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Contents

1 Acknowledgments

The project research team would like to thank their respective institutions as well as ACIAR for facilitating and supporting the research. The research involved detailed surveys and interviews with a wide range of institutions and individuals including herders, officials and traders and the project team gratefully acknowledges the time and many insights provided by these individuals. In addition, the project benefitted from numerous discussions with non-project researchers doing related research and we are also very grateful for their insights.

2 Executive summary

Grassland degradation remains a serious threat to ruminant livestock production in the northern steppes of Mongolia and Inner Mongolia. In China, where serious and widespread levels of grassland degradation had arisen, policy measures were already in place to address the degradation. However, many questions remained as to the effectiveness and efficiency of these measures in meeting the policy objectives around grassland condition and herder livelihoods. In Mongolia, the level of degradation at the start of the project was less serious than in Inner Mongolia. Yet ruminant livestock numbers were rapidly rising and by the end of the project there was serious debate among officials and the herder community as to how the issue could be dealt with.

The aim of the project was to investigate alternative policies that might better meet the grassland condition and herder livelihood objectives. The assessment of alternative policies necessitated an ex-ante analysis to try and better understand likely behavioural responses of the different economic agents to the alternative policies. To do this ex-ante analysis and policy assessment, an interdisciplinary approach was required involving a closely interconnected set of economic, biophysical, social and modelling research.

Ultimately policy makers will use their own criteria to assess policies. However, given that most of the analysis has been ex-post assessment of existing policies and that there is a dearth of ex-ante analyses about the possible impacts of alternative policies, the research provides a wealth of information to policy makers which will enable them to be better informed on likely impacts when making these decisions. While the assessment of alternative policies was the primary output, there was a lot of intermediate analyses and outputs of interest in their own right and that will also have significant impact. There has also been significant capacity building with intensive and multi-day general workshops on choice modelling, social research and bioeconomic modelling to both project and non-project participants.

There are various areas of research that could build on the project research. An analysis of herder adaptation strategies to climate, market and disease related risks would be a useful extension while a more rigorous assessment of the novel tradable livestock quota is also worth serious consideration. There are strong potential market linkages between Mongolia and Inner Mongolia in ruminant livestock product markets (primarily cashmere and meat) and while trade and market research is underway, research that built on the current project could extend that research significantly.

3 Background

The issue

China and Mongolia have vast (over 520 million hectares) inter-connected grasslands that provide the resource base to support the livelihoods of over 5 million low income pastoral households and an array of ecosystem services from improving air and water quality to acting as a carbon sink (Kemp et al. 2020a). However, concern over the condition of these grasslands and livelihoods of herders has increased through time and is now a major issue. In China, this concern has led the government to invest CNY13.6 billion per annum on grassland management programs and grassland incentive payment schemes. The fundamental and topical policy issue in China among policy makers, research scientists and society at large is *whether the existing programs and payments are: (a) efficient in meeting the environmental and livelihood objectives; and (b) can account for the heterogeneity in grassland systems and changes in socio-economic, market and climatic conditions*. In Mongolia, policy makers are concerned about *the resilience of herders and grasslands to adverse climatic events and seeking information on the management systems and impact of alternative policy and institutional settings needed to sustain grasslands and herder livelihoods*. The similarities and contrasts between the two countries provide a larger context to test ideas and principles for managing grasslands and improving herder livelihoods that has wider application throughout east and central Asia.

Research questions and approach

A series of specific research questions were investigated in the study including:

For China:

1. What incentives are needed to encourage herders to pursue grassland and livestock systems consistent with government objectives and their stated desired stocking rates?
2. What are more efficient way(s) to provide these incentives, and how effective are alternative policies or policy settings in achieving these desired stocking rates?
3. What value do urban residents in grassland areas place on grassland amenity?
4. How do the net environmental and other benefits of the practice changes compare with any opportunity costs of the practice changes and transaction costs of implementing the alternative policies?
5. Are the opportunity costs of the practice changes or size of the incentives needed influenced by household characteristics and by biophysical, market and weather conditions?

For Mongolia:

1. What are the primary grassland ecosystem services, including cultural ecosystem services that stakeholders value in Mongolia?
2. What factors do herders consider most important in their livelihoods?
3. What factors impact the behaviour, attitudes and perceptions of herders about grassland condition and grassland use?
4. Would alternative policies or incentives reduce grazing pressure in vulnerable pastures and at vulnerable times?
5. What would be the environmental benefits and opportunity costs of implementing these policies and would they improve social welfare?
6. Do livestock and livestock product subsidies incentivise or distort efficient grassland use and can marketing systems be improved?

Rationale:

The vast inter-connected grasslands of China and Mongolia that support the livelihoods of millions of low income pastoral households and that provide crucial environmental and ecosystem services are at a crossroads. Huge amounts have been invested in China on grassland incentive schemes and while grassland condition arguably has improved, stocking rates remain above the government-program-specified desired stocking rates. Policy makers are seeking ways to refine the policy measures and improve the incentives to achieve these desired stocking rates. In addition, officials are seeking to improve the efficiency of these payments so that they more accurately reflect environmental benefits, opportunity costs, heterogeneity in grassland types, and changes in socio-economic, market and climatic conditions. In Mongolia, as the number of livestock on grasslands grows and the condition of many of the grasslands deteriorates (Densambuu et al. 2018), policy makers are considering a range of new incentives and policies such as a livestock tax to address these problems but are aware that in doing so of the need to be cognizant of the impact on herder livelihoods, and the resilience of herders and grasslands to survive adverse climatic events.

This project was in a unique position to assess the incentives needed to improve grassland use and inform policy design. First, the knowledge base essential to the complex analysis of these incentives was provided by building on and adding value to previous ACIAR research on livestock systems, ruminant livestock product markets and agri-environmental schemes in China as well as established interactions between Australian, Chinese and Mongolian grassland researchers. Second, the project design and project team brought together researchers with a range of environmental economics, bio-physical, socio-ecological and livestock system skills and a strong interest in the trans-disciplinary research.

By working on these high priority issues with policy makers, the project contributes directly to refinements of existing incentives and policies as well as to the design of future incentives. The similarities and contrasts between China and Mongolia provides a larger context to test ideas for managing grasslands and ruminant livestock and improving herder livelihoods that have wide application throughout east and central Asia.

China has over 400m ha of grasslands and up to 90% are estimated to be degraded to some extent (Kemp et al. 2020a). The concerns over degradation include not only on-site impacts on grassland and livestock productivity, but off-site effects including on water and air quality, bio-diversity, desertification, soil erosion and greenhouse gas emissions. The livelihoods of low-income herders that belong to ethnic minorities in outlying areas of China are inextricably connected to grasslands. The livelihoods of the more than 4 million herder households living in pastoral and semi-pastoral counties alone and the management of the grasslands to protect and enhance the more than $150 billion in grassland environmental services they provide, is of very high priority for the Chinese government and regularly feature in Central policy documents and edicts.

In response to these concerns, China has initiated a mix of measures including moral suasion (R&D and increased extension), command and control (grazing restrictions), investments (grassland improvement and livestock breeds), and incentive based measures (support payments) in the 2000s; the aim being to improve environmental outcomes and increase pastoral household incomes. The priority and attention afforded by the Chinese government meant that funding was increased in the 12th Five Year Plan (2011-2015) to CNY13.6 billion per annum under the “Grassland eco-protection subsidy and reward mechanism” that includes two key grassland payment schemes: (a) compensation for grazing restrictions to rehabilitate seriously degraded grassland; and (b) reward payments to encourage herders to comply with stocking rates on less degraded grasslands. The eco-compensation and reward payments reflect China’s desire to shift towards innovative market based incentives in dealing with its pressing environmental issues (Brown et al. 2020c). The 13th Five-Year-Plan essentially rolled over the scheme with slightly higher amounts.

Despite the shift to payment for ecosystem service (PES) type incentive schemes, and broad agreement of their importance, officials at both central and local levels and Chinese grassland and environmental scientists and economists hold some reservations as to the effectiveness and efficiency of the existing measures and are looking at ways to improve the efficiency of these payments. Although there is some flexibility in the payment rates based on grassland types, they are generally uniform and do not fully account for variations in grassland productivity, in the value of the environmental services or in the opportunity costs to households—based on their socio-economic and other characteristics, seasonal conditions and market conditions—of the practice changes associated with these payments. This results in payment schemes that may be inefficient (not targeted to maximise environmental and net social benefits) and ineffective (in terms of household incentives to comply with the desired stocking rates). Apart from the specific grassland programs and incentives, there are a range of other policies, for instance relating to pensions and finance, that also influence the incentives to herders in their livestock and grazing management. The project also investigated these incentives and their interaction with the specific grassland programs.

The Chinese government is actively seeking ways to refine its grassland incentive payments so that they are more targeted to household, biophysical, seasonal and market conditions as part of its mix of policy measures and incentives to improve grassland environmental services and to promote viable and sustainable ruminant livestock systems This project aligns very closely with the Chinese government’s interest in a relevant and contextually sound payment policy for ecosystem services for natural resource management. The interest is such that the Chinese collaborators on the project have been able to secure co-funding for closely associated and complementary research activities and projects from highly competitive national Science Foundation and Ministry of Agriculture funding sources of over CNY17.5million.[1] The project matches the research priority of China in the ACIAR 2013/14 AOP of “integrated crop-livestock systems in favourable areas of TAR and the rangelands of western China” and fits under sustainable economic development within the Australian government’s Comprehensive Aid Policy Framework.

With grasslands and arid grazing areas accounting for more than 80% of the land area in Mongolia and supporting almost 169,710 full time herder households in 2018 (MONSIS 2019), grassland management and herder livelihoods are foremost in priorities and issues in Mongolia. Concerns have been raised by various studies that grassland condition has deteriorated with the transition to the market economy of the early 1990s while recent monitoring of grassland condition in Mongolia suggests that almost half of Mongolian rangelands are in a moderately degraded or worse state (Densambuu et al. 2018). The concern is particularly high in the medium to high precipitation areas where livestock numbers have increased substantially. The Law on Soil Conservation and Desertification

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[1] The co-funded sources in China include: Ministry of Science and Technology of China: Production, Ecology and Livelihood of Temperate Grassland in Inner Mongolia (CNY14.3 million); National Natural Science Foundation of China: Species Dioversity and Productivity of Desert Steppe Under Long-term Stocking Rate (CNY0.54 million); National Natural Science Foundation of China: Heterogeneity and Animal Behaviour Under Stocking Rate in Desert Steppe (CNY0.55 million); National Natural Science Foundation of China; The Relationship Between Aboveground Vegetation and Belowground Root under Stocking Rate in Desert Steppe (CNY0.5 million); National Natural Science Foundation of China; The Impact of Soil Erosion on Vegetation Characteristics Under Stocking Rate in Desert Steppe (CNY0.50 million); National Natural Science Foundation of China:Organism Activity Between Rhizosphere and Non-rhizosphere Under Stocking Rate in Stipa breviflora Desert Steppe (CNY0.81 million); National Natural Science Foundation of China; The Influence of Mixed Grazing of Cattle and Sheep on Stable Isotope of Greenhouse Gases from Ecosystem in Desert Steppe (CNY0.50 million); Inner Mongolia Committee of Science and Technology; Grassland Monitoring and Assessment (0.55 m RMB). Additional support may also be forthcoming from MOST as well as from the Innovation Project for Science and Technology of CAAS while a new NSFC project complementing this project will has proposed funding of CNY2million. Furthermore, IGR’s anticipated funding input to support the research is of the order of CNY0.3 million/annum.

Control, passed in 2012, defines several responsibilities for soil conservation and prevention of desertification including using seasonal rotation in grasslands and matching livestock numbers to carrying capacity, and the establishment of reserve pasture and hay making areas. Under the National Mongolian Livestock Program, animal productivity and herder livelihoods are to be improved by maintaining or restoring good-quality pasture, improving breeding, animal health, and fodder production as well as through improving processing and marketing of livestock and livestock products.

There are several key differences between Mongolia and China. The externalities associated with overgrazing are less established in Mongolia than China from both a technical and social perspective and the relatively high, in *situ*, intrinsic value placed on grasslands considered to be in good condition may exceed the off-site costs associated with poor condition grasslands. In contrast to China, Mongolia currently offers its herders no incentives to improve grassland management although there are legal penalties for overgrazing. There is substantial discussion in Mongolia as to the role of incentives and fees in affecting both livelihoods and grassland condition. The Mongolian government currently provides a number of subsidies to herders, such as the wool subsidy, but it is unclear as to whether the subsidy produces perverse incentives that affect both livelihoods and grassland condition. At the same time, a grazing users' fee has been proposed to address the significant private gain, but social cost, of grassland utilised by herders. Despite substantial interest, there is little empirical data upon which policy makers can design such a fee so that it produces the intended benefit of improving grassland condition whilst being equitable and not further impoverishing the many subsistence herders. Other policy instruments such as a livestock tax have also been canvassed in more recent times. Although Mongolian research institutes have strong skills in their respective disciplines, the complex inter-disciplinary nature of policy making needs sometimes constrain the acquisition of empirical data upon which to base policy decisions. This project aimed to inform the debate and policy making process.

4 Objectives

The overall aim of the project is to improve grassland management practices and pastoral livestock systems in China and Mongolia through research into the incentives driving these systems and the design of incentive based policies.

Objective 1. To design more efficient incentive schemes for improved grassland and livestock management in China

Activities:

1.1 Establish communication and stakeholder engagement for project design, implementation and impact
1.2 Establish context, institutional settings and characteristics of incentive schemes for grassland and livestock management
1.3 Survey households for attitudes towards and social issues associated with grazing restrictions and incentive policies
1.4 Assess grassland condition and relate condition to seasonal conditions and grazing practices
1.5 Evaluate livestock, feed and grazing management options to meet grassland environmental objectives, and describe the practice changes they represent over existing systems
1.6 Evaluate change in environmental services associated with practice changes (marginal benefits)
1.7 Interview farm households to identify opportunity costs of practice changes (marginal costs)
1.8 Relate opportunity costs (in 1.7) to household characteristics, production and market environment, and grassland type
1.9 Design more efficient incentive schemes and payment metrics based on assessment of marginal benefits (1.6) and marginal opportunity costs (1.7)

Objective 2. To design more efficient incentives for improved livelihoods and grassland condition in Mongolia

Activities:

2.1 Establish communication and stakeholder engagement for project design, implementation and impact
2.2 Establish the social and cultural context, institutional settings and characteristics of incentive schemes for grassland management
2.3 Assess grassland condition and relationship with seasonal conditions and grazing practices
2.4 Interview households and industry stakeholders to construct economic and behavioural models of herder households and markets
2.5 Identify environmental and social benefits provided by grasslands and factors impacting on the value of these benefits
2.6 Evaluate efficiency of incentive policies influencing grassland use

Objective 3. To facilitate linkages between China and Mongolia for improving grassland management

Activities:

3.1 Conduct workshops and forums to facilitate exchange of ideas between Chinese, Mongolian and Australian scientists on grassland and livestock management and incentive policies

5 Methodology

5.1 Where was the work done?

The research was done in China (Figure 1) and in Mongolia (Figure 2). In China, the research was in the Inner Mongolia Autonomous Region (IMAR), the largest grassland autonomous region/province in China, and focussed on the typical, desert and sandy steppe grasslands of central Inner Mongolia. These are centred on Xilingol League, Ulunqab City and Ordos City, which are areas of moderate to low rainfall with acknowledged grassland degradation. 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 hectares of sandy steppe which together account for one-tenth of China's total grassland areas and support the livelihoods of over 117 thousand herder households. Choice modelling surveys of urban resident valuations were done with residents in Hohhot, the capital of IMAR, near to the grassland areas used in this study.

In Mongolia, the research focussed on steppe areas in the central aimags around Ulaanbaatar, where grassland degradation is evident. Much of the biophysical research was done in the two case study soums of Altanbulag in Tuv Aimag and in Khashaat in Arkhangai Aimag. The survey of herders for the choice modelling and contingent valuation analyses and the social surveys, were done across the central aimags. Choice modelling surveys of urban resident valuations were done with residents in Ulaanbaatar.

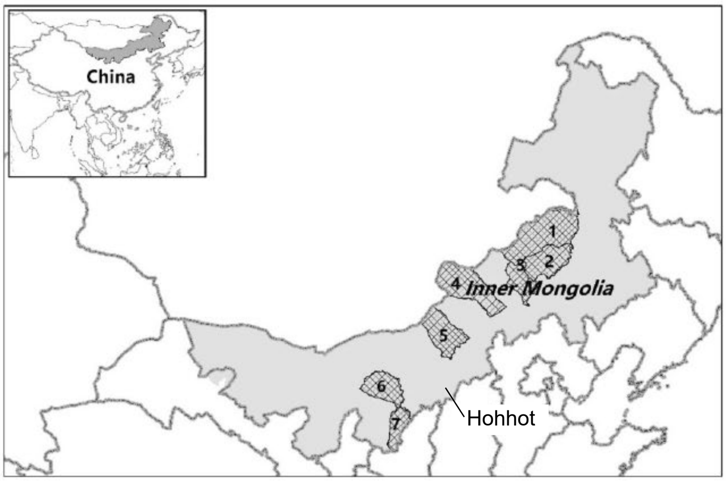

Fig. 1. Surveyed areas. Key: 1. East Wuzhumuqin Banner, 2. West Wuzhumuqin Banner, 3 Xilinhot city, 4. Solid left Banner, 5. Siziwang Banner, 6. Hangjin Banner, 7. Wushen Banner. Areas 1, 2 and 3 represent typical steppe, areas 4 and 5 represent desert steppe and areas 6 and 7 represented sandy steppe. Given that there are usually more than one grassland types in each

Figure 1. Map of study areas in China

Source: Figure 1 in Li and Bennett (2019)

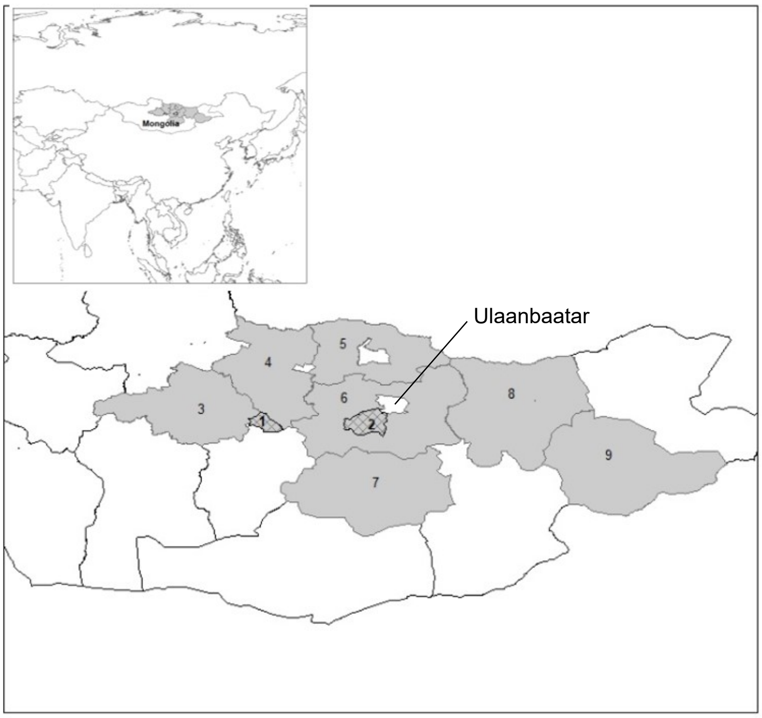

Figure 2. Map of study areas in Mongolia. 1 = Khaasaat *soum*, Arkhangai *aimag.* 2 = Altanbulag *soum*, Tuv *aimag*. 3 = Arkhangai *aimag*. 4 = Bulgan *aimag*. 5 = Selenge *aimag*. 6 = Tuv aimag. 7 = Dundgobi *aimag*. 8 = Khentii *aimag*. 9 = Sukhbaatar *aimag*.

5.2 How was the work done?

5.2.1 Overview

This section is a summarised extract from Brown et al. (2019).

An outline of the approach used in the project is shown in Figure 3. The first part of the approach was to identify an alternative set of grassland policies. This is indicated by the long dash arrows and takes account of the perspectives of herders (arrows 2 and 5), residents (arrow 3) and officials (arrow 2). A key method in assessing these policies was the development and calibration of a bioeconomic model as shown by the dotted arrows (arrows 6 to 10). The impact of the alternative policies on herder behaviour and particularly livestock numbers was determined through a contingent behaviour analysis as shown by the short dash arrows (arrows 11 and 12) which then fed into the bioeconomic model (arrow 13) for further analysis. The analysis of the alternative policies is then shown by the solid arrows. Specifically the bioeconomic model estimated the change in grassland attributes associated with the livestock number reductions (arrow 14) which when combined with residents' valuation of changes in grassland attributes (arrow 15) was used to estimate the environmental benefits of the policy induced reduction in livestock numbers (arrow 16). This was then compared with any additional administrative or transaction costs associated with the alternative policies (arrow 17) to estimate the net social benefits. These results were then combined with other analyses drawn from the socio-ecological research (arrow 18) and more detailed understanding of herder opportunity costs (arrow 19) to assess the alternative policies. Other ancillary analyses fed into the policy assessment and other stages of the analysis but are not shown in the simplified representation in Figure 3.

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 done as part of the social research assisted in the development of attribute sets and levels for the herder choice modelling. Contingent behaviour analysis of preferred alternative policies was used to determine changes in livestock numbers that then 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 the reduced livestock numbers. Biophysical research and market analysis provided 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 from 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 which often operate on different time frames but are time dependent on each other. For instance, the biophysical research providing data to calibrate the bioeconomic model occurred over several years while development of the model itself was an iterative process. Model outputs were needed before estimation of the environmental benefits while the choice modelling analysis of resident valuations of changes in grassland attributes needed to be completed before the environmental benefits could be estimated.

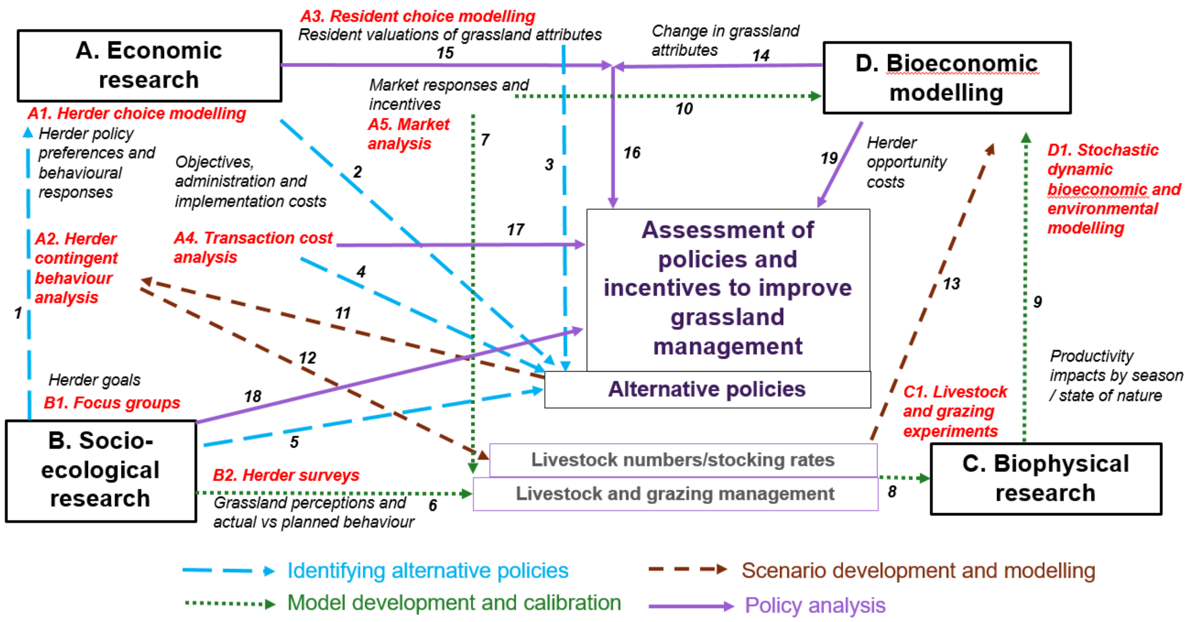

Figure 3. Overview of approach

Source: Brown et al. (2019)

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.

5.2.2 **Details**

Choice modelling and contingent behaviour analysis

This section is a modified extract from Bennett et al. (2020) with further details provided in Li and Bennett (2019) and Zhang B. et al. (2019).

Two stated preference techniques were used in this study: Choice Modelling and Contingent Behaviour. Choice Modelling involves respondents to a questionnaire being asked to make a choice between a number of alternatives that are presented as a 'choice set'. Each alternative is described using a number of attributes that take on different levels in each alternative. In this study, the alternatives presented involved different future grassland management policy settings. These settings involved a number of specific policies (attributes) taking different levels. For instance, a tax on livestock is one potential policy used as an attribute and it can take on differing rates. The current policy 'mix', or 'status quo' option, is always presented to respondents in a choice set to create a reference point for choice. In a Choice Modelling questionnaire, multiple choice sets are presented to respondents. The choice sets are different from each other in that the alternatives (apart from the current policy mix) are all different. The different choice alternatives are created using an experimental design to create a statistically appropriate mix of policy options.

Lhagvaa and Dj interview herders during pilot surveys for choice modelling analysis

Responses to a Choice Modelling questionnaire provide insights into the preferences of herders across different policy options. Response data can be analysed using different types of logit models to show how each of the policy options, along with respondents' socio-economic characteristics, affect the probability that a choice is made. The 'trade-offs' that herders make in selecting their preferred policy mix from within each choice set show their willingness to accept one policy over another. For instance, herders will demonstrate how much extra in pension payments they are willing (on average) to accept in order to be charged an extra yuan per stock equivalent in a livestock tax. This allows an understanding to be developed as to the relative '(un)popularity' of different policy instruments.

In this way, Choice Modelling allows the quantitative estimation of the extent of trade-offs that respondents are willing to make between the attributes that describe the choice alternatives in a choice set. This capacity means that Choice Modelling can also be used to estimate values for non-marketed goods and services. For valuation applications, alternative future resource management options are presented to respondents as choice alternatives.

Those options are described by attributes that are the goods and services for which value estimates are sought. An additional attribute is a cost to be paid by respondents if they opt for a change away from a continuation of the status quo. By including a cost attribute, the trade-offs between the non-marketed attributes and money can be established in the same way as trade-offs between policy attributes are estimated.

In the context of this study, the valuation capacity of Choice Modelling was used to estimate the willingness to pay of urban residents for changes to the environmental and social conditions that would result from changes in grassland management policies. The non-marketed goods and services impacted by policy and so-valued included, among others, the frequency of dust storms experienced and the potential loss of the herder culture as a result of out-migration.

Contingent Behaviour is another survey based stated preference technique that involves people being asked what action they would expect to take under a set of pre-specified conditions. In the context of this study, respondents were asked about their intended stocking rates under different policy mixes. The specific policy circumstances put to respondents were the policy alternatives set out in the Choice Modelling choice sets. Hence a respondent, in each choice set, was asked which policy option they preferred and then asked to state the stocking rate they would expect to use under that policy option. They were also asked for their current stocking rate given the current policy mix. In this way respondents provided data on their expected grassland management strategy across an array of different policy alternatives. This was sufficient to allow the estimation of relationships between stocking rates and the levels taken by each policy instrument using multiple regression techniques.

To apply the Choice Modelling and Contingent Behaviour methods, four separate surveys were conducted: two surveys of herders, one in Inner Mongolia and the other in Mongolia, and two surveys of urban residents, one in Hohhot, the capital of Inner Mongolia, and the other in Ulaanbaatar, the capital of Mongolia. In all surveys, random samples of the relevant populations were sought. Geographic sampling involving the selection, at random, of specific regions or areas was used as a starting point for the herder samples. The complexities of locating herders in relatively remote and hard to access areas required the use of convenience sampling once regions were selected. For the urban samples, snowball sampling using the mobile phone application ‘WeChat’ was used in Hohhot while more conventional grid cell sampling was used in Ulaanbaatar supplemented by some convenience sampling in heavily frequented sites. Some sampling bias was caused by all of these different approaches.

Both herder surveys were conducted using personal interviews. In Inner Mongolia, a total of 339 valid responses were collected while 267 questionnaires from Mongolian herders were completed. The Hohhot residents survey was web-based (427 respondents) and designed to suit mobile phone application. In Ulaanbaatar, 376 residents were interviewed in person.

The data collected from all the surveys were analysed using Stata software. The Choice Modelling data were analysed initially using Conditional Logit but these analyses were extended to take into account the heterogeneity of preferences through the use of Random Parameter Logit models. The Contingent Behaviour data were analysed using multiple regression techniques.

Biophysical and bioeconomic modelling

Details of the model are provided in Behrendt et al. (2020a,b).

The biophysical modelling benefited from the many aspects in common between the grasslands and livestock systems in IMAR and Mongolia as that meant common parameter sets could be developed and used for simulations. Specifically access was available to a larger data set from IMAR that had been developed over several years in a previous ACIAR project (Kemp, 2020). This was updated with current information. In Mongolia, a study was done over two years to monitor, every three months, the grasslands and animals for ten households in the two soums being investigated so as to provide the biophysical data.

The opportunity costs for herders of changed stocking rates or practices associated with the policy alternatives as well as the impact on grassland attributes and environmental services associated with these practice changes was estimated using a stochastic, dynamic bio-economic model of representative herder households known as the 'StageTHREE Sustainable Grasslands Model' (SGM). The framework for the model is shown in Figure 4. The SGM has been developed using Matlab and some specialised additional tools. A runtime version is available that can be used independent of the specialised software and full model specifications and functionality are detailed in Behrendt et al. (2020a) and Behrendt et al. (2020b). The model was calibrated using local farm surveys and measurements of grassland and animal productivity. In Inner Mongolia, grassland data on compositional change and animal growth and loss data, were from the long-term Siziwang Experiment (IMAR) which has been running since 2004 (Wang *et al*. 2020). This site is on the desert steppe. Other data from experiments on the typical steppe and measurements from the sandy steppe were used for relevant simulations. In addition, farm surveys were used to calibrate other parameters. In Mongolia, data from the biophysical research was used to calibrate grassland growth, ground cover and condition, changes in livestock liveweight, and the grazing management practices. Modelling outputs from all sites were validated using published literature and data from other experimental sites within IMAR and Mongolia, as well as expert opinion.

