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Refining China's grassland policies: an interdisciplinary and ex-ante analysis

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Abstract. China is about to embark on a new round of grassland policies as part of its 14th Five-Year-Plan. Although current grassland policies have generally been perceived positively in arresting widespread grassland degradation, concerns have arisen that the current policies may not be effective in achieving the desired reduction in livestock numbers. Furthermore, there are concerns the incentive-based payments that are part of these policy programs may not reflect herder opportunity costs or the marginal environmental benefits of the program, with associated issues of herder satisfaction and compliance. Changes to current policy settings are being considered in response to these concerns. This paper reports on an interdisciplinary and ex-ante analysis of alternative policy settings affecting grazing and livestock management in terms of their environmental impacts, net social benefits and other impacts. The analysis finds that a bundle of instruments involving both positive and negative herder incentives is needed if desired stocking rates are to be achieved. The impact on herder incomes, both positive and negative depending on the grassland biome, along with transaction costs of implementing the policies, have the most influence on net social benefits.

Keywords: China, grasslands, incentives, policy, stocking rates.

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Introduction

Northern China contains some of the world's most well-known grasslands that have supported generations of herder households and provide an array of environmental services (Kemp *et al.* 2020). Since 2000, China has invested substantial resources to address grassland degradation, with an increasing focus on strengthening herder incentives to manage grasslands sustainably. A revised national Grassland Law (PRC 2002) in 2002 preceded a suite of grazing restrictions and associated compensation measures formalised in the 12th Five-Year-Plan in the Grassland Ecological Subsidy and Award Scheme (GESAS). The scheme included full grazing bans with compensation payments for severely degraded grasslands, whereas for grasslands in better condition, herders received so-called reward balance payments to operate within contracted stocking rates deemed desirable by the government for good grassland condition.[1] GESAS was rolled over in the 13th Five-Year-Plan with increased full grazing ban and reward balance payments. The rollover was based on the perception that GESAS had addressed grassland degradation to some extent, but that more needed to be done. Academic debate on the effectiveness and merits of the scheme are mixed, while officials themselves have alluded to

[1]GESAS was trialled in Tibet from 2009 and extended to 8 pastoral provinces and autonomous regions in the 12th Five-Year-Plan. Details of GESAS are in 'Guidance on the implementation of the grassland ecosystem subsidy and award scheme in 2011', Ministry of Agriculture and Rural Affairs, The People's Republic of China (http://www.moa.gov.cn/nybgb/2011/dqq/201805/t20180522_6142764.htm).

some shortcomings. A range of studies have been behind this debate, ranging from statistical analysis of large-scale surveys (Gao *et al.* 2016) to opinions based on anecdotal observations (Hu *et al.* 2015). Many of the studies have focussed on a single disciplinary area or particular aspect such as the grassland ecological condition (Li *et al.* 2015*b*) or herder incomes (Gao *et al.* 2016). Furthermore, the studies have tended to be ex-post assessments or impact analyses of previous policy measures whether this be of income, behaviour or grassland condition (Conte 2015; Pan *et al.* 2017; Huang *et al.* 2018). In contrast, this paper draws on an interdisciplinary study to investigate a range of impacts, and conduct a forward-looking analysis in assessing potential policy options.

Consideration of new grassland policies in the 14th Five Year Plan began in 2020, and this paper aims to provide information to support these considerations and future policy refinements. It does so by: (a) examining alternative policy settings and their potential impacts on grassland condition, herder livelihoods, environmental attributes and net social benefits; and (b) highlighting issues that need to be addressed in the next round of grassland policies. In contrast to ex-post studies, ex-ante analysis presents methodological challenges in identifying likely behavioural responses to alternative policy settings. After presentation of a conceptual framework, the suite of methods used to identify potential alternative policy settings and their potential impacts is described. The complex nature of grassland and pastoral systems means an interdisciplinary approach is needed for policy analysis. Drawing on the methods outlined, an investigation of eight alternative policy settings is presented. Specific policy settings that will emerge in the 14th Five Year Plan will be the outcome of various political, social, economic and environmental considerations. The aim of the analysis is to assist officials and advisors in making informed decisions.

The study is based on the grassland steppes[2] of central Inner Mongolia. The heterogeneity of grasslands, grazing systems and household systems in China means that the impact of grassland policies will vary across areas. Nevertheless, as outlined in the Study Scope section, the study area accounts for a significant share of China's grassland areas, herder household numbers and ruminant livestock numbers and production. Inner Mongolia has also been at the forefront of the development of China's grassland policies (Brown *et al.* 2008, see chapter 4). Furthermore, the approach outlined in the paper can be used to examine the impacts in other areas and other grazing and household systems.

Conceptual framework and review of literature

Policies addressing grassland degradation are framed by the perspectives of different agencies and grassland stakeholders and, in particular, whether the degradation should be considered an environmental, livelihood or land management issue. In China, policy makers often cite twin goals[3] of improving both grassland condition and herder incomes, although different agencies such as the Ministry of Agriculture and Rural Affairs, the National Forestry and Grassland Bureau and the Development Reform Commission have their own specific objectives and emphases in relation to grasslands and pastoral areas.

From an environmental perspective, Kemp *et al.* (2020, see table 4.1) outline an array of provisioning, regulating, cultural and supporting services provided by grasslands based on the Millennium Ecosystem Assessment (2005). The level of these services depends on the condition of the grasslands, including species composition, ground cover and standing biomass. In turn, grassland condition is affected by weather and soil conditions as well as grazing pressure. Thus, whether reduced livestock numbers will improve grassland condition and associated environmental services depends on the extent of the reduction in numbers, as well as the rainfall and soil conditions of the grassland biome.[4] The grassland services and any grazing-mediated impacts will be of concern at different landscape and administrative levels. For instance, soil erosion and topsoil removal will affect local grassland users, but dust emissions and storms will affect large cities in grassland areas and, depending on weather conditions, even municipalities in eastern areas and in nearby countries. Other environmental attributes dependent on livestock and grazing management such as greenhouse gas emissions have more global impacts. The different level of impacts will influence grassland policies and their implementation given the need to reconcile objectives at the different administrative levels.

