow very well on limited grassland, well below the levels of herbage mass considered optimal in more productive environments where compensatory gain is not evident (Nicol 1987). Programs such as GrazFeed (Freer *et al.* 2007) can be modified to accommodate

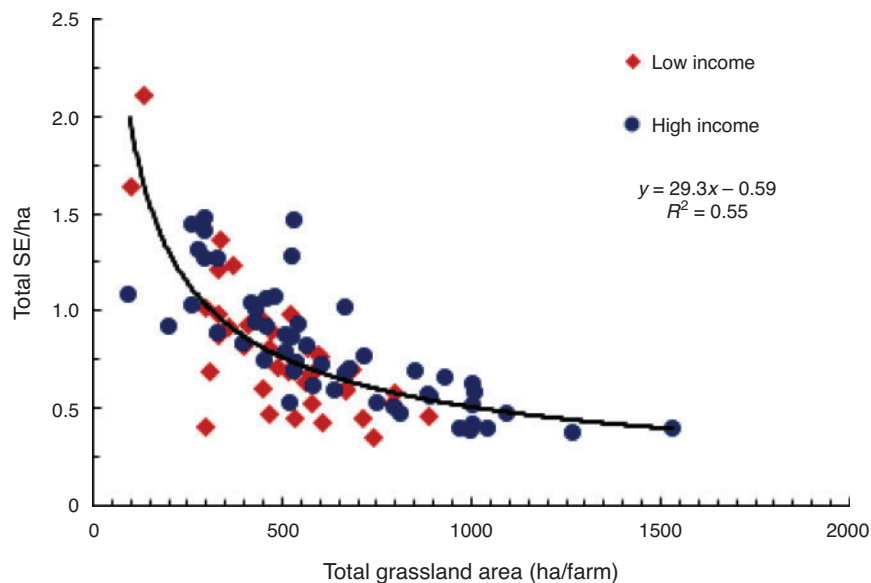


Fig. 2. Stocking rate per farm in relation to grassland area for farms on the desert steppe in Inner Mongolia. Data is from a survey that grouped farms with high or low incomes.

this, although it is not always evident for how long compensatory gain applies.

Lambing and calving often occur in the middle of winter, when ewes and cows are losing weight (Kemp Michalk 2011a). The sheep, goats, cows and yaks fall pregnant in late summer when nutrition and body condition peaks. Lamb weights are often only 2 kg at birth, just over half that of many Australian flocks. Of the lambs born, 90% often survive because they are kept apart from their mothers from birth, allowed milk for short periods in the morning and evening, and fed supplements from 7–10 days of age, but growth rates are poor. The ewes produce little milk, due to their poor condition. In general, female sheep and goats rarely become pregnant before they are 2–3 years old and cows before 4 years of age. Sheep, goats, yaks and cattle are often only producing offspring every second year. Herders now collect milk from yaks and cows for sale, further reducing the amount available for calves. The net effect which is very evident on the Tibetan Plateau, of this is that the mature body size of female yaks has declined from 250 to 140 kg (J. P. Wu, unpubl. data).

A key to improving animal productivity is management through the long cold season. Herders did have shelters, but they only provided minimal protection from cold winds. Winters with heavy snowfalls occur at intervals, and the loss of livestock and human lives can be severe. After severe snowfalls in the 1990s where 2 m head of livestock died, a program was started in China to modify existing sheds to make them warmer, and to build better sheds. The south-facing roof was changed to a plastic or glass cover to help trap heat using the glasshouse effect, and air gaps were blocked. Some sheds had heaters, often coupled to methane digesters using animal and human waste. In general, warm sheds reduce weight loss, even if the animals do not receive more or better supplements (Wu *et al.* 2020). The generally poor nutrition of livestock through winter, due to

sub-maintenance forage and supplement quality, was reflected in the result that weight loss started at 5°C, a higher temperature than would be expected in well fed animals (Kemp 2020).