The SGM has been designed for research environments which often have limited access to complex data. It integrates both established and published empirical and mechanistic/process based sub-models, some of which are parsimonious in approach. The SGM operates as a simulation model that is executed for each nominated grazing area (field or paddock level) on a daily time step and contains 13 biophysical sub-models[2] accounting for: grassland dry matter digestibility (DMD) and selective grazing and its impact on grassland composition; herd/flock structure, size and culling policies[3]; supplementary feeding policies; growth, production and daily state variables for each age cohort of females, male progeny and breeding males; growth indices and grassland growth; deep soil water drainage and rainfall run-off; soil erosion from wind and water run-off; and greenhouse gas emissions (based on the Tier 2 IPCC guidelines) and expressed as global warming potential (GWP100).The grassland composition and soil depth/fertility sub-models predict changes at an annual time step. Livestock production and system externalities are aggregated to determine the environmental, economic and financial performance of the system at the enterprise and whole farm/household level.

The model financially (e.g. annual cash flow, equity) and economically (i.e. net present value) accounts for any change in livestock numbers from the status quo, and the farming systems are modelled as typical Mongolian sheep enterprises for the three different steppes (desert, typical and sandy steppe). Using the typical system over a 10 year simulation period for each iteration, a sample of test simulation output data for annual cash flow were normalized through a Box Cox transformation and an iterative process was applied to calculate the minimum required number of Monte Carlo iterations. As the random sequence for both price and climate risk were seeded, each modelled flock size scenario used identical random sets. This allowed for a significant reduction in the number of iterations required and facilitated calculation of opportunity costs under discrete states of nature. The convergence

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[2] The source of the underlying parameters for these sub models is reported in Behrendt et al. (2020b).

[3] Due to the more sporadic nature of livestock mortalities in Mongolia (in part due to dzuds), the livestock sub-models were modified to model mortalities above that of the expected basal mortality rate. These were calibrated using aimag level statistical data on mortalities (National Statistics Office of Mongolia).

in sampling intensity occurred with at least 250 iterations to achieve a 95% confidence interval and an allowable error of no more than ±2.5% of the estimated mean annual cash flow.

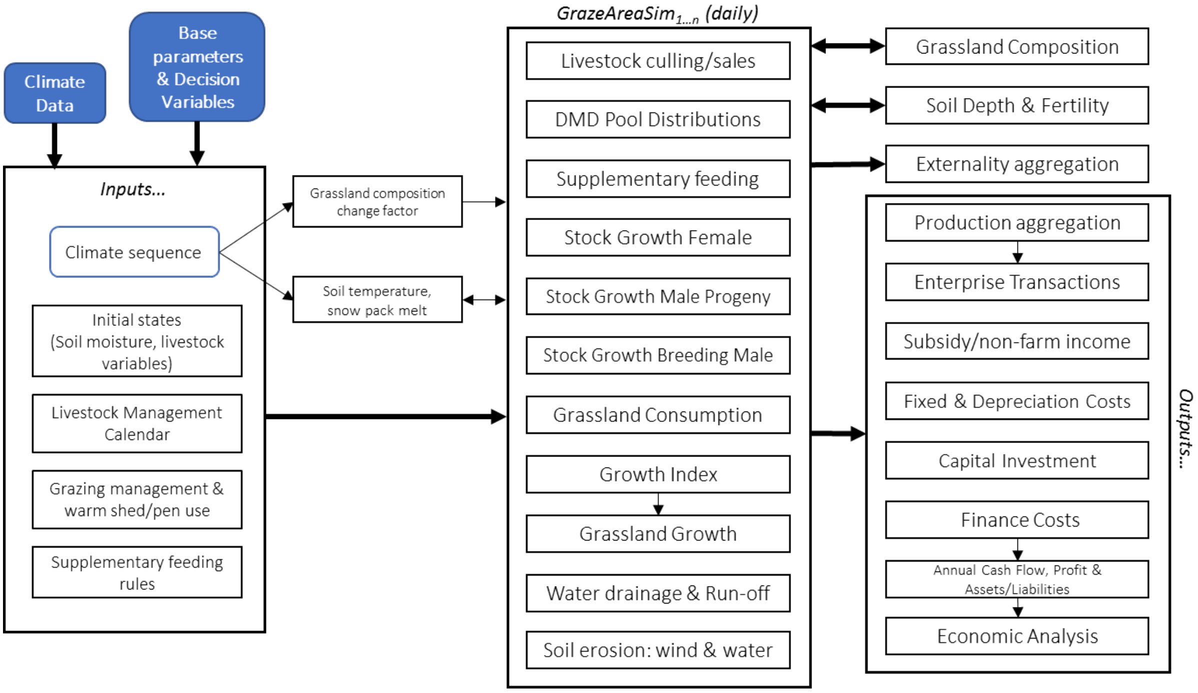

Figure 4. StageTHREE Sustainable Grasslands Model framework

Source: Behrendt et al. (2020b).

A key aspect of the model is its stochastic nature and two key random input variables are considered, namely climate and output prices. Monte Carlo simulation procedures draw upon uniformly distributed annual sequences of daily climate data (2006-2019) and normally distributed prices for outputs (2012-2018 in IMAR and 2012-19 in Mongolia[4]) over a 10-year simulation period. To estimate opportunity costs at discrete states of nature, combinations of Livestock Prices (LP), Wool Prices (WP) and Growing Season condition (GS), a discrete state of nature is firstly defined as the ratio of the mean price or growing season. The GS ratio is based on the ratio of each year's total annual rainfall to the mean long-term annual rainfall for the biome being simulated. As there will be variation in herder cash flows in both the short and medium/long term that may influence herder decision making, the SGM is capable of comparing and reporting both the outcomes for the entire simulation period and the final year, which is analogous with a steady state system. For calculating opportunity costs in IMAR, the difference between the resulting annual household cash flows for herders outside of GESAS (no reduction in stocking rate and no payment) and herders who voluntarily reduced their stocking rate (without GESAS payment) are then calculated for each combination of LP, WP and GS ratio. This is done separately for both the final year's cash flow outcomes and for each year over the entire simulation period. Additionally, other environmental services provided by herders and the externalities of production are predicted by the SGM and reported in this study for both the entire simulation period and under a steady state (final year outcome). A similar approach was taken in Mongolia to estimate economic impact on herders and associated environmental outcomes from expected herder behavioural responses to alternative policy sets. For both IMAR and Mongolia, simulations

[4] *Mongolian mutton and goat meat prices were modified using an aimag level seasonality index to reflect the expected local meat price seasonality.*

from the *SGM* enabled response curves for a range of environmental[5], production and economic[6] outcomes to be derived. This allowed multiple combinations of policy sets to be assessed for the expected marginal changes.

Biophysical research

The biophysical research aimed to quantify key aspects of the grassland / livestock production system in each study area and to contribute to the project aims to:

- Assess grassland condition and relate condition to seasonal conditions and grazing practices; and
- Evaluate livestock, feed and grazing management options to meet grassland environmental objectives, and describe the practice changes they represent over existing systems.

The data collected were used in calibrating the SGM, to establish the control situation and to describe the state of grasslands and of animal production to identify some of the major limitations for improving the grasslands and herder livelihoods. As discussed in Kemp (2020) herders in China and Mongolia typically are focused on survival, rather than on optimising production. In China though, herders are now shifting more from a survival mode to one where they wish to improve the quantity and quality of animal products to increase their incomes. It is important to consider how the system constraints will affect these desired shifts.

In IMAR sampling was continued on the long-term desert steppe grazing experiment (Wang *et al*. 2020) and used data from the typical steppe grazing experiment done as part of the previous ACIAR project (Zhang *et al*. 2020). Other data was collected from demonstration farms in associated Chinese projects (Li *et al*., 2020) and some historical data on grassland production and farm baseline survey. These various sources were used to calibrate the SGM and to identify the grassland characteristics associated with improved environmental services from the grasslands.

Project and ACIAR review team visit field work sites and herders in Altanbulag Soum

In Mongolia, data on grassland productivity and animal liveweights were obtained every three months for two years. This was done for five herders at Altanbulag and five herders at Khaasaat. Sampling varied across the landscape as the herders moved. The aim was to get a general idea of feed supply and animal demand for the SGM. All animals were ear tagged,

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[5] *Includes fractional ground cover, dust emission frequency and quantity of erosion, grassland biomass and condition.*

[6] *Includes final year annual cash flow, net present value as an annuity and its variability.*

a new practice in Mongolia. It was found that the Mongolian ear tags were lost from many animals and this limited the analysis of flock and herd structures over time – only general average weights could be obtained, rather than following what each animal did. Data from the initial measurements did though enable the age and sex structure at that time to be analysed. All the livestock (sheep, goats, cattle and horses) owned by the herder were routinely measured. This created a database of some 100,000 observations that was then summarised to show the general patterns in liveweight gain and loss through time, as well as flock and herd structures. Each animal was also estimated as a 50kg sheep equivalent (*i.e.* divide their weight by 50) to provide a common basis for comparison across livestock types and between herders. The same approach applies in the SGM model. Biomass was recorded for each species within fixed quadrats located within the area the herder indicated they would be grazing.

Experiments were done using small, fenced plots to assess how grazing, or resting at different times through the year, affected grassland composition and production. Previous work in Inner Mongolia (Kemp 2020) had shown that early summer rests resulted in more grass growth over summer, while more intense grazing in winter resulted in severe reductions in growth during the following summer (Wang *et al*. 2020). Changing grazing practices can be a policy decision that improves grassland condition. These plots were located where herders said they would be grazing, but that was not very successful. Herders changed their grazing plans in part because the forage supply, where the plots were located, deteriorated because of seasonal conditions. These plots though still provided some information on grassland productivity for comparison with measurements in the grazed areas.

Social analysis

In Mongolia, social analysis contributed to the following research questions:

1. What are the primary grassland ecosystem services, including cultural ecosystem services that stakeholders value in Mongolia?
2. What factors do herders consider most important in their livelihoods?
3. What factors impact the behaviour, attitudes and perceptions of herders about grassland condition and grassland use?

Five herder focus groups were held in Altanbulag *soum* (Tuv *aimag*) and Khaasaat *soum* (Arkhangai *aimag*) during 2016. Focus groups sought to scope key livelihood aims, challenges, opportunities and causal pathways as understood by pastoralists.

Based on the results of these focus groups, two survey instruments were then designed. The first involved ongoing quarterly surveys (4 seasons in each of 2 years) of 10 selected herders directly involved in the areas where the biophysical research was being carried out (see Figure 2). The survey elicited herders' perceptions of weather and pasture conditions. Drawing upon the theory of planned behaviour (Azjen 1991) (Figure 5), the survey was also designed to identify the herders' management intentions in response to these conditions, and then compare them with their actual behaviour. The survey also sought to elicit key constraints to intended 'pro-environmental' behaviours.

The second survey was a single point of time semi-structured survey involving a larger number of herders. Survey design drew upon various theoretical frameworks, including the use of life satisfaction to understand wellbeing (e.g. Larson et al 2018), the Millennium Ecosystem Assessment (2005) and the theory of planned behaviour (Azjen 1991). For example, the survey drew from the Millennium Ecosystem Assessment (2005) to understand what well-being domains were important for respondents, and how satisfied they were with the components identified as important. This was done by eliciting the importance of domain and context-relevant items (see Figure 6) with overall satisfaction with these domains being assessed via stated life satisfaction.

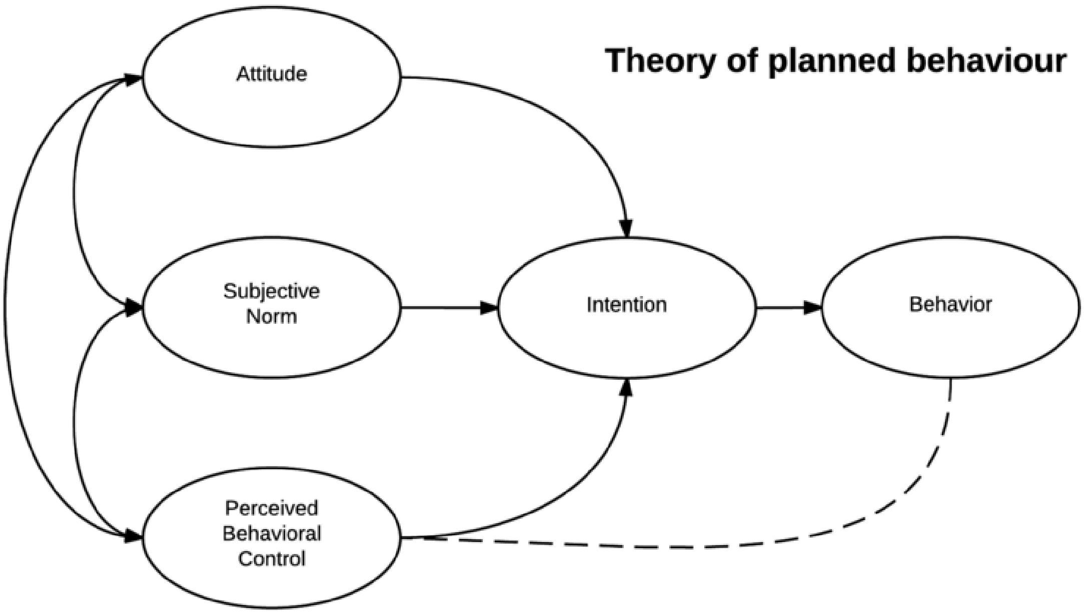

Figure 5 Theory of planned behaviour linking the drivers of pro-environmental behaviours, intention to act, and subsequent behaviour.
Source: Richard Orzana, Creative Commons and based on Theory of Planned Behaviour (Azjen 1991).

Contextually relevant items within each domain were then used as indicators of which domains were most important to individuals, and how satisfied individuals may be with each. During 2017, a pilot survey of twenty herders in the central steppe Arkhangai and Bulgan *aimags* that provided three indicator items for each of the five livelihood domains highlighted core livelihood domains important to herders. After modification of other parts of the survey, a total of 101 additional herders were then surveyed during 2018.

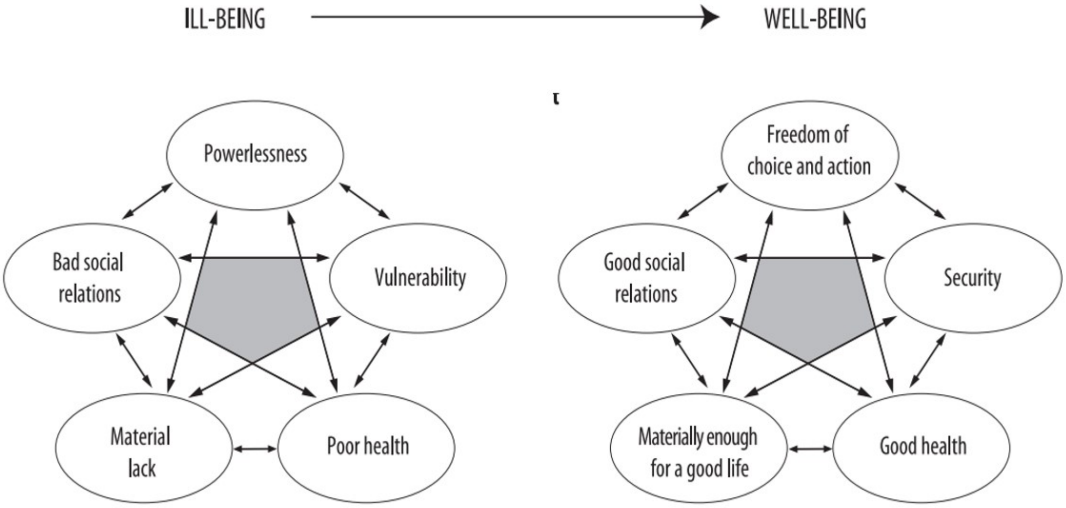

Figure 6 Components of a 'meaningful' livelihood as conceptualised by the Millennium Ecosystem Assessment (2005).

Quantitative data from the semi-structured survey was entered into an Excel Spreadsheet and then imported into SPSS (IBM Corp 2017) for analysis. After checking all data for normality, differences between life satisfaction now and ten years ago were analysed using the non-parametric Wilcoxon signed rank test. Pearson's correlations were used to assess relationships between demographic variables and life satisfaction. Qualitative data related to reasons for change in life satisfaction were manually coded in Excel as per Millennium Ecosystem Assessment (2005) well-being domains. Data from the smaller, repeated survey was coded in NVIVO to elicit key themes.

Marketing analysis

In Mongolia, detailed surveys for ruminant meat (sheepmeat, goatmeat and beef) market actors as well as cashmere, wool and skin dealers were designed to gather information on the value chains and marketing issues associated with these value chains. The surveys involved interviews with stallholders at wholesale markets, slaughter and exchange points, and retailers. Cashmere and wool dealers were to be interviewed during the (brief) purchase season from April through May while some companies were also interviewed. In total, the design involved 100 interviews with actors across different parts of the supply chain.

Market integration and price transmission analysis were done for Mongolia (sheepmeat and beef) and between China and Mongolia (beef, sheepmeat and cashmere) using monthly prices for different regions and centres in Mongolia while the inter-country comparison compared Ulaanbaatar with Beijing prices. The Mongolian analysis was done by Enkh-Orchlon Lkhagvadorj as part of her Master's thesis with the analysis and methods reported in Lkhagvadorj (2017) and with some results also reported in Brown et al. (2020b). The price transmission analysis between Chinese and Inner Mongolian prices was done using standard cointegration analysis methods.

Intra-year (monthly) seasonal price variations were investigated by using monthly price statistics from the National Statistics Office of Mongolia and China Livestock Yearbooks from January 2012 to December 2017. The statistical analysis and estimation of seasonal indices was done using Stata.

The marketing analysis (both value chain and welfare) analysis is ongoing as part of Enkh-Orchlon Lkhagvadorj's PhD study at ANU.

Transaction cost analysis

The transaction cost analysis in Inner Mongolia was based on interviews and data collection in the areas (leagues, banners and sumus) in the choice modelling survey. Specifically officials from the three cities/leagues of the survey areas Xilingol League (primarily typical steppe grassland), Ulanqab City (desert steppe) and Ordos City (sandy steppe) were selected. Within these leagues, six banners were selected namely Xilinhot, Dongwu and Xiwu Banners in Xilingol League, Siziwang Banner in Ulanqab City, and Wushen and Hangjin Banners in Ordos City. For each of these banners, and on advice from local officials, one representative sumu was selected. Thus, in total, 15 semi structured interviews (3 city/leagues, 6 banners and 6 sumus) were done covering the three main grassland types. The average league, banner and sumu estimates were then scaled out to the 6 leagues, 32 banners and 89 sumus in this region.

Transaction costs were initially decomposed into four components: enactment costs, implementation costs, enforcement costs and prosecution costs. However, enforcement and prosecution costs are combined into a single grouping because of their close connection in the Chinese grassland policy case while because of the advent of and potential for remote technology to monitor livestock and grassland use, remote technology costs were added to the framework. Key aspects about each of these categories include: *Enactment costs* include the costs of policy design and information collection. They relate to the design and implementation costs for specific grassland policy instruments, or changes in these instruments, rather than general information and design costs associated with broad policy areas; I*mplementation costs* include the costs of program awareness, communication and moral suasion; *Detection and monitoring costs* include levels of compliance, costs of detecting violations of program conditions, and the monitoring of environmental outcomes to ensure herders' behaviour is consistent with policy design; *Remote technology costs* include the costs of resources, equipment and staff to purchase and use technology such as remote satellites and drones; *Prosecution costs* refer to the costs of dealing with violators both formally and informally. The costs in each category are then disaggregated or based on staff costs, vehicle costs and other associated costs. Staff costs are for staff from two categories namely formal officials working at grassland-monitoring stations and who are paid on a salary basis, and informal grassland defenders employed by regional grassland-monitoring stations. The latter category is mostly from the grass roots level and are supplementary staff to help formal officials monitor daily herder behavior and grassland use. Thus grassland defenders have a closer connection with herders than do formal officials and are required to monitor grazing activities more frequently. Staff costs include daily allowances while working in the field. Vehicle costs relate to additional vehicles required including maintenance costs and operating costs such as fuel and based on the frequency of utilization of the vehicles for the specific related tasks. Other costs include the costs of training (materials, venue and related costs) as well as any required equipment costs.

The analysis draws on multiple, mixed methods with data drawn from a range of sources including: public budget statements and records of relevant agencies on staff, vehicle, and other costs associated with GESAS. Specific data on salaries were obtained from the annual public budget statement of the agencies; Official statistical yearbooks, including yearbooks not widely published, were used for macro statistical information on items such as land size information; semi-structured interviews based on questionnaires were conducted with officials and staff from grassland monitoring stations at different administrative levels to gather information on costs associated with staff and vehicles as well as on time allocation associated with current and alternative grassland policy settings. Three pilot semi-structured interviews were conducted in Ulanqab City of Inner Mongolia in March 2018. A revised version of the interview was then used for the majority of interviews done in 2018. Triangulation of the information from all three sources as well as further statistical analysis of the primary information was used in the analysis.

The eight policy alternatives used in the policy assessment include settings such as increases in herder pensions, increase in term length for soft loans. However, the system costs of implementing these policies is already sunk into these programs and increasing the level of pensions or term of the loans is unlikely to impact transaction costs. The main transaction costs associated with the alternative grassland policies was associated with increasing levels of compliance (from 10% to 50% to 70%). Thus the focus of the transaction cost analysis was on the grassland monitoring and supervision agencies and the additional costs that they would occur in increasing the levels of compliance.

Institutional analysis

The institutional analysis in the project was designed to provide background and context for many areas of the project research and so was done in the initial stages of the project. The analysis drew on the following information sources or approaches namely:

- Collation of details of policy instruments from official government sources and at different administrative levels
- Triangulation of information about specific policy instrument details and notional objectives against their implementation at a local level through interviews and focus groups conducted with local officials and herders
- Collation of time series statistical information on a range of macroeconomic indicators as well as commodity specific indicators compiled from various official yearbooks and statistical sources. In the case of China, a searchable database was

constructed to navigate the many different statistics. In the case of Mongolia, the information was compiled in a report given access to information in the MONSIS database.
- Critique of literature about formal and informal institutions in China and Mongolia. Especially in the case of formal institutions in China and informal institutions in Mongolia, the project team were aware of the studies and researchers in these areas (including their own research) and were well placed to provide a critical and comprehensive review.

The statistical databases and policy information was not updated on a systematic and regular basis as it was intended to provide the initial contextual background. However, updates on specific indicators and specific policy areas were updated as required for different parts of the project research.

Structural equation modelling

Full details of the methods used in this analysis are provided in Zhang J. et al. (2019).

Structural equation modelling was applied in the analysis of herder satisfaction and behavioural drivers (livestock practices, herder incomes and employment) under existing grassland policies in Inner Mongolia. The data was collected from a large scale panel survey of herders of 8 counties in Xilingol (Xilinhaote, Lanqi, Baiqi and Dongsuqi), Ordos (Hangjin and Wushen) and Ulanqab (Siziwang and Chayouhou) cities from 2010 (immediately prior to GESAS, Grassland Ecological Subsidy and Award Scheme), 2013 (mid-point of first GESAS) and 2016 (after first round of GESAS). Structural equation modelling (SEM) allows for more than one measure to represent constructs and represents a combination of confirmatory factor analysis and path analysis, where the factor analysis shows how well observed variables combine to represent underlying latent variables while the path analysis then establishes the relationship among latent variables which can be described as: (a) no directional relationship; (b) direct effects; or (c) indirect effects.

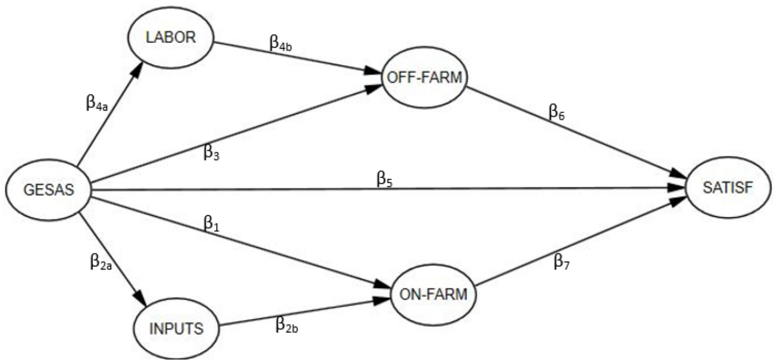

Figure 7 Path diagram of impact of GESAS on herder behaviour and satisfaction
Source: Zhang J. et al. (2019)

Structural equation modelling was done through three steps. First, a conceptual model of the latent variables influential in the relationship between GESAS and herder satisfaction was constructed. One hypothesis embedded in the model was that GESAS impacts two pivotal inputs of the herder household, namely livestock feed and own labour. On the one hand, GESAS imposing grazing restrictions or stocking rate limits is likely to force herders to consider more intensive supplementary feeding systems, either to compensate for the banned/reduced access to grazing or to increase production from less livestock numbers. Per unit livestock costs may rise with more intensive feeding systems, while some additional ruminant livestock product like meat and cashmere may also rise with more intensive feeding systems. The impact of systems change on on-farm incomes thus depends on whether additional gain is able to offset the extra costs. On the other hand, GESAS may also impact the utilisation of household own labour. Grazing bans may free up household labour but the aforementioned scale up in intensity of feeding systems may have the reverse effect. In turn, the amount of discretionary labour available to the herder household will affect the opportunities for off-farm employment and off-farm income. The on-farm and off-farm income, along with the effort required by the household to generate these incomes, then feed into the satisfaction or utility of the herder households.

Guided by the theoretical relationship in the first step, observable variables are identified in the second step to describe each latent variable. The principle of identification is eliminating the variables that exhibit significant bivariate correlations (>0.85 statistically; an extremely high bivariate correlation indicates poor discriminant validity and potential multi-collinearity which thereby affect the SEM estimates), and then comparing the factor loadings of each observed variable on its latent variable through the confirmative factor analysis, which shows whether and how well the specific latent variable are measured by the specific observed variables.

In the final step of the approach, several relationships between the latent variables is estimated using the following equations:

$$Y_{inputs} = \beta_{2a} \times GESAS + \delta_{input}$$

$$Y_{on-farm} = \beta_1 \times GESAS + \beta_{2b} \times Y_{inputs} + \delta_{on-farm}$$

$$Y_{labor} = \beta_{4a} \times GESAS + \delta_{labor}$$

$$Y_{off-farm} = \beta_3 \times GESAS + \beta_{4b} \times Y_{labor} + \delta_{off-farm}$$

$$Y_{satisf} = \beta_5 \times GESAS + \beta_6 \times Y_{on-farm} + \beta_7 \times Y_{off-farm} + \delta_{satisf}$$

Where GESAS, Y_{inputs}, Y_{labor}, $Y_{on\text{-}farm}$, $Y_{off\text{-}farm}$, Y_{satisf} are latent variables, β is regression coefficient and δ is the measurement error, with the subscripts corresponding to the assumed pathways in Figure 7. These five equations are linked and inference about them is simultaneous rather than being independent of each other. The direct effect is the pathway from the exogenous variable to the outcome while controlling for the mediator. Correspondingly, the pathways from the exogenous variable to the outcome through the mediator are described as the indirect effect. Thus as the path diagram in Figure 7 shown, β_1, β_3 and β_5 represent the direct effects from GESAS to ONFARM, OFFFARM and SATISF respectively; β_{2a} and β_{2b} refer to the indirect effects from GESAS to ONFARM through INPUTS, β_{4a} and β_{4b} are the indirect effects from GESAS to OFFFARM through LABOR, while β_1-β_7, β_{2a}-β_{2b}-β_7, β_3-β_6, and β_{4a}-β_{4b}-β_6 are the indirect effects from GESAS to SATISF through ONFARM and OFFFARM respectively. The total effect of GESAS to ONFARM, OFFFARM and SATISF is the sum of the direct and indirect effects of the exogenous variable on the outcome. The variables identification in step 2 and relationships verification in step 3 were done through SPSS-AMOS 24.0.

5.3 Who was involved in the work?

The research was done as part of research teams that spanned different research institutions in different countries. The table below indicates the institutions and key researchers involved in the different aspects of the research.

	Inner Mongolia	Mongolia
Choice modelling and contingent behaviour analysis	CEM, IGR, ANU (JB, LP, QG, ZB)	SEB, ANU (JB, LD, EL, DB)
Biophysical research	CGRE, IGR, CSU (DK, KB, HG, LP, HX, ZM, LZ, WZ)	RIAH, CSU, JCU (DK, KB, JA, UG, GJ, DL, GL)
Bioeconomic modelling	CSU/HAU, CGRE (KB, LZ)	CSU/HAU, RIAH (KB, GJ)
Social analysis	JCU, CEM, IGR (JA, LP)	JCU, RIAH, SEB (JA, UG, GJ, DL, DB, LD)
Marketing and other economic analyses	CEM, UQ, HAU (QG, ZB, ZJ, SW, CB, KB)	SEB, UQ, HAU (LD, EL, CB, KB)
ANU- Australia National University; CEM - College of Economics and Management IMAU; CGRE - College of Grasslands, Resources and Ecology IMAU; CSU - Charles Sturt University; HAU - Harper Adams University; IGR - Institute for Grassland Research CAAS; JCU - James Cook University; RIAH - Research Institute of Animal Husbandry MULS; SEB - School of Economics and Business MULS; UQ - University of Queensland. *JA - Jane Addison; JB - Jeff Bennett; CB – Colin Brown; DB - Duinkherjav Bukhbat; LD - Lkhagvadorj Dorjburegdaa; UG - Udval Gombosuren; DK - David Kemp; GJ - Gantuya Jargalsaikhan; HG - Han Guodong; HX - Hou Xiangyang; KB-Karl Behrendt; LP - Li Ping; LZ - Li Zhiguo; EL – Enkh-Orchlon Lkhagvadorj; DL – Davaasambuu Lkhagvasuren; GL - Gankhuyag Luvsan; QG - Qiao Guanghua; SW - Scott Waldron; WZ - Wang Zhongwu; ZB - Zhang Bao; ZJ - Zhang Jing; ZM - Zhao Mengli*		

6 Achievements against activities and outputs/milestones

Objective 1: To design more efficient incentive schemes for improved grassland and livestock management in China

no.	activity	outputs/ milestones	achievements
1.1	Establish communication and stakeholder engagement for project design, implementation and impact	Series of project coordination meetings to define and review responsibilities and tasks and progress. Series of local consultative group meetings in case study areas for engagement with target communities. Series of central consultative group meetings for engagement with key officials	• Full joint project meeting involving key Chinese, Mongolian and Australian researchers to review annual activities and coordinate work plans held in Hohhot (June 2017), Ulaanbaatar (April 2018) and Canberra (February 2019). • Face-to-face held between key Australian team members and joint Chinese team throughout the year associated with Australian visits and supplemented in intervening periods with WeChat meetings. • Policy briefing to key Central level grassland officials and academics in Beijing in April 2018 based on preliminary findings • Ongoing consultation with Inner Mongolian grassland officials (meetings of project leaders with officials and external stakeholders in October and November 2018 and in December 2019) • Participation and presentation of project and project findings at key conferences/meetings including: 8th International Conference on Economic and Social Sustainable Development of Mongolian Plateau Pastoral Areas, Hohhot, December 2020 (see Brown et al. 2019); MULS 60th Anniversary Conference; AARES 2017 and 2019 conferences (see Behrendt et al. 2019a), and Australian rangelands Congress (Behrendt et al. 2019b).
1.2	Establish context, institutional settings and characteristics of incentive schemes for grassland and livestock management	Report on formal policy and institutional settings related to or impacting on grassland management incentive schemes	• Initial master statistical database prepared along with report on institutional settings. Subsequent selective updates done as required • Institutional settings reported in Addison et al. (2020a)
1.3	Survey households for attitudes towards and social issues associated with grazing restrictions and incentive policies	Paper on attitudes toward and impact of existing incentive policies	• Focus groups and interviews with households revealed herder attitudes, social issues and what constitutes a meaningful livelihood and are reported in Addison et al. (2020b). • Herder attitudes to existing grassland policies were analysed through structural equation modelling and reported in Ecological Economics (Zhang J. et al., 2019). The analysis provided a range of insights into herder attitudes and perceptions to grazing restrictions and particular in relation to impacts on household income, labour (on and off-farm), and expectations. • Herder preferences for alternative grassland policy settings have been identified through the choice modelling analysis and are reported in Li and Bennett (2019) and Bennett et al. (2020). Li et al. (2020) provide an ordinal ranking of the 1024 potential policy options (attribute and level of the attributes) • Herder attitudes to sustainable stocking rates are reported in (Hou et al. 2020).