Common and Stagl (2005) outline a broad classification of environmental policies as decentralised, command and control, or market based incentives. From a historical perspective, many environmental problems in China in the 20th Century were dealt with using a command and control type approach that focussed on direct regulation, clean-up and rectification programs, and state mandated technological improvements (Rozelle *et al.* 1997). They highlighted various issues ranging from weak, under-resourced institutions to production-oriented Ministries being responsible for implementing and enforcing environmental policies. Use rights to most grasslands in China were contracted to herder households from the mid-1990s, well over a decade after similar land use rights to crop farmers in rural areas, reflecting the difficulty of defining these rights and the collective nature of grassland resources and management in many pastoral areas (see section 3.1 in Brown *et al.* 2008). In the 21st century, China shifted attention in dealing with agri-environmental issues to

[2]Three grassland steppes account for almost all of the study area covered in the analysis. These include two of the major grassland steppes in China, namely typical steppe and desert steppe, as well as the sandy steppe, sometimes called steppe desert, characteristic of grasslands on the Ordos plateau. Typical steppe occurs in semiarid climate zones with precipitation of around 350 mm per annum and usually at an altitude of 1000 to 1500 m above sea level. The plant species are characteristically drought tolerant with bunch grasses dominating (Kang *et al.* 2007). Desert steppes occur in areas with annual precipitation between 150 and 250 mm and under the influence of continental climatic conditions. Small bunchgrass dominates the desert steppe category (Kang *et al.* 2007). Sandy steppe, sometimes also known as steppe desert, is a steppe located on the Ordos Plateau (Wu 1980; Li *et al.* 2015*a*).

[3]See, for example, Ministry of Agriculture and Ministry of Finance (2011), Guiding Opinions on the Implementation of the Grassland Ecological Subsidy and Award Scheme (GESAS) in 2011 (http://www.moa.gov.cn/nybgb/2011/dqq/201805/t20180522_6142764.htm).

[4]For instance, various studies reviewed in von Wehrden *et al.* (2012) highlight conditions where landscape condition may be driven more by abiotic than biotic factors.

market based incentives (see Zhang *et al.* 2010 for a review), most notably in the sloping land conversion program or 'Grain for Green' program (Bennett *et al.* 2008).[5] The main intent of the incentive schemes is to achieve a more efficient way of achieving the environmental objectives by incentivising agents to secure these outcomes, and to avoid some of the problems of the command and control type policies highlighted by Rozelle *et al.* (1997). This was also reflected in grassland policy where GESAS had two main components; (i) an incentive payment to entice herders to stock at set stocking rates deemed desirable for grassland condition, and (ii) a payment to compensate for full grazing bans on severely degraded land. Further policy reforms have sought to strengthen these incentives, although questions remain as to whether the incentives alone will be sufficient to achieve the desired environmental outcomes.

Assessment across alternative policy instruments requires consideration of their net social benefits to society which, in turn, involves estimation of the anticipated benefits and costs. A cost benefit analysis framework is appropriate for this assessment. On the benefits side, the environmental impacts of reduced grazing pressure resulting from alternative policies must be forecast, and the change in environmental conditions valued.

As the alternative policies seek to reduce grazing pressure towards the target GESAS level, a cost of the policy may be the opportunity cost to herders of fewer livestock. This cost depends on the stocking rate and characteristics of the grassland system. The Jones and Sandland (1974) model, contextualised for Inner Mongolian grasslands in Kemp and Michalk (2011), highlighted that individual livestock production declines with increasing stocking rates as animals compete for the fixed feed resource, but that with increasing grazing pressure, grassland quality can decline as less palatable species increase. Conversely livestock production per unit area rises with increased numbers but only up to the point where competition and productivity impacts outweigh the increasing number effect. Whether herders incur a cost in reducing their livestock numbers on their contracted grassland,[6] or benefit from fewer livestock, depends on their stocking rates relative to the maximum of production per unit of area, as well as on costs and product quality.[7] This is an empirical matter investigated later in the paper. The impact on herder returns feeds into estimation of net social benefits designed to assess societal costs and benefits across alternative policies. The stochastic nature of ruminant product markets and grassland production conditions means that policy makers are often interested in the variation in herder returns across different years.

Apart from any impact on herder incomes, there may be transaction or system and administrative costs in implementing the policies (Fan *et al.* 2012). The transaction costs will vary depending on the type of environmental policy. For instance, command and control policies may require major resources in monitoring and enforcement, whereas decentralised measures in China of contracting out of grassland use rights incur significant information (boundary definition) and dispute resolution costs. Market based incentives require significant set up costs and potential monitoring and enforcement, although ongoing information requirements may be less. Because many of the design elements of GESAS are already in place, and as many of the alternative policies involve refinements to the policies rather than wholescale new systems, it is the incremental change in these transaction costs that is relevant.

An increase in incentive payments to herders does not form part of the real costs to society as these are transfer payments between the government and herders. There may be distortionary costs associated with raising program funds (Dahlby 2008), but although the transfers are large from the herder and grassland program perspective, the aggregate payments are small relative to overall Chinese consolidated revenue, but any distortionary effects are unclear. Nonetheless the transfer payments will still be relevant to policy makers as they weigh up the net benefits of alternative policies against the transfers required to affect these policy objectives.

Apart from the environmental and economic impacts, officials and policy advisors within MARA, the National Forestry and Grassland Bureau and other grassland and livestock agencies will be interested in how alternative policies affect key pasture attributes including pasture biomass, ground cover, species composition and palatability, and, in turn, livestock productivity and herder incomes.

Although GESAS is at the centre of grassland policies, a range of non-grassland-specific policies also affect herder management decisions (Brown *et al.* 2008). For instance, the New Rural Social Pension Program significantly improved the welfare and subjective wellbeing of the elderly in rural areas of China, making them less reliant on adult children for financial support (Ding 2017). However, the current low level of pensions for herders may encourage them to stock at higher rates as they approach retirement in order to secure future incomes. In addition, mortgage loans, rural micro-credit and households' joint guarantee loans seek to alleviate the difficulty for farmers and herders in accessing loans in rural China and to facilitate the large-scale circulation of rural land (Yang *et al.* 2018). However, the short-term (annual) nature of the loans poses unique challenges for herders compared with crop farmers, given the longer time frames associated with ruminant livestock production systems compared with annual cropping, and may limit herders' ability to implement sustainable livestock and grazing systems. Analyses in this paper investigate changes in these non-grassland-specific policies that affect grassland degradation and herder behaviour.

[5]Other ecological payment schemes widely used in China in the 21st Century for forests, water, sloping land and wetlands are reviewed in studies such as Deng *et al.* (2011), Ye and Zhu (2014) and Xie *et al.* (2015).

[6]Most use rights to grasslands in China have been contracted out to individual herders. In some regions, although more remote summer grasslands have been contracted out, they are often still grazed collectively by groups of households. The informal institutions that govern this collective grazing affect the livestock numbers of each herder often more so than formal enforcement of numbers on self-managed winter grasslands (Addison *et al.* 2020). The nuances of the grazing arrangements are accounted for in the model behind the empirical results.

[7]Maximising profit will be at lower stocking rates than maximising livestock production due to lower costs and any impact on product quality of higher grazing pressure.