Reducing stocking rates

Improving the livestock grassland system requires the investigation of options applicable throughout the year. Over summer when grazing is the main forage available, grassland management is important. Through the cold months, the better use of supplements and sheds are obvious needs. To help plan what could be done in Chinese grasslands, a series of models were developed during the program (Behrendt *et al.* 2020). Three of these models are based on estimating the energy balance of livestock in relation to the feed supply and livestock and grassland management. The first model is a steady-state energy balance, useful for quickly identifying system weak points. The second uses linear programming to optimise the steady-state system. The third is dynamic, long-term, investigates the more useful options and estimates the effects of management practices on grassland sustainability. The fourth model uses a different approach. Using body condition score and other data for every animal in a flock, it estimates the gross margin per animal and then ranks those animals to determine which should be kept and which can be culled. Studies to collect data to validate and use the models (Behrendt *et al.* 2020) were conducted in the Provinces of Inner Mongolia and Gansu, two of the main grassland areas. Initially, surveys were done in selected villages to define the typical livestock system.

The modelling work showed the gross livestock energy deficiency through the cold seasons. Energy intake only exceeds maintenance for about four months each year. Because the stocking rates were higher than would have been the case in the previous century, this resulted in limited forage per head and

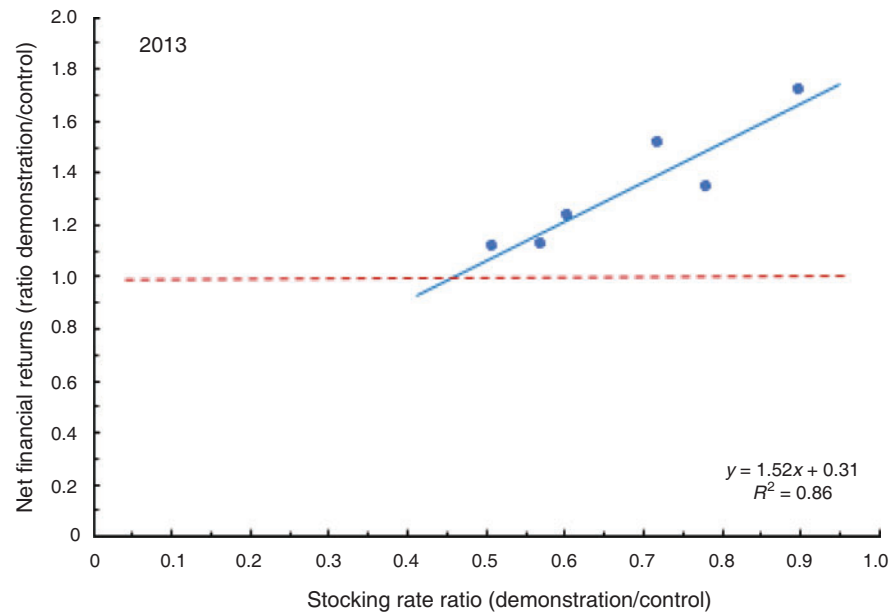


Fig. 3. Net financial returns ratio in relation to the stocking rate ratio for demonstration vs control farms in six villages across Inner Mongolia in 2013 (Li *et al.* 2020).

only moderate animal growth rates. The system was clearly feed limited. Modelling in several different locations showed that a ~50% reduction in stocking rates would improve incomes and then give the grasslands a chance to recover. However, the financial gains were limited unless other changes were made, including better use of more supplements through winter, use of warm sheds and then wider issues of developing better markets.