1.4	Assess grassland condition and relate condition to seasonal conditions and grazing practices	Report on grassland condition assessments of select sites Paper on relationship of grassland condition to seasonal conditions and grazing practices	• Bio-economic models of 'typical farms/households' on typical steppe, desert and sandy steppes were calibrated based on data on livestock and grazing systems • The data was collated from various sources including household surveys and which revealed various aspects of the livestock systems and the changing practices. • General relationships were identified and reported in Kemp et al. (2020a) and were based on a review of outcomes from sustainable grazing experiments in the typical and desert steppe (chapters in Kemp 2020)
1.5	Evaluate livestock, feed and grazing management options to meet grassland environmental objectives, and describe the practice changes they represent over existing systems	Report on farming systems model calibrated to local conditions and scenarios Paper on best practice management options to meet environmental policy objectives	• The models calibrated to the typical, desert and sandy steppe are reported in Behrendt et al. (2020b), Behrendt et al. (2019b) and Behrendt et al. (2020c) • Stocking rate reductions associated with alternative policies and used in the policy assessment identified through contingent behaviour analysis associated with choice modelling survey of herders and reported in Li and Bennett (2019) • Impact of the practice changes associated with the alternative policies on herder incomes, variability of income identified and assessed using the bioeconomic model. • Discussion and analysis of management options arising from the biophysical research underpinning the data has also been reported in Behrendt et al. (2019b), Behrendt et al. (2020b) and Kemp et al. (2020a). • Analysis of grassland rental and rental prices done and reported in Qiao et al. (2018). Reveals impacts of rental of grassland use rights on grazing pressures and strategies to reduce grazing pressures. Factors impacting grassland rental also identified.
1.6	Evaluate change in environmental services associated with practice changes (marginal benefits)	Report on environmental and social benefits of livestock and grazing system practice changes	• The change in environmental services (grassland condition, dust emission events and dust loads, ground cover, and greenhouse gas emissions) for 8 alternative grassland policy options (each involving different stocking rate reductions as determined from the analysis under 1.5) was estimated for typical, desert and sandy steppe using the bioeconomic model reported in Behrendt et al. (2020b). • Hohhot residents' valuations of marginal change in environmental services relevant to the policy analysis were identified through choice modelling analysis and presented in a paper at the 2018 World Congress of Environmental and Resource Economics and published in Zhang B. et al. (2019). • A clarification of how grassland environmental services can best be understood and applied by herders is reported in (Kemp et al, 2020b)

1.7	Interview farm households to identify opportunity costs of practice changes (marginal costs);	Paper on choice model of household response to grazing/livestock options and incentive payments Report on comparison of model determined (1.5) and stated (1.7) opportunity costs	• Opportunity cost of practice changes associated with alternative policy settings estimated using bioeconomic model described in Section 5.2.2. • Farm survey data used to calibrate models used to determine opportunity costs
1.8	Relate opportunity costs (in 1.7) to household characteristics, production and market environment, and grassland type	Paper on econometric models linking opportunity costs to household, bio-physical, weather and market characteristics	• Model analysis of opportunity costs under different production and market conditions and for different regions and household types completed. • Preliminary analysis presented at AARES conference in February 2019 (Behrendt et al. 2019a) and reported in Behrendt et al. (no date b)
1.9	Design more efficient incentive and payment schemes based on assessment of marginal benefits (1.6) and marginal opportunity costs (1.7)	Report/paper on parameters for efficient incentive payment schemes Report/paper on net social benefits of incentive policies	• Identification of 8 alternative policy options based on previous objectives completed. • Marginal environmental benefits and opportunity costs associated with alternative policy options determined from objectives 1.6 and 1.7 and combined in a net social benefit analysis of policy alternatives and reported in Brown et al. (no date a) and presented in Section 7.1.1. • Transaction costs associated with alternative policy settings reported in Addison et al. (2020a) and presented in Section 7.1.5, and included in net social cost benefit analysis. • Other impacts (environmental indicators, variability of herder incomes, program (transfer) payments, pasture impacts) integrated into assessment of alternative policy options alongside the estimation of net social benefits and reported in Brown et al. (no date a) and presented in Section 7.1.1.

Objective 2: To design more efficient incentives for improved livelihoods and grassland condition in Mongolia …

no.	**activity**	**outputs/ milestones**	**achievements**

2.1	Establish communication and stakeholder engagement for project design, implementation and impact	Series of project coordination meetings to define and review responsibilities and tasks and progress Series of local consultative group meetings in case study areas for engagement with target communities Series of central consultative group meetings for engagement with key officials	• Full joint project meeting involving key Chinese, Mongolian and Australian researchers to review annual activities and coordinate work plans held in Hohhot (June 2017), Ulaanbaatar (April 2018) and Canberra (February 2019). • Face-to-face held between key Australian team members and joint Mongolian team throughout the year associated with Australian visits and supplemented in intervening periods with Skype meetings. • Ongoing consultation with Mongolian grassland officials. In particular meetings with key MOFALI officials during each Australian visit. Key meetings of the Australian and Mongolian project leaders with officials and external stakeholders in November 2018 and December 2019 to discuss preliminary research findings and implications for evolving policy discussions • Participation and presentation of project and project findings at key conferences/meetings including: MULS 60th Anniversary Conference; 8th International Conference on Economic and Social Sustainable Development of Mongolian Plateau Pastoral Areas, Hohhot, December 2020 (Brown et al. 2019); and AARES 2019 conference. • Local officials and groups met as part of herder surveys associated with choice modelling and social surveys • Briefings by members of the Mongolian project team of Ministry officials and political representatives and advisors on key findings from the project
2.2	Establish social and cultural context, institutional settings and characteristics of incentive schemes for grassland management	Report on institutional settings	• Initial background report prepared in 2016 with ongoing update as required • Institutional settings reported in Addison et al. (2020a) • Analysis of social surveys of households completed and partly reported in Addison et al. (2020b) and discussed in Section 7.2.4
2.3	Assess grassland condition and relationship with seasonal conditions and grazing practices	Report on biophysical models of grazing and livestock systems Report on spatiality and temporality of overgrazing within case study soums and their relationship with grazing/ livestock practices	• Spatial and temporal mapping of grassland condition, and perceived drivers of change, by focus groups in the case study areas • Ongoing seasonal biophysical monitoring at selected sites (4 seasons and under different grazing practices over 2 years) • Associated ongoing seasonal survey of small group of selected households in monitoring sites to establish relationship between grassland condition and grazing practices and perceptions of grassland condition. Data summarised and used to check parameters in the Sustainable Grazing Model. The severe weight losses through winter are evident. • Bioeconomc model has been calibrated and used to simulate grazing systems in both case study soums. Two manuscripts are under preparation on: strategy analysis for Mongolian herders: modelling impacts on herder livelihoods and environmental outcomes (Behrendt et al, in prep); and understanding and modelling livestock mortality in Mongolian systems (Behrendt et al, in prep).

2.4	Interview households and industry stakeholders to construct economic and behavioural models of herder households and markets	Report on economic models of herder households Report on value chains for ruminant livestock products	• Herder preferences for alternative grassland policies as well as their behavioural responses to alternative policy settings done through a choice modelling survey of herders to and associated contingent behaviour analysis. Findings presented at AARES conference in 2019 and reported in Bennett et al. (2020) and discussed in Sections 7.2.1 and 7.2.2. • Biophysical calibration of bioeconomic model for steppe regions of Mongolia done and set up for both case study soums (including the modelling of highly variable mortality rates due to dzuds). Information to calibrate model drew upon economic and social surveys done with select group of representative herders. • Design of market analysis surveys with meat/livestock dealers and cashmere/wool traders done, but full surveys and analysis in progress. Initial findings of market analysis including value chains reported in Brown et al. (2020b, Section 5.3). • Policies impacting livestock markets and price transmission and seasonal variation reported in Brown et al. (2020b, Section 5.2). • Livelihood objectives and planned behaviour analysed in social surveys of households done and partly reported in Addison et al. (2020c) and discussed in Section 7.2.4.
2.5	Identify environmental and social benefits provided by grasslands and factors impacting on value of these benefits	Report on value of environmental and other grassland services	• Ulaanbaatar residents' valuations of marginal change in environmental services and value of grassland environmental amenity relevant to the policy analysis identified through choice modelling analysis and presented in a paper at 2019 AARES conference and reported in Bennett et al. (2020) and discussed in Section 7.2.3. • Social attitudes and values and perceptions of herders of services provided by grasslands including what constitutes a meaningful livelihood for Mongolian herders and how grassland services impact the livelihood determined with a preliminary report presented in Addison et al. (2020c) and discussed in Section 7.2.4. • A clarification of how grassland environmental services can best be understood and applied by herders is reported in (Kemp et al, 2020b).

2.6	Evaluate efficiency of incentive policies influencing grassland use	Paper on analysis of grazing user fee options Paper on analysis of livestock product subsidies Paper on analysis of livestock and grazing interventions Report on analysis of new incentive policies including embryonic PES schemes	• Alternative policy instruments identified based on choice modelling survey of herder policy preferences and discussions with policy officials. Herder policy preferences reported in Bennett et al. (2020) and discussed in Section 7.2.1. • Contingent behaviour analysis associated with choice modelling survey of herder policy preferences used to determine behavioural response of herders to alternative policy settings in terms of reduction in livestock numbers reported in Bennett et al. (2020) and discussed in Section 7.2.2. • Change in environmental services (grassland condition, dust emission events and dust loads, ground cover, and greenhouse gas emissions) associated with the stocking rate reductions of the alternative policy options have been determined using the bioeconomic model. Will be combined with resident valuations of changes in grassland attributes/environmental services (objective 2.5) to estimate value of environmental benefits of policy options. • Estimation of opportunity costs for herders of stocking rate reductions associated with alternative policy settings have been determined through bioeconomic modelling. • Net social benefits including both the environmental benefits and opportunity costs of alternative policies and incentives have been determined (Section 7.2.1).

Objective 3: To facilitate linkages between China and Mongolia for improving grassland management …

no.	activity	outputs/ milestones	achievements
3.1	Conduct workshops and forums to facilitate exchange of ideas between Chinese, Mongolian and Australian scientists on grassland and livestock management and incentive policies	Workshop/ forum reports	• Participation of Chinese, Mongolian and Australian team members at annual IMAU/MULS conference. These conferences have become larger and more international and attended by more-and-more Mongolian and Inner Mongolian officials. They provide perhaps the foremost forum for Mongolian and Inner Mongolian academics and grassland researchers to exchange ideas. Key papers on these projects presented at the conferences including Brown et al. (2019) and Kemp et al. (2019). • Edward Elgar book (Brown, 2020) designed as a comparative analysis between Chinese and Mongolian grasslands on all aspects considered in project. Each chapter is co-authored by researchers from the Chinese, Mongolian and Australian project teams.

7 Key results and discussion

As outlined in Section 5, there were a series of inter-related interdisciplinary analyses associated with the project. The end point for the inter-related analyses was assessment of alternative grassland policy options for which the key findings are discussed below. However, the intermediate analyses have findings of interest in their own right and are also discussed in this section. As Inner Mongolia and Mongolia had separate objectives in the project, the results are reported for each region in Sections 7.1 and 7.2 respectively. Nevertheless, given the overarching objectives of the study, many similar analyses were performed in both regions and where direct comparisons were made then these are reported in Section 7.3. Despite the broad similarity in approaches in both Inner Mongolia and Mongolia, there were some differences reflecting the different issues, contexts and available data and this is evident in the sub-sections in Sections 7.1 and 7.2.

7.1 Inner Mongolia

7.1.1 Assessment of alternative policies

Modified extract from Brown et al. (under review)

Based on the approach outlined in Section 5.2.1, the project assessed 8 policy options shown in Table 1. Indicators associated with the policy assessments of each of the policy options are outlined in Table 2, Table 3 and Table 4. The values for each of the policy options in each of these tables are changes relative to the values under the current policy settings which are listed in the ‘Base value’ column.

Anticipated stocking rate reductions associated with each of the policy options are listed in the first row in Table 2 and were estimated as part of the contingent behaviour analysis reported in Section 7.1.3 using the methods described in Section 5.2.2 (see also Li et al., 2019). Environmental impacts associated with these reductions in stocking rates in terms of reductions in dust storms, wind erosion, fractional ground cover and greenhouse gas emissions, are indicated in the subsequent rows as estimated by the bioeconomic model reported in Section 5.2.2 (Behrendt et al. 2020a, 2020b). Only modest impacts on the number of dust storms and wind erosion were found. This is not surprising given the non-equilibrial nature of these steppe grasslands and weather variability where abiotic drivers may be more important in the occurrence of dust storms than biotic drivers or grazing practices (see Ellis and Swift 1988), especially given the livestock reductions are also relatively modest. Similarly the policy options only had a minor impact on ground cover. Reductions in greenhouse gas emissions ranged from 0.73 (option 2) to 9.87 (option 7) GWP100 million tons CO_2e/annum for the typical, desert and sandy steppe in the study region.

The value of environmental impacts of local urban residents are reported in Table 3. As outlined in Sections 5.2.1 and 5.2.2, 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 Table 2. Based on the results reported in Section 7.1.4, the value to an urban household of one less dust storm was estimated as CNY44/annum while a one per cent increase in ground cover was estimated at CNY22/annum. The single policy instruments led to environmental benefits of between CNY3.5 and 18.3 million but increased to between CNY19.7 million and CNY47.3 million for the policy bundles.

Table 1 Alternative policy options for Inner Mongolia[a]

		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 'soft loan' term length	5 years (+ 4 years)	Herders able 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 GESAS reward balance payment	CNY10/mu (+ CNY7.5/mu)	Reduce pressure to overstock to meet income constraints through higher GESAS payments
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 + CNY7.5mu)	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 + CNY7.5mu)	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 + CNY5mu)	Achieves GESAS stocking rates but more preferred by herders than Option 7 and at lower government payments than Option 6

Notes:

[a] Current policies for which the alternative policies were assessed against are: 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 reward balance payment of CNY2.5/mu.

The environmental benefits were weighed up against the costs of the policies including the opportunity costs for herders in terms of their loss in producer surplus or income from the reduction in stocking rates as well as the transaction (administrative and system) costs of implementing the policy and these costs are shown in Table 3. The opportunity costs were estimated using the bioeconomic model described in Section 5.2.2 and represent a median value across different states of nature of the loss in herder surplus. Although herders realise less income from fewer livestock, there is an offsetting effect on pasture and livestock productivity. Indeed if stocking rates and grazing pressure are very high, a reduction in livestock numbers may increase livestock production and herder incomes per hectare. This is clearly demonstrated in Table 3 when comparing the disaggregated opportunity costs across the grassland types. Stocking rates remain well in excess of GESAS rates for the typical steppe, and so a reduction in livestock numbers leads to a significant rise in herder incomes (up to CNY86.5/ha/year for Option 7) as the productivity impacts outweigh the effect on incomes of lower numbers. However the reduction in livestock numbers leads to a large reduction in herder incomes (up to -CNY94.5/ha/year for Option 7) for the desert steppe where stocking rates are still in excess of, but much closer to, GESAS rates than the typical steppe**.** However, the larger area and number of herders of the typical steppe means that 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 listed in Table 3 is transaction costs. Many of the policy options (options 1, 2, 4, 5 and 6) have no change in these costs as the systems are already in place under the current policy with the policy changes simply involving changes in instrument levels. However the policy options with an increased level of enforcement (Options 3 and 7 where enforcement levels rise from 10% to 70% and Option 8 in which enforcement rises from 10 to 50%) increase transaction costs by between CNY372 million and CNY408 million. These transaction costs are lower than the change in herder incomes for options 3, 7 and 8 but exceed the corresponding environmental benefits.

Table 2. Assessment of alternative policy options[1] in Inner Mongolia[2] : Environmental impacts

Alternative policy options	Base Value[3]	1	2	3	4	5	6	7	8
Reduction in stocking rates (SE/ha)		0.091	0.024	0.149	0.082	0.041	0.156	0.387	0.311
Reduction in dust storms (number/annum)	55	0.02	0.01	0.03	0.02	0.01	0.04	0.09	0.07
Reduction in fractional ground cover (%)	30	0.89	0.27	1.43	0.81	0.37	1.53	3.67	2.96
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
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

Notes:

1. *Alternative policy options as defined in Table 1.*
2. *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.*
3. *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.*

Subtracting the costs from the benefits leads to substantial net social benefits of between CNY163 million for option 2 (loan length) to CNY929 million for Option 7 (largest stocking rate reduction bundle) as shown in Table 3. This is primarily because of the rise in herder incomes for the typical steppe herders associated with the pasture and livestock productivity impacts of the lower stocking rates rather than because of the environmental benefits. For the desert steppe where lower livestock numbers reduced herder incomes, 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 drive these net social benefits.

Various assumptions lie behind the estimate of these net social benefits and so the results should be interpreted with caution. The respondents in the choice modelling survey used to estimate the marginal environmental valuations of urban households were younger, higher income and more educated than the population of Hohhot as a whole (Zhang B. et al. 2019) and so the valuations may be overstated. On the other hand, only large urban centres in and around central grassland areas in Inner Mongolia were used to scale the environmental benefits whereas dust storms and the aesthetic appeal of the grasslands may impact urban residents in other areas. Furthermore only the reduction in physical greenhouse gas emissions, and not their value, appear in row 1d given the absence of accurate valuations on a reduction in these emissions in China. Inclusion of these environmental benefits would increase the overall magnitude of the net social benefits. The costs may also be understated. Direct payments and subsidies of the policy options are not considered costs but transfer payments. However, 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 are overlooked in the analysis but also means that costs in Table 3 may be a lower bound. Further deails of the sensitivity analysis on some of these key parameters are reported in Brown et al. (in preparation).

Table 3 Assessment of alternative policy options[1] in Inner Mongolia[2] : Economic impacts

Policy Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Environmental benefits (CNY million)	11.3	3.5	18.3	10.4	4.8	19.7	47.3	38.1
Change in herder NPV (CNY million)	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
Change in transaction costs (CNY million)	0	0	408.4	0	0	0	408.4	372.4
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)	-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

Notes:
1. Alternative policy options as defined in Table 1.
2. 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.
3. 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.

Table 4 Assessment of alternative policy options[1] in Inner Mongolia[2] : Other impacts

Policy Options[1]	**Base Value[3]**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Change in direct payments (CNY million)		113.8	0.00	0.00	0.00	3160.8	3274.6	3274.6	2221.0
Change in standard deviation of herder income (CNY/household)	32890	-10921	-4194	-13856	-10302	-6505	-14128	-19808	-18318
Pasture impacts									
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

Notes:
1. Alternative policy options as defined in Table 1.
2. 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.
3. 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.

Apart from the main environmental and economic impacts in Table 2 and Table 3, other indicators will be of interest to policy makers and advisors and these are shown in Table 4. Although transfer payments rather than a resource cost to society, changes in direct payments of alternative policies will be of interest to Chinese policy makers as they weigh up the transfers needed to achieve their desired policy outcomes. For instance, increasing pensions from CNY300/month to CNY1200/month requires the government to find another CNY114 million for retiring herders in the study area. Higher GESAS payments (Options 5 to 8) increase direct payments by between CNY2.2 and 3.3 billion in the study area alone which represents a substantial increase on grassland support payments to China as a whole. The increase in direct payments are large relative to the environmental benefits and to the transaction costs reported in Table 3.

Changing weather and market conditions mean that the impact of the policy options on herder incomes varies from year to year. Table 4 reveals that alternative policies lead to a substantial reduction in the standard deviation of herder incomes ranging from CNY517 to CNY7489/household. The impact of the alternative policies on key pasture indicators are also presented in Table 4 and highlight that the alternative policies do lead to a significant rise in July biomass and proportion of desirable species and especially in overgrazed areas of the typical steppe.

7.1.2 Herder policy preferences

The purpose of this analysis was to investigate herder's preferences for alternative policy instruments. An issue with previous grassland policies has been the level of compliance and so a better understanding of herder preferences for different policies may aid the design of effective policies. The analysis also enables herders' willingness to trade-off between different policies to be determined. The information is useful from a political perspective by allowing policy makers to gauge the reception that herders are likely to give the introduction of any policy change.

This section is a modified extract from Bennett et al. (2020) with further details also provided in Li and Bennett (2019).

The five policy options used as attributes (and the levels taken under the varying choice alternatives with the first value representing the status quo) were selected in consultation with policy makers and with herders who participated in focus group discussions. For the Inner Mongolian case the selected policies were:

1. Pension paid to herders over 60 years of age (CNY300, 600, 900, 1200)
2. Loan period (1 year, 2, 3, 5)
3. Enforcement of existing grazing restrictions as the probability of being caught (10, 30, 50 and 70 per cent)
4. Penalty for overgrazing per sheep equivalent (CNY100, 200, 400, 600)
5. Subsidy per mu (CNY2.5, 5, 7.5, 10)

The results of the analysis are shown below in Table 3. All the attribute coefficients are significantly different from zero. This indicates that all the policy instruments were of some influence in herders' choices. The positive signs on the coefficients for pension, loan and subsidy shows that herders prefer more of these policies. The negative signs on enforcement and penalty indicates a dislike for these policy instruments. These signs are consistent with a priori expectations.

The statistically significant attribute coefficients estimated in each model can be used to determine the willingness to trade-off between different policies. By dividing the respective coefficients to determine how much, on average, herders are willing to give up in additional subsidies in order to secure a higher pension. By using one policy as a 'reference point', the relative preferences across herders for the other policies can be established. In the case of Inner Mongolia, the reference point is set as the amount paid per mu as a cash subsidy to herders for grazing restrictions. Comparing policies is not straightforward because they are defined in different units and hence will impact different herders in different ways. However, on average, it can be concluded that herders would be willing to give up CNY0.47 per mu in order to receive an additional CNY1 per month as a pension paid after they turn 60 years. In contrast, herders have indicated that they would need to be paid an extra CNY0.47 per mu in subsidies in order to accept additional penalties of CNY1 per sheep equivalent beyond their permitted level.

Table 5. Herders' policy preferences Inner Mongolia

Variable	Coefficient (Standard error)	Coefficient (Standard error)
Pension	0.001*** (0.000)	0.002*** (0.000)
Loan	0.181*** (0,022)	0.263*** (0.049)
Penalty	-0.001*** (0.000)	-0.002*** (0.000)
Enforcement	-0.014*** (0.002)	-0.029*** (0.005)
Subsidy	0.225*** (0.016)	0.422*** (0.046)
ASC	-2.162*** (0.352)	1.449*** (0.504)
Contracted land	0.001*** (0.000)	
Rented land	-0.001*** (0.000)	-0.002*** (0.001)
Grassland for hay production	0.003*** (0.001)	0.004** (0.002)
Age of respondents	0.028*** (0.007)	
Education of respondents		-0.124*** (0.046)
Desert Steppe	0.759*** (0.182)	1.141*** (0.407)
Sandy Steppe	1.218*** (0.189)	1.134*** (0.382)
Standard Deviations		
(Random Parameters)		
Pension		0.004 (0.001)
Loan		-0.466 (0.071)
Penalty		0.003 (0.001)
Enforcement		0.037 (0.005)
Subsidy		0.592 (0.067)
Log likelihood	-1470.48	-1197.72
Number of obs	5085	5085
LR chi2(8)	783.33	559.18
Prob> chi2	0.0000	0.0000
Pseudo R2	0.210	-
AIC	2964.96	2427.44
BIC	3043.37	2531.99

*Note: *** significant at the 1 percent level，** significant at the 5 percent level.*
Source: Table 7.2 in Bennett et al. (2020)

7.1.3 Contingent behaviour analysis

The purpose of this analysis was to examine the behavioural response of herders to alternative policy instruments and particular their response in terms of change in livestock numbers. This enabled an idea of the effectiveness of different policy instruments in reducing grazing pressure on the grasslands and fed directly into the assessment of policy alternatives outlined in Section 7.1.1and Table 1*.*

This section is a modified extract from Bennett et al. (2020) with further details also provided in Li and Bennett (2019).

Asking respondents to state their intended stock management under various combinations of policy initiatives set out in the Choice Modelling choice sets provides the data necessary to estimate a relationship between stocking rates and policy instrument levels. The number of sheep equivalents was requested along with the amount of land leased in or out. Combined with initially collected data on the area grazed and current stock numbers, this information provided the necessary data for the calculation of a stocking rate dependent variable. The two dependent variables were then regressed against the policy attributes as presented in the choice sets. In addition, socio-economic characteristics of the respondent herders were introduced as independent variables. The results of these analyses are presented in Table 5.

A clear result from the Inner Mongolian analysis is that two policy instruments, loan length and the reward balance payment, do not have a significant influence on herders' stocking rate decisions. The ineffectiveness of the payment policy is consistent with evidence that the current policy regime, which has the reward balance payment scheme as its main measure, has not achieved its intended goal. In contrast, increasing pensions, enforcement and punishment are all effective at reducing stocking rate intentions.

Table 6. Contingent Behaviour model of stocking rate (SE/ha) for Inner Mongolia

Variable	Coefficient
Policies	
Pension *(1000CNY/month)*	-0.106***
Loan *(years)*	-0.008
Enforcement *(per cent probability)*	-0.002***
Punishment *(1000CNY/excess sheep)*	-0.164***
Payment *(1000CNY/mu)*	-5.531
Constant	1.184***
Socio-economic	
Contracted area *(100 ha)*	-0.031***
Rented area *(100 ha)*	0.012***
Land used for hay *(100ha)*	-0.039***
Age	-0.006***
Household size	0.028***
Ethnicity	0.138***
Years of education	0.011***
Desert steppe	-0.073**
Sandy steppe	0.693***
Number of obs	3590
Prob>chi2	0.0000
AIC	7251.864
BIC	7344.653

*Note: **, *** significant at the 5 percent and 1 percent levels, respectively.*
Source: Table 7.6 in Bennett et al. (2020)

7.1.4 Urban resident valuations of grassland amenity

The purpose of this analysis was to identify the value urban residents placed on incremental changes to different grassland attributes or environmental services provided by the grasslands (such as a reduction in dust emissions). This was a crucial step in estimating the environmental benefits of alternative policies aimed at reducing grazing pressures.

This section is a modified extract from Bennett et al. (2020) with further details also provided in Li and Bennett (2019).

Selecting the non-marketed environmental goods and services that are impacted by grassland condition and that are of value to people living in regional urban areas involved discussions with ecologists, policy advisers and a sample of residents of Hohhot. For the residents of Hohhot, the goods and services selected to become the attributes in a Choice Modelling application were:

1. Landscape appearance (depicted using photographs of grasslands with varying levels of ground cover);
2. Herder culture (measured by the average age of herders); and
3. Sandstorms (measured by the number of sandstorms experienced per annum).

The payment vehicle included in the Choice Modelling choice sets to allow for the estimation of monetary values for the other non-monetary attributes was an increase in the household electricity bill. This was selected because of its wide coverage across the population.

Table 7. Conditional logit and random parameter logit model results: Hohhot

Variables	Conditional logit Coefficient	Random parameter logit Coefficient	Standard Deviation
Attributes			
Landscape 2[a]	0.2860***	0.4482***	-0.4531*
Landscape 3	0.7932***	1.3520***	-0.8811***
Landscape 4	1.3136***	2.4128***	2.8103***
Culture	0.1249***	0.1247***	0.1421***
Sandstorm	-0.0811***	-0.1218***	0.3494***
asc	-2.2668***	-1.2741	
cost	-0.0039***	-0.0027*	
Socio-economic			
age	-0.0042	-0.0048	
gender	-0.2914**	-0.2801	
education	0.1199***	0.1299***	
ethnic	-0.0796	-0.2192	
years	0.0103	0.0121	
Income[b]	0.1153*	0.0232	
Observations	8,352	8,352	
Log-likelihood	-2442.9079	-2247.6414	
Prob>chi2	0	0	
Pseudo R2	0.2013	-	
AIC	4911.816	4531.283	
BIC	5003.209	4657.827	

Notes: *** p<0.01, ** p<0.05, * p<0.1.
[a] The landscape attribute was coded as a sequence of dummy variables, with landscape at its projected future condition without changed management, acting as the base level.
[b] Income was transformed into logarithm.
Source: Table 7.9 in Bennett et al. (2020)

The data collected were analysed using conditional and then random parameter logit models. The probability of choosing an alternative was explained using these models in terms of the attributes displayed in the choice sets and the respondents' socio economic characteristics. The estimated models are displayed in Table 6. In both sets of models, the RPL model is preferred given the highly significant standard deviations associated with the distributions of the attribute coefficients. In both RPL models, all attributes have the expected signs and are significant except for the culture attributes. In the Mongolian case, culture (measured as the percentage of herders in the population) was insignificant. In the Hohhot case, the culture attribute (measured as the average age of herders, under the hypothesis that the older the herder population the more likely that traditions will be lost over time) is significant and positive, contrary to expectations.