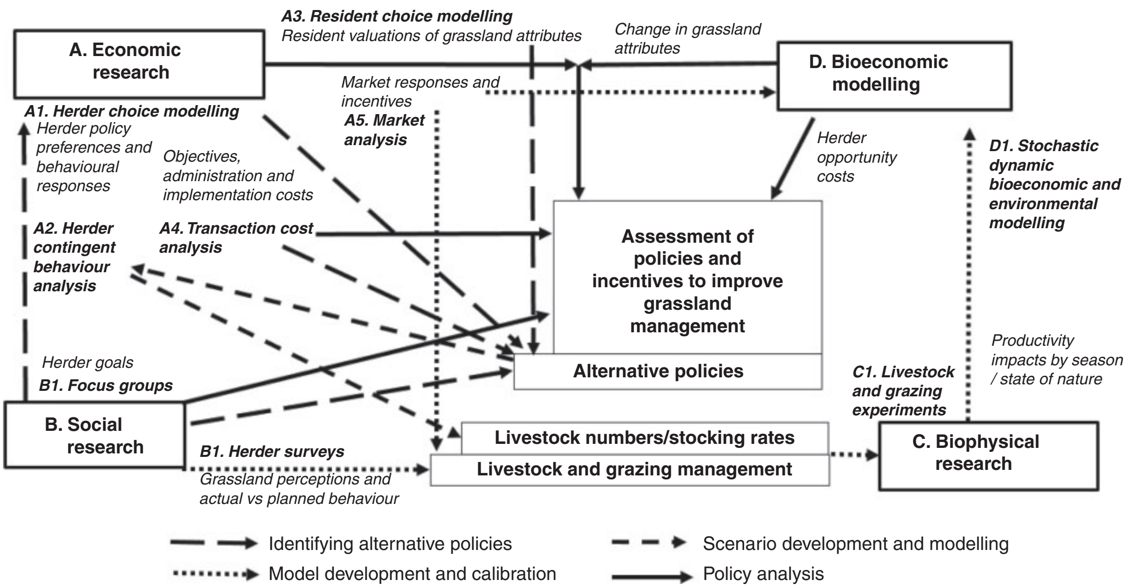

Fig. 1. Overview of the interdisciplinary approach.

Methods

Approach

The interdisciplinary approach used to identify and assess alternative grassland policies, and drawing on the conceptual framework presented above, is outlined in Fig. 1. The approach draws on a range of individual methods. Describing each of these methods is beyond a single paper, so an outline of these methods is presented with detailed description of the individual methods reported elsewhere. For instance, details of the choice modelling analysis of Inner Mongolian herders' preferences and their contingent behavioural responses to alternative policy settings are reported in Li and Bennett (2019) and a choice modelling survey of Hohhot residents' valuation of grassland attributes appears in Zhang *et al.* (2019). The stochastic dynamic bioeconomic model is at the core of estimating the impact of the behavioural responses on grassland and environmental attributes and herder incomes, and a comprehensive description of the model appears in Behrendt *et al.* (2020*a*) and Behrendt *et al.* (2020*b*) and is reported in other applications such as Liu *et al.* (2020). The transaction cost analysis is described in Addison *et al.* (2020, see section 2.1.5).

The four main disciplinary pillars in the approach appear as the corner boxes in Fig. 1 and include: economic research (A); social research (B); biophysical research (C); and bioeconomic modelling (D). Within the pillars, multiple methods were drawn upon. For instance, the economic analysis included: choice modelling analysis of herder preferences; contingent behaviour analysis of herder response to alternative policies; choice modelling analysis of resident valuations of grassland attributes; transaction cost analysis of implementing alternative policies; and economic analysis of markets.

The first part of the approach, indicated by the long dash arrows in Fig. 1, was to identify an alternative set of grassland policies drawing on the perspectives of herders, residents and officials. A key method in assessing these policies was the development and calibration of a bioeconomic model indicated by the dotted arrows. The impact of the alternative policies on herder behaviour, and particularly livestock numbers, was determined through contingent behaviour analysis, as shown by the short dash arrows and which then fed into the bioeconomic model.

Analysis of the alternative policies is highlighted by the solid arrows in Fig. 1. Specifically, the bioeconomic model estimated changes in grassland attributes associated with the reduced livestock numbers which, when combined with residents' valuation of changes in grassland attributes, was used to estimate the environmental benefits of the policy-induced reduction in livestock numbers. This was compared with any change in transaction costs associated with the alternative policies, along with herder opportunity costs of the new grazing practices and herd structures to estimate net social benefits. Other ancillary analyses fed into the policy assessment, including the social research, but not all are shown in the simplified representation in Fig. 1.

A key aspect of the approach is that it is interdisciplinary rather than multidisciplinary. That is, the disciplinary analyses were not done in isolation, but were highly inter-connected. For instance, focus groups conducted as part of the social research assisted in the development of attribute sets and levels for herder choice modelling. Contingent behaviour analysis of preferred alternative policies used to determine change in livestock numbers fed into the bioeconomic model, which in turn estimated the change in grassland attributes (such as vegetative cover) and environmental attributes (such as dust emissions) associated with reduced livestock numbers. Biophysical research and market analysis fed information to calibrate the bioeconomic model for representative herder households. Resident valuations of changes in grassland and environmental attributes determined in the resident choice modelling were combined with the marginal change in grassland and environmental attributes determined by the bioeconomic modelling to estimate resident valuations of environmental benefits of the alternative policy settings. The aggregated environmental benefits were added to the societal costs of implementing the alternative policies to estimate net social benefits. Thus, assessment of the policies was based on an interconnected set of analyses from all pillars of the research. The interdisciplinary approach poses several challenges including the need for researchers with a cross-disciplinary perspective, as well as time co-ordination across the different analyses that often operate on different time frames but are time dependent on each other.[8]

Another feature of the approach is its ex-ante nature which distinguishes it from many other studies of grassland policies which focus on ex-post impact analysis. The essence of the choice modelling and contingent behaviour analyses was to understand the behavioural response of herders and other grassland actors to potential alternative incentives and policies. The bioeconomic modelling simulated the economic, biophysical and environmental impacts of any change in behavioural responses. The herder social surveys sought to understand drivers behind the behavioural responses.

Study Scope

The geographic focal area of the study was grasslands of central Inner Mongolia Autonomous Region. Specifically, the study covers typical, desert and sandy steppe areas (see footnote 2 for a definition of these steppes) in six leagues, 32 banners and 89 sumus in this region. The grasslands in the study area include 26.6 million hectares of typical steppe, 10.7 million hectares of desert steppe and 2.1 million ha of sandy steppe. Although there are many different grassland types and grazing systems throughout China, the study area includes some of China's most important grasslands which account for one-tenth of China's total grassland areas and which support the livelihoods of over 117 thousand herder households.

Management of these grasslands not only affects grass and livestock productivity of importance to herder incomes, but also a range of environmental attributes including dust storms, water erosion and water quality and greenhouse gas emissions. The study identifies environmental impacts of alternative policy settings, but focuses on urban households in the major cities located in the central grasslands region including Hohhot, Baotou, Xilinhot and Chifeng.