In parallel with the modelling, grazing experiments (Zhang *et al.* 2015; Badgery *et al.* 2020; Wang *et al.* 2020) were established on the typical and desert steppe to examine the effects on botanical composition and other ecosystem components. In both cases it was shown that a halving of the then current district stocking rates resulted in better outcomes for species composition and plant cover, and also optimised other services such as methane uptake by soils. For both grassland types, the optimal stocking rate meant that the average herbage mass over summer was at or above 0.5t DM/ha. This provides a better management guideline for herders on when to start grazing in summer and when to move animals to fresh grasslands. Managing on herbage mass can be learnt as it has been by farmers in Australia and New Zealand. The key is to learn to visually recognise the critical value and not necessarily all other possible values. Managing to this level meant an average consumption rate of grassland by livestock of 10% on the desert steppe and 20% on the typical steppe. These values are about half what is measured using the differences in herbage mass, inside and outside a cage, i.e. a common method of estimating utilisation. Managing to maintain herbage mass above a critical value of residual biomass means that herders do not need to be constrained by a fixed stocking rate, but can vary their animal numbers, depending upon management needs and seasonal conditions. This is particularly important where control over the amount of grazing area or other grazing animals is limited.

To investigate the benefits from combining a few system changes, demonstrations were established on existing farms, initially on a small scale and then across Inner Mongolia (Li *et al.* 2020). In six villages, the demonstration farms had a reduced stocking rate compared with the controls. In addition, the demonstration farms fed more supplements (not always to the level that would satisfy maintenance requirements), with some culling of unproductive animals and better use of warm sheds through winter. The combined effect of these changes on net financial returns shows that stocking rates could be halved before there was a decline in income compared with the controls (Fig. 3). These data are for 2013, a year after the modified practices commenced on the demonstration farms; 2012 showed a smaller effect while herders learnt new skills. The grazing experiments showed that a halving of stocking rates is often required to maintain desirable species and to initiate grassland rehabilitation. However, this is not always the most profitable position (Fig. 3). Profit comes from meat, milk and fibre. In the farm demonstrations, the more profitable farms had a high stocking rate, but those animals were not necessarily on the grasslands. Animals were spending more time in sheds and yards, being fed with supplements; it was not possible to quantify what that meant for actual stocking rates on the grassland. A farm survey across 15 counties in Inner Mongolia from 2009–2014, found that, where herders decreased stocking rates, their profit increased and where stocking rates increased most showed a decline in profit (Li *et al.* 2018).

An independent line of evidence demonstrated another means whereby animal numbers can be reduced without reducing incomes (Kemp Michalk 2011a). The model developed to estimate the gross margin for each animal in a flock used a consensus on how body condition score, teeth, and udder condition would influence the production of lambs for meat

and fibre. A close examination of ~5000 sheep across 12 farms found that many were in poor condition, some had no teeth or working udders, and were in fact a net cost to the herder. The lambing rate on these farms was often only 60%. When the animals that were a net cost or marginal gross margin were removed from a flock, the net household income remained the same or improved. On several farms, up to half the animals could be removed, based on their poor productivity. In addition, because these are feed limited systems, that meant the available forage for the remaining animals increased, contributing to the gains found on demonstration farms.

The poor state of animals on many farms is typical of the 'keeper' model discussed earlier. When traders arrive to buy animals, they demand to inspect all the animals and they select which ones to buy. That means over time progressively older flocks with poorer quality animals eventuate. The cycle is only broken during a winter with heavy snow falls and high death rates (in Mongolia half or more of the national flock has died in recent times when such conditions occur) that effectively reduces stocking rates and results in higher rates of fecundity and a renewal of the flock. This pattern is reminiscent of wild animal populations, with boom-bust cycles. Simply culling the unproductive animals often achieves the desired reduction in stocking rates without harming household incomes.

Reorganising the system

Herders across China have sustained their livelihoods for millennia on the extensive grasslands, but over the last 50 years the human and animal numbers on the grasslands have increased dramatically, arguably to unsustainable levels. Solving this problem requires changes in policy, changes in markets, and improved education and training of herders. The first step though is recognising the level of production that is sustainable from the grasslands.

Considerable research in recent years on Chinese grasslands shows how their productivity has declined. The work outlined here (see also Badgery *et al.* 2020) has shown that on average a halving of stocking rates is often needed to optimise the proportion of more-desirable species within the grassland. It is though, a matter of 'working with what you have', rather than aiming for an ideal. An example of this is discussed in Badgery *et al.* (2020). On the typical steppe grazing experiment, the aim was to optimise the proportion of the grass *Leymus chinensis* and minimise the semi-shrub *Artemisia frigida*, which increases with degradation (Zhang *et al.* 2015). Conversely, on the desert steppe grazing experiment the objective was to optimise the amount of *A. frigida* and limit the unpalatable grass *Stipa breviflora* (Wang *et al.* 2020) because it reflects a more degraded state. There are generally no data to adequately describe what may have been an ideal grassland condition a century ago, nor the better practices to minimise the proportions of unpalatable species in degraded grasslands. The results reported by Badgery *et al.* (2020) show that maintaining the herbage mass above 0.5 t DM/ha through summer, does enable better management of species and optimises animal production, which provides an easier criterion for managing the grassland than a sole focus on stocking rates. Only one observation is known (Badgery *et al.* 2020) for the effect of winter grazing on grasslands (Wang *et al.*

2020), and that found heavy winter grazing reduced grassland growth in the following summer by 50%. In general, grasslands should only be grazed in summer when above a critical value for herbage mass. In winter, animals are in better condition when kept in warm sheds even if poorly fed, as the energy costs of walking in very cold conditions (less than -20°C) cannot be replaced by the available forage.

There is a need to identify sustainable levels of 'consumption'. In China, there are recommendations for 'utilisation' levels, determined from grassland measurements inside and outside a cage, typically left in place for the entire 3–4 months of summer. In general, livestock consumption rates (estimated using programs such as GrazFeed, Freer *et al.* 2007) are about half that estimated for utilisation by using a cage. The Chinese recommendations assume the entire utilisation estimate is consumed by livestock, whereas losses occur from, for example, leaf age, micro and meso herbivores and fungi, and there are no corrections for species palatability. Therefore, recommended utilisation rates and hence the derived stocking rates, are much higher than those experiments have shown will optimise both species composition and animal production, although they are closer to herders' practices. The recommendations align with usage rates of the grassland that maximise the number of animals able to survive on the grassland ('keeper' model), rather than those optimal for production per head and net income ('producer') (Kemp 2020).

The work discussed here has mainly been conducted in Inner Mongolia. The recognition that overgrazing is a problem varies with regions. In Siziwang county, where this program has been implemented for the last twenty years, livestock numbers have halved, with 2000 households agreeing to reduce their stocking rates (Kemp 2020). In this county, stocking rate reductions have been supported by cross-breeding (a farmers' association provides improved rams and training), improved livestock nutrition (both ewes and lambs), feedlots for lambs (which never graze the grasslands and hence reduce stocking rates), price premiums for animals reaching target weights by early summer, construction of more efficient, warm sheds, and direct marketing to restaurants in Beijing, avoiding the many traders often in the marketing chain. These system changes emphasise the need to increase productivity per head, rather than maximise animals per hectare. These changes have been driven by local herder leaders and officials, working with University staff. Demonstration farms with reduced stocking rates and better feeding of livestock, were used to demonstrate that changes were viable (Li *et al.* 2020). System improvements and better marketing are important to help reduce stocking rates, with the reductions then reinforced through the local government. Small subsidies are paid to facilitate these changes. In other districts, total grazing bans for five years have been implemented with larger government payments to support herder households, although there is then little income from livestock production.

The Siziwang results show that herders can change practices and help develop better production and marketing practices. Herders are interested in improving the grasslands, although not all agree that the grasslands are in poor condition (Hou *et al.* 2014; P Li, unpubl. data) or, if grassland condition is poor, that the poor condition is due to overgrazing (Li XL *et al.* 2017). This later point probably reflects the fact that the current condition of

grasslands has existed for several decades, i.e. it appears normal, and that those herders wish to have more livestock. Discussions with older herders indicate the grassland condition has seriously deteriorated.

Herder populations are ageing, and their children are encouraged to move to towns and cities and seek better employment. Older herders then semi-retire and rent out their land. This leads to an overall reduction in stocking rates (Fig. 3). However, rented land is often over-grazed as it is typically on a one-year lease, and there is no incentive for appropriate management. The renting herders only have 'user rights' to their allocated land, which tends to be their winter grazing areas, which are now in better condition. There is a clear need to revise the system of land use so that herders are aware if they look after rented land, they can maintain use of it. Land could be reallocated when herders and their children no longer wish to use it. When herders rent land, there is an incentive to maximise short term returns, to cover the rent. It may be more appropriate for government to pay a pension to herders who rent their land to others, and for them to receive no payments from herders who are then allowed to use that land, reducing costs and pressures to overgraze. At present, any subsidy payments to reduce stocking are paid to the herder who has the user right, not to the user of the land, which further encourages overstocking by renting herders.

Not all grassland areas would require a 50% reduction in stocking rates. Changing the pattern of land use could also reduce grazing intensities in some districts. A grazing experiment on the Tibetan Plateau in Gansu found that treatments stocked at the district stocking rates were very productive, and the grasslands were in good condition (Badgery *et al.* 2020). However, outside the experiment in the valley floor the poor condition of the grassland was clearly evident. The problem was that the herders wanted their animals in the valleys near main roads, so they could easily meet traders to sell their livestock. The solution requires some reorganisation of marketing practices, so that herders could remain with their livestock in the hills, and deliver the stock they wish to sell to centralised markets. This would also enable herders to choose which animals to sell and to retain the best animals for breeding, a skill few appear to possess.

Discussion

The large grassland program in China outlined here, using farm surveys, modelling, grazing experiments and farm demonstrations, has demonstrated that grasslands can be improved by stocking rates reduction of 50% without depressing household incomes, provided that additional changes in animal management practices and other policy changes are implemented (Kemp 2020). Reducing animal numbers does not necessarily mean reducing overall productivity, since when unproductive animals are removed, production per head increases because the system is feed limited.

The Chinese Government has an emphasis on better environmental outcomes that take priority in grassland areas. The central officials charged with managing grasslands were moved from the Ministry of Agriculture to the State Forestry and Grassland Administration in 2018, lessening the connections with agriculture. Previously, some officials had expressed the view that all grazing should be banned. Grazing bans have been

used for periods of five years to help rehabilitate grasslands, but the evidence of beneficial outcomes is variable (Hou *et al.* 2014), in part because compliance with bans has been uneven. The desert steppe grazing experiment demonstrated 8 years were required before treatment differences emerged, and up to 12 years before those differences were clear (Wang *et al.* 2020). These grasslands have been grazed for millennia, and when appropriate stocking rates are used they are maintained in a desirable state. Grazing is part of the solution, and herder households need to be seen as the prime landscape managers.

A survey of 262 households in Inner Mongolia found that for each 1% increase in Government payments, the grazing intensity was reduced by only 0.2–0.5%, which increased herder incomes by only 0.1–0.7%, depending upon Prefecture (Gao *et al.* 2016). But each additional year of education resulted in a 3.6% decrease in grazing intensity and an 8.7% increase in income. The need for education, including training, will be vital to help herders' transition from 'keeper' to 'producer'. The farm demonstrations proved to be central to helping herders make this transition, supported by village leaders who drove the process of change. In the desert steppe site at Siziwang, Inner Mongolia, the village leader introduced better sheep genetics, but to access that and training courses on better feeding of livestock plus access to more profitable markets, stocking rate reduction was mandatory. Older herders may not readily change, but when it can be demonstrated that herding can be more profitable with the changes discussed in this paper, then younger herders are interested in adopting those changes.

Conflicts of interest

The authors declare no conflicts of interest.

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