The frequency of sandstorms attribute was significant and positively signed in both models. This is the attribute that is most closely connected to the bio-physical modelling that predicts the outcomes of alternative policies. The willingness to pay for a decrease in the frequency of dust storms by one per annum is estimated by dividing the coefficient of the sandstorm attribute by the cost attribute coefficient. In the case of Hohhot, that willingness to pay (on average per household per annum) is equal to CNY45.

7.1.5 Transaction cost analysis

The purpose of this analysis was to estimate the administrative/resource costs of implementing the alternative grassland policies which is a critical element of determining the net social benefits of the alternative policies.

Table 7 to Table 9 present overview results of the transaction cost analysis. The results highlight: a) the magnitude of total transaction costs under current GESAS schemes; (b) the change in transaction costs under alternative grassland policies; (c) the decomposition of the transaction costs by category of costs; and (d) the incidence of the transaction costs at different administrative levels.

Table 8. Transaction costs associated with current grassland policy settings

	Current policies			Alternative policies		
	League	Banner	Sumu	League	Banner	Sumu
	--Transaction costs (CNY thousand) --			*--Transaction costs CNY thousand (% change in transaction costs from current to alternative policies) --*		
Average of surveyed administrative units[a]						
Enactment	170	123	0	263 (55)	280 (128)	0 (0)
Implementation	137	122	77	310 (126)	197 (61)	133 (73)
Enforcement	8,877	1,443	392	10,257 (16)	3,740 (159)	1,460 (272)
Remote technology	137	350	0	21,973 (15,938)	1,707 (388)	0 (0)
Total	9,320	2,038	468	32,803 (252)	5,923 (191)	1,593 (240)
Total administrative units[b]	*--Transaction costs (CNY million)--*			*--Transaction costs (CNY million)--*		
Enactment	2.04	9.00	0.00	3.16	20.44	0.00
Implementation	1.64	8.88	46.38	3.72	14.36	80.67
Enforcement	106.52	105.36	236.96	123.08	273.02	883.30
Remote technology	1.64	25.55	0.00	263.68	124.59	0.00
Total	111.84	148.80	283.34	393.64	432.40	963.97

[a] Average of the 3 city/leagues (Xilingol League, Ordos and Ulanqab), 6 banners (Xilinhot, Dongwu, Xiwu, Siziwang, Wushen and Hangjin) and 6 sumus (Baoligen, Wuliyasitai, Haoletugaole, Chaganbilige, Galutu and Xini) in the survey.
[b] Scaled up costs to 12 leagues, 73 banners and 605 sumus in Inner Mongolia Autonomous Region.

Table 7 reports transaction costs of the current schemes for the average of administrative units interviewed of CNY9.32 million at the city/league level, CNY2.04 million at the banner level, and CNY0.46 million at the sumu level. The shift to alternative policies would result in a marked increase in transaction costs (right hand side of Table 7) with transaction costs doubling at the banner and sumu level and by around 2.5 times at the city/league level. The second part of Table 7 scales the average transaction costs from the surveyed cities/leagues, banners and sumus to all relevant pastoral cities/leagues, banners and sumus in Inner Mongolia. The different characteristics of each of the administrative units means that transaction costs will vary between each other and so the aggregate or scaled up figures only provide an indicator of the aggregate transaction costs for the whole autonomous region. Under the current policy, estimated transaction costs are CNY543.98 million for Inner Mongolia while these costs increase to CNY1790.01million under the alternative policies.

Table 8 focusses attention on the breakdown of transaction costs by type. The overwhelming majority of costs associated with the current policies at the city/league (95%), banner (71%) level and sumu (83.6%) are in enforcement highlighting the importance of enforcement costs in considering changes to the policy. Much of the enforcement costs relate to monitoring and involve considerable resources for each of the administrative levels. Implementation costs are also evident at the sumu level and at a relatively higher level of importance (16.4%). Some cities/leagues have adopted drone technology as well as manual monitoring to monitor grassland conditions. The manual monitoring involves considerable costs and resources in vehicle costs, fuel and oil and staff. Cities/leagues such as Xilinhot currently apply remote sensing for grassland monitoring and plan to keep investing public funds on new monitoring technology for the future and so remote technology costs are relatively higher in Xilinhot than in other leagues.

The right hand side of Table 8 highlights the relative importance of the transaction cost categories changes under the alternative policy. In particular, remote technology takes on a pre-eminent role in the alternative policies with this category accounting for two-thirds of the transaction costs and enforcement accounting for the remaining third. In the current policy settings, remote technology costs were focussed mainly at the banner level and while they continue to increase in relative importance at this level (from 17% to 29% of total transaction costs), enforcement costs remain the major category. There are also substantial changes at the sumu level. Under the alternative policies, there is a more substantial role for enforcement at the grass roots (sumu) level and this is reflected in over 91% of the transaction costs being in this category whereas implement costs markedly decrease with most of these roles being done by the higher administrative levels.

Table 9. Change in transaction costs under alternative grassland policies

	Percentage of total transaction costs by category: Current policies			Percentage of total transaction costs by category: Alternative policies		
	League[a]	Banner[b]	Sumu[c]	League[a]	Banner[b]	Sumu[c]
		-- % --			-- % --	
Enactment	1.8	6.0	0	0.8	4.7	0
Implementation	1.5	6.0	16.4	0.9	3.3	8.4
Enforcement	95.2	70.8	83.6	31.3	63.1	91.6
Remote technology	1.5	17.2	0	67.0	28.8	0
Total	100	100	100	100	100	100

[a] Average of Xilingol league and Ordos and Ulanqab cities.
[b] Average of Xilinhot, Dongwu, Xiwu, Siziwang, Wushen and Hangjin banners.
[c] Average of Baoligen, Wuliyasitai, Haoletugaole, Chaganbilige, Galutu and Xini sumus.

Table 8 highlights the incidence of the transaction costs at the different administrative levels for both the current and alternative policy settings. Under both policy settings, transaction costs for the average of banners and average of sumus in the survey are much lower than for the average of leagues in the survey (around one-fifth and one-twentieth respectively). Of course there are a much larger number of sumus and banners than leagues in grassland areas and so the majority of the transaction costs may still be incurred at the lower administrative levels. However, on an individual basis, individual cities/leagues have a much larger role and burden than individual banners and sumus, and have much larger resources to cover the transaction costs compared with banners and sumus. Indeed in many cases most of the resource costs will ultimately be covered by funding from the city/league level. The right hand side of Table 9 highlights how the policy change has impacted on the incidence of the transaction costs. More of the transaction costs for individual banners, relative to the individual city/leagues they report to, occur in the fields of enactment and enforcement costs while they have a much reduced relative role in remote technology. Much of the enforcement costs relate to monitoring and while the cities/leagues now have a much larger role in remote technology, the banners and sumus still have to employ staff and other resources to do ground monitoring. For individual sumus, their role and transaction costs in enforcement, relative to the individual leagues, has risen while their implementation cost importance reduced.

Table 10. Incidence of transaction costs at different administrative levels[a]

	Current policies		Alternative policies	
	Banner	Sumu	Banner	Sumu
	% of League transaction costs (%)		*% of League transaction costs (%)*	
Enactment	73	0	106	0
Implementation	89	56	63	43
Enforcement	16	4	36	14
Remote technology	256	0	8	0
Total	22	5	18	5

[a] The figures in the table are the transaction costs by category for the average banner (Xilinhot, Dongwu, Xiwu, Siziwang, Wushen and Hangjin) and average sumu (Baoligen, Wuliyasitai, Haoletugaole, Chaganbilige, Galutu and Xini) in the survey as a percentage of the transaction costs for the average of city/leagues (Xilingol League, Ordos and Ulanqab) in the survey.

7.1.6 Reward balance payments under uncertainty

The purpose of this analysis was to examine the impact of uncertainty and different states of nature on the analysis and discussion of policies. In addition, the analysis had a close association with Objective 1.8 of “Relate opportunity costs to household characteristics, production and market environment, and grassland type” and Objective 1.9 of “Design more efficient incentive schemes and payment metrics based on assessment of marginal benefits and marginal opportunity costs”. In this instance, the reward balance payments under the GESAS scheme were compared with the opportunity costs to herders of complying with the GESAS stocking rates under different states of nature so as to identify how compliance incentive may be impacted under different states of nature.

Cumulative distribution functions (CDFs) of herders’ annual household cash flow under stocking rates within GESAS and outside GESAS appear in Figure 5. In up to 10% of years, no additional payment is needed to ensure compliance (Figure 5a). This is due to the sale of livestock capital as herders comply with the reduced stocking rates under GESAS, but also because of the higher production under low stocking rates. For most years (88% of the time), herder cash flows of operating outside GESAS greatly exceed the cash flows of operating within GESAS, increasing the risk of non-compliance. Figure 4b indicates that in just over 90% of years, that under longer-term steady state conditions, herder household cash flow exceeds the cash flow inclusive of payments being offered within GESAS (CNY25.5/ha for the desert steppe). Figure 5b also indicates that only in around 1.5% of years are there no cash flow disadvantages from herders reducing their stocking rate, which represents the small gains made from improvements in per animal production under lower stocking rates. This is also reflected in the slope and spread of the Reduced Stocking Rate CDF, which is steeper with a reduced range of outcomes, hence a more resilient system with less risk, albeit with lower overall cash flows. The difference between the Reduced stocking rate CDF and Outside GESAS CDF of Annual Cash Flows at different discrete states of nature represents the herder’s household opportunity cost for a reduced stocking rate, or in equivalence, the minimum payment required for herders to comply with GESAS under these states of nature.

a) 10-yr aggregated data b) Final year data

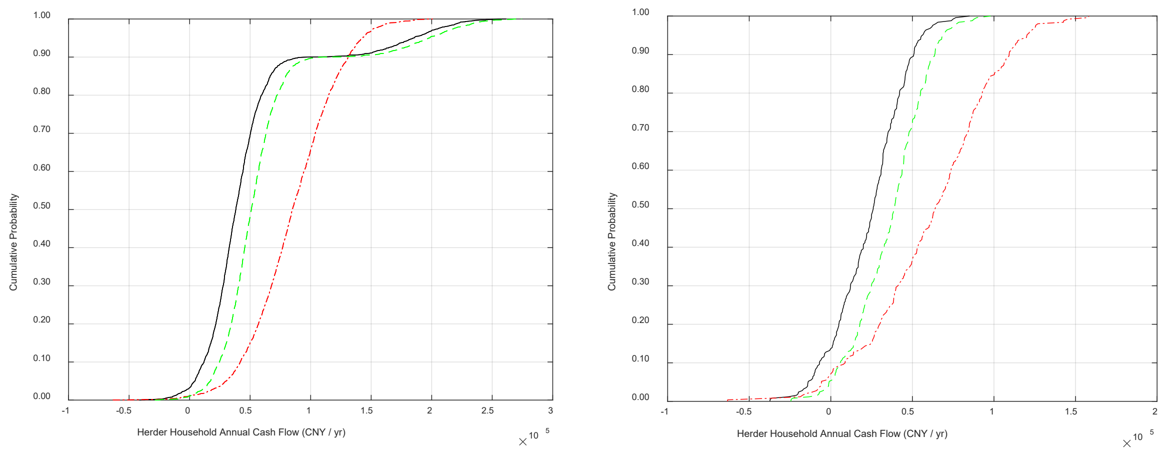

Figure 8. Cumulative Distribution Functions for herder's annual cash flows under reduced stocking rates with no subsidy (–), within GESAS (– –) and outside of GESAS (– ·) in: a) all 10-years of the simulation period; and b) only the final year of the simulation period (Year 10)

Source: Behrendt (under review a)

Using elemental wise pairing of LP, WP and GS ratio, the opportunity costs under all modelled discrete states of nature are calculated. Figure 6 shows the cumulative distribution function for all calculations of opportunity cost for both all years of the simulation period and for the final year (steady state) of the simulation horizon. Corresponding to the findings in Figure 5, Figure 6 indicates that for all years simulated, around 10% of years herders incur no opportunity costs, while in around 89% of years the opportunity cost exceeds the current level of GESAS reward balance payment. If only the final year of the simulation period is considered then in only 1.5% of years are there no opportunity costs for herders (and so where they would benefit from reducing stocking rates) while for 92% of years the opportunity costs greatly exceed the GESAS reward balance payment offered.

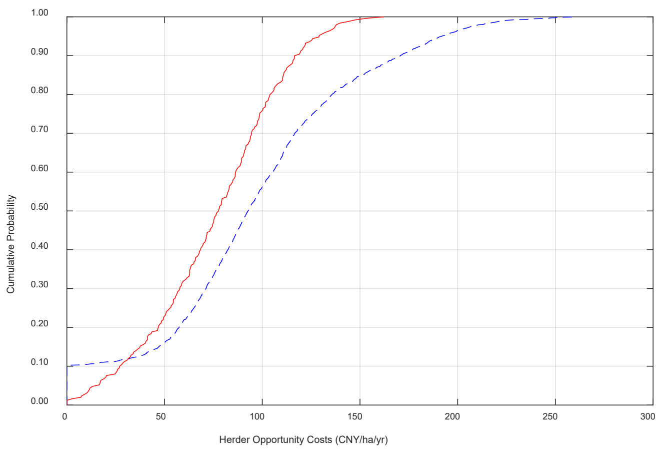

Figure 9. Cumulative Distribution Functions for herder's annual opportunity costs of a stocking rate reduction over the entire 10-year simulation period (– –) and under more steady state conditions (–) (final year of simulation period).
Source: Behrendt (under review a)

Due to the significant variation in these key output variables of importance to policy makers, it is critical for policy and livestock and grazing strategy design to define and understand the distribution of outcomes rather than rely on average expected outcomes. This includes understanding the distribution of environmental outcomes associated with the different stocking rates and how these link with grassland policy. The modelling indicates that there is a proportion of years under different states of nature in which no incentive is required for herders to voluntarily or independently adjust stocking rates. These are predominantly the result of herders selling surplus animals to meet requirements for stocking rate adjustments, but also due to improved per animal performance under reduced stocking rates as a result of improved grassland condition and nutrition. Additionally, there are a significant proportion of years, or states of nature, where a much larger incentive (RB payment) would be needed to offset opportunity costs of herders for reducing stocking rates and meeting GESAS requirements. In states of nature where no incentive is required (low prices and below average growing seasons), herder incomes are likely to be very low, whereas states of nature with high opportunity costs (requiring greater incentives for compliance) are associated with periods of much higher incomes. These findings highlight the need to unbundle the environmental incentive and welfare components of GESAS if the twin objectives of reversing ongoing grassland degradation and improving herders household incomes are to be achieved. The unbundling would also serve the purpose of herders perceiving the payment as an ecocompensation payment for an environmental service rather than as a welfare entitlement (Zhang J. et al., 2019).

The developed framework and findings from this study suggest that it should be possible to design more efficient programs and policies more closely aligned with weather and market states. Additionally, it provides policy analysts and researchers with better information on the importance of RB program payments to herder household incomes. It also provides insight into the expected gains in environmental services provided by herders which comply with policies, and thus provide the opportunity to understand the benefits and costs of the ecocompensation policies at farm and societal levels.

A challenge in implementing more dynamic payments for environmental services policy is in relating thresholds to objective and widely understood weather and market states. In addition, as this modelling study relates only to a single type of desert steppe household, there is a need to identify, define and model an appropriate number of representative herder households given the heterogeneity of herders and biomes across the grasslands of IMAR. There is also the additional policy challenge in delivering such a program consistently over a number of years to ensure its revenue neutrality, especially in situations where policy makers will be under pressure to change the policy (increase the payments) when conditions are in poor states of nature.

7.1.7 Biophysical research

Results from the biophysical studies of the grassland for IMAR have been published in Kemp (2020a,c), particularly for the desert and typical steppes (Wang et al., 2020, Zhang et al., 2020). These studies were used to parameterise the SGM while other parts of the data collected were used to check if the SGM predictions aligned with actual field data. The main outcomes for grassland management will be summarised here.

In IMAR it was shown that the current stocking rates needed to be halved to then maintain the plant species composition in a desirable state, and to maintain the herbage mass and ground cover at a level that would reduce soil erosion to what were historical rates. An important finding was that of the forage grown each summer, the sustainable consumption rate by livestock was only 20% for the typical steppe and 10% for the desert steppe, reflecting the lower productivity of the desert steppe. Higher rates of consumption resulted in the decline of desirable plant species with increasing bare ground and wind erosion. Herders would typically exceed these consumption rates by several factors. In the literature, authors often quote a utilisation figure based on the differences between grazed and ungrazed areas. A utilisation figure is typically about twice that actually consumed by livestock as it includes the effects of many other loss factors *e.g.* fungi, insects, leaf age etc.

While the sustainable consumption rates varied with grassland type, the optimum herbage mass over summer that aligned with these consumption rates, was 0.5 t dry matter per hectare for both grassland types. That meant over summer grazing should be managed to maintain an average of 0.5 t DM/ha, as that is associated with better animal production and grassland condition. This provides herders and officials with a readily measurable parameter for managing the grasslands sustainably. Herbage mass can be assessed using rapid techniques and remote sensing. This criterion was built into the SGM to find the optimal set of grassland management techniques (Behrendt et al. 2020c). Using herbage mass as the main criteria for management is easier for herders and officials than trying to define exact stocking rates or do detailed assessments of plant species composition. Other analyses showed (Kemp et al., 2020b) that the environmental services provided by grasslands that were identified by herders, were all associated with the herbage mass of the grassland *e.g.* plant species composition, soil erosion, clean water delivery *etc.* As the grasslands across IMAR and Mongolia have many similarities in plant species, productivity, precipitation, temperatures *etc.*, the in-depth work in IMAR meant that we could expect similar effects in Mongolia. The SGM was used to estimate these effects.

7.1.8 Transfer of grassland use rights

Grasslands in China are owned by the state or collective with use rights to the grasslands contracted out to herder households. In the absence of a land market and clearly defined property rights, the transfer of use rights including rental of grassland use rights has become a critical element of management of these grasslands. The purpose of this section is to report on two related project analyses that shed light on the transfer of grassland. In the first analysis reported in Qiao et al. (2018), an ex-post statistical analysis of herders in the project areas revealed the impact of grassland rental on herder stocking rates on their total area of land (contracted plus rented) as well as the factors influencing the rental of grassland use rights in these areas. In the second analysis which was part of the choice modelling survey of herder households and associated contingent valuation analysis discussed in Section 7.1.2 and reported in Li and Bennett (2019), herder intentions on stock numbers and grassland rental were elicited for different policy scenarios. Together these analyses reveal powerful policy insights for grassland management and transfer of use rights in these areas.

A panel survey of herder households in key study grassland areas of Inner Mongolia revealed significant variation among herder households which, in turn, influences their decisions relating to rental land as shown in Table 10. Around one-third of the households rented in land while one-twelfth rented out land raising the scope for renting as a means of grassland management. Despite the significant scope, the rental of the grassland is still constrained or rudimentary in nature. Much of the rental is between family members or within the village with exchanges not necessarily reflecting the true marginal valuations of either party. From a policy perspective, one concern is whether renters would conserve grassland resources in the same way as owners of the grassland user rights, especially for the year-by-year, repeat, oral agreements. Improving the formal grassland rental system so that the property rights of renters become clearer may be warranted on the basis that this would promote longer-term renting and reduce incentives to degrade the rented grassland.

The empirical analysis revealed the importance of the grassland rental system in that renting grassland facilitates a level of specialisation. As a group, households renting in land had less own grassland area, more livestock numbers, more intensive production systems and limited off-farm income. Their decision was independent of the type of grassland or the subsidies they received. Conversely, households were more likely to rent out their grassland if some of their land was subject to grazing bans, if they had fewer livestock and if they were on the typical steppe where rental prices were higher.

Furthermore, the empirical analysis revealed that not only has grassland rental facilitated specialisation, it has also reduced overall grazing pressures. The combined stocking rates on their own contracted plus rented grassland for households renting in land were lower than households not renting land. Thus improvements in land transfer may improve livelihoods and grazing pressures. Nevertheless they do not provide a panacea for grassland degradation and need to be considered alongside stronger incentives, enforcement and policy settings to restrict grazing pressures. Factors such as off-farm income were shown to be important in both household livelihoods and decision on rentals. But unlike the case of agricultural households in eastern areas of China, a large proportion of herder households do not have the same level of off-farm income opportunities and so this limits the extent to which it can become part of an overall household management strategy. Despite the significant structural and demographic changes in the pastoral region, facilitating off-farm opportunities in a challenging context may improve the management options for herders remaining in the pastoral area.

The contingent behaviour analysis reported in Li and Bennett (2019) highlighted that while grassland rental offers potential for herders to access more land and adjust their overall stocking rates towards desired stocking levels, care needs to be exercised in monitoring behaviour on the rental land as they suggested that herders may increase their stocking rates on the rented land. This highlights the need for a package of measures that might include not only improved grassland circulation but also monitoring of livestock numbers on the different types of grassland.

Table 11. Descriptive statistics of sample households by rental

	All households		No rental households		Rent in households		Rent out households	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Continuous variables [a]								
Age (years)	48.3	11.1	48.6	11.4	47.2	10.7	49.4	10.9
Education (years)	7.6	3.7	7.3	3.8	8.0	3.5	8.6	2.9
Family size (person)	3.6	1.3	3.5	1.28	3.8	1.3	3.2	0.9
Own grassland (mu)	2908	3454	2987	3653	2873	3338	2429	1896
Rent area (mu)	NA[b]	NA	NA	NA	2901	3620	2188	1954
Total grassland (mu)	3710	4768	2987	3653	5774	6146	241	471
Off farm income (thousand CNY)	16.8	45.1	16.2	51.1	18.6	36.4	15.3	16.3
Livestock numbers (SE)	296	494	234.3	187.1	456.9	803.3	80.0	160.5
Stocking rate (mu/SE)	14.0	12.0	13.4	11.8	15.6	12.5	3.3	0.9
Rent price (CNY/mu)	7.7	5.43	NA	NA	8.1	5.6	5.8	4.3

Source: Based on Qiao et al. (2019), Table 3.

7.1.9 *GESAS impacts and herder satisfaction*

GESAS (Grassland Ecological Subsidy and Award Scheme) is the main grassland policy instrument in Inner Mongolia and the base for the comparison of alternative policies in the project. One of the project collaborators had a large panel data survey of herders in the project study areas that included herders' assessment of satisfaction with GESAS and was done at the start (2011), middle (2013) and end (2016) of the first round of GESAS. Thus an ex-post analysis of this useful set of panel data was done using structural equation modelling to examine the factors impacting herders' satisfaction of GESAS. This provided useful context and additional information to the herder behavioural responses identified elsewhere in the project.

As described in Section 5.2.2, a Structural Equation Modelling (SEM) approach was applied to evaluate the impacts of GESAS on livestock practices, herder incomes and employment, and overall herder satisfaction in Inner Mongolia.

The findings revealed that: a) The intensive use of on-farm inputs mediated the effects of lower stocking-rate under the scheme on on-farm income. GESAS imposed grazing restrictions or stocking rate limits forces herders to consider more intensive supplementary feeding systems, resulting in cost increases. However, the per unit rise in livestock costs was less than the rise in ruminant livestock product prices during the period between 2010 and 2015. Thus more intensively feeding the remaining livestock in combination with the GESAS payments resulted in an increase in incomes; b) the increased incomes were not significant enough for own labour to be diverted to the more intensive livestock production and away from off-farm labour, but the off-farm income did change less in the households with more subsidies. In turn, households with less subsidies had to increase their off-farm income under the pressures of rising family expenditures; c) Despite the transfer payments and improved on-farm income under GESAS, a certain level of dissatisfaction was indicated as the compensation was insufficient to cover the extra effort expended by herders and could not meet the livelihood expectations of most herders. Herders were dissatisfied overall based on the conditions imposed as part of the transfer payments and the extra effort required to achieve the small income changes experienced over the previous five years of the program.

A follow-on study may be needed to understand whether the consequences of the second round GESAS (2015-2020) and its impact on households' livelihoods are similar to the findings of the first round GESAS (2010-2015). There are a number of reasons why different responses and findings may emerge. First, an alternative set of feed and ruminant price market developments may not necessarily have resulted in the same outcome on on-farm income. Second, whether the own labour was kept in intensive feeding or freed up for off-farm employment may only have become evident over a longer time frame and so may have influenced households' perceptions and satisfaction of household's satisfaction to GESAS. Suggestions on what further study may be needed are outlined in the recommendations in Section 9.2.

7.1.10 *Institutions*

This section is a modified extract from Addison et al. (2020a).

Formal institutions

To help frame what is a complex institutional context, four different levels of formal institutions settings are discussed for Inner Mongolia. These levels are edicts, legislation, regulations and standards, and programs based on a framework outlined in Brown et al. (2008, Chapter 4). Edicts set direction for grassland management, legislation sets the legal framework for grassland use and direct the development of national and provincial regulations and standards on grassland management. Legislation and regulations refine details and provide mechanisms for funding to implement major grassland conservation programs including grassland management incentives.

Government edicts set the direction of national grassland management in China. The key edicts relating to grasslands are: Several Opinions of the State Council on Strengthening Grassland Conservation and Construction[7] (Guofa [2002] No. 19); and National Grassland Conservation, Construction, and Utilization Master Plan[8] (Nongfa [2007] No.11). These opinions issued by the State Council lay out the main priorities and measures for grassland management. They emphasize establishment of grassland conservation mechanisms including conservation of "basic grassland" or grassland that cannot be converted to other uses, implementation of forage–livestock balance and promotion of rotational grazing as well as seasonal and full grazing restrictions. The edicts emphasize: increased investment in basic infrastructure including fencing, water points, livestock shelter, and forage storage; greater investment in rehabilitation of degraded grasslands; and support for grazing bans. The grassland plan issued by the Ministry of Agriculture specifies objectives, priorities, key programs, and targets for each region's grassland conservation and use by 2020. The general aims sought by 2020 are to achieve 'green grasslands, strong grassland husbandry, and rich farmers and herdsmen' through implementation of a series of measures such as

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[7] *Government of the PRC, State Council (2002), Several Opinions of the State Council On Strengthening Grassland Conservation and Construction (Guofa [2002] No. 19), Beijing.*
[8] *Government of the PRC, Ministry of Agriculture (2007), National Grassland Conservation, Construction, and Utilization Master Plan, Beijing.*

fencing, grassland improvement, artificial grassland construction, scientific breeding, livestock improvement, grazing bans and rotational grazing.

Although opinions and plans play a crucial role in directing grassland institutions, four main laws—the Grassland Law, Prevention and Control of Desertification Law, Agricultural Law and Livestock Law—provide the legal basis for government edicts. The Grassland Law[9] was first enacted in 1985 and amended in 2002. The 2002 amendments specified government responsibilities in relation to planning, use, and conservation of grasslands. The amendments introduced a new basis for grassland tenure clarifying that ownership of grasslands lies with the state, encouraged the contracting of use rights to herders and promoted ways to ensure sustainable use of contracted grasslands. The Law of the People's Republic of China on Prevention and Control of Desertification[10]—the world's first integrated law dedicated to combating desertification—provides a legal framework to support implementation of China's National Action Programme to Combat Desertification and is the legal basis for establishing a system of incentives to encourage land rehabilitation by resource users. According to China's 2017 report to the United Nations Convention to Combat Desertification, the target is to achieve zero growth in desertified land by 2021. The Agricultural Law and Livestock Law are not specific to grasslands but, as highlighted in Brown et al. (2008, Section 4.2), impact grassland cultivation and livestock production.

Based notionally on economic efficiency with social justice, China's new rural "separating three property rights (STPR)" land reform was implemented in agriculture from 2003 and grasslands from 2007 as a trade-off between ensuring rural migrant workers' social security and meeting the demands of developing a modern intensified agriculture. This land reform does not affect public ownership of rural land but divides households' contractual use rights into two parts—non-tradable household contractual rights and tradable rural land use rights—leaving rural people free to trade their household-contracted land use rights. Li et al. (2018) highlighted some strong negative effects of trading grassland use rights including predatory land use and grassland degradation as land tenants tend to prefer short-term gains to long-term sustainable productivity from their rented grassland. Land tenants are not eligible for subsidies from grassland authorities and so the current grassland eco-compensation subsides lose their effectiveness in adjusting the behaviour of actual managers of the rented grasslands. Conversely Qiao et al. (2018) in a survey and analysis of grassland rental in Inner Mongolia found that herder households who rented in grassland often doubled their grassland areas and stocked at a rate less than households who did not rent in grassland. The studies highlight the need for careful design of the land reform measures to avoid any adverse or perverse incentives that might offset any gains from structural adjustment of herd and grazing structures.

The impact of legislation depends on the appropriateness of the underlying regulations and standards as these form the technical basis and incentives for interpretation and enforcement of laws. Regulations and standards are determined by specific institutions often drawing on research by specialized agencies. For instance, the Grassland Law specifies that the State manages grassland utilization according to the grassland carrying capacity needed to achieve a grassland-livestock balance. Under this framework, livestock stocking rates are based on the availability of grass and feed resources or, alternatively, feed resources are to be developed to meet livestock consumption needs. A national

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[9] *Government of the PRC (2002), The Grassland Law of the People's Republic of China, Beijing.*

[10] *Government of the PRC (2002), Law of the People's Republic of China on Prevention and Control of Desertification, Beijing.*

standard[11] for determining carrying capacity was issued in 2002 by the Ministry of Agriculture while the Grassland-livestock Balance Management Regulation[12] governing the determination of carrying capacity was issued in 2005 by Ministerial Decree. These two standards provide the central parameters of the 2011 Grassland Ecology Conservation Subsidy and Reward Scheme[13] that, as highlighted below, is the primary grassland policy instrument. A number of provinces and autonomous regions have issued local management regulations and measures to implement the legislation. Local grassland implementation measures or management regulations specify regulations for ownership, planning, construction, use, protection, supervision and inspection, and legal liability of grasslands. Several provinces have introduced regulations governing monitoring, implementation, and management of grassland–livestock balance. In some provinces, the regulations have only been issued relatively recently since 2011, and implementation of the grassland–livestock balance schemes is an ongoing task.