As mentioned above, the individual methods and data for these methods are described elsewhere. However, to provide an idea of the scope of the methods, the survey of herder households for the choice modelling and contingent behaviour analysis included 362 household herders across Xilingol, Ulunqab and Ordos Leagues. The choice modelling survey of urban resident valuations of grassland and environmental attributes involved completed questionnaires from 427 urban households in Hohhot. Transaction costs were estimated following detailed structured interviews with grassland monitoring officials in three leagues, six banners and six sumus.

Current and alternative policy settings

The approach outlined in Fig. 1 identified eight policy options worthy of consideration in terms of their preference to herders (identified in the herder choice modelling analysis), effectiveness in reducing stocking rates (identified in the contingent behaviour analysis) and improving environmental attributes of value to residents (identified in the resident choice modelling analysis), and feasibility in implementation including political feasibility (identified in the transaction cost analysis and associated interviews with officials). Table 1 outlines the current policy settings and details the eight alternative policy settings, including their difference with current policy settings and the rationale behind them. The eight alternative policies are the basis of the policy assessment reported in Table 2.

Policy Options 1–5 in Table 1 are single policy instruments identified as having a statistically significant stocking rate response in the contingent behaviour analysis (Li and Bennett 2019). The contingent behaviour analysis revealed modest impacts on livestock numbers of changing these instruments. Thus, the levels were set at the maximum used in the choice modelling sets to assess livestock number reductions more in line with policy objectives, but that avoided extrapolating beyond rates in the choice modelling analysis. The maximum levels of the policy attributes in the choice modelling sets were based on focus groups with herders and interviews with officials, and so represent plausible limits on these policy variables. Nevertheless, none of the options alone were sufficient to reduce stocking rates to the target levels specified in GESAS, and so three bundled instruments (Options 6–8) were included. Option 6 is the bundle most preferred by herders (Li *et al.* 2020), whereas Option 7 results in the greatest reduction in livestock numbers. Because Option 6 did not achieve the stocking rate reduction required, and Option 7 would be unpopular (and so unlikely to be complied with), another bundle (Option 8) was included, which met the stocking rate reduction required under GESAS, and would be more acceptable to herders.

Results and discussion

Assessment of each of the policy options described in Table 1 are outlined in Table 2. The values for each of the policy options are changes relative to the current policy settings listed in the 'Base value' column. In line with the conceptual framework presented above, the impacts in Table 2 are sorted by environmental impacts, economic (net social benefit) impacts, and other impacts (including direct payments, variability of income and pasture characteristics). Each of the impacts is of interest in its own right, and each will have different importance to various stakeholders. Nonetheless, as highlighted above, the overall policy assessment should consider all impacts together.

Environmental impacts

Stocking rate reductions associated with each of the policy options (Row 1a in Table 2) were estimated as part of the

[8]For instance, the biophysical research underpinning data in the bioeconomic model occurred over several periods, whereas development of the model itself was an iterative process. Model outputs were needed before estimation of the environmental benefits, but the choice modelling analysis of resident valuations of changes in grassland attributes needed to be completed before the environmental benefits could be estimated.

Table 1. Current and alternative policy settings

Current policy setting	Pension for eligible herders (over 60 years of age) of CNY300/month; Subsidised loan term length of 1 year; Enforcement rate of GESAS stocking rates of 10%; Fine for exceeding GESAS stocking rate of CNY100/excess SE (sheep equivalent); GESAS payment of CNY2.5/mu (15 mu equals 1 ha)		
Alternative policy settings	Setting	Difference from current settings	Rationale
Single policy instruments			
1 Higher herder pension	CNY1200/month	+ CNY900/month	Reduce pressure on older herders to increase livestock numbers to raise income for retirement
2 Longer loan length	5 years	+ 4 years	Allow herders to manage flock/herd over longer time frame and avoid management distortions from liquidity issues
3 Stricter enforcement	70%	+ 60%	Incentivise compliance through greater likelihood of being caught exceeding GESAS stocking rates
4 Larger fine	CNY600/excess SE	+ CNY500/excess SE	Incentivise compliance through increased fines of exceeding GESAS stocking rates
5 Higher incentive payment	CNY10/mu	+ CNY7.5/mu	Reduce income pressures to overstock through higher GESAS reward balance payment
		Bundled instruments	
6 Herder preferred bundle	Pension CNY1200/month, loan 5 years, enforcement 10%, fine CNY100/excess SE, GESAS payment CNY 10/mu)	Pension + CNY900/month, loan + 4 years, GESAS payment + CNY7.5 mu	Policy levels set to most preferred level by herders in choice modelling analysis (see Li *et al.* (2020) and involving higher payments with no extra enforcement or fines)
7 Largest stocking rate reduction bundle	Pension CNY1200/month, loan 5 years, enforcement 70%, fine CNY 600/excess SE, GESAS payment CNY10/mu)	Pension + CNY900/month, loan + 4 years, enforcement +60%, fine +CNY500/excess SE, GESAS payment + CNY7.5 mu	Policy mix identified in choice modelling analysis as achieving greatest stocking rate reduction (higher payments, enforcement and fines)
8 GESAS desired reduction bundle	Pension CNY1200/mu, loan 3 years, enforcement 50%, fine CNY600/excess SE, GESAS payment CNY7.5/mu	Pension + CNY900/month, loan + 2 years, enforcement +40%, fine +CNY500/excess SE, GESAS payment + CNY5 mu	Achieves GESAS stocking rates but more preferred by herders than Option 7 and at lower government payments than Option 6

contingent behaviour analysis (Li and Bennett 2019), with herders indirectly indicating their likely reduction in livestock numbers to different policy settings. The environmental impacts associated with these stocking rate reductions in terms of reductions in dust storms, wind erosion, fractional ground cover and greenhouse gas emissions, are indicated in Rows 1b–1e as estimated by the stochastic dynamic bioeconomic model reported in Behrendt *et al.* (2020*a*).

The results highlight modest impacts in terms of the number of dust storms and wind erosion. The single instrument options had less than 0.03 reduction in dust storms per annum, and a reduction in soil erosion from wind of less than 0.03 t/km^2. annum. Even the bundled options achieved less than 0.09 reduction in dust storms per annum. This is unsurprising given the nature of these steppe grasslands and the weather variability, where abiotic drivers may be more important in dust storm occurrence than either biotic drivers or grazing practices, especially where livestock reductions are relatively modest.[9] Similarly, the policy options only modestly affect fractional ground cover, with single policy instruments increasing fractional ground cover by between 0.3 and 1.4%, and the bundled instruments by 1.5–3.7%.

Although the focus groups and the resident choice modelling study identified environmental impacts of importance to local residents, other environmental impacts such as a reduction in greenhouse gas emissions associated with better managed grasslands would also be relevant to policy makers. These are reported in Row 1e in Table 2. Reductions in greenhouse gas emissions ranged from 0.63 (Option 2) to 9.74 (Option 7) GWP_{100} million tons CO_2e/annum for the typical, desert and sandy steppe in the study region.