Guided by the legislation, regulations and standards, some major national programs for which the State provides financial subsidies include Beijing-Tianjin Sandstorm Source Control Program[14], the Grassland Retirement Program[15] and the Grassland Ecology Conservation Subsidy and Award Scheme (GESAS). The Beijing-Tianjin Sandstorm Source Control Program was first formulated for sandstorm control in 2000 by the Ministry of Water Resources, the State Forestry Administration, the Ministry of Agriculture, and five provinces, municipalities and autonomous regions (Beijing, Tianjin, Hebei, Shanxi, and IMAR). This program set out objectives, investments, and subsidy mechanisms to be provided by the central government. Subsidies were paid to farmers and herders for pasture construction, grass seeding, fencing and livestock shelters. The first wave of the Beijing-Tianjin Sandstorm Source Control Program was carried out from 2001 to 2010 while the second wave is from 2013 to 2022. Initially proposed in 2003, the Grassland Retirement Program was formally issued by the Office for Western Development of the State Council in 2005. It targets degraded grassland and provides subsidies in cash and grain for participating households in areas with full grazing bans, seasonal bans or rotational bans. Building on the Grassland Retirement Program, GESAS was piloted in Tibet Autonomous Region in 2009 but scaled up in 2011 to pastoral and agro-pastoral areas of eight provinces and autonomous regions (Gansu, Qinghai, Sichuan, Yunnan, IMAR, Tibet, Ningxia and Xinjiang). The objectives of this scheme are to prevent grassland degradation, accelerate industrial transformation of animal husbandry, and ensure income for rural herders. The subsidies provided by the scheme are to compensate for grazing bans and provide funds for forage seeds and production materials while 'rewards' are paid for maintaining a grassland–livestock balance. The first wave of the GESAS was from 2011 to 2015 while the second wave from 2016 to 2020 is under way. In contrast to previous national schemes, provinces have more autonomy in implementing the scheme resulting in diversity in subsidy type and levels across the country taking into account carrying capacity, contribution to ecosystem improvement, grassland area, population, and social stability.

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11 Government of the PRC, Ministry of Agriculture (MOA). 2002. Calculation of Reasonable Carrying Capacity for Natural Grasslands: Agriculture Sector Standard for the People's Republic of China. Beijing.

12 Government of the PRC, MOA. 2005. The Forage–Livestock Balance Management Method. Ministerial Decree (2005) No. 48. Beijing.

13 Government of the PRC, MOA. 2011. Implementation Guidance on Grassland Ecology Conservation Subsidy and Reward Mechanism. Beijing.

14 Government of the PRC, State Forestry Administration. 2000. Plan for Beijing–Tianjin Sandstorm Source Control Program (2001–2010). Beijing.

15 Government of the PRC, State Council, Office for Western Development. 2005. Notification of "Suggestions on Policy and Measures for Further Improvement of the Grassland Retirement Program" (Guoxiban Nong [2005] No.15). Beijing.

Formal institutions not directly related to grassland access but that influence herder behaviour

China Farmers' Professional Cooperative Law

Guided by national government edict in Document No. 1[16] , the Farmers' Professional Cooperative Law was enacted in October 2007 requiring all provincial and local level governments to guide and support farmers and herders to form economic cooperative organizations. It not only recognizes the legal corporation status of farmers' professional cooperatives but also provides assistance for cooperative development including establishing credit, financial, taxation and registration systems. Given the small scale, dispersed and decentralised nature of herder households, professional cooperatives have been argued by political leaders and some scholars as a way of securing grassland use rights and promoting sustainable grassland use. In a case study from Inner Mongolia, Tang and Gavin (2015) argued that the Farmers' Professional Cooperative Law had re-established herders' rights to self-organize. Along with assistance from external organizations, they argued this promoted revitalization of traditional communal herding practices. This included broader participation and collective choice along with re-establishment of natural resource management more congruent with local ecological conditions such as communal grazing with seasonal rotation that may overcome problems with management on the small individual contracted areas. However, other scholars have criticized rural cooperatives for creating a 'free-rider' problem and 'fake' cooperatives. Brown et al. (2008, Section 5.2) noted that many less successful rural cooperatives in pastoral areas have been organised from the top-down (government orchestrated) rather than bottom-up (organically driven by households).

New Rural Social Endowment Insurance

In response to aging of China's rural population along with rapid social changes in rural China, the State Council issued an edict on the Guidance of Piloting New-type Rural Social Endowment Insurance Projects which led to the New Rural Social Pension Program being introduced in September 2009. Previously the elderly in rural China relied on filial support. However, the rise in off-farm employment, rural-to-urban migration as well as land circulation changed the nature of the extended family in rural China often leaving the elderly without traditional family support enjoyed by previous generations (Zhao et al. 2016). The New Rural Social Pension Program targets all rural residents over the age of 16 not enrolled in school or urban pension schemes. It is funded largely by central and local governments with rural residents paying an individual premium with five available choices from CNY100 to 500 per year. After a minimum of 15 payment years and reaching the age of 60, pensioners receive a monthly payment (CNY55/month in 2018) from the central government and also a monthly payment from their accumulated individual accounts. Li et al. (2018) evaluated the performance of the New Rural Society Endowment Insurance Program and argued that the program significantly improved the welfare and subjective well-being in old age with the elderly less reliant on adult children for financial support. In regard to herders and grassland condition, focus groups with herders in Inner Mongolia revealed that the current low level of pensions for herders meant that herders may stock at higher rates as they approach retirement in order to secure future incomes and that higher pensions may alter these incentives to stock at higher rates. The pension was one of the policy alternatives considered in the choice modelling analysis.

Rural credit program

Rural credit cooperatives and banks that lend to agriculture are being reformed and commercialized but agricultural lending is still mainly driven by policy. Under the slogan of

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[16] "Document No. 1" is the first policy document released every year and the most important policy "theme" put out by the Central government of China.

'solving three rural problems'[17] aimed at increasing the incomes of rural households and reducing the gap between rural and urban incomes, Chinese financial institutions have sought to innovate and increase the level of rural financial services. For instance, the China Banking Regulatory Commission issued 'Guidelines for Relaxing Access Policies for Rural Banking and Financial Institutions' in December 2006. Financial intermediaries such as village banks, finance companies, and rural mutual cooperatives were encouraged to form and were included among officially supervised financial institutions. In 2007, the China Banking Regulatory Commission issued 'Guiding Opinions for Financial Institutions Devoting Major Efforts to Developing Rural Microcredit Business'. The opinions encourage service targets extending from traditional farmers and herders to rural households with multiple business to individual commercial households and to various micro-enterprises in rural areas. The amount of loan can be increased to CNY100 000-300 000 in developed regions and CNY10 000-50 000 in underdeveloped regions while the term of the loan can be extended by financial institutions depending on circumstances such as farmers and herders' credit rating and risk level. In 2008, the China Banking Regulatory Commission and the Central Bank of China issued "Guidelines for Piloting Microcredit Companies" to commercialize microfinance aimed at improving rural finance organization and service system in rural China. With the support of these policies, rural micro-credit and households' joint guarantee loans have become the two main financial products popular among farmers and herders.

In 2015, the State Council issued a 'Guiding Opinions on Pilot Projects for the Implementation of Mortgage Loans for the Operation Right of Rural Contracted Land and Farmers' Housing Property Rights'[18] (Guofa [2015] No. 45). The guide enables the mortgaging of 'land operation rights and farmers' housing property rights' and protects farmers' rights and interests on land. In 2016, the People's Bank of China, the China Banking Regulatory Commission, the China Insurance Regulatory Commission, the Ministry of Finance and the Ministry of Agriculture issued the 'Interim Measures for the Pilot Program of the Loans Secured against the Operation Right of Rural Contracted Land'[19] (Yinfa [2016] No. 79). The interim measures specified different loan conditions for farmers who acquire land operation rights through the household contracting system compared with farmers who obtain land operation rights through land circulation. The interim measures encourage lenders to issue medium and long-term loans within the remaining operation rights use period of rural land effectively increasing the medium and long-term credit input for livestock production. Mortgage loans together with rural micro-credit and households' joint guarantee loans seek to alleviate farmers' difficulty in accessing loans in rural China. This is a step towards market-oriented rural land reform aimed at providing a cheaper way for farmers and herders to access rural finance to improve the productivity of rural land. It is also a prerequisite for large-scale circulation of rural land. However, current trials at the local level lack legal or institutional guarantees and are subject to local regulations. When a default occurs, the financial institution lacks legal support for the disposal of collateral due to property rights disputes and uncertainty of ownership. Thus effectiveness of this instrument has been questioned.

17 *"Three Rural problems" refers to rural people (farmer), rural areas, and agriculture. In Chinese, all three of these terms contain the character nong which can be translated as either "rural" or "agriculture."*
18 *Government of the PRC, State Council (2015), Guiding Opinions on Pilot Projects for the Implementation of Mortgage Loans for the Operation Right of Rural Contracted Land and Farmers' Housing Property Rights (Guofa [2015] No.45). Beijing.*
19 *People's Bank of China (2016), Interim Measures for the Pilot Program of the Loans Secured against the Operation Right of Rural Contracted Land (Yinfa [2016] No. 79).*

Informal institutions

Formal institutions in China's Inner Mongolia are far more complex and influential than those in Mongolia (Wang et al. 2013a, b; Addison 2016) but informal institutions persist. Many Inner Mongolian pastoralists continue to practice otor, a response to environmental variability more commonly associated with Mongolian pastoralism (Xie and Li 2008). In Inner Mongolia, short-distance otor consists of moving livestock within the village boundary with longer-distance otor occurring outside village boundaries. While previously otor had been arranged by village leaders, as was the case during the collective era, it is now the responsibility of individual households. Despite the costs of such moves, both short and long-term otor are frequent responses to weather-driven feed gaps, particularly from spring through autumn when livestock prices are low and the price of penning can be double that of otor.

Many persistent informal institutions blend customary norms and strategies with adaptive responses to formal institutions or are hybridised versions of informal and formal institutions or informal and market-based strategies. Some form of common grassland use in response to significant environmental variability is still evident even if in a modified form. For example, traditionally social networks and otor-makers gifted otor-recipients some livestock and worked together with otor-recipients (Li and Huntsinger 2011). These relationships have been replaced with instrumental and utilitarian relationships with rental payments made prior to the otor-maker entering the recipients' contracted grassland. This change has increased transactions costs, uncertainty and reduced drought resilience (Li and Huntsinger 2011). The devolution of responsibility of otor to individual households has reduced access to information and knowledge networks that improve relocation decision-making (Li and Huntsinger 2011). Nonetheless the practice persists due to otor's relative economic advantages in a climatically variable context.

Grassland pooling expands the area of land available to an individual herder and is used by some Inner Mongolian herders to account for spatial variability in grassland production (Li et al. 2007; Yu and Farrell 2013). Group herding arrangements, where small groups of several, often related, households pool their livestock to take care of them in rotation and where economies of scale are realised by reducing the workload and freeing up the labour force, became technically illegal after the grazing ban (see Section 2.1.3) (Yu and Farrell 2013). Thus the relative proportion of households engaged in group herding arrangements or contracting cooperatively with commercial herders fluctuates with different policy initiatives such as the shift between the grazing ban, the pilot open grazing period and suspension of this policy. Even with privatisation, significant fence construction has not occurred reflecting both the persistence of common use of the grasslands as an informal institution and the high associated costs. In areas with significant fencing, otor costs have increased as herders must be moved around them (Li and Huntsinger 2011). Although self-organising activities based upon mutual trust and long-term relationships still exist, they have been challenged by formal institutions such as the grazing ban.

Other herder responses to formal institutions have evolved, although whether these should be understood as informal institutions—like shared strategies—or simply non-compliance is debatable. Night-time grazing, 11pm to 4am, in response to grazing bans and higher relative costs of rearing sheep in sheds is frequent (Yu and Farrell 2013) and has become particularly prevalent with less intensive monitoring. Yu and Farrell (2013) note that more than 54 per cent of herding interviewees admitted to grazing almost every day with half being fined less than twice. It is likely that informal institutions and responses are more dominant in remote areas in part because enforcement is relatively lax (Yu and Farrell 2013).

7.2 Mongolia

The choice modelling analysis of herder preferences and urban residents along with the contingent behaviour analysis of herders mirrored the analyses in Inner Mongolia although different attribute sets and other parameters were used reflecting the differences in the policy and urban settings between Mongolia and Inner Mongolia. Thus the purpose of these analyses are as described in Section 7.1.

7.2.1 Assessment of alternative policies

The policy alternatives analysed for Mongolia were based primarily on the choice modelling and contingent valuation analysis of herder policy preferences (Sections 7.2.2 and 7.2.3) along with the discussions with policy officials and the results of the policy assessment are presented in Table 11. Specifically the variables in the contingent valuation analysis shown to have a significant effect on livestock numbers, namely a livestock tax and a livestock quota, were included in the analysis. Policies aimed at facilitating trade and market development for ruminant livestock products were significant in herder policy preferences but did not have a significant impact on numbers as highlighted in Sections 7.2.2 and 7.2.3.

The livestock tax is a tax on livestock on a per sheep equivalent basis. The livestock quota is a tradable quota scheme on livestock numbers herders can keep, again on a sheep equivalent basis, with the policy alternatives specifying the initial entitlements as a proportion of current livestock numbers. A livestock tax in Mongolia previously existed with a mixed reception. However, as livestock numbers and grassland degradation increased in the second half of the 2010s then both political and herder interest in the reintroduction of a livestock tax increased. The livestock quota scheme was chosen in the attributes in the choice modelling analysis of herder preferences as a completely new and very different policy instrument and based on the project team's conceptual analysis[20] of instruments that may address the degradation issue. Nonetheless both officials and herders understood how such a scheme might work and were favourably disposed to including it in the analysis of policy alternatives.

Both the livestock tax and the livestock quota alternative policies were set at the upper bounds of the choice sets in order to achieve the level of reduction in livestock numbers being sought by policy makers of around 150 sheep equivalents for the areas and herders in the choice modelling survey. Alternative 1 ('Large tax') sets the livestock tax at MNT5000/SE or the upper bound of the choice modelling set. As shown in Table 11, and as estimated in the contingent valuation analysis, herders may respond with an average reduction of 90SE. Alternative 2 ('Large quota') sets the initial entitlements under the livestock quota scheme as 40% less than current livestock numbers resulting in a reduction of 144SE per household. Because the livestock tax may be at the upper bounds of what is considered politically feasible (for instance, proposals during the 2020 elections were more in the line of a livestock tax of MNT1000/SE) and did not achieve the desired reduction in livestock numbers, the remaining two options were a combination of the livestock tax and the livestock

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[20] For instance, a tradable quota system would facilitate structural adjustment by enabling herders to move out of, or back into, herding. Some herders could still have large herds but would need to buy the quota and so compensate other herders in order to do so compared with the current situation where effectively they face only peer pressure to restrict the livestock numbers and external costs they impose on other herders. It would also facilitate otor and reserve grasslands whereby temporary migrating herders could compensate the soum by purchasing a soum held quota on these areas. Furthermore the quota entitlements would give more control over total livestock numbers and could also facilitate a change in these numbers based on seasonal conditions. Nevertheless there are many aspects of the operation of a livestock quota scheme that have not been fully investigated in the project but that warrant further investigation and this is raised in the recommendations in Section 9.2.

quota. Alternative 3 (‘Large tax, Medium quota’) combines a livestock tax of MNT5000/SE with a livestock quota with a 25% reduction in entitlements which, based on the contingent valuation analysis, would be likely to achieve the 150SE reduction in livestock numbers. Alternative 4 (‘Medium tax, Higher quota) also achieves a 150SE reduction in livestock numbers based on the contingent valuation analysis but does so through a combination of a livestock tax set at MNT3000/SE and a livestock quota set at a very high level of 60% of livestock numbers.

The livestock number reductions associated with the alternative policies were then input to the bioeconomic model described in Section 5.2.2 to estimate the incremental impact on environmental attributes. Class 1 grassland as a proportion of total grassland did rise (row 1b in Table 11), albeit modestly, by around 0.8%. The increase was more notable in Altanbulag (0.98%) than in Khashaat (0.63%). However, there was only a very modest reduction in the number of dust storms (row 1c) and in wind erosion (row 1e). When combined with Ulaanbaatar residents’ valuations of an increase in the proportion of Class 1 grasslands and a reduction in the number of dust storms (see Section 7.2.4) then the total environmental benefits of the four alternatives ranged from MNT13.339 billion to MNT22.232 billion. Row 1d also outlines the extent of GHG emission reductions associated with the lower livestock numbers.[21]

The environmental benefits must then be assessed against the opportunity costs to herders of lower livestock numbers. However, as was the case with the desert steppe in Inner Mongolia where grazing pressures were high and reported in Section 7.1.1, the lower livestock numbers actually increase herder incomes because of offsetting productivity impacts. This is especially the case in Khashaat where livestock numbers relative to grassland biomass are higher. The positive income impact (reported for Khashaat and Altanbulag in MNT/ha/annum) is small but still a positive contribution to what are otherwise large negative incomes for herders in these areas. Despite the modest positive income impacts, and as was the case with Inner Mongolia, the impacts on herder incomes far outweigh the magnitude of the environmental benefits (by a factor of 10 and compare row 2b with 2a).Thus while the policies may have the added benefit of modestly improving environmental outcomes, the main beneficiary will be herders. An important caveat to this is that it assumes that herders outside modelled geographical areas would not respond to increases in primary productivity by moving into the area. Such policies may thus need to be accompanied by strengthened institutions, or be applied across a large geographical area.

[21] While these results suggest that grassland improvement changes are small, they are in the right direction, as shown in the previous ACIAR research in Inner Mongolia (Kemp 2020). Thus more radical policy changes to re-organise the livestock system may be needed if substantial grassland improvements are to be made (such as limiting grazing to maintain the herbage mass above 0.5 t DM/ha as discussed in the biophysical sections of this report. This has not been tested in Mongolia as it is not yet clear how that can best be done as it would require better management of all livestock through winter. Previous work in Inner Mongolia indicated that warm sheds and better forage supply may help achieve those aims, but it is not clear if this is feasible or viable in Mongolia, given limited financial and forage resources and the climatic constraints. Thus future research is needed to fully investigate these options.

Table 12 Mongolia policy assessment

	Policy Scenario[1]	1. Large tax	2. Large quota	3. Higher tax, medium quota bundle	4. Medium tax, higher quota bundle
1. Environmental impacts[2]					
1a	**(Herder household) Livestock number reduction (SE)**	**90**	**144**	**150**	**150**
1b	**Increase in class 1 grassland as proportion of total grassland (%)**	**0.49**	**0.78**	**0.82**	**0.82**
	Khashaat	*0.60*	*0.63*	*0.63*	*0.63*
	Altanbulag	*0.94*	*0.98*	*0.98*	*0.98*
1c	**Reduction in dust storms (number)**	**0.01**	**0.01**	**0.01**	**0.01**
	Khashaat	*0.01*	*0.01*	*0.01*	*0.01*
	Altanbulag	*0.01*	*0.01*	*0.01*	*0.01*
1d	**Reduction in GHG emissions (GWP100 million tons CO2e/annum)**	**1.16**	**1.85**	**1.93**	**1.93**
	Khashaat (GWP100 tons CO2e/annum/household)	*55.24*	*57.54*	*57.54*	*57.54*
	Altanbulag (GWP100 tons CO2e/annum/household)	*28.24*	*29.39*	*29.39*	*29.39*
1e	**Reduction in wind erosion (t/km^2/annum)**	**0.01**	**0.02**	**0.02**	**0.02**
	Khashaat	0.00	0.00	0.00	0.00
	Altanbulag	0.04	0.04	0.04	0.04
2. Economic impacts (Net Social Benefits)[3]					
2a	**Environmental benefits (MNT billion)**	**13.514**	**21.623**	**22.524**	**22.524**
2b	**Change in herder income/surplus (MNT billion)[5]**	**164.588**	**253.513**	**262.939**	**263**
	Khashaat (MNT/ha/yr)	*18682*	*19376*	*19376*	*19376*
	Altanbulag (MNT/ha/yr)	*7295*	*7539*	*7539*	*7539*
2c	**Net social benefit (MNT billion)** *[=2a+2b)*	**178.102**	**275.136**	**285.462**	**285.462**
3. Direct payments and other impacts					
3a	**Change in direct payments (MNT billion)**	**107**	**0**	**107**	**64**
3b	**Change in standard deviation of herder income (MNT)**				
	Khashaat (MNT/ha/yr)	*-240*	*-366*	*-379*	*-379*
	Altanbulag (MNT/ha/yr)	*-558*	*-892*	*-929*	*-929*
4. Pasture impacts					
4a	**Increase in July biomass (kg DM/ha)**	**9.98**	**15.97**	**16.64**	**16.64**
	Khashaat (kg DM/ha)	*13.3*	*13.8*	*13.8*	*13.8*
	Altanbulag (kg DM/ha)	*18.4*	*19.2*	*19.2*	*19.2*
4b	**Increase in proportion desireable species (%)**	**1.92**	**3.06**	**3.19**	**3.19**
	Khashaat (%)	*3.79*	*3.95*	*3.95*	*3.95*
	Altanbulag (%)	*2.42*	*2.52*	*2.52*	*2.52*
4c	**Increase in grassland height (cm)**	**0.12**	**0.19**	**0.19**	**0.19**
	Khashaat (cm)	*0.23*	*0.24*	*0.24*	*0.24*
	Altanbulag (cm)	*0.14*	*0.15*	*0.15*	*0.15*

1 *Policy scenarios are: 1. Livestock tax of MNT5000/SE; 2. Livestock quota scheme with entitlements at 40% of current levels; 3. Combination of livestock quota set at 25% of current levels and uniform livestock tax of MNT5000/SE; 4. Combination of livestock quota set at 60% of current levels and uniform livestock tax of MNT3000/SE.*

2 *Environmental benefits are based on valuations of urban households in Ulaanbaatar as determined through a choice modelling survey and analysis. The time frame for impacts is 10 years but the values are amortised (annualised) values. In 2017, 365,961 households in 6 sampled districts in UB; Response rate of 30% for public areas and 5% for knocking on doors, and so 109788 households for 30% response rate and 18,298 households at 5% response rate. Assumes non-respondents hold zero values. WTP estimated for 10 years at 5.4% and 12.6% discount rates.*

3 *The net social benefits do not include transaction costs. It is anticipated that most of the implementation of the policy measures such as livestock taxes would be done by local (soum) officials and integrated into their existing systems while the central level administration is already in place. Thus the major issue is whether local officials will implement the policies as intended and the incentives for them to do so. This is highlighted in 3b but may involve local soums being able to retain some of the revenues generated by the livestock tax or quotas to use for implementation and ongoing operation of the policy instruments and also to use for local herder welfare initiatives. The design would need to ensure that any soum re-investment of funds did not facilitate greater livestock numbers and hence work against the tax.*

4 *Estimated as change in net present value as an annuity and calculated as MNT/ha/year.*

The costs to society of implementing the policies also include the transaction costs. While there would be some initial system setup costs associated with the livestock quota, most of the transaction costs would fall on soum level governments who would be responsible for monitoring and enforcing the livestock numbers under the quota and for monitoring numbers for the livestock tax. Given the close connection between soum officials and local herders, incentives may be needed to implement these types of policies. What is proposed is that the revenues generated by the livestock tax are fully reinvested within the soum from where they originate rather than be funnelled to the Central government for consolidated revenue. This may provide more incentive for soum officials to comply with the programs while it would also increase perceived policy legitimacy if local officials can argue that funds from the tax are going to areas such as improved infrastructure or grassland and livestock improvement. Thus while row 3a is a transfer payment from herders to the government, it may also be an indicator of the transaction costs needed to effect the programs.

Row 3b indicates the impact of the policies and reduced livestock on the standard deviation of herder incomes and highlights a small reduction in this standard deviation both in Khashaat and in Altanbulag. Given the importance of risk and risk management to Mongolian herders, even a modest decline in standard deviation may be welcomed. The impacts of the policies and associated livestock reductions on characteristics of the grassland are as indicated in Section 4 of Table 11. July biomass increases by around 16kg DM/ha, the proportion of desirable species by around 3%, and there is an increase in grassland height of around 2mm.

Overall the findings indicate that while alternative policy instruments may be able to bring about the reduction in livestock numbers desired by officials, that the impacts on the grasslands, on the environmental benefits, and on herder incomes may be modest.

7.2.2 **Herder policy preferences**

Modified extract from Bennett et al. (2020)

For the Mongolian case, the six policy instruments following the focus groups with herders and interviews with officials:

1. Livestock product market expansion into China and Russia resulting in product price rises (0, 10, 20 and 30 per cent)
2. Increased transport and communication infrastructure resulting in lower production costs (0, 5, 10 and 15 per cent)
3. Loan size (MNT5, 10, 15 and 20million)
4. Interest rate per month (2.5, 0.66, 1 and 1.5 per cent)
5. Livestock tax per sheep equivalent (MNT0, 1000, 3000, 5000)
6. Livestock rights as a percentage of current herd size (100, 60, 80 and 90 per cent)

The last of the Mongolian policy instruments warrants further explanation. The concept is based on a transferable ‘quota’ of livestock that would be set according to grassland carrying capacity on a regional basis. The total quota would be distributed amongst herders on the basis of historical stocking rates and would represent a proportional reduction in current stock numbers. If a herder wanted to maintain their current stock numbers, they would need to purchase ‘livestock rights’ from herders who are looking to exit the industry or at least to scale back. Fines would be imposed where stock numbers exceeded the ownership of livestock rights.

The results of the analysis are shown in Table 12. The loan attribute was insignificant and thus not of importance to herders. Infrastructure was of marginal importance but market expansion, interest rates, livestock rights and livestock tax were all highly influential in herders’ choices of their preferred policy mix. The signs on these attributes show that they preferred lower interest rates and livestock taxes but more market expansion and higher livestock quotas. Again the signs are in accord with expectations.

The (statistically significant) attribute coefficients estimated in each model can be used to determine the willingness to trade-off between different policies. For Mongolia, the willingness to pay more in livestock tax in order to see the market expand can be determined. By using one policy as a ‘reference point’, the relative preferences across herders for the other policies can be established. For Mongolia, the baseline policy selected to illustrate the potential for policy comparisons is the livestock tax. Increasing the loan size is not included because it did not influence herder respondents’ choices. Mongolian herders (on average) would be willing to pay a livestock tax of MNT55 per sheep equivalent to have a one percentage point increase in livestock product prices and MNT13 per sheep equivalent for a one percentage point decrease in production costs. An interest rate cut of one percentage point is worth a livestock tax of MNT601 per sheep equivalent. Again, interpretation of the livestock rights policy relative value is complex. Herders would be willing to pay a tax of MNT22 per sheep equivalent to have the quota relaxed by one percentage point. From a different perspective, to have one percentage point reduction in their allowed herd size, herders would need to have the livestock tax reduced by MNT22 per sheep equivalent. Given that there is currently no livestock tax, this is equivalent to the requirement of a compensation payment of MNT22 per sheep equivalent.

Table 13. Herders’ policy preferences – Mongolia

Variables	***Coefficient (Standard error)***	***Coefficient (Standard error)***
Market	0.073*** (0.007)	0.108*** (0.011)
Infrastructure	0.014 (0.011)	0.027* (0.015)
Loan	0.009 (0.011)	-0.025 (0.018)
Interest rate	-0.800*** (0.094)	-1.168*** (0.159)
Livestock rights	0.030*** (0.004)	0.043*** (0.007)
Livestock tax	-0.001*** (0.000)	-0.002*** (0.000)
ASC	0.846*** (0.235)	2.013*** (0.340)
Education	1.417** (0.499)	1.849* (1.057)
Number of children	0.202** (0.067)	0.191 (0.118)
Employment	0.821 (0.435)	1.505 (0.916)
Per capita income	0.0572* (0.024)	
Additional herding	-0.209 (0.260)	
Standard Deviations *(Random Parameters Model)*		
Market		-0.039** (0.018)
Infrastructure		-0.019 (0.023)
Loan		-0.057* (0.03)
Interest rate		0.886*** (0.176)
Livestock rights		-0.053*** (0.009)
Livestock tax		-0.0007*** (0.000)
Log likelihood	-917.6	-823.6
Number of obs	4806	4806
LR chi2(8)	1684.7	193.88
Prob> chi2	0.000	0.000
Pseudo R2	0.478	-
AIC	1857.2	1679.3
BIC	1928.4	1782.9

*Note: *** significant at the 1 per cent level, ** 5 per cent and * 10 per cent.*
Source: Bennett et al. (2020) Table 7.3.

7.2.3 Contingent behaviour analysis

Modified extract from Bennett et al. (2020)

For the Mongolian herder respondents, the Contingent Behaviour question was split into two parts. First respondents were asked if they would increase, decrease or hold constant the number of animals they graze under the changed policy. Then, on a sliding scale, they were asked the extent of the change they would make. The so created dependent variable was thus stock numbers rather than stocking rate. This reflects the nomadic life style of the herders and the common property status of the forage resource.

In the Mongolian context, it would appear that herders would not respond to the introduction of market stimulation, cost saving or loan size initiatives in terms of reducing their herd sizes (Table 14). However, higher interest rates and a livestock tax would be effective at reducing grazing pressure. The positive sign on the livestock rights policy ('quota') shows that herders planned to increase their stock numbers as the quota on stock increased. In other words, as the percentage of the current herd that herders were permitted to keep increases, their herd size increases. Looking at this from another perspective, it shows that a smaller quota would cause the herd size to decrease. Hence the livestock rights policy would likely be effective at lowering stock numbers.

Table 14. Contingent Behaviour model of stock numbers for Mongolia

Variables	Coefficient
Policies	
Market *(percentage increase in average livestock price of last five years)*	-0.066
Infrastructure *(percentage reduction in production cost)*	-0.900
Loan size *(MNT)*	1.102
Loan interest *(monthly percentage interest rate)*	-25.787***
Livestock quota *(rights as percentage of current herd size)*	2.419***
Livestock tax *(MNT per sheep unit)*	-0.019***
Socio-economic	
Age	-4.452***
Education	87.332***
Number of children	26.752***
Livestock	0.961***
Loan	90.110***
Resource income	-68.017*
Additional herding	46.583**
_cons	45.481
R2	0.868
Number of obs	1602

*Note: *, ** and *** significant at 10, 5 and 1 per cent levels respectively. For socio-economic variables (interacted with the alternative specific constant): age (age in years); education (education with 1 for higher education of respondent and 0 otherwise); employment (whether herder has any other forms of employment; equals 1 if the herder is employed and 0 otherwise); number of children (number of children below the age of 16), total livestock number (livestock in sheep equivalent); Loan (loan with 1 for having a bank loan and 0 otherwise); annual per capita income in MNT (pcincome); Additional herding; 1 if they have additional livestock and 0 otherwise); herder earned income from natural resources (resourceincome with 1 for earning income and 0 otherwise).*

Source: Bennett et al. (2020), Table 7.6

7.2.4 Urban resident valuations of grassland amenity

Modified extract from Bennett et al. (2020).