Economic/net social benefit impacts

Estimates of the value of environmental impacts of local urban residents are reported in Row 2a in Table 2. As outlined in *Methods* section, the valuation was done through a choice modelling analysis of urban households in Hohhot to determine their willingness to pay for changes in grassland attributes, and applying these to the changes in grassland environmental attributes reported in Rows 1b and 1c. Based on the analysis of Zhang *et al.* (2019), the value to an urban household of one less dust storm was estimated as CNY44/annum, whereas a 1% increase in fractional ground cover was estimated at CNY22/annum. The single policy instruments led to environmental

[9]Although the number of dust storms may not be greatly affected by the livestock numbers, the severity of these storms may be reduced. The reduction in wind erosion (item 1d in Table 2) can be used as an indicator of this severity, but also suggests only a modest reduction in severity.

Table 2. Assessment of alternative policy options[A]

Policy options	Base value[B]	1. Higher pension	2. Longer loan length	3. Higher Enforcement	4. Higher punishment	5. Higher GESAS payment	6. Herder preferred bundle	7. Largest stocking rate reduction bundle	8. GESAS desired reduction bundle
1. Environmental impacts[C]									
1a Reduction in stocking rates (SE/ha)[C]		0.091	0.024	0.149	0.082	0.041	0.156	0.387	0.311
1b Reduction in dust storms (number/annum)	55	0.02	0.01	0.03	0.02	0.01	0.04	0.09	0.07
1c Increase in fractional ground cover (%)	30	0.89	0.27	1.43	0.81	0.37	1.53	3.67	2.96
1d Reduction in wind erosion (t/km^2/annum)	188	0.02	0.01	0.03	0.02	0.01	0.03	0.08	0.06
1e Reduction in GHG emissions(GWP100 million tons CO2e/annum)	49	2.27	0.63	3.71	2.05	1.05	3.88	9.74	7.83
2. Economic (Net Social Benefit) impacts									
2a Environmental benefits (CNY million)[D]		11.3	3.5	18.3	10.4	4.8	19.7	47.3	38.1
2b Change in herder NPV (CNY million)[E]		555.4	159.3	828.2	507.3	269.3	856.9	1289.8	1257.8
• Desert Steppe (CNY/ha/annum)		−18.9	−4.7	−32.0	−16.9	−8.3	−33.6	−94.5	−73.0
• Typical steppe (CNY/ha/annum)		28.1	7.8	43.5	25.5	13.2	45.2	86.5	76.3
• Sandy steppe (CNY/ha/annum)		5.6	1.7	7.6	5.2	2.9	7.8	3.0	6.7
2c Change in transaction costs (CNY million)[F]		0	0	408.4	0	0	0	408.4	372.4
2d Net social benefits (CNY million) [= *2a-2b-2c*]		566.7	162.8	438.1	517.7	274.1	876.6	928.8	923.5
• Desert Steppe (CNY million)[G]		−199.3	−49.5	−362.3	−178.5	−87.1	−355.2	−1024.9	−794.7
• Typical steppe (CNY million)		753.4	208.4	867.7	684.6	354.8	1214.1	2029.2	1778.8
• Sandy steppe (CNY million)		12.6	3.9	−67.3	11.6	6.4	17.7	−75.5	−60.6
3. Other impacts/indicators									
3a Change in direct payments (CNY million)		113.8	0.00	0.00	0.00	3160.8	3274.6	3274.6	2221.0
3b Change in standard deviation of herder income (CNY/household)[H]	24300	−10921	−4194	−13856	−10302	−6505	−14128	−19808	−18318
3c Pasture impacts[I]									
Increase in July biomass (kg DM/ha)	508	23.97	9.26	36.68	21.97	13.21	38.40	89.29	72.47
Increase in proportion desirable species (%)	15	6.59	1.89	10.28	5.64	3.29	10.95	24.64	20.62
Increase in grassland height (cm)	9	0.27	0.10	0.44	0.27	0.10	0.45	1.19	0.98

[A]Analysis based on typical, desert and sandy steppe in 6 leagues, 32 banners and 89 sumus. Impacts determined in the bioeconomic model for typical, desert and sandy steppes and then weighted based on the number of households or area in each steppe depending on the indicator. Environmental benefits based on urban household valuations in Hohhot, Baotou, Ordos, Xilinhot and Chifeng cities. The time frame for impacts is 10 years but values are amortised (annualised) values. Policy options are as defined in Table 1.

[B]The 'Base value' column refers to values of the indicators under current policy settings with values in other columns indicating change in value from the current to alternative policy setting.

[C]Reduction in stocking rates based on results of contingent behaviour analysis (Li and Bennett 2019). Other environmental indicators estimated using stochastic dynamic bioeconomic model (Behrendt *et al.* 2020*a*) and based on the stocking rate reductions.

[D]Environmental benefits of urban households in Hohhot, Baotou, Xilinhot and Chifeng drawing on environmental impacts in (1) and on resident valuations from choice modelling survey (Zhang *et al.* 2019).

[E]Change in herder net present value expressed as an annuity. Does not include change in transfer payments (PES payments, pensions, fines) which are shown in (3a).

[F]Transaction costs based on interviews with officials in 3 leagues, 6 banners and 6 sumus covering typical, desert and sandy steppe as reported in Addison *et al.* (2020, section 2.1.5). Values averaged across interviewed banners and sumus by grassland type and then scaled up by number of leagues, banners and sumus for each grassland type.

[G]Net social benefits are determined and listed for each steppe type based on: an apportioning of the environmental benefits in (2a) based on steppe area; the change in herder NPV (2b) for each steppe type; and estimation of transaction costs (2c) for each steppe type based on the number of administrative units at each level.

[H]Stochastic environment means variable herder incomes under all policy settings. Thus, the indicator reveals the extent to which the policy option mitigates or exacerbates the variation.

[I]Increase in proportion of desirable species, biomass and grassland height during July (summer) from the lower stocking rates as determined by the bioeconomic model (Behrendt *et al.* 2020*a*) and based on the stocking rate reductions.

benefits between CNY3.5 and 18.3 million. The policy bundle most preferred by herders (Option 6) generates environmental benefits of CNY19.7 million, but the other policy bundles led to environmental benefits 2–2.5 times this amount.

The environmental benefits were then weighed up against the costs of the policies. The two main costs considered (Rows 2b and 2c in Table 1) as outlined in Conceptual Framework section are: opportunity costs for herders in terms of their loss in producer surplus or income from the reduction in stocking rates; and the transaction (administrative and system) costs of implementing the policy. The opportunity costs were estimated using the stochastic dynamic bioeconomic model and represent a median value across different types of years of the loss in herder surplus.[10] Although herders realise less income from fewer livestock, there is an offsetting effect on pasture and livestock productivity. Indeed, as indicated in the Conceptual Framework section above, if stocking rates and grazing pressure are very high, a reduction in livestock numbers may increase livestock production and herder incomes per hectare. Table 2 disaggregates the herder income effects by steppe type to show this effect. For the typical steppe where stocking rates remain well in excess of GESAS rates, a reduction in livestock numbers leads to a significant rise in herder incomes (CNY86.5/ha.year for Option 7), as the productivity impacts outweigh the effect on incomes of lower livestock numbers. Conversely, for the desert steppe, where stocking rates are still in excess of but much closer to GESAS rates compared with the typical steppe, the reduction in livestock numbers leads to an even greater reduction in herder incomes (–CNY94.5/ha.year for Option 7).[11] Because of the much larger area and number of herders of the typical steppe, the aggregate change in herder income is positive and large (ranging from CNY159 million for Option 2 to CNY1.29 billion for Option 7).

The other cost is transaction costs (Row 2c in Table 2). Some policy options (Options 1, 2, 4, 5 and 6) have no changes in these costs as the systems are already in place under the current policy, with policy changes simply involving changes in instrument levels. The main increase is for policy options with an increased level of enforcement. Specifically, Options 3 and 7, in which enforcement levels rise from 10 to 70%, increase transaction costs by CNY408 million per annum, whereas Option 8 (enforcement rises from 10 to 50%) increases transaction costs by CNY372 million. These costs are much lower than the change in herder net present value (NPV) for Options 3, 7 and 8, but still exceed the environmental benefits.

Subtracting the costs from the benefits leads to the net social benefits reported in Row 2d in Table 2. The net social benefits are positive and substantial, ranging from CNY163 million for Option 2 (loan length) to CNY929 million for Option 7 (largest stocking rate reduction bundle). However, this is not because of the environmental benefits, but because of the rise in herder NPV for the typical steppe herders associated with the pasture and livestock productivity impacts of the lower stocking rates. For the desert steppe herders, where the lower livestock numbers reduced herder NPV, the net social benefits for the policy options are negative and large, ranging from –CNY50 million to –CNY1025 million. Irrespective of whether the policies lead to positive (typical steppe) or negative (desert steppe) net social benefits, it is the change in herder NPV rather than the environmental benefits that are primarily driving the net social benefits reported in Table 2.

Other impacts

Apart from the main environmental and economic impacts in parts 1 and 2 of Table 2, other indicators will be of interest to policy makers and advisors. Change in direct payments of the alternative policies (Row 3a) will be of interest to policy makers as they weigh up the transfers needed to bring about their desired policy outcomes. Increasing pensions from CNY300/month to CNY1200/month requires the government to find another CNY114 million for retiring herders in the study area. However, it is policy options involving higher GESAS payments (Options 5–8) that will be of most interest, as they increase direct payments by between CNY2.2 and 3.3 billion in the study area alone, and so represent a substantial increase on overall current China grassland support payments. The increase in direct payments is large relative to the environmental benefits estimated in Row 2a and to the transaction costs reported in Row 2c.

Policy makers will be concerned about how the different policy alternatives will affect the variation in herder incomes, and the stochastic dynamic model is well placed to provide this information. Row 3b in Table 2 reveals that alternative policies do lead to a substantial reduction in the standard deviation of herder incomes, ranging from CNY517 to CNY7489/household. In the typical steppe, the standard deviation decreases and herder NPVs increase with the alternative policy options, and so the coefficient of variation decreases markedly from 105% in the base (existing policy) case to 37% for Option 7. In the desert steppe, whereas the standard deviation falls, herder NPVs fall further, increasing the coefficient of variation. However at least for Options 1–6, the increase in coefficient of variation is modest at around 1%.

The impact of the alternative policies on key pasture indicators is shown in Rows 3c. The results demonstrate that the alternative policies do lead to a significant rise in July herbage mass and the proportion of desirable species, especially in overgrazed areas of the typical steppe (disaggregated results not reported in Table 2).

Sensitivity analysis

The net social benefits presented in Table 2 and discussed in the previous section should be interpreted with caution as various assumptions underlie the estimates. For instance, respondents in the choice modelling survey reported in Zhang *et al.* (2019), and used to estimate the marginal environmental valuations of

[10]Specifically, the loss is estimated as the annualised value of the change in herder net present value (NPV) after a 10-year period. The stochastic simulation model calculates this for different combinations of types of years (states of nature), with the value being the 50th percentile of the cumulative distribution function of herder annualised NPVs. The value does not include any change in subsidy payments or fines as these are transfer payments.

[11]Although the declines in herder NPV in the desert steppe for some of the higher enforcement policy bundles and lower stocking rate options such as Option 7 are large, they are more than offset by the higher PES payments associated with these options (such as CNY112.5/ha.year for Option 7).

urban households, were more educated, had higher income and were younger than the population of Hohhot as a whole, and so the environmental benefits may be overstated. Conversely, only the large urban centres in and around central grassland areas in Inner Mongolia were used to scale the environmental benefits, whereas dust storms may affect urban residents in other areas and so the benefits may be understated. Similarly, the aesthetic appeal of the grasslands may extend beyond the residents of the large urban centres in Inner Mongolia to tourists from other parts of China and the rest of the world. If urban households from the other major northern municipalities of Beijing, Tianjin, Datong Zhangjiakou are included, and if all urban households have the same valuation as those in the survey, then the environmental benefits increase markedly from CNY3.5 to 47.3 million across the eight policy options to between CNY96 and 1293 million. Under these assumptions, the environmental benefits are of similar magnitude to the increase in herder NPV and so consolidate the net social benefits of the alternative policies. Furthermore only the reduction in physical greenhouse gas emissions, and not their value, appear in Row 1e given difficulties in attributing a value in China to these emission.[12] Assuming a value of CNY50/ton CO_2e emitted entails benefits ranging from CNY60 million for Option 2 to CNY 550 million for Option 7 and so would also markedly increase the environmental benefits and net social benefits.

However, it is not only the benefits but also the costs that may be understated. Direct payments and subsidies of the policy options are not considered as costs but as transfer payments. As mentioned in the Conceptual Framework section, the public finance literature (Dahlby 2008) indicates there may be distortionary or real costs to society in raising the fiscal revenues to fund these policy programs. The difficulty in estimating these distortionary costs in China, if they exist for grassland payments, means they have not been included in the analysis, but may also mean that costs in Table 2 are a lower bound.

Although the impact of the policy options on herder incomes is highlighted in Row 2b, it varies from year to year depending on weather and market conditions. Row 3b highlights the marked standard deviation of herder household incomes under the existing policy (CNY24300) as well as the extent that the alternative policies reduce the standard deviation. The opportunity cost to herders of complying with the GESAS reward balance stocking rates relative to the size of the GESAS payment will also vary from year-to-year (Behrendt *et al.* 2019).

The higher enforcement options involve substantial transaction costs amounting to between 48% (Option 3) and 29% (Option 7) of total benefits. Implementation and more efficient use of remote sensing and drone technologies offer scope to reduce but not eliminate these costs, as even now, under their partial use, they still account for over half of the additional transaction costs associated with the higher enforcement options.

Policy implications and concluding remarks

Specific policy settings arrived at in the next round of grassland policies will be the outcome of a range of political, social, economic and environmental considerations, not all of which are captured here. Nonetheless, the insights gained from the ex-ante impact analysis of the eight potential policy options may provide some guidance for future grassland policy direction.

The analysis revealed that single policy options alone would be insufficient to reduce stocking rates to the target levels set in current GESAS programs, and so a bundle of measures is needed. Furthermore, the policy instruments most favoured by herders would be insufficient to reduce stocking rates to the target GESAS levels. Thus, a mix of both positive (carrot) and negative (stick) incentives are needed. The positive incentives include higher pensions and PES payments, whereas the negative incentives include higher levels of enforcement and higher punishment for exceeding set stocking rates.

The choice modelling, contingent behaviour and transaction cost analysis, along with the bioeconomic modelling revealed that: (a) only policy options with high levels of enforcement reduced stocking rates to the desired levels; and (b) costs of enforcement are by far the largest transaction cost and can exceed the environmental benefits of the policy change. Thus, measures aimed at reducing the cost of effective enforcement are crucial and underpin the workability of any grassland program.

The alternative policies produced relatively small improvements in environmental conditions. The small improvements arose from the modest reduction in livestock numbers as well as the importance of abiotic drivers relative to grazing mediated factors in these weather variable steppe areas. As China approaches almost two decades of grassland restrictions and programs, stocking rates have come down (Kemp 2020, chapter 2), although not to the program target levels considered sustainable, particularly in areas such as the typical steppe. Any herder-induced overgrazing impact on environmental attributes may have been larger at the high stocking rates in the 1990s (see chapter 2 in Brown *et al.* 2008). However, changes in environmental attributes could now be dominated more by weather conditions than by management practices under current stocking rates. As stocking rates decline to sustainable levels in terms of grassland condition, the environmental impact of policies affecting grazing practices will also decline. Nonetheless, whereas the marginal returns in terms of environmental and grassland improvements may be modest and declining, policy makers may still view the incremental gains of critical importance and worth pursuing, even at high cost.

Stocking rates relative to the GESAS specified rates vary across the different steppes, being much higher in the typical steppe than in the desert steppe. The analysis revealed that the level of excess stock numbers is critical in the net social benefits of policies aiming to reduce livestock numbers, and in the impact on herder incomes. For the highly overgrazed typical steppe, reduced stocking rates had a major positive impact on

[12]GAO (2020) reported that official social damage costs in the US of carbon emissions of USD7 per ton although these were revised down from a previous USD50 per ton and reflected domestic US damage costs and not global damage costs. The costs to achieve emissions targets in countries such as the United Kingdom and Germany are also listed in the report. However, it is difficult to relate these costs directly to social damage costs of greenhouse gas emissions in China or to the cost of meeting emissions targets in China.

pasture and livestock productivity, and on herder incomes as well as net social benefits. Conversely for the less, but still overgrazed (relative to the GESAS specified stocking rates) desert steppe, the improvement in pasture and livestock productivity was insufficient to offset the opportunity cost of fewer livestock, and herder NPVs and net social benefits declined. Thus, the analysis reveals the importance of a targeted policy approach to the different steppe areas. For areas such as the desert steppe, it also highlights the need for research programs to focus on identifying additional livestock and grassland management practices that improve the economic viability of herders under lower stocking rates as highlighted in Kemp (2020, see chapter 3).

The alternative policy options markedly reduce the standard deviation in herder incomes, even if median incomes rise (typical steppe) or fall (desert steppe). The lack of risk management and risk tolerance options for herders means that the reduction in variation in incomes will be viewed favourably by officials and policy advisors which may promote pursuit of these options.

Grassland policies and the state of the grasslands in China have come a long way since 2000. Nevertheless, it is evident that grassland policies require a process of ongoing review and improvement to ensure efficient and effective policies in meeting environmental and livelihood goals. The interdisciplinary, ex-ante analysis reported in this paper provides information for this ongoing process of improvement and for the next round of policy development.

Conflicts of interest

The authors declare no conflicts of interest.

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References

Addison, J., Brown, C. G., Lkhagvadorj, E., Zhang, J., Waldron, S., Zhang, B., and Bukhbat, D. (2020). Institutions and macrodevelopments. *In*: 'Common Grasslands in Asia: A Comparative Analysis of Chinese and Mongolian Grasslands'. (Ed. C. G. Brown.) pp. 12 –47. (Edward Elgar Publishing: Cheltenham, UK.)

Behrendt, K., Brown, C., Qiao, G., and Zhang, B. (2019). Eco-compensation payments under uncertainty: the case of the Grassland Reward Balance Scheme in China. *In*: '63rd Annual Conference of the Australian Agricultural and Resource Economics Society.' February 2019. (Melbourne: Vic.)

Behrendt, K., Liu, H., Kemp, D. R., and Takahashi, T. (2020*a*). Sustainability modelling of grassland systems. *In*: 'Sustainable Chinese Grasslands. ACIAR Monograph 210'. (Ed. D. R. Kemp.) pp. 97–124. (Australian Centre for International Agricultural Research: Canberra, ACT.)

Behrendt, K., Liu, H., Takahashi, T., and Kemp, D. (2020*b*). StageTHREE Sustainable Grassland Model (v. 1.07) – Model description and users guide. Revised February 2020, pp. 69.

Bennett, J., Wang, X., and Zhang, L. (2008). 'Environmental Protection in China: Land-use Management.' (Edward Elgar Publishing: Cheltenham, UK.)

Brown, C. G., Waldron, S. A., and Longworth, J. W. (2008). 'Sustainable Development in Western China: Managing People, Livestock and Grasslands in Pastoral Areas.' (Edward Elgar Publishing: Cheltenham, UK.)

Common, M., and Stagl, S. (2005). Environmental policy instruments. *In*: 'Ecological Economics: An Introduction'. (Eds M. Common and S. Stagl.) pp. 402–441. (Cambridge University Press: Cambridge, UK.)

Conte, T. J. (2015). The effects of China's grassland contract policy on Mongolian herders' attitudes towards grassland management in north-eastern Inner Mongolia. *Journal of Political Ecology* **22**, 79–97. doi:10.2458/v22i1.21079

Dahlby, B. (2008). 'The Marginal Cost of Public Funds: Theory and Applications.' (MIT Press: Cambridge, MA, USA.)

Deng, H., Zheng, P., Liu, T., and Liu, X. (2011). Forest ecosystem services and eco-compensation mechanisms in China. *Environmental Management* **48**, 1079–1085. doi:10.1007/s00267-011-9742-0

Ding, Y. (2017). Personal life satisfaction of China's rural elderly: effect of the New Rural Pension Programme. *Journal of International Development* **29**, 52–66. doi:10.1002/jid.3264

Fan, S., Xu, Y., Duan, S., Lan, J., and Xu, J. (2012). Measurement of transaction cost of rest-grazing policy. *Chinese Journal of Eco-Agriculture* **20**, 1248–1253. doi:10.3724/SP.J.1011.2012.01248

Gao, L., Kinnucan, H. W., Zhang, Y., and Qiao, G. (2016). The effects of a subsidy for grassland protection on livestock numbers, grazing intensity, and herders' income in Inner Mongolia. *Land Use Policy* **54**, 302–312. doi:10.1016/j.landusepol.2016.02.016

GAO (United States Government Accountability Office) (2020). Social Costs of Carbon. GAO Report GAO-20-254. Washington, USA.

Hu, Z. T., Kong, D. S., Wei, J., and Jin, L. S. (2015). Grassland eco-compensation: equivalent relationship between livestock reduction and compensation. *Ziran Ziyuan Xuebao* **30**, 1846–1859.

Huang, L., Shao, Q., Liu, J., and Lu, Q. (2018). Improving ecological conservation and restoration through payment for ecosystem services in Northeastern Tibetan Plateau, China. *Ecosystem Services* **31**, 181–193. doi:10.1016/j.ecoser.2018.04.005

Jones, R. J., and Sandland, R. L. (1974). The relation between animal gain and stocking rate: derivation of the relation from the results of grazing trials. *Journal of Agricultural Science* **83**, 335–342. doi:10.1017/S0021859600052035

Kang, L., Han, X., Zhang, Z., and Sun, O. J. (2007). Grassland ecosystems in China: review of current knowledge and research advancements. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* **362**, 997–1008. doi:10.1098/rstb.2007.2029

Kemp, D. R. (Ed.) (2020). 'Sustainable Chinese Grasslands. ACIAR Monograph 210.' (Australian Centre for International Agricultural Research: Canberra, ACT.)

Kemp, D., and Michalk, D. (Eds) (2011). Development of sustainable livestock systems on grasslands in north-western China. *In*: 'ACIAR Proceedings 134'. (Australian Centre for International Agricultural Research: Canberra, ACT.)

Kemp, D., Li, P., Addison, J., Behrendt, K., Wang, Z., Han, G., Zhao, M., Gombosuren, U., and Hou, X. (2020). Grassland environmental services. *In*: 'Common Grasslands in Asia: A Comparative Analysis of Chinese and Mongolian Grasslands'. (Ed. C. G. Brown.) pp. 78–95. (Edward Elgar Publishing: Cheltenham, UK.)

Li, P., and Bennett, J. (2019). Understanding herders' stocking rate decisions in response to policy initiatives. *The Science of the Total Environment* **672**, 141–149. doi:10.1016/j.scitotenv.2019.03.407

Li, Z., Han, G., Zhao, M., Wang, J., Wang, Z., Kemp, D. R., Michalk, D. L., Wilkes, A., Behrendt, K., Wang, H., and Langford, C. (2015*a*). Identifying management strategies to improve sustainability and household income for herders on the desert steppe in Inner Mongolia, China. *Agricultural Systems* **132**, 62–72. doi:10.1016/j.agsy.2014.08.011

Li, Y., Fan, M., and Li, W. (2015*b*). Application of payment for ecosystem services in China's rangeland conservation initiatives: a social-ecological system perspective. *The Rangeland Journal* **37**, 285–296. doi:10.1071/RJ14014

Li, P., Bennett, J., and Zhang, B. (2020). Ranking policies to achieve sustainable stocking rates in Inner Mongolia. *Journal of Environmental Economics and Policy* **9**, 421–429. doi:10.1080/21606544.2020.1726210

Liu, H., Behrendt, K., Wu, J., Du, W., and Kemp, D. R. (2020). Modelling the sustainability of Qinghai-Tibetan Plateau grasslands. *In*: 'Sustainable Chinese Grasslands'. (Ed. D. R. Kemp.) pp. 125–152. (Australian Centre for International Agricultural Research: Canberra, ACT.)

Millennium Ecosystem Assessment (2005). 'Ecosystems and Human Well-being: Synthesis.' (Island Press: Washington, DC.)

Ministry of Agriculture and Ministry of Finance (2011). Guiding Opinions on the Implementation of the Grassland Ecological Subsidy and Award Scheme (GESAS) in 2011. Available at: http://www.moa.gov.cn/nybgb/2011/dqq/201805/t20180522_6142764.htm.

Pan, X., Xu, L., Yang, Z., and Yu, B. (2017). Payments for ecosystem services in China: policy, practice, and progress. *Journal of Cleaner Production* **158**, 200–208. doi:10.1016/j.jclepro.2017.04.127

PRC (2002). The Grassland Law of the People's Republic of China. Government of Peoples Republic of China, Beijing.

Rozelle, S., Huang, J., and Zhang, L. (1997). Poverty, population and environmental degradation in China. *Food Policy* **22**, 229–251. doi:10.1016/S0306-9192(97)00011-0

von Wehrden, H., Hanspach, J., Kaczensky, P., Fischer, J., and Wesche, K. (2012). Global assessment of the non-equilibrium concept in rangelands. *Ecological Applications* **22**, 393–399. doi:10.1890/11-0802.1

Wu, Z. (1980). 'Vegetation of China.' pp. 505–582. (Science Press: Beijing, China.) [in Chinese]

Xie, G., Cao, S., Lu, C., Zhang, C., and Yu, X. (2015). Current status and future trends for eco-compensation in China. *Journal of Resources and Ecology* **6**, 355–362. doi:10.5814/j.issn.1674-764x.2015.06.002

Yang, X., Luo, J., and Yan, W. (2018). Heterogeneous effects of rural land property mortgage loan program on income: evidence from the western China. *China Agricultural Economic Review* **10**, 695–711. doi:10.1108/CAER-12-2015-0179

Ye, H., and Zhu, L. (2014). Analysis on Inner Mongolia grassland ecological compensation practices. *Caoye Kexue* **31**, 1587–1596.

Zhang, B., Li, W., and Xie, G. (2010). Ecosystem services research in China: progress and perspective. *Ecological Economics* **69**, 1389–1395. doi:10.1016/j.ecolecon.2010.03.009

Zhang, B., Bennett, J., and Qiao, G. (2019). Estimating non-market environmental values for grassland protection in Inner Mongolia. *Environment and Development Economics* **24**, 361–375. doi:10.1017/S1355770X19000056