Selecting the non-marketed environmental goods and services that are impacted by grassland condition and that are of value to people living in regional urban areas involved discussions with ecologists, policy advisers and a sample of residents of Ulaanbaatar. For the residents of Ulaanbaatar, the attributes selected were:

1. Grassland condition (measured by the percentage of national grasslands in top grade condition);
2. Herder culture (measured by the percentage of herders in the national population);
3. Sandstorms (measured by the number of sandstorms experienced per annum); and
4. Meat safety (measured by the probability of buying infected meat).

The payment vehicle included in the Choice Modelling choice sets to allow for the estimation of monetary values for the other non-monetary attributes was an increase in the household electricity bill. This was selected because of its wide coverage across the population. A sample choice set from the Mongolian application in Ulaanbaatar is displayed in Table 15.

Table 15. Sample choice set: Ulaanbaatar residents' questionnaire

		Current level	Alternative 1 (no new policy)	Alternative 2	Alternative 3
			Results in 10 years' time		
Grassland condition	Percentage of grassland class 1 condition 	35%	20%	47%	41%
Herder culture	Percentage of herders in total population	32%	29%	37%	34%
Environmental problem	Annual number of dust storms	15	22	12	12
Meat safety	Chance of buying infected meat	6%	8%	2%	8%
Payment	Payment to be added on the monthly electricity bill	0	0	1000	2000
I like this option the best:					

Source: Bennett et al. (2020), Table 7.6

As shown in Table 16, the RPL model is preferred given the highly significant standard deviations associated with the distributions of the attribute coefficients. All attributes have the expected signs and are significant except for the culture attributes. Culture (measured as the percentage of herders in the population) was insignificant. The frequency of sandstorms attribute was significant and positively signed. This is the attribute that is most closely connected to the bio-physical modelling that predicts the outcomes of alternative policies. The willingness to pay for a decrease in the frequency of dust storms by one per annum is estimated by dividing the coefficient of the sandstorm attribute by the cost attribute coefficient. For Ulaanbaatar, the estimate is MNT382 (on average per household per annum).

The data collected from both samples were analysed using conditional and then random parameter logit models. The probability of choosing an alternative was explained using those models in terms of the attributes displayed in the choice sets and the respondents' socio economic characteristics. The estimated models are displayed in Table 16.

Table 16. Conditional logit and random parameter logit model results: Ulaanbaatar

Variables	Conditional logit	Random parameter logit	Standard Deviation
	Coefficient	*Coefficient*	
Attributes			
Grassland	0.201	2.164***	-5.253***
Meat	-18.499***	-28.420***	28.836***
Culture	-0.016	0.900	6.675***
Sandstorm	-0.060***	-0.110***	0.139***
Asc	2.222***	1.990***	
Cost	-0.0002***	-0.0003***	
Socio-economic			
Age	-0.020**		
Gender	0.335*		
Education	0.817***	0.816***	
House	-0.700***	0.575**	
Travel	-0.041***	-0.030	
UB		-0.018**	
Employment	-0.452**		
Observations			
Log-likelihood	1022.82	179.05	
Prob>chi2	0	0	
Pseudo R2	0.206	-	
AIC	3958.11	3794.84	
BIC	4039.95	3890.32	

Notes: *** p<0.01, ** p<0.05, * p<0.1.

Source: Bennett et al. (2020), Table 7.10

7.2.5 Meaningful livelihoods, livelihood strategies and more livelihood focussed environmental policies

Modified from Addison et al (2020), Addison et al (2020b), Addison et al (2020d) and Addison et al (in prep)

Meaningful livelihoods

Recognising the complexity of understanding livelihoods, a mixture of focus groups, structured surveys and non-market valuation techniques was drawn upon in Mongolia.

Mean life satisfaction in 2009 (immediately after the last extreme winter) was 4.7 (range 2-7, mode 6, n = 100), with mean life satisfaction in 2019 (following a mild climatic period) being 4.6 (range 1 – 5, mode = 5, n =99). There was no significant change in overall life satisfaction between 2009 and 2019 amongst the sample population (n=101, p=0.587). Pearson's correlations found a strong positive relationship (r^2=0.279, p<=0.01, n=86) between total livestock numbers in 2019 and life satisfaction in 2019, but no significant relationship between life satisfaction in 2019 or 2009 and current age or education level.

Table 17 Cited reasons for changes in life satisfaction between 2019 and 2009, as per Millennium Ecosystem Assessment (2005) domains.
Data drawn from the coding of qualitative responses. + = cited positive change, - = cited negative change, () = count.

Domain	+ (Positive change)	- (Negative change)
Material goods: including secure and adequate livelihoods, income and assets, enough food, shelter etc, and access to goods	• Livestock number grew (58) • Increased number of material goods (5) • Household income increased (4) • Improved housing (4) • Higher prices (4) • Improved sales (3) • Livestock quality improved (1) **TOTAL = 79**	• Decline in price of livestock and livestock products (20) • Increase in price of consumer goods/living costs (7) • Livestock number stagnate or declined (5) • Increase in loans/debt (2) • Decline in material goods due to costs of older children (2) • Livestock number increased but poor quality (1) **TOTAL = 36**
Health: being strong, feeling well, and having a healthy physical environment	- **TOTAL = 0**	- **TOTAL = 0**
Social relations: social cohesion, mutual respect, good gender and family relations, and the ability to help others, including children	• Family size increased/children born (12) • Children grown and doing well (12) • New or strong marriage (4) • Relationships between herders has improved (1) **TOTAL = 29**	• Excessive immigration of herders/too many herders (7) • Local government ineffective or corrupt (5) • Decline in moral values e.g. increased selfishness amongst herders (4) • Ineffective policies (2) • Herders are law breaking (2) • Families split by need to have young children in school (1) • Loss of herder tradition (1) • Divorce/difficult family relations (1) • Children without jobs (1) • Lack of potential spouses in area (1) • Lack of young herders (1) **TOTAL = 26**
Security: secure access to natural and other resources, safety, living in a predictable and controllable environment	• Improved grassland productivity (3) • Improved water availability (1) • Herders stopped cutting trees (1) • Registration of winter and spring places (1) **TOTAL = 6**	• The grass is no longer growing or is degraded (46) • Surface water or wells in decline or insufficient (22) • The environment has changed in general (18) • Precipitation insufficient or droughts more frequent (12) • Livestock numbers exceeded the grassland capacity (11) • Dzuds are bad, worse or more frequent (7) • Farming activities have caused problems of access to grazing lands (7) • Increased risk or management of livestock disease (3) • Land-use competition between herders (3) • Land-use competition between herders and mining (2) • Forests have declined (2) • Rodent or locust numbers are excessive (2) • Wildlife numbers have declined (1) • Grass diversity has declined (1) **TOTAL = 133**
Freedom and choice: having control over what happens and being able to achieve what a person values doing or being	• In positions of political influence/social standing (2) • Became more experienced at herding (1) • Enjoying the countryside/ herder lifestyle (1) **TOTAL = 4**	• .Inability to move livestock due to presence of other herders (2) • Inability to move due to extent of land degradation (1) • Inability to move livestock due to presence of mining companies (2) • Increasingly restrictive laws (1) **TOTAL = 6**

Table 18 Relative importance and satisfaction with Millennium Ecosystem Assessment domains and items from pilot survey of herders (n=20) in Arkhangai and Bulgan aimags

Domain	Item	Importance (mean)	Importance (rank)	Satisfaction (mean)	Satisfaction (rank)
Material goods: including secure and adequate livelihoods, income and assets, enough food, shelter etc, and access to goods	Predictable and consistent prices at markets	9.8	3	3.0	9
	Your ability to purchase items (like motorbikes) to make herding easier	9.1	6	6.3	6
	Your ability to save for your children's university fees or marriages	9.6	4	5	7
	Mean	*9.5*	*3*	*4.8*	*5*
Health: being strong, feeling well, and having a healthy physical environment	Your ability to access healthcare in your *soum*	9.4	5	6.8	5
	Your tiredness and busyness	7.9	7	8.5	3
	Affording good healthcare	10.0	1	5.5	7
	Mean	*9.1*	*4*	*6.9*	*3*
Social relations: social cohesion, mutual respect, good gender and family relations, and the ability to help others, including children	Ability to cooperate with other herders	9.9	2	7.5	4
	Strong local leaders	9.9	2	5.5	7
	Respect between men and women in the household	10.0	1	10.0	1
	Mean	*9.9*	*1*	*7.7*	*1*
Security: secure access to natural and other resources, safety, living in a predictable and controllable environment	Access to good quality and quantity pasture for your livestock	10.0	1	4.3	8
	Your family's ability to withstand *dzud*	10.0	1	7.0	5
	Your ability to grow your livestock number during good years	9.8	3	7.5	4
	Mean	*9.9*	*1*	*6.3*	*4*
Freedom and choice: having control over what happens and being able to achieve what a person values doing or being	Your ability to *otor* or move within your *soum*	9.4	5	4.7	8
	Your enjoyment of herding	10.0	1	9.0	2
	The ability of your children to do something other than herding	9.9	2	7.7	4
	Mean	*9.8*	*2*	*7.1*	*2*

There was substantial change in individual wellbeing domains between the two time periods. There was a large positive increase in the Material Goods domain, largely due to a cited increase in livestock numbers during the ten year time period (Table 17). In contrast, the Security domain experienced a significant decline. This was largely due to perceived declines in natural resource availability (or availability per unit of livestock), and competition between herders to access the declining resource. This qualitative data is supported by significant declines in satisfaction with access to pasture (from mean 5.77 to 2.29, p = 0.000, n=98), a household's ability to withstand *dzud* (from mean 5.74 to 4.71, p=0.000, n=98) and a household's ability to *otor*/make long distance migrations with livestock (mean 5.63 to 3.1, p=0.000, n=95). Inelasticity in the wellbeing-ecosystem services relationship through time is thus likely due to the inverse relationship between Material Goods and Security driven by non-equilibrial dynamics/ecosystem stocks.

The other domains of Health, Social Relations and Freedom and Choice experienced no net change (positive or negative). However, Social Relations, when disaggregated further, experienced significant levels of change with positive and negative changes largely evening each other out. Positive changes tended to relate to changes within the family, such as adult children getting married. Negative changes tended to relate to broader social relations, such as an increase in pastoralist migration to urban centres.

Table 16 suggests that Security and Social Relations may be as important to herder livelihoods (as measured using life satisfaction as a surrogate) as Material Goods. This is also supported by earlier pilot surveys. A pilot survey of twenty herders in the central steppe Arkhangai and Bulgan *aimags* provided three indicator items for each of the five livelihood domains. The most highly ranked domains from this survey in terms of importance were Social Relations and Security (Table 18). Of all domains, herders were most satisfied with Social Relations and Freedom and Choice, and least satisfied with Material Goods.

Livelihood strategies

Herder focus groups across Tuv, Arkhangai, Bulgan, Sukhbaatar and Khentii *aimags* described the current state (following the Drivers-Pressures-State-Impact-Response framework) of the grassland that resulted from pressures and impacts since the early 1990s. These included significant long-term increases in shrubs such as *Caragana microphylla*, heavily grazed *Achnatherum splendens*, reduced biomass of palatable species such as *Stipa krylovii*, reduced floristic diversity, and a significant increase in biomass by unpalatable species such as *Artemisia* spp., *Salsola* spp. and *Corispermum* sp. Cited pressures and drivers included: overstocking including its interactions with 'hoofed *dzud*'; unregulated grassland use (in-migration of people and livestock from other regions, poorly defined *soum* boundaries, lack of leadership in coordinating grassland use); poor government support and collaboration on issues of grassland access and promotion of secure use rights; lack of infrastructure (wells and protection of hay fields); reduced migration or nomadism; types of livestock (such as more horses and goats); and meteorological or hydrological changes. These changes in grassland state were seen to have negative flow-on affects to livelihoods via increased conflict between herders, changes in goat and sheep weaning rates, delayed birthing month and greater mortality during spring.

An important caveat is that herders often linked recent, short-term weather patterns—which were seen as favourable by the aforementioned focus groups—with positive livelihood benefits that overrode some of the longer-term drivers. Thus these shorter term, faster drivers are important to consider. Faster drivers of environmental and livelihood change, and relationships between them, may be best understood using shorter time frames, more local spatial scales, and perspectives of individuals. The longitudinal study of herder intentions and responses to seasonal conditions suggested that positive feedbacks between low levels of palatable forage or poor grassland condition, institutional pressures or vacuums, and reduced choices around livelihood strategies, compounded a livelihood vulnerability 'trap'. For example, two herders from Arkhangai *aimag* were unable to action what they felt was needed for their livelihoods between spring 2017 and 2018 due to financial constraints, underpinned by poor seasonal conditions and thus household revenue, and institutional weaknesses. These actions, including fencing pasture and increasing mobility, are commonly cited ways in which grassland condition could be improved in Mongolia. The livelihood trap can be temporarily relieved or masked during periods of good weather but the strategies that herders use to then buffer the inevitable return to poor seasons, other than to increase herd size (see below), is unclear. Thus most management is reactive to climatic variability rather than proactive.

When asked about goals as a herder from a closed list of options, Arkhangai and Bulgan *aimag* herders (n=20) placed 'building up herd size' at the bottom of the list in terms of importance. The most important herding-specific goals were maintaining the herding culture and tradition, making sure the pasture was not overgrazed, enjoying herding, not worrying too much about the future, and improving livestock breeding. However, it is also important to note that when asked an open ended question about herder goals, many cited a desire to become or maintain a *miangat malchiin* status (having a herd size more than 1000). Responses from this pilot survey of herders also linked livelihoods with increases in herd sizes, and the larger survey statistically linked herd size and life satisfaction.

The combined social datasets suggest that the emphasis by herders on livestock numbers likely reflects risk mitigating behaviour associated with the increased exposure of their livelihoods to environmental shocks that accompanied transition to the market economy. Since herders do not have large social safety nets, many herders maximize the number of livestock in the hope of earning higher income but, more importantly, to increase the number of surviving animals in the case of disasters. That is, their primary livelihood strategy is not to minimize risks but to maximize the number of animals that survive *dzud* in order to continue within a pastoral livelihood, a strategy with empirical support if a herder's ultimate aim is to continue as a pastoral household. In a pastoral context with non-exclusive rights to the forage resource, this reflects the strongly linked nature of Material Goods, Security and Social Relations.

Implications for policy

Policy for the benefit of grassland condition and herder livelihoods will thus likely need to consider all the three most important domains (Material Goods, Security and Social Relations). However, policy interventions that promote Security and Strong relations may still improve livelihoods, thus proving attractive to Mongolian herders, even if they have minimal impact on household wealth. Policies focused on institutions for pasture access are directly relevant to Social Relations and Security; much of the herder-to-herder conflict that concerns herders is generated by unclear formal or informal institutions related to pasture use. Herders also cite unregulated crowding around *bags*, *soums* and waterpoints as facilitating grassland degradation. Much of the focus of policy reform in Mongolia has been on tenure such as the introduction of community-based natural resource management co-management models. These approaches that encourage herders to self-organise for pasture management appear to have yielded social benefits that positively contribute to the Social Relations and Security livelihood domains. However, it is unclear what benefit these models have had on Material Goods. Policy interventions that couple community-based natural resource management with Material Goods, such as the pilot Payment for Ecosystem Services scheme described by Upton (2020) may prove more beneficial.

It is important to note that we found no evidence that suggested extension to fill a perceived knowledge gap, or perceived attitudinal constraint, on the part of herders, would prove effective.

7.2.6 Institutions

Formal institutions

Pastoralism is both a cultural and economic activity with a long and rich history in Mongolia: the 1992 Constitution states that ‘livestock is the national wealth of the country and subject to State protection’. Various other formal institutions are designed to protect the social and economic values of the sector.

The Mongolian Law on Land 1994 (revised 2002) is the main legislation currently governing use of pasture in Mongolia. The Law on Land defined pastoral areas as common-use public property with its privatisation banned. The law was developed ‘to regulate possession, use of land by a citizen, entity and organisation’ (Article 1.1), defining land as ‘a piece of space including the land surface, its soil, forests, water and plants’ (Article 3.1.1.). Under the Law on Land, pasture use largely remains collective as ‘summer and autumn settlements and rangelands shall be allocated to bags and khot ails (neighbouring families) and shall be used collectively’ (Article 52.2). Possession rights for winter/spring camps are inheritable (Article 30.2). ‘Certificate holders may transfer their certificates or put them as collateral in a legally allowed manner’ but only to ‘Mongolian citizens, companies and organisations’ (Article 38.1). Possession rights are for 15-60 years, with the possibility of extending possession for a maximum of 40 years (Article 30.1). The size of land that can be possessed is 0.07 hectares (700 m2) for private gers and houses for the purposes of household needs (Article 29.1). The Law on Land makes provision for exclusive lease rights for the immediate area of land. Exclusive rights cannot be obtained legally for pasture surrounding the registered household area but Table 19 outlined informal institutions related to pasture surrounding the registered household area.

The State Central Administrative organisation in charge of land issues has responsibility to ‘formulate and implement methodology, guidelines and regulations for definition of land degradation and damage levels and desertification types for combating those damages and land rehabilitation’ (Article 19.1.9). Soum governments are required to create annual land management plans consistent with more general plans created by higher order governments (Article 20.1.2). Government also has the power to ‘make decisions on eviction of persons who caused significant degradation of land based on conclusion of authorized professional organisation’ (Article 20.2.6). Pasture use at the local level is not prescriptive under the Law on Land, and is largely up to the discretion of lower order officials as ‘terms for letting or prohibiting animals graze in winter and spring pastures shall be set forth by soum and district [bag] Governor taking into account citizen’s proposals and hay yield of the particular year’ (Article 52.2), with annual planning sometimes done at Resident Representative Meetings. The responsibility of determining ‘soum-level reserve rangelands to be used in the events of natural disasters, dzud and droughts, including its boundaries and limits’ is at the aimag level, as is ‘aimag-level reserve rangelands’ (Article 52.9). Inter-soum and inter-aimag movement is facilitated through Article 52.8 which states that ‘in the event of a need of evacuation or a movement to territories of other aimags or soums due to natural disasters or other emergencies, the relevant level governments shall make a decision to reach an agreement.’

A series of focus groups with herders in Tuv and Arkhangai aimags facilitated by some of the authors in 2016 to better understand drivers of environmental and livelihood change highlighted herder perceptions that formal institutions governing grassland access such as the Law on Land were only weakly enforced. In general herders felt that soum governance, the level at which many Law on Land institutions should be enacted, is generally poorly implemented. For example, while herders believed a local level tax is supposed to be levied on in-coming otoring herders during dzud, this is rarely collected.

Apart from the Law on Land, community based natural resource management (CBNRM) also exist in Mongolia. Over 2000 herder groups of varying types, many of which can be classed as CBNRM groups, have been established by development agencies in Mongolia. These groups are generally not legal entities in terms of spatial boundaries. Although Article 52.2 of the Law on Land provides for collective action, the institutions of CBNRM groups are not specifically formalised under the Law on Land. That said, some CBNRM groups do have formal agreements with soum governments. The legality of these agreements is unclear as are the implications of these agreements for use of the land such as collateral for loans. It is also unclear how the spatiality of collective action provided for under the Law on Land reconciles legally with the spatiality of these groups. In many cases, the institutions of CBNRM, the Law on Land and informal institutions merge, although the manifestation of this tripartite merger can vary in space and time. Thus CBNRM institutions can be considered to exist in addition to or as an extension of the institutions of the Law on Land rather than as a separate institutional arrangement.

CBNRM groups were designed with the assumption that land degradation and herder conflict over access to the forage resource is significant and that both are caused by unregulated access to pasture by livestock. Thus the underlying premise of CBNRM groups are that environmental and economic benefits follow from collective action among herders to regulate pasture use. Development agencies have tended to initiate and facilitate herder group establishment and design generally using participatory methods, creating an opportunity for herders to transform informal institutions to formalised rules under a CBNRM institutional setting. The participation of women and poor herder households, collective action and a democratic structure are often emphasised. Aid money usually accompanies the establishment of such groups. These factors are designed to influence rule-making in ways that were not, or may not currently be, socially embedded.

The operating arrangements of CBNRM groups vary between region and development agency facilitating their establishment. CBNRM groups vary in terms of aims, membership size, or legal recognition making it difficult to easily define them. Some have spatial boundaries with the general expectation being that herders will regulate grazing pressures within the spatially defined area. Other CBNRMs are designated community managed areas that are only spatially defined to determine membership eligibility. In general, however, members agree to provide mutual assistance to each other in activities such as providing labour for maintaining winter shelters or long distance migration, and to work towards sustainably managing the pasture resources of their CBNRM area. Eligibility for CBNRM membership is typically based on a herding household having pre-existing formal or informal rights to a permanent winter/spring camp within the project area. Development agencies often provide funding and support for activities of the CBNRM group, at least initially, including fencing of winter/spring pastures, community centres, business loans and information sharing workshops.

The relationship between CBNRM, grassland condition and herder livelihoods appears to be patchy. Addison et al. (2013) found little evidence of improved grassland condition in desert steppe CBNRM groups and little evidence of mechanisms by which grassland condition could be improved, such as regulation of grazing pressures, were present within the groups examined. In other ecological zones, Fernandez-Gimenez et al. (2015) noted higher adaptive capacity among CBNRM herders in response to dzud.

Formal institutions not related to grassland access

In Mongolia, a series of herder focus groups was facilitated by some of the authors in Tuv and Arkhangai aimags to better understand drivers of environmental and livelihood change. The focus groups framed by the Drivers-Pressures-State-Impacts and Responses model highlighted that herders saw formal institutions as ‘responses’ that both resulted from ‘impacts’ and also became ‘drivers’ of environmental and livelihood change. The formal institutions that herders cited as being important for environmental change or their livelihoods were not those related to grassland access with the exception of registration of winter camps under the Law on Land and a general belief that local governance of resource use was poor. Instead herders nominated insurance, cashmere subsidy, wool subsidy, co-operatives for wool sales, Soum Development Fund, decrease in compulsory schooling age by one year, lack of a legal cap on livestock numbers, and soum purchase of fodder as the most significant policy responses to and drivers of poor livelihoods and environmental change. These policies and other relevant initiatives are as follows:

Livestock production initiatives

The overall objective of the National Mongolian Livestock Program (2010-2021) is to modernize the country's livestock sector so that it is economically viable and competitive in the market economy as well as being adaptable to changing climatic and social conditions. The Program recognises the need to shift from a focus on livestock numbers to livestock productivity and receives 3 per cent of the national budget. While the government previously supported the livestock sector through provision of subsidised veterinary medicines and services, the first phase (2010-2015) of the program aimed to develop favourable legal conditions, establish a professional veterinarian service, obtain certification from the World Organisation for Animal Health on Mongolia's disease free status for important infectious diseases, improve pasture management, and improve herders' living conditions through improved markets. Subsidies and grants to help herders manage climatic shocks such as dzud—including rodent control, pasture irrigation and emergency fodder reserves—are also administered through this program (Gunjal and Annor-Frempong 2014).

Livestock insurance

Several government-led attempts to introduce livestock insurance in Mongolia failed primarily due to moral hazard whereby herders have perverse incentives not to manage their herds to minimise dzud impacts as well as high transaction costs of verifying losses. A lack of understanding by herders as to how insurance works also contributed to these failures. Most recently, the World Bank in conjunction with the Government of Mongolia initiated a project to ascertain the viability of index based livestock insurance to reduce the impact of livestock mortality for herder livelihoods using a market-based approach and to overcome some of the moral hazard related problems of previous attempts (World Bank 2016). In essence losses were indexed to a soum level livestock mortality rather than assessment of individual herder based dzud losses. The scheme combined self-insurance, market-based insurance and social insurance whereby herders bear the risk of small losses with larger losses being transferred to the private insurance industry and with extreme losses being borne by the government to ensure involvement of the private insurance industry and facilitate a premium level that would engage herders. Pay-outs to individual herders are triggered by mortality rates at the soum level exceeding a threshold thus avoiding some moral hazard related problems.

Fodder storage and reserves

The Mongolian government has sought to mitigate the impact of dzuds through the distribution of hay and fodder reserves to aimags and soums. However, there has been a significant decline in fodder availability and quality over the last few decades with fodder crops only 6 per cent of 1989 levels by 2011 (Rasmussen and Dorlig 2011). The State Emergency Fodder Fund supplied 200kt of fodder to herders during 1990/91, a figure that dropped to 18kt by 1994/95 (Asian Development Bank 1995). The Fund was subsequently disbanded in 1996 on advice from the Asian Development Bank as transportation costs exceeded the feeding value. Ad hoc fodder subsidies are employed on occasion with Addison (2012) noting that soum governments subsidised fodder during the 2009/2010 dzud to a level of about 50 per cent making prices on par with those in a good year. Nevertheless both subsidised and commercial fodder were still generally in short supply.

The government has instigated other initiatives to increase the quantity and type of hay and fodder available to the livestock industry. The Livestock Fodder Program supported enterprises and herders with investment funding for small tractors with hay and feed equipment (50 per cent subsidisation) and for small and medium sized hay and fodder producing enterprises (Rasmussen and Dorlig 2011). Funding was also made available for fencing hay fields. After the 1999/2001 dzuds, the system of national reserves was re-established whereby aimags and soums were directed to establish additional local reserves. There are now soum, aimag and national strategic reserves for feed and fodder, although no budget for the soum reserves. Aimag reserves are established under the Ministry of Food, Agriculture and Light Industry with procurement supported by state and local budgets. Fodder storage facilities remain in poor condition (Rasmussen and Dorlig 2011).

Taxes

By 2018 there was no livestock or grassland use tax in Mongolia other than for annual leasing of winter/spring shelters as outlined under the Law on Land. Taxes on the export of raw and washed cashmere and wool were abolished after they led to an estimated 50 per cent of raw cashmere being smuggled into China (Gunjal and Annor-Frempong 2014) and are discussed in Chapter 5. Herders have full tax exemption whereas other farmers pay 50 per cent tax on their taxable income (Gunjal and Annor-Frempong 2014).

Soum Development Fund

The Soum Development Fund provides loans to small and medium business owners at the soum to encourage establishment of new production facilities and contribute to job creation. For example, herders from Khashaat soum in Arkhangai aimag where individuals can receive a maximum of MNT20 million have used the loan to produce and sell aaruul and liquor from pastoral products. Carpentry workshops, leather product producers, canteens and car wheel repair shops have also been funded. Loans and interest must be repaid within three years with interest rates much lower than the open market.

Subsidies and co-operatives

Long standing subsidy programs include the Livestock Conservation Fund, the Fund for Wool and Cashmere Processors, the Meat Stabilization Fund, Veterinary Services/Vaccines Subsidization Program and Tax Concessions to Herders and Farmers (Gunjal and Annor-Frempong 2014). Subsidies to herders that are largely output-based payments for wool and cashmere are funded through the Livestock Conservation Fund and discussed in more detail in Section 5.2. These subsidies are designed to funnel cashmere and wool through the wholescale trading market in an attempt to offset the growing influence of Chinese traders. Some differentiation in payment levels was made to improve quality with subsidies at around MNT2000 per kg for fine and moderate micron sheep wool and MNT1000 for coarser wool although most of the wool in Mongolia is coarse wool. The camel wool subsidy is lower at about MNT1000 per kg. A Cooperative Law enacted in 1998 followed by the Government Act N221 in 2013 states that only members of cooperatives may access the state subsidy for wool. In Tuv aimag in 2014 there were 78 registered agricultural cooperatives with a total of 2935 members (Hilliova et al. 2017). With entrance fees ranging from MNT10 000 to MNT300 000 in Tuv aimag in 2014, smaller, less-educated and lower annual income herders tend not to be cooperative members with Board members having higher annual household incomes and education levels. A lack of membership was not seen as a barrier to accessing the subsidy. However, it was common practice among cooperative members to purchase product from non-members and declare it as their own to receive State subsidies. With few other services offered by co-operatives, Hilliova et al. (2017) concluded that cooperatives operate purely for herders—members and non-members alike—to access State subsidies.

Informal institutions

Informal institutions have always been important local and day-to-day drivers of herder resource use. Since the collapse of the Soviet Union and devolution of grassland responsibility from the State to local actors, land and resource rights in Mongolia have been characterised by informal land and resource rights (Upton 2012). These informal institutions are strongly linked to climatic variability as it relates to primary productivity and climatic shocks like dzuds. Addison (2016) identified key shared strategies, norms and rules related to grassland access in the Mongolian Gobi Desert many of which apply to steppe areas (Table 19).

While climate drivers underpin the informal institutions outlined in Table 19, other social, economic and institutional factors are influential. The ‘or else’ sanction of these norms and rules have strengthened in recent years with retreat of the state from the pastoral sector, increased freedom of movement and increase in livestock numbers. A decline in permanent water points, due to decaying infrastructure, and hence fewer areas of good pasture have led to a strengthening of sanctions as herders cluster around a more patchy pastoral resource. Defining and policing of clear boundaries has arisen not only for aimags but soums as locals attempt to keep out livestock from other regions. Once herders would have only ‘frowned upon’ or ignored ‘rule breaking’ but the grazing of animals in areas families customarily forage now often leads to conflict. Herder-to-herder conflict is prevalent in steppe areas with herders in Arkhangai, Bulgan, Khentii, Sukhbaatar and Tuv aimags all acknowledging the problem during interviews by the authors. Accompanying the concern about trespassing herders is concern about the loss of a perceived harmonious traditional way of living where neighbours were good-natured about sharing available pasture resources.

7.2.7 Biophysical research

The biophysical research done in Mongolia, relied on the experience gained in IMAR. The objective was to obtain some basic information on the productivity and composition of grasslands and also on flock/herd structures and productivity. This was done to then check that the parameters in the SGM for Mongolia were appropriate. In addition, the intent was to identify and quantify the main constraints on livestock production in Mongolia. These results would have influenced the responses of the herders surveyed for other parts of this project. The data obtained was from ten herders flocks/herds in Altanbulag and Khashaat, areas in central Mongolia considered to be over-grazed. Some background on Mongolian grasslands is presented in Kemp et al. (2020a).

During this study the climate was similar to average conditions in 2017 and 2018 (Figure 10). Temperatures were above freezing for about five months each year. The average temperature in January declined below -20°C. Peak precipitation was in late summer.

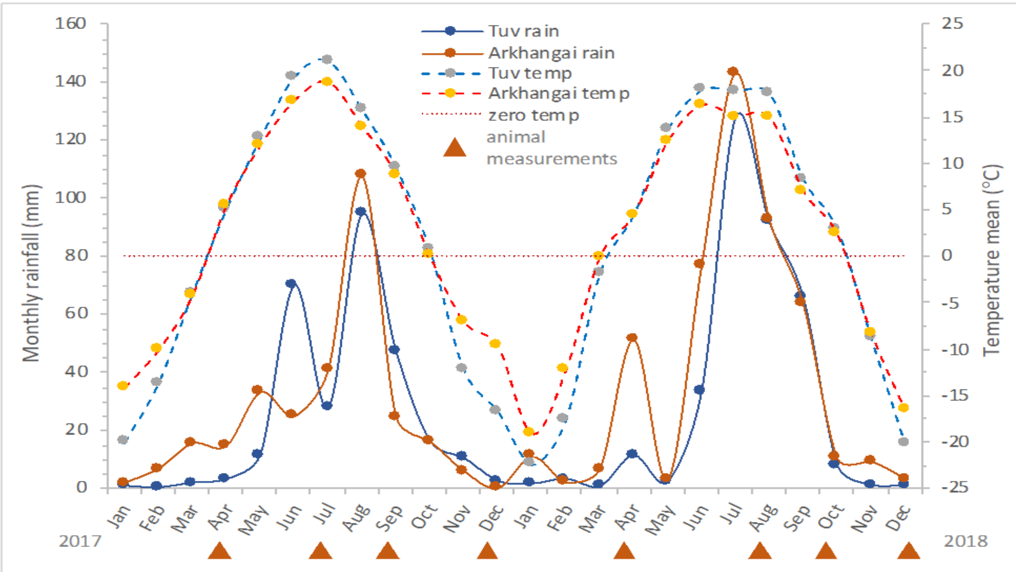


Figure 10 Monthly temperatures and rainfall at Tuv and Arkhangai in 2017 and 2018

Note: Triangles indicate when grasslands and animals were measured.

Table 19 Examples of informal institutions—shared strategies, norms and rules—governing grassland access

Institution	Attribute	Deonic	Aim	Condition	Or else	Exceptions	Territoriality
Rule 1	Herders	must not	graze their livestock	outside their *soum* (that is, herders outside the *soum* in which they are registered, or are not registered in but may have birth or familiar rights recognized by their peers).	They may be 'chased away' by other pastoralists.	Negotiations, preferably with the State and local pastoralists may remove or weaken sanction.	Rule weakens during periods of low resource availability (for herder wishing to rule-break) with negotiation. Negotiations more difficult (costly) during periods of low resource availability (for herder being asked to receive newcomers). Higher spatial variability in the resource may increase negotiation success.
Rule 2	Herders	must not	use	a winter/spring shelter that is recognised as belonging to another herder through the Law on Land or through historical precedence.	Registered pastoralist may 'chase them away' if discovered.	Negotiations involving labour sharing or cash payment and livestock can circumvent rule.	Rule strengthens during periods of low resource availability, and low resource variability, making negotiations more difficult (or costly for herder being asked to receive newcomers).
Rule 3	Herders	must not	graze their livestock	within a few kilometres of a winter/spring shelter that is recognised as belonging to another herder through the Law on Land or through historical precedence.	Registered pastoralist may 'chase them away' if discovered.	Negotiations involving labour sharing or cash payment and livestock can circumvent rule.	Rule will strengthen during periods of low resource availability, and low resource variability, making negotiations more difficult (or costly for herder being asked to receive newcomers).
Rule 4	Herders	must	graze their livestock	at a distance as far from another herder's *ger* as forage allows so herds do not become confused, or forage within a few kilometres of the *ger* is quickly consumed.	Pre-established pastoralist may 'chase them away'.	Negotiations involving labour sharing or cash payment and livestock can circumvent rule.	-
Rule 5	Herders	must	allow access of any livestock	to permanent water points.	'Frowned upon' if discovered not allowing access.	-	-

Table 19 (cont.) Examples of informal institutions—shared strategies, norms and rules—governing grassland access

Institution	Attribute	Deonic	Aim	Condition	Or else	Exceptions	Territoriality
Rule 6	Herders	must not	graze	winter or spring pastures at times other than winter or spring.	They may be 'frowned upon'.	More acceptable for herders with few livestock to graze winter/spring pastures than herders with more livestock.	During periods of low resource availability, herders may graze their own winter/spring pastures out of season
Norm 1	Herders	may	graze their livestock	wherever forage is available during summer	-	Rules 1, 2 and 3 override this norm.	Mobility is high during this time, and summer pastures are 'first in, first served'.
Norm 2	Herders	may	graze their livestock	within a few kilometres of a settlement at any time of year	-		Resource defence prohibitively expensive due to high density of herders, hence defence declines.
Norm 3	Herders	may	split	households, with livestock being pooled and one household being freed up for other activities	-	-	Splitting households is more common in the period proceeding resource scarcity.
Norm 4	Herders	may	share	registered winter/spring camps with other pastoralists	-	Negotiations that often involve labour sharing, or payment by cash and livestock, are generally needed.	Sharing is more common during resource scarcity
Norm 5	Herders	may	rent	winter/spring camps from absent pastoralists with rights to camp under the Law on Land	-		Renting is more common in the period proceeding resource scarcity.
Shared strategy 1	Herders	must	maintain mobility	in response to forage variability, to the best of their financial ability.	-	Herders with fewer livestock, or specific reasons for reduced mobility (such as desire to be near the *soum* centre where children are at school), may be less mobile.	High mobility is associated with resource scarcity and variability.

Note: Institutional components defined as per Crawford and Ostrom (1995).
Source: Modified from Addison (2016).

The grassland data obtained from the areas being grazed by the ten households studied, shows the low levels of productivity in the two Aimags studied (Figure 11). For a large part of the study period, the herbage mass was less than 0.5t dry matter per hectare, particularly in Altanbulag. This data is for the critical, desirable *i.e.* palatable, plant species upon which animal production depends. Research in Inner Mongolia (Wang et al, 2020, Zhang et al 2020) found that grazing needs to maintain the herbage mass above 0.5t dry matter per hectare to maintain, or increase, these desirable species. Data from ungrazed fenced plots showed that under the seasonal conditions of this study the grassland took two years for the accumulated herbage mass to exceed the threshold of 0.5t dry matter per hectare. The low level of productivity can be related to the rainfall pattern. General experience is that when there is less rain early in summer (Figure 10) total grassland growth is less for that year. However, the generally low levels of grassland growth in these two regions arguably reflects grazing pressures more so than a climate effect.

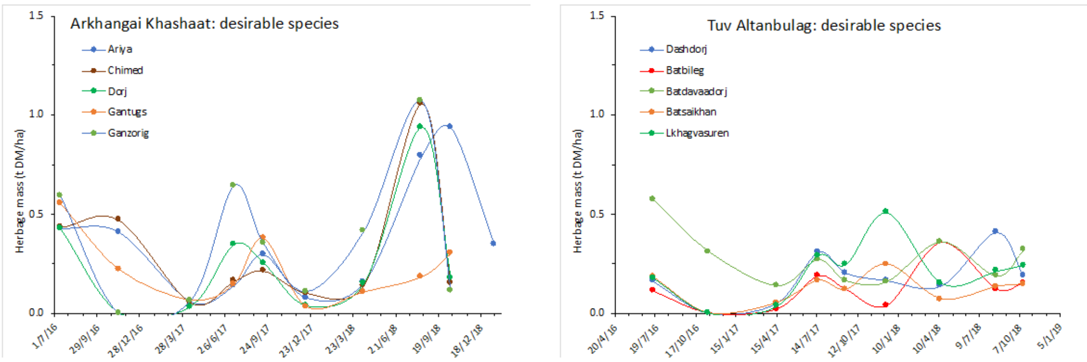


Figure 11 Herbage mass in the grazed grasslands in the two study regions from 2016 to 2018

Note: Data is from the separate areas being used by ten households.

To illustrate the current over-stocking problem in Mongolia, the trends in livestock numbers for Khashaat and Altanbulag are shown in Figure 12. These data are expressed as Sheep Equivalents, using the standard ratios commonly used in Mongolia. The big change that occurred in Mongolia, was in 1990 when the first democratic Government was elected. This removed regulation of livestock numbers. The rapid increase in livestock numbers after 1990 is clearly evident in these central Aimags. The same pattern applied across Mongolia (Kemp et al., 2020a). The large declines in livestock numbers at various times are the years of dzuds, when massive livestock deaths have occurred. It then takes some years to recover. Prior to 1990 livestock numbers were regulated and more fodder was stored for feeding through winter. In general, the main changes in livestock species, has been the increasing numbers of sheep and goats, which now comprise about half the livestock biomass. The average stocking rates in SE/ha since 1970, for each Aimag, have increased from 1.2 to 2.0 in Khashaat and 0.4 to 1.0 in Altanbulag, reflecting the wider doubling of stocking rates across Mongolia since 1990, similar to what has occurred in Inner Mongolia (Kemp 2020a).

The herder surveys done through 2017-18 showed that over that period there was decline in animal numbers and stocking rates (Figure 13), reflecting the poor grassland growth (Figure 11). In Khashaat the reduction was about 30%, as they had lower stocking rates to start with. Herders in Altanbulag had more animals and a higher stocking rate than those at Khashaat, reflecting the general trends in those aimags.

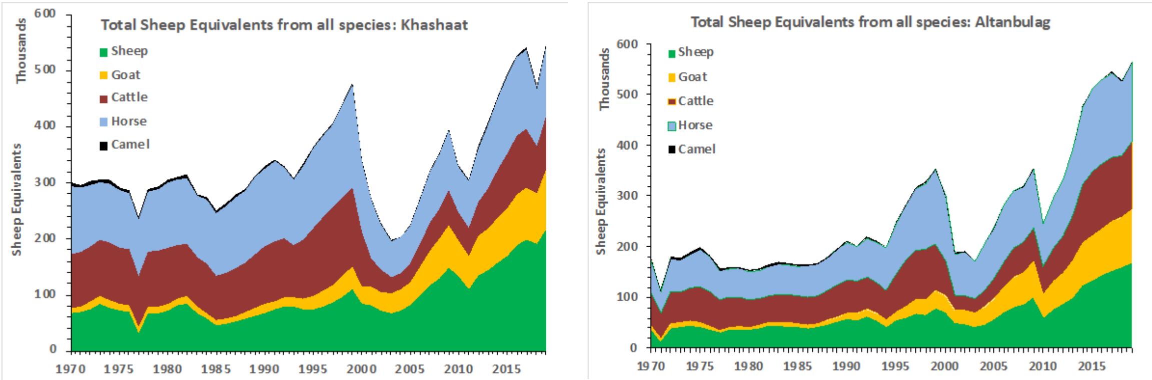


Figure 12 Total sheep equivalents for all livestock species in Khashaat and Altanbulag from 1970-2019.

The estimates of the area used for grazing, and to estimate stocking rates, are problematic as boundaries are largely notional, though these data show that the herders studied were possibly stocking at a lower rate than estimated for the whole aimag. The combination of over-grazing and severe winters means that animals do not reach their mature body size until four years of age, about twice as long as would apply in Australia. In addition, the reproductive rates can be often only 50%. These factors mean that livestock production is inefficient and that extra animals need to be in each flock or herd so that herders can earn the income they need. Stocking rates can be reduced considerably when coupled with better management of livestock. In IMAR farm demonstrations showed that halving of stocking rates and then better management of the remaining animals increased incomes (Li et al., 2020). These results do show that the system was under stress during this study and hence herder responses recorded in other parts of this program would reflect their sensitivity to over-grazing and a decline in environmental services.

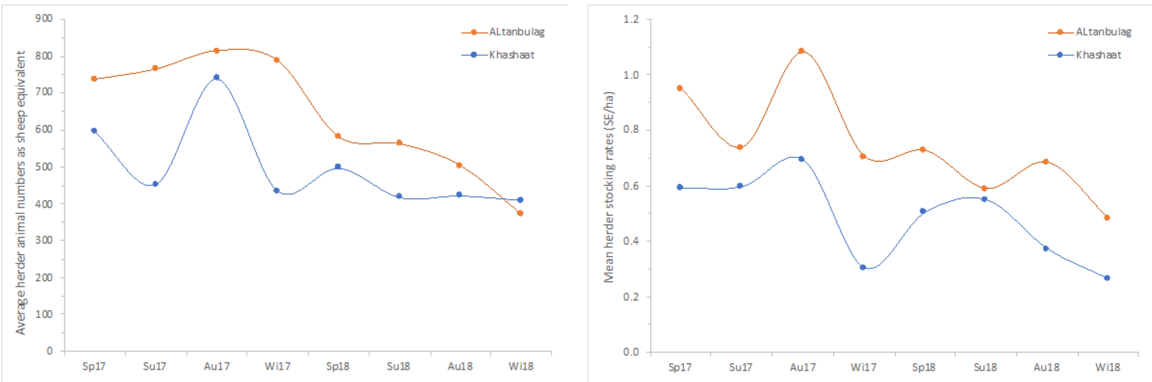


Figure 13 Average total sheep equivalents (sheep, goats, cattle & horses) and average stocking rates for the herders surveyed in Khashaat and in Altanbulag from spring 2017 to winter 2018

Each year in IMAR and Mongolia, severe winter conditions result in substantial weight loss of all animals. For mature animals this often means that the maximum liveweights at the end of summer, early autumn are similar to what they were a year before. Much of the animal growth through summer is simply regaining the liveweight lost through winter. There is a very strong relationship between liveweights in autumn, early winter and liveweights in the following spring as shown by the data for Altanbulag (Figure 13); similar data was found for Khaasat. The liveweight in spring averaged 0.6kg for small animals and 0.56kg for larger animals (no significant difference) for each kg the previous autumn. This meant that 30 and 50kg small animals lost 21% or 29% respectively, of their liveweight over winter, while 200 and 400 kg large animals lost 15% or 30% respectively of their liveweight over winter. Individual animals did lose up to 50%, a result predicted by the SGM. This regular and severe weight loss means that in the SGM a ‘reference’ weight needs to be set to better estimate the nutritional requirements and rates of change in liveweights. The reference weight is the highest value that the animals had previously reached. A further consequence is that the weight gain in summer is to a large extent compensatory gain, which gives a false idea of how well the animals grow on meagre grasslands. That in turn can lead to herders arguing that their animal production is not suffering.

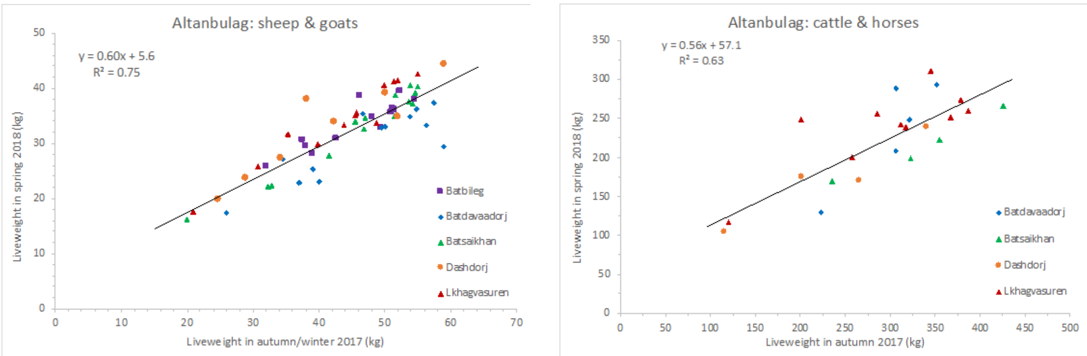


Figure 14 Relationship between liveweights in autumn 2017 (late September or early December) and liveweight in spring 2018 (late April) for sheep and goats, and cattle and horses for the five herder households in Altanbulag *(Note only four had cattle and horses)*

Weight loss over winter is arguably the major constraint on livestock production in Mongolia and IMAR. Results are very similar in each region. This reflects the extreme climate, aggravated by the lack of suitable forage. Modelling has shown that the energy costs of walking animals to grasslands in winter could never be replaced, no matter how nutritious the available forage was (Kemp 2020). In IMAR, warm sheds are now widely used. These sheds are to some extent a replacement for lack of suitable fodder. Keeping animals in a shed through winter does reduce the grazing pressure on grasslands. However, because the idea of warm sheds is foreign to Mongolian herders, we did not include their provision as an option in the surveys and other modelling work done. That needs to be explored in future work, along with improving the provision of stored fodder.

Winter through spring is also the time when lambs, kids, goats, foals are born. Their mothers are invariably in poor condition and unable to produce much milk for long. This restricts animal growth rates. China’s programs to improve and, or build warm sheds, and to increase the supply of conserved fodder and food supplements has helped to reduce weight loss and thereby help herders move from a mode of survival to one where they can produce more animal products for markets, thereby improving household incomes.

The data collected from herders enabled a check on the common ratios used in Mongolia to estimate ‘sheep head’ equivalents (Table 20). No herders surveyed had any camels to check their weights. This information is useful for refining estimates of actual grazing pressures on the grasslands and for refining relative impacts of different livestock species. This data shows that the average sheep was less than 50kg and other species were generally smaller than the common ratios would imply e.g. on average, cattle were 250kg or less, and horses less than 300kg. The larger sheep equivalent values are for summer and the smaller ones for winter. The summer values are more important as they define the ‘reference weight’ for animals in the SGM, which is more useful for estimating consumption rates of grassland. While this data does suggest that the index values used in Mongolia are a bit optimistic, that may not be a problem as the index values provide a small buffer.

Table 20 Mongolian index ratios commonly used to estimate sheep head equivalents, compared to the mean range from weights of animals for a 50kg sheep equivalent (SE)

Livestock	Index to sheep head	Sheep equivalent (50kg) from weights
Sheep	1	0.7-0.9
Goat	0.9	0.6-0.8
Cattle	6	3.9-5.2
Horse	7	4.4-6.1
Camel	5	

7.3 Comparative analysis

The theme of the Edward Elgar book (Brown (2020) was a comparison on Inner Mongolia and Mongolia across many aspects of the project research and the comparative insights are drawn in this publication. The sections below highlight a few of these comparative insights.

7.3.1 Institutions

Climatic variability on the Mongolian steppe has been a primary driver of informal institutions in Mongolia and Inner Mongolia, and formal institutions in Mongolia. Where formal institutions have not been well aligned with this variability, rule-breaking or inefficiencies have arisen with subsequent implications for livelihoods and social costs, as well as grassland condition. In Mongolia, perceptions of weakened informal institutions and largely absent implementation of climatically appropriate formal institutions are perceived to have contributed to both herder-against-herder conflict and to overgrazing. This is particularly the case in locations where internal migration has led to a ‘clustering’ of herders and livestock seeking to better access markets and services not available in more remote parts of the country. Policy responses have included attempts by government to improve supplementary feed and veterinarian services as well as biosecurity with a view to improving export options but the social data suggests herders see the government policy responses as very weak. The development sector has promoted the use of community based natural resource management to encourage herders to work together towards better regulating grazing pressures. The relationship between community based natural resource management and improved grassland condition in parts of Mongolia is still weak but some social benefits are emerging. Whether recent government investments in the pastoral sector improve livelihoods and grassland condition is yet to be seen. In Inner Mongolia, formal institutions are a far more dominant driver of pastoral change. While high transaction costs and subsequent low enforcement has led to rule-breaking, such as illegal night-time grazing, potentially muffling intended environmental improvements from the introduction of new formal institutions, these institutions have still resulted in the desired outcome of structural adjustment. Urbanisation has increased dramatically and herders who remain have experienced improved incomes albeit due to increased commodity prices rather than policy reform.

7.3.2 Environmental services

Rating the environmental services on the typical steppe versus the steppe indicates that in general, the average grassland across the whole area of each grassland type in Mongolia is in better condition than in Inner Mongolia (Figure 15). This does not mean that all the grasslands in Mongolia are in good condition as highlighted in Densambuu et al. (2018). In Inner Mongolia, residual herbage mass, clean water delivery, soil carbon storage and erosion reduction all had the lowest rating. These are all components of low grassland productivity. In Mongolia, conditions are generally better though relative to other components, residual herbage, soil erosion and soil carbon rated the lowest. Total plant growth, and plant functional group diversity were services that were in a relatively better position. Animal production per head was around the mean rating for both grasslands but again better in Mongolia. Collectively these ratings reinforce the view that grasslands are over-grazed and that herders do not achieve animal production levels anywhere near the potential.

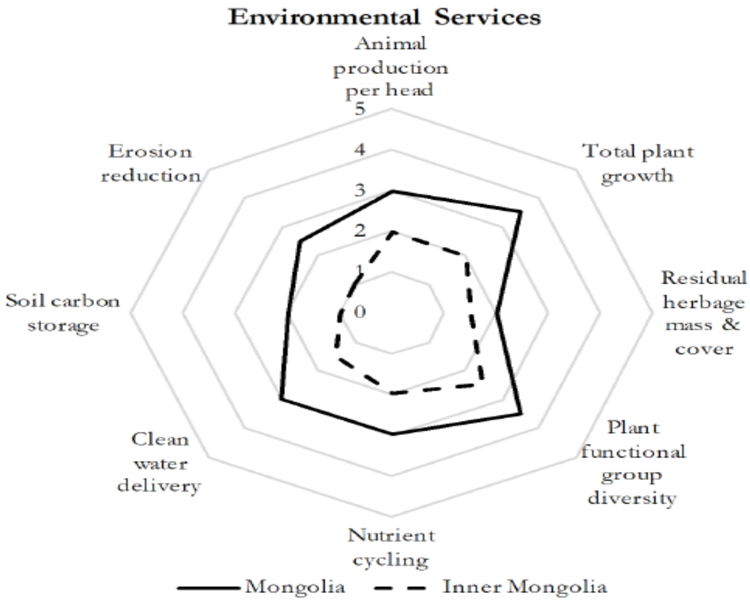


Figure 15. Rating of grassland environmental services

Source: Kemp et al. (2020b)

7.3.3 Marketing

Extract from Brown et al. (2020b)

Markets are a powerful conduit for incentives to influence herder behaviour and grazing systems. Indeed arguably market and price developments have had a much more overwhelming impact on herder behaviour and grazing strategies than direct policy initiatives. Thus governments in Mongolia and China often employ policy instruments designed at influencing markets and, through them, incentives to herders. The analysis reveals that market integration and price transmission in ruminant livestock product markets in China is strong. Transmission is also evident in Mongolia but factors such as disease incidence and transport infrastructure influence price transmission. Marketing systems are also more developed in China while there is a much greater seasonal pattern in meat prices in Mongolia than in Inner Mongolia. The seasonal pattern of prices and limited marketing channels at different times of the year in Mongolia may limit or influence the options herders have to raise incomes or implement grazing strategies that improve grassland condition. While markets operate more-or-less effectively as evidenced by the price transmission, there is still considerable scope to improve markets in Mongolia and Inner Mongolia in a way that allows herders to improve their livestock value per unit grazing pressure. Both Mongolia and China have implemented proactive industry policies for ruminant livestock industries designed at influencing the markets for these industries and the incomes of herders reliant upon them. However, whereas the policies in China have primarily targeted influencing supply, policies in Mongolia have more directly targeted product prices.

Monthly indices of cashmere prices in Mongolia and China from 1980 to 2018 reveal a similar pattern of cashmere prices in China and Mongolia. Several factors are likely to influence cashmere price transmission between China and Mongolia. From 2008 to 2010, a number of policy changes occurred, the most significant being the annulment of cashmere tariffs in Mongolia and policies restricting the sales of cashmere to China. Preliminary empirical analysis of price transmission suggest structural breaks around this period. Furthermore the observations are consistent with the shift in the global cashmere industry (both production, processing and consumption) to China. Mongolia has sought to incentivise herders not to sell to Chinese traders and to retain cashmere for processing in Mongolia. Furthermore Mongolia has preferential tariff rate quota access to lucrative European Union markets relative to China. Nevertheless even if these measures are influential in restricting the trade of scoured cashmere to China, the dominance of China in the global cashmere industry is still likely to impact the Mongolian industry. For meat markets, prices for Chinese beef and mutton and for Mongolian meat and mutton (converted to Chinese yuan) are shown in Figure 15. Empirical co-integration analysis supports the casual observation of no price transmission at least, at a 5 per cent level of significance, as was the case for cashmere. The integration results are not surprising in that there is relatively small trade in meat products between the two countries. Notionally there is potential for significant trade in meat products between the two countries as China struggles to keep up with the rising demand for beef and sheepmeat in spite of efforts to grow these industries, while Mongolia also has a large production relative to its population even with its high average per capita meat consumption. However, disease outbreaks, concerns and protocols restrict the movement of livestock and meat between Mongolia and China. Addressing these disease issues and developing infrastructure to facilitate cross-border trade in livestock and beef would require substantial investments by the Chinese and Mongolian governments. The significant gap between Mongolian and Chinese prices in Figure 16 reflects the barriers to ruminant meat and livestock trade between Mongolia and China.

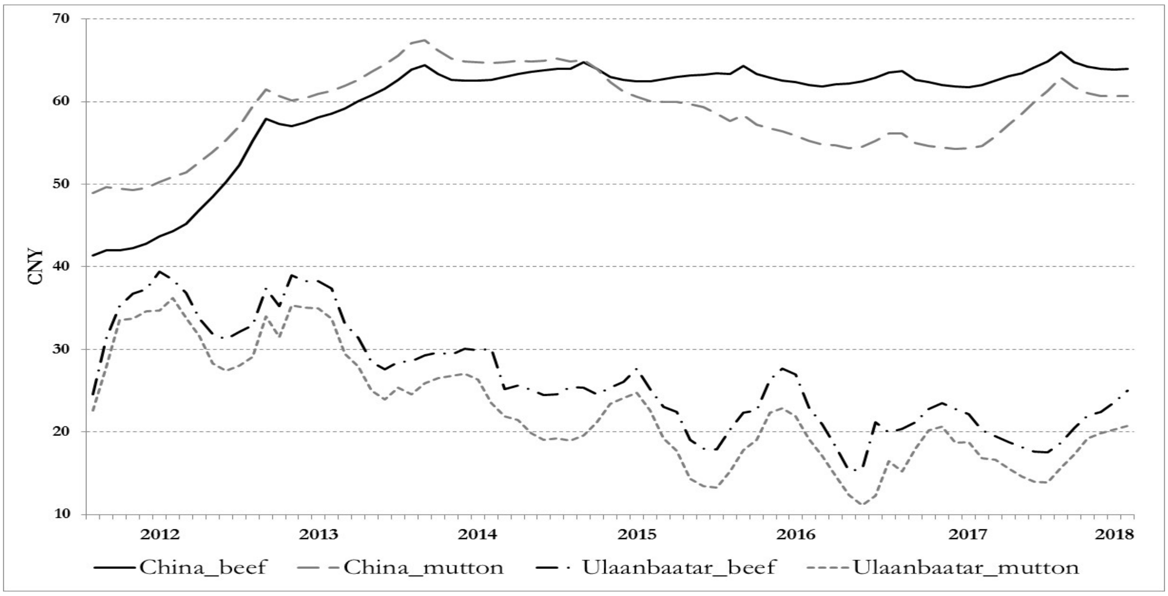


Figure 16. Monthly mutton and beef prices: China and Ulaanbaatar: 2011 to 2018
Source: Brown et al. (2020b), Figure 5.2.

Despite other similarities in grazing and livestock systems between Mongolia and China highlighted in the book, the two countries exhibit very different seasonal patterns in prices. Seasonal monthly price indices for beef, mutton and cashmere in Mongolia and China are displayed in Figure 16. The price series for beef and mutton are similar in each country but exhibit a very different seasonal pattern between the countries. That is, beef and mutton prices are highest in Mongolia towards the end of spring and lowest in late autumn while for China they are highest in winter and lowest in summer. Furthermore the intra-year (monthly) variation in prices is much larger in Mongolia than it is in China. Specifically while the monthly China mutton and beef prices vary in a band of less than 5 per cent, the Mongolian seasonal index for beef has a range of 23.2 per cent, with a high in June (111.4 per cent) and a low in November (88.2 per cent) while the Mongolian seasonal index for mutton has an even larger range of 33.1 per cent, with a high in June (116.5 per cent) and low in November (83.4 per cent). Thus Chinese meat prices are stable across the year while Mongolian prices exhibit a large seasonal variation. Some reasons for the differences include: (a) China has a huge domestic market with significant storage capacity and well developed meat marketing channels; and (b) many herders in Mongolia sell sheep, cattle and goats in Autumn when livestock are at their highest liveweight and prior to winter. This period also coincides with significant household cash expenditures such as paying education or university fees in September. For China, the seasonal or intra-year variation in meat prices is lower than the inter-year variation. In Mongolia, the intra-year variation is larger than the inter-year variation although the latter is also significant in Mongolia (around 5 and 10 per cent for beef and around 11 per cent for mutton between 2012 and 2017). Both the inter- and intra-year variation in ruminant livestock product prices impacts markedly on grazing and production systems and on how herders respond to different incentives and policy instruments as they take advantage of the different prices. The monthly price indices for cashmere as indicated in Figure 17 are also relatively stable and much less than the inter-year variations. Although the seasonal movements are similar in China and Mongolia, the variation in Mongolia is larger than China. China's peak index is in March (101.2 per cent) and the low in December (98.3 per cent)—only a 2.9 per cent seasonal index range compared with Mongolia's peak in March (103.3 per cent) and low in June (96.2 per cent)—a 7.1 per cent seasonal index range.

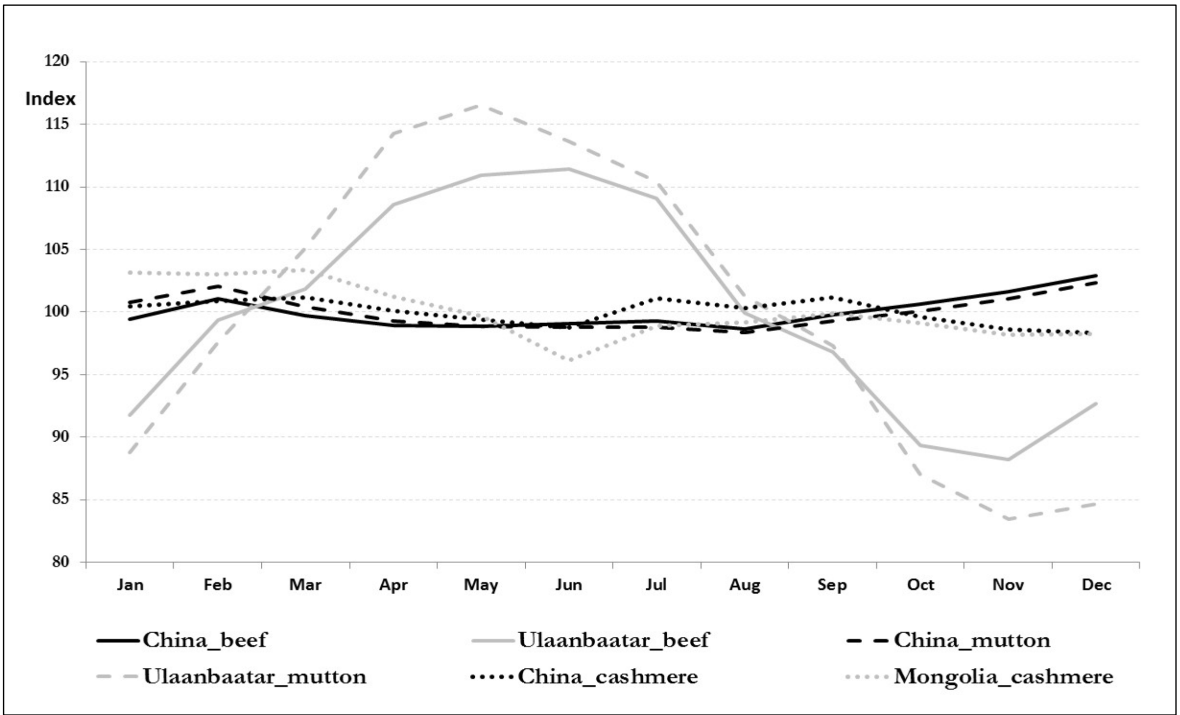


Figure 17. Seasonal variations in China and Mongolia in beef, mutton and cashmere
Source: Brown et al. (2020b), Figure 5.4.

7.3.4 Factors affecting herder behaviour

Extract from Addison et al. (2020)

Herders navigate through complex and sometimes conflicting social, economic and environmental influences in pursuit of a meaningful livelihood, which can vary through time, space and between individuals. Social research with Mongolian herders suggests that social relations and security are important, and potentially under-considered, livelihood domains. These domains are negatively impacted by interwoven and complex drivers including weakened institutions, greater exposure to climatic shocks, declining pasture condition and access to markets. Material goods, while having higher levels of dissatisfaction, are considered a less important contributor to a meaningful livelihood. Herder strategies for achieving these understandings of a meaningful livelihood are varied but many herders ultimately rely upon increasing their herd size as a core strategy for managing risk. What constitutes a meaningful livelihood in Inner Mongolia is less clear but herders appear to be responsive to opportunities to increase incomes for reasons including building capital for retirement. Non-compliance to formal institutions with significant opportunity costs to herder incomes is common particularly where monitoring and enforcement are perceived to be weak, and there is some evidence that structural adjustment that has accompanied grazing bans may reverse once bans end. In Mongolia, policy options that provide a compensatory alternative to the core risk management strategy of building herd sizes, while being cognisant of the important role of social relations and security in a meaningful livelihood, may find traction among herders.

8 Impacts

8.1 Scientific impacts – now and in 5 years

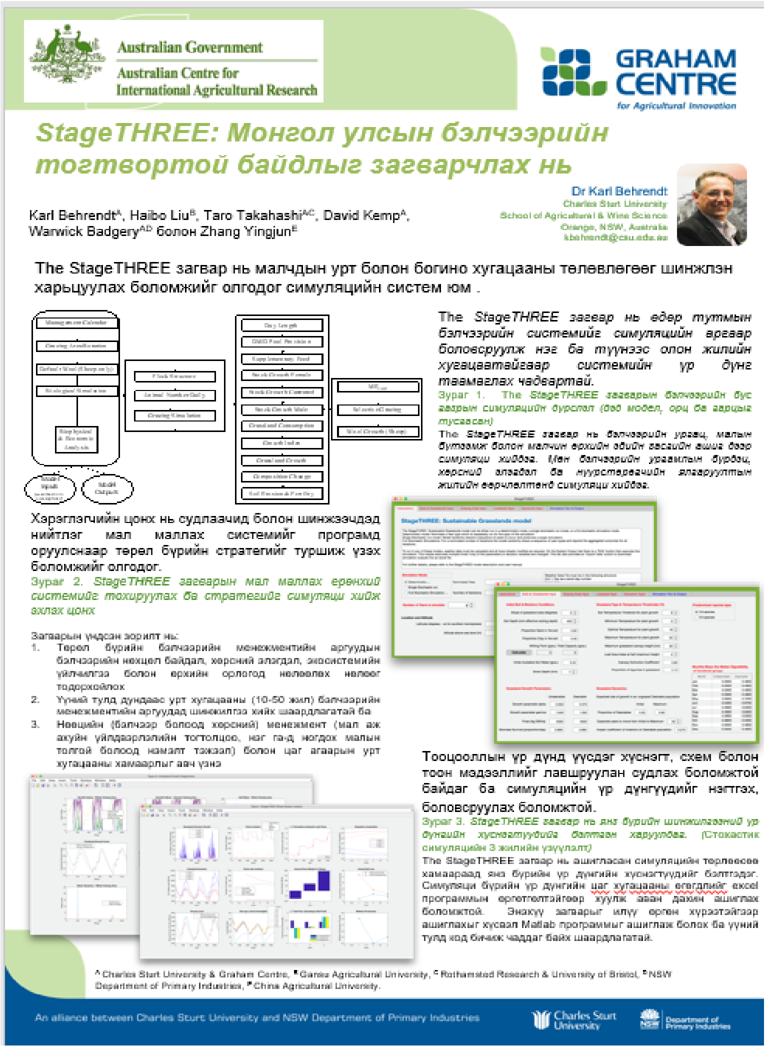
There are several ways in which the project is likely to impact scientific practices, approaches and knowledge. As the project findings are just being published, these impacts are yet to occur while the impacts are of a diffuse nature. There are three main areas of impact.

First, the approach of using choice modelling of urban residents to estimate the environmental amenity of grasslands is new in Mongolia and Inner Mongolia and likely to influence future grassland researchers and studies both in these countries and elsewhere. Furthermore, using choice modelling to identify herder preferences for alternative policies and the understanding of preference rankings for policy options that achieve stocking rate targets and, in particular, the contingent behaviour analysis identifying the behavioural response of herders to alternative policies is a new approach in Inner Mongolia and Mongolia. To date analysis of grassland policies in China have been dominated by ex-post studies of the impacts rather than ex-ante analysis of behavioural responses and so is likely to catch the attention of many grassland scientists and influence their research and methods in the coming years. In addition, most grassland policy analyses in China are not based on social benefit cost analysis and so the research will also promote this type of analysis among future grassland researchers.

Second, while analysis of social, socio-ecological and socio-economic issues associated with herders in the pastoral areas of Mongolia and Inner Mongolia has been done, the systematic social survey and analysis of this survey in Mongolia, in particular, is likely to contribute to discovery by: (a) using the Theory of Planned Behaviour to look at herder intentions and responses in a longitudinal manner; and (b) ‘unpacking’ what a livelihood actually means, as herd size has been the standard surrogate generally used. This is likely to have a widespread impact among the scientific community but also and in particular, the NGO sector.

Third, the development of the stochastic dynamic bio-economic model is likely to have a lasting scientific impact. No other model exists that covers the economic, biophysical environmental, household and livestock systems in such a comprehensive and rigorous manner nor that can represent the stochastic and dynamic elements so characteristic of these grazing and pastoral systems. Furthermore, the project has facilitated the collection of accurate, detailed and relevant data needed to calibrate the model so that it can accurately represent different herder households in different agro-ecological zones. Thus, the model is likely to be used and become a benchmark for the analysis of herder households in these regions. The model has also been applied to other agro-ecological zones, such as UK pasture and livestock systems, and in the analysis of precision livestock grazing (Behrendt et al. 2019c) but this work and these applications would not have been possible without the model development under the ACIAR project.

Fourth, the Mongolian and Inner Mongolian scientists are being mentored in using more effective methods for analysing grassland/livestock systems. In particular there is advice and encouragement to use rapid assessment techniques to gain a better measure of how the landscape is responding to different management practices – techniques that will be important for monitoring the impact of grassland policies.



Mongolian presentation poster for bioeconomic model

8.2 Capacity impacts – now and in 5 years

There are several ways in which the project has had a capacity impact. Most of the methods used in the project were new to researchers in the institutions where the research was done. Before the primary research, general and intensive (multi-day) training sessions were done on the different methods and approaches. These sessions were open to both project and non-project researchers and were focussed on the methods rather than the project per se. This applied particularly in the cases of the choice modelling, bioeconomic modelling and social surveys. A significant proportion of the participants at these training sessions are not active members of the project research and so are likely to use these methods in other applications.

Jeff Bennett presents choice modelling workshops in Hohhot and Ulaanbaatar

In the case of the bioeconomic model, detailed model documentation and user guides, access to the model, and detailed one-on-one interaction with particular project researchers is likely to mean that the model will be used in a range of applications long after the project is completed. Both Inner Mongolian and Mongolian researchers have now been introduced to improved techniques to study grassland / livestock systems as demonstrated in Inner Mongolia with an increasing number of high quality papers being published. Several key personnel plan to present a panel session on the work done at the International Grassland / Rangeland Congress in Kenya in 2021.

Apart from the general impacts, there are specific impacts with individual project researchers. Two of the Mongolian project researchers (Enkh-Orchlon Lkagvadorj and Bukhbat Duinkherjav) are doing their PhD studies as part of their John Allwright Fellowships while the choice modelling and bioeconomic modelling has involved intensive interaction with several project researchers. A key aspect is that many of these project researchers are young scientists who are likely to have influential future roles in their institutions and on grassland research. Another project researcher, Professor Li Ping, was previously the recipient of a John Dillon Fellowship and her exposure to much of the social and choice modelling research in the project combined with her prominent role in the Grassland Research Institute is likely to have a significant capacity impact on grassland research in China. Similarly, Dr Zhang Bao has been heavily involved in the choice modelling and economic analyses in the project while he was undertaking his PhD and also had an extended stay in Australia during the formative research stages where he also was mentored and had the opportunity to present his research at major academic conferences in Australia. As a young academic, the skills and knowledge he has developed through the project are likely to have a considerable impact over time. As Dr Zhang has taken up a position within the College of Economics and Management at IMAU then the impact of the project is direct and will extend beyond the immediate study.

8.3 Community impacts – now and in 5 years

The different areas of the project are involved in different ‘communities’ beyond the immediate scientific networks. In Mongolia, there has been regular interaction with researchers on the Swiss Development Corporation ‘Green Gold’ project as the projects are complementary. Professor Karl Behrendt’s modelling community and farm data benchmarking networks extend well beyond the grassland scientific community. In China, the project team’s networks extend to a range of government agencies and contacts that again extend beyond the immediate grassland agencies.

This project has contributed to the Global Sustainable Development Goals for:

- Poverty alleviation – the modelling has shown that reductions in stocking rates can increase net financial returns to herder households.
- Quality education – There has been a focus in the project on mentoring the next generation of research leaders.
- Gender equality – A high proportion of the Mongolian and Chinese researchers and students involved in the project are female while they were also the main group at the training workshops.
- Reduced inequalities – The project has sought to identify ways to improve the incomes and livelihoods of herders in both Mongolia and China and who are among the poorest groups in these countries.
- Climate action – Modelling has shown that reduced stocking rates have reduced greenhouse gas production per unit of animal product, adding to work done in the previous ACIAR project (Zhang et al, 2020).
- Partnerships – The project has been a partnership between the Australian, Mongolian and Chinese Governments, with engagement to officials and policy advisors on how policy changes can improve herder livelihoods and grassland condition.

8.3.1 Economic impacts

Attribution to the project of uptake of new practices, market prices or policy changes (as per the 'Instructions for preparing an annual report') is confounded by a plethora of time-dependent factors that influence policy decisions, market developments and technology uptake even where there are seemingly clear impact pathways. This is no less the case in this project where political considerations and market and social complexities will influence these decisions. Nonetheless, the nature of the project impacts is likely to be as follows. First because the project identifies ex-ante behavioural responses through the choice modelling and income impacts through the modelling, the information provided to officials in making grassland policy decisions and to herders in making livestock and grazing management choices will include the opportunity costs for herders and society at large in making particular decisions. Second, because the project identifies net social benefits associated with alternative policies, information will be available to policy makers on maximising the wellbeing of society. Third, irrespective of ultimately what political decisions are made regarding grassland policies, because information is provided on alternative grassland policies, the optimal strategies for herders to pursue is identified while awareness of any potential impacts will enable policy makers to mitigate potentially adverse impacts on herders.

The policy assessment of the eight alternative policy instruments in Inner Mongolia in Section 7.1.1 estimated net social benefits of between CNY162.8 and 928.9 million while it also estimated the net social benefits for the different grassland biomes and identified the relative importance of the different environmental benefits and resource costs in these estimates. As mentioned above it is difficult to predict whether any of these alternative policies will eventuate in the new grassland policies about to be developed, or to attribute the impact of the analysis in the uptake of these policies although key results of the analysis are being presented directly to key grassland officials in the Bureau of Forestry and Grasslands and other agencies involved in the revision to grassland policies. In Mongolia, the policy assessment of the four alternative policy instruments in Section 7.2.1 estimated net social benefits of between MNT178.1 and 285.5 billion and identified the relative importance of the different environmental benefits in these estimates.

8.3.2 Social impacts

As with the economic factors, it is difficult to attribute specific social impacts to the project. However, in that there is a dearth of knowledge about the social and socio-ecological factors impacting herders in Mongolia, the detailed surveys and analysis in the project will provide a wealth of information to policy makers in formulating policies. Although political decisions may again be made that are not necessarily in the best interests of the wellbeing of herders, an improved understanding of these social factors may avoid any unintended or unforeseen consequences of particular grassland policy decisions. In particular, the social analysis in Mongolia revealed what was important to herders in terms of their livelihoods including domains such as social relations and security. A better understanding of what domains are important to herders in their livelihoods may enable policy makers to refine the grassland policies to account for considerations beyond incomes, grassland condition and environmental benefits alone.

The research was also able to identify herder preferences for different policy instruments as well as impacts and herder satisfaction with existing instruments. This has enabled more insights into the political ‘acceptability’ of different policy instruments which among other things may influence compliance with the programs and a better understanding of the rationale behind the programs and intended benefits for herders. In Inner Mongolia, the project collaborators have identified that both provincial and local government agencies have adopted findings from the projects and have started to change their attitude for environmental payment of grasslands.

8.3.3 Environmental impacts

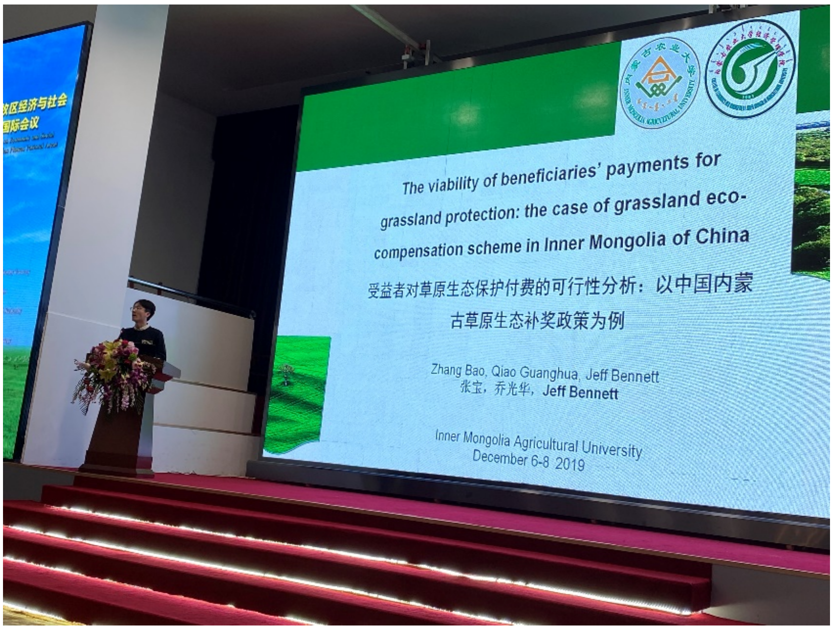
Grassland policy proposals involve an intricate and nuanced set of trade-offs between environmental, economic and social goals. However, the unique approach in the project enables valuation of environmental benefits associated with likely grassland policy changes as well as the net social benefits (after account for resource costs) of the alternative grassland policies to be estimated. The choice modelling analyses were able to identify the value urban residents placed on grassland amenity and different environmental attributes while the modelling was able to determine the impact of alternative policies on attributes such as grassland condition, dust events and overall dust emissions. This will enable grassland policy makers to make more informed choices on grassland policies that impact the environment. In that relatively little is known about the value of the grassland amenity then they are more likely to have been overlooked in previous assessments of grassland policies resulting in less than optimal environmental outcomes. The project is likely to strengthen these environmental outcomes and be able to identify policies most able to meet societal environmental goals.

The modelling was also able to determine the impact of livestock reductions under the alternative polices on greenhouse gas emissions. In Inner Mongolia, the policy assessment of the eight alternative policies estimated reductions in greenhouse gas emissions of between 0.63 and 9.74 GWP100 million tons CO_2e/annum, and reductions in wind erosion of between 0.01 and 0.08 t/km^2/annum (Table 1). In Mongolia, the assessment of the four alternative policies estimated reductions in greenhouse gas emissions of between 1.16 and 1.93 GWP100 million tons CO_2e/annum, and reductions in wind erosion of between 0.01 and 0.04 t/km^2/annum (Table 10).

8.4 Communication and dissemination activities

The strategies and activities to disseminate and communicate the findings from the project can be categorised into three main areas namely written publications, oral presentations and direct meetings/briefings with policy officials and their advisors.

For the written publications, there has been a multi-dimensional strategy with multiple objectives. The publications and particularly journal papers have enabled a level of peer review and academic critique crucial to the academic integrity of the research. However, they have also been used to disseminate the academic findings widely among grassland and other researchers many of whom are influential in grassland policy debates. The reference list in Section 10 highlights that a range of key journal have been targeted such as the Rangeland Journal, Environmental Economics, and Land Use and Policy. However, a deliberate part of the publication strategy has also been the preparation of two key books/monographs. Edward Elgar publishers are a highly respected academic publisher with a focus on applied economics but often with a policy and interdisciplinary focus. The book provided the ideal forum to present the academic findings of the project but in a way that was easily communicated to other professional and lay readers and hence to many policy advisors. The structure and theme of the book also had a strong inter-country comparative theme which apart from addressing Objective 3 and having a benefit of bringing the research teams from the different countries together on particular topics as highlighted elsewhere in this report. It also raised themes of interest to policy advisors in both countries. The ACIAR book/monograph edited by David Kemp while being a culmination of research findings from the series of ACIAR and other projects in northern China also drew heavily on the research from the current project, and the ACIAR distribution network also provided a widespread but different distribution network to the Elgar network.



Zhang Bao presents a paper on behalf of project team at international conference in Hohhot in December 2019

The second communication and dissemination strategy was presentation at key national and international conferences. Multiple papers on key aspects of the research were presented at both the 2017 and 2019 Australian Agricultural and Resource Economics Society as well as the World Ecological Economics Society. Project team members also presented at the Rangelands Congress in Saskatoon in 2016. Presentation of final project findings scheduled for a series of international conferences in 2020 with presentations by key project researchers have been severely impacted by the COVID-19 travel restrictions. The IGC in Kenya where a dedicated panel session was planned has been postponed to 2021 while a key economics conference in Brussels presenting the model and international workshop on the multidimensional aspects of grassland have also been postponed or changed to a virtual platform (virtual conference for the International Symposium on Society and Natural Resources, July 2020). It is to be hoped that the project findings can still be presented at these key international fora even though the deferred events are now scheduled for after project completion.

Another specific but highly relevant and targeted conference that the project team has participated is the International Conference on Economic and Social Sustainable Development of Mongolian Plateau Pastoral Areas jointly organised by Inner Mongolia Agricultural University and Mongolia University of Life Sciences. From humble beginnings, this conference has grown to be a key grassland conference with the 8th Conference in Hohhot in December 2019 hosting more than 150 delegates including overseas delegates, academics from other key Chinese and Mongolian universities (Renmin University and National University of Mongolia) and also attracted many officials and policy advisors. On behalf of the project team, Colin Brown was able to outline the project and particularly the approach used in the project as outlined in Section 5.1.1 of this report at a keynote paper (Brown et al. 2019) in this conference while David Kemp (Kemp et al. 2019b), Li Ping and Zhang Bao also presented papers on different aspects of the project. Similarly Colin Brown on behalf of the project team was able to outline the project at an international workshop as part of Mongolia University of Life Sciences 60th Anniversary celebrations held in Ulaanbaatar in November 2018 and attended by a range of Mongolian government officials.

The third part of the dissemination strategy has been more direct engagement and meetings with policy advisors and officials. A policy briefing of interim policy findings was presented to key Chinese central level grassland officials in Beijing in April 2018. The Inner Mongolian project team have also been disseminating the findings, implications and insights from the completed analysis to key Central level and Autonomous Region officials through policy briefs and meetings. All findings were presented at the Annual Meeting of Chinese Grassland Society in Xian, Shanxi Province in November 21-23，2019 and Annual Meeting of Ecological Society of China in Kunming, Yunnan Province in November 28 December 1，2019. Li Ping, on behalf of IGR, extracted the main findings from the project and presented them to policy makers from National Forestry and Grassland Bureau, Ministry of Agriculture and Rural Affairs and provincial level governments by formal presentation and work reports. A presentation made in National Forestry and Grassland Bureau in July was published on the web of the National Forestry and Grassland Bureau and later was printed as a work report to disseminate among all provincial level Forestry and Grassland Bureaus. Two reports on grassland eco-compensation estimation and optimization was signed by high level officials from the Ministry of Agriculture and Rural Affairs and the Inner Mongolia Political Consultative Conference. Li Ping also gave a presentation in training courses on grassland eco-compensation policy held by the Ministry of Agriculture and Rural Affairs and local governments. More than 300 local officials attended the courses in 2019 and 70 were present in 2020 due to the COVID-19 limitation.

In Mongolia, all major visits of the Australian team have been accompanied by visits to senior policy officials in the Ministry of Food Agriculture and Light Industry ensuring a regular (around 6 month) interaction and engagement with these key officials. Project findings were also communicated to the main political parties in the lead up to the July 2020 general elections. A policy forum, modelled on similar forums organised by the Green Gold project, was scheduled for October 2020 to present the key Mongolian findings as the basis for discussion among officials and academics on future Mongolian grassland policies but has been delayed by local elections in Mongolia and is now scheduled for mid-2021. In addition, policy workshops/forums are planned at this time in 7 aimags where the study was done and which will involve soum officials. These local level officials and herder leaders are crucial in the policy implementation process in Mongolia. Although presidential and regional elections and COVID-19 travel restrictions disrupted planning for these activities in 2020, it is still hoped that they will proceed as intended.

Mongolian and Australian project leaders meet with Ministry and Australian officials in Ulaanbaatar

9 Conclusions and recommendations

9.1 Conclusions

Some of the key findings from the research include:

- In Inner Mongolia, a “carrot and stick” incentive approach may be needed to bring current stocking rates down to the level required under GESAS. Specifically, policies preferred by herders (higher pensions, longer loan terms and higher ecocompensation payments) are unlikely to achieve the stocking rate reductions alone. Similarly increasing enforcement levels from a current 10% to 70% and increasing punishment for overstocking from CNY100 to CNY600/sheep equivalent will markedly reduce the acceptability of the policies to herders and so may result in ineffective implementation. A bundle of both positive reinforcement and punitive measures may be needed to bring stocking rates down to the sustainable level and improve compliance.
- In Mongolia, monthly interest rates, a livestock tax, and a reduced allocated flock/herd size under a livestock quota scheme were identified as policy instruments that did have a significant effect on livestock numbers that herders would keep. However, the effectiveness varied across instruments with increasing interest rates having a relatively modest impact compared to a modest livestock tax which had a larger impact.
- Frequency of sandstorms and condition of the grasslands were important to residents in both Hohhot and Ulaanbaatar where they indicated a willingness to pay for grassland support policies that improve grassland condition and reduce sandstorm frequency.
- In terms of the net social benefits of alternative policy instruments, the environmental benefits in both Mongolia and Inner Mongolia were smaller than the impact on herder incomes (both positive and negative depending on the level of overgrazing). Thus while the environmental benefits may be the target of these measures, the impact on herder incomes cannot be overlooked in the design and assessment of these policies.
- In Inner Mongolia, transaction costs are significant and relate almost entirely to enforcement of livestock numbers. Indeed, improving monitoring, enforcement and compliance from the current low levels and in a cost effective manner is crucial to the success of any future grassland programs and should be a priority in the design of these programs. In Mongolia, the transaction costs of implementing policies such as the livestock tax or livestock quota will fall heavily on the local soum governments. Consideration needs to be given to ensuring revenues generated by these instruments can be retained and reinvested at the local level so as to align the incentives and compliance of the measures with local herders and officials and to make a more direct connection between the policies and livestock and grassland improvement.
- The opportunity costs for herders in Inner Mongolia to comply with the grassland restrictions under GESAS vary greatly across states of nature (seasonal production and market conditions) whereas the payments are uniform across years. Thus consideration should be given to aligning the payments closer to the opportunity costs both to improve compliance and improve the efficiency of these payments. In both Mongolia and Inner Mongolia, the variability in herder incomes across different states of nature is substantial and a major issue for herders especially in Mongolia. Developing risk management strategies and programs to help herders cope with weather, market and disease related risks should be a crucial part of future programs.
- Social relations and security are important, and potentially under-considered, livelihood domains in Mongolia with material goods being considered by herders as a less important contributor to a meaningful livelihood. This suggests it may be important that new policies foster social relations and strengthen security if their aims are to improve livelihoods. What constitutes a meaningful livelihood in Inner Mongolia is less clear but herders appear more responsive to opportunities to increase incomes.
- Identifying profitable livestock systems under more constrained livestock numbers is crucial to the success of the policy instruments in an environment where incomes of

many herders especially in Mongolia are low. Strengthening institutional arrangements such as improving the grassland rental and circulation system in Inner Mongolia is also important in achieving these profitable livestock systems.

- There are many important interactions between Mongolia and China in relation to grasslands and ruminant livestock systems. One of the most important interactions, though with a potential far from fully realised, is the marketing system for ruminant livestock products. To date, most attention has focussed on the all-important trade protocols. However, there is much less attention or knowledge on the in-country supply and value chains and especially the assembly chains in Mongolia and distribution chains in China. Improving these supply and value chains and marketing systems may yield significant benefit to both countries and extending down to improved grassland management and livestock and grazing systems.

9.2 Recommendations

1) Build on research in Mongolia: The ACIAR project was the first project in Mongolia and the profile of the project and ACIAR research within MOFALI is beginning to materialise (MOFALI officials have expressed interest in supporting research similar to previous ACIAR/LPS projects) while the model of research is considered an ideal way for Australia to support Mongolia by the diplomatic staff (personnel communication Australian diplomatic staff in Ulaanbaatar). The project had a strong capacity building focus in Mongolia with training in key economic, modelling, social and livestock and grazing research while building up core data sets was also part of the research. While there have been major capacity building results in the project, these efforts could be built upon. Although there are stand-alone research outcomes and impacts from the research in Mongolia as highlighted in Section 7.2 and Section 8, the research provides an excellent base to explore rigorously other key research problems in Mongolia including but not limited to: (a) assessment of herders' vulnerability to climate, market and disease related risks as well as evaluation of different adaptation strategies (would build on social and bioeconomic modelling from current project but would need to be extended to a much broader range of areas and systems in Mongolia and would also focus on herder vulnerability and adaptation including evaluating strategies to improve livestock performance through winter); and (b) more rigorous assessment and trial of cap and trade livestock quota scheme (this instrument emerged in the surveys and analysis of policy instruments as an important potential future instrument that could facilitate herder adaptation and strategies to reduce grazing pressure, but a more detailed and rigorous assessment is needed to fully evaluate the relative merits and to demonstrate these merits). As highlighted in Addison et al. (2020b), the research in Mongolia not only has benefits for Mongolia and Mongolian herders but can also provide critical insights for understanding a range of issues in Australian pastoral and semi-arid systems.
2) In China, the project has built on a long history of ACIAR research in pastoral areas of China which demonstrably have improved grazing systems, ruminant livestock marketing systems and resource management systems in China. Nevertheless there are some areas where joint Sino-Australian research building on the current project could make further contributions again including but not limited to: (a) evaluation of precision livestock systems in a lower stocking rate/grazing pressure environment (Identification of profitable systems that may promote compliance under programs with grazing restrictions); (b) assessment of value and supply chains for ruminant livestock products in trade between Mongolia and China (Research in this area is underway but with a focus on trade protocols and with limited research on the assembly supply chains in Mongolia and distribution supply chains in China. This gap could be filled by building on the understanding of herder and marketing systems in the current project.); and (c) investigation of longer-term perceptions of grassland programs (The SEM analysis of herder perceptions and reasons behind these perceptions in Section 7.1.9

drew on panel data at three critical periods – start, mid and end- of the first round of grassland programs. When combined with the knowledge drawn from the choice modelling and contingent behaviour analysis, this yielded powerful insights into herder perceptions of the grassland programs. The panel data set on which the SEM analysis was based is unique in providing insights into how perceptions change over the course of the program and as impacts become revealed and agents such as herders adapt to these impacts. The opportunity to redo the panel analysis but at the end of the second round of the grassland program (2020) would yield additional powerful and detailed insights into the dynamics of herder preferences and reasons behind their actions.)

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10.2 List of publications produced by project

The publications produced by the project by type are listed below. Full details of the reference are provided in Section 10.1.

A variety of publications and publication types has been produced by the project reflecting different target audiences and stages of the research. A flagship book publication covering most areas of the project and with a comparative analysis of Mongolia and Inner Mongolia can be found in Brown (2020) while a monograph integrating research from this project with research from previous and related ACIAR projects can be found in Kemp (2020). An overview of the approach used in the project can be found in Brown et al. (2019) although specific details of the research methods used are provided in the separate publications. A mapping of the publications to the specific project objectives can be found in Section 6. Findings from specific areas of the research are also scattered through the publications although the main findings from the assessment of policy options in Inner Mongolia can be found in Brown et al. (under review).

Books

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- Kemp, D.R (ed). (2020). *Sustainable Chinese Grasslands*. Australian Centre for International Agricultural Research, Monograph 210 ISBN 978-1-922345-21-9 (print) ISBN 978-1-922345-20-2 (online) ISSN 1031-8194 (print) ISSN 1447-090X (online) pp 332.

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11 Appendixes

11.1 Appendix 1: