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Review

A critical review of degradation assumptions applied to Mongolia's Gobi Desert

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Abstract. Several assumptions about the levels and causes of rangeland degradation in Mongolia are widely accepted by a range of stakeholders. These assumptions have become important in terms of guiding strategies and policy directions. This paper provides a critical analysis of five widely-held assumptions about rangeland degradation in Mongolia to the more specific case of the rangelands of the Gobi Desert. These assumptions are: (i) there are too many animals; (ii) the relative increase in goat numbers has led to desertification; (iii) rainfall is declining; (iv) there is declining pasture biomass; and (v) Mongolian rangelands are degraded. Biophysical and social data from the Dundgobi and Omnogobi desert steppe areas suggest not all of these assumptions are supported all of the time, and that the processes upon which these assumptions are based are often more complex or dynamic than is commonly recognised. In designing policy and programs, more attention to these dynamics and complexities is needed.

Additional keywords: climate, desertification, goats, Gobi Desert, livestock.

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Introduction

It is widely believed by a range of stakeholders – policy-makers, non-government organisations (NGO) and the local and international media – that the rangelands of Mongolia are degraded. The 'soft' literature of NGO and consultant reports, and other non-peer-reviewed academic publications, often refer to the nation's widespread rangeland degradation (or 'desertification' as it is more commonly called) (e.g. Batjargal 1997; Johnson *et al*. 2006; Mau and Dash 2007; United Nations Development Program 2007; Enkh-Amgalan 2008; The World Bank 2009; Mongolian Society for Rangeland Management 2010; Usukh *et al*. 2010; Leisher *et al*. 2012).

An increase in the number of livestock, particularly goats, is commonly cited as a major contributing cause of landscape degradation in Mongolia (e.g. United Nations Development Program 2007; Bayanmonkh 2009; Index Based Livestock Insurance Project Implementation Unit 2009; Sheehy and Damiran 2009; Whitten 2009; Sternberg 2010; Reeves 2011; Leisher *et al*. 2012). A change in rainfall patterns, particularly the decline of rainfall and subsequent decline in forage productivity, is another commonly cited cause (e.g. Bayanmonkh 2009; Index Based Livestock Insurance Project Implementation Unit 2009; Nakamura 2009). As a result of such perceptions, policy responses and program designs, such as the draft Pastureland Law (United Nations Development Program 2008; Dorligsuren 2010) and NGO-facilitated pasture user/pastoralist groups (e.g. Schmidt 2006; United Nations Development Program 2007; Usukh *et al*. 2010; The World Bank 2011; Leisher *et al*. 2012) have been, or are proposed to be, applied across Mongolian rangelands based on these assumptions.

Despite the influence of such perceptions on policy design and prescriptions, the national status of Mongolia's rangelands is not well documented. Nor is there scientific consensus about the condition of these rangelands (Sternberg 2009). A lack of a national monitoring system has contributed to conflicting understandings of the status and trend of rangelands at the national level because assessments have used different scales, indicators and sampling regimes, or have cited figures that are out of context from methods or methodological assumptions. For example, Batsuuri (2009) stated that 90% of the country was affected by desertification and land degradation, 70% of which was medium or severe. Awaadorj and Badrakh (2007) stated that 30% of Mongolia's rangeland area was degraded. Mau and Dash (2007) put this figure at 80%, while Bayankhishig (2009) stated that 77.2% was degraded to some extent. Sneath (1998) quoted Sheehy (1995) as stating that only 9% of the country was degraded. The 70% figure that is the most commonly cited (e.g. Sukhtulga 2009; Dorligsuren 2010) is also contested (The World Bank 2003).

In contrast to much of the soft literature, English language peer-reviewed literature increasingly recognises that vegetation communities in arid or semiarid areas may display non-equilibrium dynamics in response to grazing (Briske *et al*. 2003; 2010). Precipitation patterns are also increasingly recognised as the overriding factor affecting vegetation dynamics at the more local spatial scale of the Mongolian desert steppe region (Lavrenko and Karamysheva 1993; Wesche and Retzer 2005; Ronnenberg *et al*. 2008; Sasaki *et al*. 2009*a*; Wesche *et al*. 2010). Empirical research assessing the effect of grazing pressures on vegetation dynamics over several seasons increasingly recognises that the current pastoral system may have a low impact on at least some rangeland condition indicators in desert steppe areas (Wesche and Retzer 2005; Wesche *et al.* 2010; Cheng *et al.* 2011).

The implication of non-equilibrium systems for both understanding rangeland change and designing policy responses in the Gobi Desert is significant. Non-equilibrium theory accepts that 'boom and bust' livestock dynamics are typical (Begzsuren *et al*. 2004) and may not always be a cause of degradation as was previously believed (Ellis and Swift 1988; Abel and Blaikie 1989; Retzer 2006). Fixed livestock carrying capacities in non-equilibrium systems may be inappropriate (Scoones 1989; Leeuw and Tothill 1990; Bartels *et al*. 1993). Short-term vegetation attributes may not be suitable indicators of long-term change (Reynolds *et al*. 2007).

This paper uses a case study to review the applicability of commonly held assumptions about degradation of Mongolia's rangelands to the more localised spatial and temporal scales of desert steppe areas of the Gobi Desert. Assumptions explored are: (i) there are too many animals; (ii) goats have proportionally increased and this is causing desertification; (iii) rainfall is declining; (iv) there is declining pasture biomass; and (v) Mongolian rangelands are degraded. We analyse indicators of rangeland condition as well as pastoralists' accounts and secondary data to critique, through triangulation where possible, assumptions of degradation and their causal factors. We highlight where there is conflicting evidence or where inappropriate causal assumptions have been applied across landscapes. In doing so, we aim to provide a more nuanced understanding of the processes contributing to biophysical change in the Mongolian Gobi Desert. Such an understanding is crucial, especially where interventions to the existing systems are mooted.

Materials and methods

Site description: the Gobi Desert

The Gobi Desert is located across northern parts of the People's Republic of China and southern *aimags* (provinces) in the country of Mongolia (Fig. 1). Broadly undulating with occasional rocky rises, the Gobi Desert is located on a relatively high plateau. The northern areas of the Mongolian Gobi Desert, where this paper's study sites are located, have relatively high annual precipitation, increased vegetation cover and dominance of perennial forbs and grasses, and are generally referred to as 'desert steppe.' More southern areas often referred to as 'true desert' or 'hyper-desert,' have a more rocky subsurface and greater dominance of sub-shrubs (Lavrenko and Karamysheva 1993).

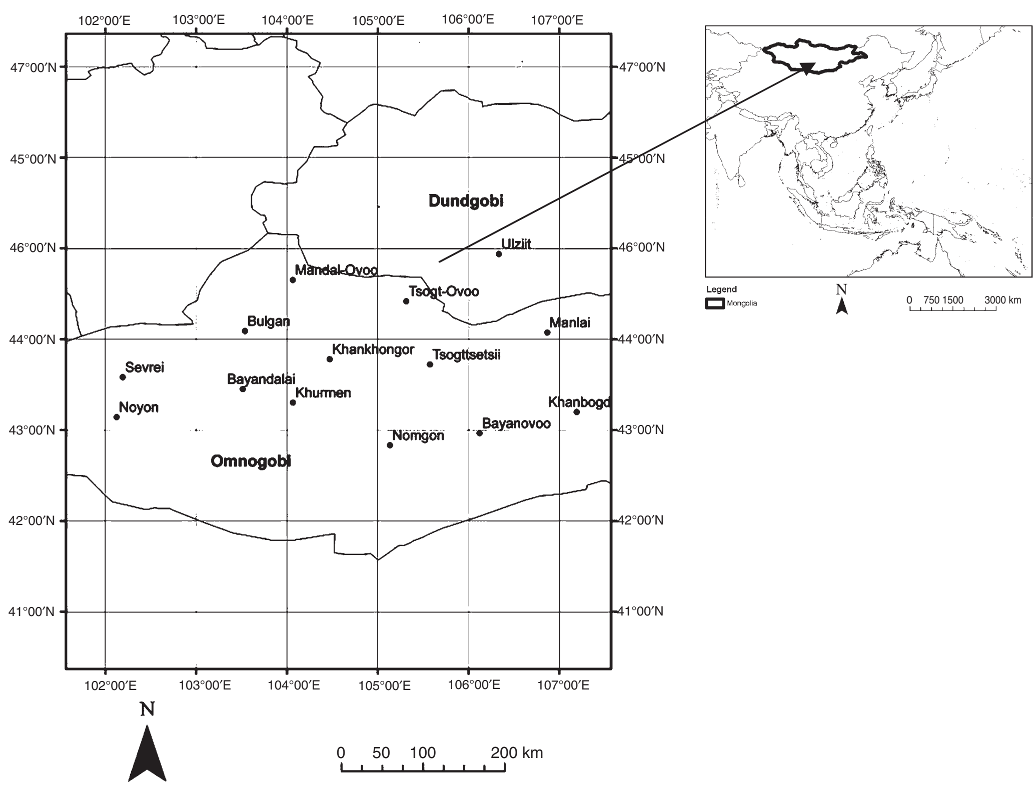

Fig. 1. Gobi Desert *aimags* (provinces) and *soums* (districts) selected for analysis. *Aimags* are Dundgobi and Omnogobi. Location of *soum* centres where meteorological data was acquired are indicated by solid points. The bolded line shows the Mongolian border.

Most precipitation in the Mongolian Gobi Desert falls as summer rain (Institute of Meteorology and Hydrology 2010). Annual average precipitation between 1990 and 2010 for this paper's study sites varied between 132 mm (Bulgan *soum*) (district) and 67.5 mm (Sevrei *soum*) (Institute of Meteorology and Hydrology 2010; see Fig. 1 for locations of *soums*). Precipitation is spatio-temporally variable, with the dynamics of the pastoral system commonly described as non-equilibrium (Ellis and Swift 1988; Fernandez-Gimenez and Allen-Diaz 2001; Wesche and Retzer 2005; Marin 2010). Co-efficients of variation (CV) of annual precipitation are moderate to high, with minimum and maximum CV at study sites of 26% (Bulgan *soum*) and 49% (Tsogttsetsii *soum*) between 1990 and 2010, respectively. Temperatures show significant intra-annual variability, with the coldest mean minimum in January (–20°C) and warmest mean maximum in July (23°C) (Johnson *et al.* 2006). The extremely cold annual periods are predictable. Rarer, seemingly stochastic *dzuds* (a multifaceted term implying atypical winter conditions, sometimes preceded by a drier than usual summer, that negatively impact pastoral production) add another level of unpredictability to the pastoral landscape.

The Gobi Desert has been used for mobile pastoralism for well over a thousand years (Lattimore 1938; Humphrey 1978; Fernandez-Gimenez 1999). For most of the 20th century, socialist policies supported pastoralism through the provision of fodder, livestock transport and veterinary care. The sinking of wells and building of winter–spring infrastructure also increased during this time. With the transition to a market economy during the early 1990s, the government retreated from provision of services to pastoralists, largely devolving the management of production risks back to the individual household. Pastoralist numbers generally increased through the 1990s with urban-rural drift (Fernandez-Gimenez and Batbuyan 2004) but this trend has reversed in recent years (National Statistical Office of Mongolia 2010). Spatially, pastoralists, and therefore grazing pressures, have also tended to move closer towards areas of economic activity (such as market towns, transport links and artisanal mining areas) since the 1990s. Despite these broad national-scale changes, the general pattern of mobility of desert steppe pastoralists in both socialist and post-socialist periods has reflected precipitation variability, manifesting in frequent movements during summer–autumn months, with more permanent winter–spring camps (Fernandez-Gimenez and Batbuyan 2004).

Rangeland condition

Fifty rangeland sites were assessed for indicators of rangeland condition across central and northern Omnogobi *aimag*, and southern Dundgobi *aimag* (Table 1 and Fig. 1) to explore assumption (v), Mongolian rangelands are degraded. Sites were assessed between June and October 2010. Pastoralists classed precipitation patterns as 'fair' to 'good' in promoting vegetation growth during this time period. Soil-based and perennial vegetation indicators were used as a more reliable indicator of rangeland condition than vegetation diversity surveys, or biomass assessments that rely upon the clipping of vegetation, as these reflect shorter term fluctuations in vegetation cover and composition. However, species presence and phenology were recorded.

Sites were a randomly selected subset of the forage model verification sites used in the Gobi Forage project (Texas A&M University, Global Livestock CRSP, Mercy Corps Mongolia and USAID 2011). These sites had been selected to be spatially representative of both land types and rangelands utilised by pastoralists. Sites were all classed as desert steppe (Lavrenko and Karamysheva 1993). Sixty-two percent of sites were calcisols, 32% kastanozems, 4% regosols and 2% solonchaks (IUSS Working Group WRB 2007). A broad, landscape-scale approach to sampling was taken to maximise spatial representativeness. Sites were generally located at least 1 km from a livestock waterpoint to minimise any localised effect

Table 1. Location, source and temporal span of data assessed or sourced for this paper

Aimag	*Soum*	Frequency Source	Number of rangeland condition surveys One-off Field-based by authors June–Oct. 2010	Number of interviews One-off Field-based by authors Aug.–Oct. 2010	Temporal range of biomass data Maximum yearly Institute of Meteorology and Hydrology	Temporal range of climatic data Monthly average *Soum* officials, or the Institute of Meteorology and Hydrology	Temporal range of livestock data Annual count *Soum* or *aimag* officials
Dundgobi	Ulziit		16	15	1990–2010	1990–2010	–
Omnogobi	Tsogt-ovoo		2	6	–	–	1960–2010
	Manlai		5	7	–	–	1960–2010
	Bulgan		8	6	1990–2010	1990–2010	1960–2010
	Bayandalai		5	4	1990–2010	1990–2010	1960–2010
	Tsogttsetsii		3	5	1990–2010	1990–2010	1960–2010
	Khanbogd		0	1	1990–2010	1990–2010	–
	Sevrei		3	4	1990–2010	1990–2010	–
	Noyon		1	0	–	–	–
	Nomgon		1	0	–	–	–
	Bayan-ovoo		1	0	–	–	–
	Khankhongor		3	0	–	–	–
	Mandal-ovoo		1	2	–	–	–
	Gurvantes		0	0	–	–	–
	Khurmen		1	0	–	–	–

that increased grazing pressures may have had on the area immediately surrounding the waterpoint (Sasaki *et al*. 2009*b*). Unrepresentative features in the landscape, such as mountain-tops, or areas relatively close to settlements, were avoided.

A 50-m line transect was laid parallel to the identified main erosive vector at each site (Fig. 2). Wind was assessed to be a more erosive vector than water at the majority of relatively flat sites. If obvious hummock-lags were visible, the dominant wind direction was calculated based on the direction of sediment deposition. As a default the prevailing spring wind direction was chosen since spring is when vegetation/obstructive cover is lowest, and hence the most likely time for accelerated soil movement.

The length and width of obstructive patches and interpatches along each transect were assessed using a version of Landscape Function Analysis (LFA) (Tongway 2008). This version is as follows. Patch/interpatch lengths were recorded along each transect until 70 patch or interpatch lengths were obtained. One limitation of the method at the samples sites was that it was difficult to balance spatial representativeness and patch/interpatch assumptions. On some sites, the dominance of gravel lag/fine rock armouring meant that when each rock of more than 1 cm diameter was recorded as a patch (in accordance with LFA methods), 70 replicate patch/interpatch samples were obtained over a very short transect distance (e.g. <5 m). The alternative to this, defining 'patches' at the vegetation community level, would have meant transects tens of kilometres long.

Perennial species were identified to species level where possible, or to genus level where not. In the few instances where the genus was not identifiable, the functional type was recorded. Some Gobi Desert perennial plant species, such as the perennial forb *Allium polyrrhizum* Turcz. et Rgl., are geophytes, contracting to underground bulbs in dry and/or cold periods. They have the potential to contribute to cover during good seasons and presumably contribute to soil stability, despite not fulfilling all perennial functions under LFA criteria (e.g. protection of the soil surface from rain splash in spring–early summer), or as a source of feed for grazing livestock in poor rainfall seasons. If bulbs were visible along the transect, they were recorded separately from non-geophytic perennials.

Five 1-m^2 quadrats were laid equi-distance along the LFA transect. This quadrat size is the maximum commonly used in Mongolian desert steppe areas – see, for example, Sasaki *et al*. (2009*b*); Sheehy and Damiran (2009); Texas A&M University, Global Livestock CRSP, Mercy Corps Mongolia and USAID (2011). Visual assessments suggested quadrat size was reasonably representative of both the composition and patterning of the pasture type, particularly given that unrepresentative landscape features were deliberately avoided in site selection. In each quadrat, % fine gravel, % coarse gravel, and % bare ground were assessed visually. The extent (presence/absence), severity (1–4, with 4 being most severe) and type of erosion features (rilling, pedestalling, hummocking, sheeting, terracettes, scalding, gullying) were noted. Percentage projected cover was visually assessed. Indicators of field texture (score of 1–4 where 1 = clay, 4 = sand), slake-ability of a soil ped (score of 0–4 where 0 = too unconsolidated to create a ped, 1 = slakes within seconds, 4 = intact), deposited materials (score of 1–4 where 1 = >50%, 4 = <5%), biological crusts (0 = absent, 1 = present) and crust-brokenness (score of 0–4 where 0 = no crust, 1 = extremely broken, 4 = intact) were assessed. Surface erosive types were classified following Friedel *et al*. (1993), with categories relevant to sites assessed including (i) topsoil intact, (ii) topsoil eroding, (iii) mobile sandy deposits and (iv) depositional mobile sand. Major erosive features encountered along each transect were also assessed for breadth and length.

Indicators of local pasture utilisation were recorded at each site to help understand whether over-utilisation was occurring during the survey period. The qualitative degree of utilisation and plant species consumed were noted at either the quadrat or site scale. Livestock pads and relative dung densities were noted.

Interviews

Fifty pastoral households in nine *soums* (Table 1) were interviewed with the help of a translator between August and October 2010. The aim of these semi-structured interviews was to help understand the extent and nature of changes in the rangelands, and potential causal mechanisms by which these may have occurred (assumptions i–v). Interviews were between 1 and 2 h long. This method allowed landscape-scale perspectives to be gained from a reasonable sample size of herders while not imposing on the hospitality of respondents. We recognise that the sole reliance on semi-structured interviews do not provide the in-depth insights that might have been achieved from more detailed ethnographies.

The initial intention was to interview pastoralists located as close to rangeland condition survey sites as possible. The patchiness of forage availability throughout the area, and subsequent dispersal of pastoralists, meant that this was not always possible. Pastoralists were instead selected for interview if they were located near or between fixed rangeland condition sites, or were nominated by a previous pastoralist. The final sample of pastoralists was well spread spatially across multiple *soums*.

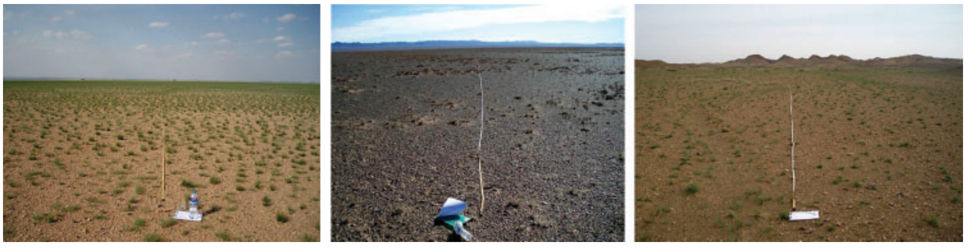

Fig. 2. Select rangeland condition sites in Omnogobi *aimag*. Sites are RCUG0035, RCUG0006 and RCUG0036.

Pastoralists were directly approached at their *gers* (mobile tents). Basic demographic information was elicited (see Table 2 for the main questions). Pastoralists were additionally asked for their perceptions of rangeland change since they had begun herding. The oldest person present was often directly asked this question to get a better understanding of temporal change unless it was apparent that they were unable to assist. Often more than one household member responded.

Notes were taken during the interview, with interviews additionally tape recorded if consent was given, then transcribed into English. A second transcriber cross-checked a subset of interviews.

Secondary data

Livestock data were sourced and analysed to better understand how changing grazing pressures may, or may not, have contributed to changing rangeland condition over time (assumptions i and ii). Official records of the annual number of livestock, by type, were sourced for the 1960–2008 time period from an Omnogobi *aimag* official for each Omnogobi *soum*. Annual livestock numbers for 2009 and 2010 were additionally sourced from local officials or extrapolated from stated mortality rates from five Omnogobi *soums* within the research area. It is these five *soums* whose livestock figures were assessed for this paper. All data were converted into sheep forage unit (SFU) (1 goat = 0.8 sheep, 1 cow = 5 sheep, 1 horse = 6 sheep, 1 camel = 6 sheep) (Sheehy and Damiran 2009).

To test assumptions of a declining pasture source (assumptions iii and iv), precipitation and temperature data for each month from 1990 to 2010 in seven *soums* were sourced from the Mongolian Academy of Science's Institute of Hydrology and Meteorology in Ulaanbaatar, and/or local *soum* Institute branches. For the same purpose, maximum yearly, non-grazed, livestock available biomass for six *soums* within the study area was also sourced from the Institute of Hydrology and Meteorology. The cost of sourcing data covering longer time periods or for more *soums* was prohibitive. The methodology of assessment of biomass data was described by Munkhtsetseg *et al*. (2007), and as follows. The pasture yield (dry biomass) was measured at local plant observation sites, protected from grazing, at 10-day intervals. Measurements began when the grass height exceeded 3 cm and continued until the grass reached the senescence stage. Four plots with areas of 1 m^2 were assessed, with vegetation under 1 cm not measured so as to not include biomass inaccessible to livestock.

Table 2. Key questions asked during pastoralist interviews

- What administrative area is this?
- How many people are in your household?
- For how many years has the most experienced person been herding?
- How many animals do you have?
- How do you define a 'good year'?
- When was the last 'good year'?
- How do you define a 'bad year'?
- When was the last 'bad year'?
- Please draw a map of where you moved in the last 'good year'
- Please draw a map of where you moved in the last 'bad year'
- Has the pasture changed since you started herding?
  (If yes to the above), how has the pasture changed since you started herding? (Prompts): vegetation change? Soil changes? Water changes? Precipitation changes? Temperature changes?
  (If yes to the above), why has the pasture changed since you started herding?

Data analysis

Means and standard deviations of rangeland condition indicators were calculated. The palatability of plant species was recorded as per Damiran (2005). Interview responses were entered into thematic spreadsheets for both quantitative analysis (summing of similar response) and qualitative analysis (identification of relevant quotes, patterns and themes). Livestock, biomass, rainfall and temperature data were imported into SPSS (SPSS Inc. 2003) for linear regression analysis. Rainfall and temperature records were additionally grouped by season: summer (June, July, August), autumn (September, October, November), winter (December, January, February) and spring (March, April, May), and then imported into SPSS (SPSS Inc. 2003) for regression analysis.

Results

Rangeland condition

Vegetation-based indicators

Projected perennial cover was low, between ~9 and 13% (Table 4). *Stipa* spp. constituted ~32% (Table 3) of all vegetation patches recorded. Over 50% of individual plants were preferred or desirable species for sheep, goats and camels, all year round; ~20% were additionally preferred or desirable to most of the three livestock types, most of the year.

The proportion of unpalatable plant species found during the survey was low. The only perennial unpalatable 'increasers' encountered on rangeland condition sites were *Artemisia adamsii* Bess, recorded twice (0.28% of perennials recorded), and *Peganum nigellastrum* Bunge, also recorded twice. Another 'increaser,' *Atriplex sibirica* L., was recorded on one site. Although these species were not abundant on sites that were deliberately selected for their representativeness, both species were additionally sighted around winter camps, *soum* centres and areas immediately around permanent water points that had high livestock densities but were not geographically representative.

About 55% of all perennial species were found to have flowered or seeded in at least one site by the time of the 2010 survey. In many areas that pastoralists said had received winter–spring precipitation from the 2009–10 *dzud* but not substantive spring–summer rainfall, *Allium* spp. had flowered/seeded but *Stipa* spp. desiccated before reaching full maturity. *Cleistogenes* sp. was rarely noted on any site, despite being a dominant desert steppe species (Sodnomdarjaa and Johnson 2003).

Soil-based indicators

Soils were relatively unstable (as assessed by the slake test), litter cover was ~1% on all soil types and there was a lack of biological crusts (Table 4). Despite apparent inherent instability and the presence of a strong erosive vector (wind), there were very few signs of current accelerated erosion on study sites. Signs of

Table 3. The five most abundant perennial species classed as 'patches' along all rangeland condition survey lines

Palatability for sheep, goats and camels have been included because sheep and goats apply the greatest grazing pressure in the area, and camels exert disproportionally high grazing pressure during/after extreme *dzuds* when feed gaps are likely to be most severe due to their lower *dzud* mortality rates. Palatability as per Damiran (2005). Dashes indicate data missing from this source. P = preferred. D = desirable. T = toxic. C = consumed but undesirable

Species	%		January– March	April– June	July–September	October–December
Stipa spp.	32.2	Goats	P	P	P	P
		Sheep	P	P	P	P
		Camels	P	P	P	P
Allium polyrrhizum Turcz. et Rgl.	21.4	Goats	D	P	P	D
		Sheep	D	P	P	D
		Camels	D	P	P	D
Anabasis brevifolia	8.2	Goats	D	P	P	D
		Sheep	D	P	P	D
		Camels	D	T	C	D
Allium mongolicum Rgl.	7.0	Goats	C	P	P	C
		Sheep	C	P	P	C
		Camels			–	
Unknown shrub	4.9			–		

Table 4. Site stability descriptions by soil type (IUSS Working Group WRB 2007)

Surface erosive-type classifications modified from Friedel *et al.* (1993), with only present categories displayed; landscape organisation and indicators other than non-vegetative cover types modified from Tongway (2008). Values are means, with standard deviation between sites in brackets. n = number of subsamples (5 subsamples along 50 transects for soil-based indicators and projected cover). Categorical data are rounded to 1 d.p., percentage data are rounded to the nearest whole number. Number of sites: calcisols (sites = 31, subsamples = 155), kastanozems (sites = 16, subsamples = 80), regosols (sites = 2, subsamples = 10), solanchak (sites = 1, subsamples = 5). Plant community compositions between sites at this paper's scale of assessment were not discrete enough that it would be meaningful to differentiate out indicators according to vegetation type

Indicator	Description	Calcisol	Kastanozem	Regosol	Solanchak
Projected cover	%	11 (9.1)	13 (7.0)	11 (4.8)	9 (6.0)
Slake test	Score of 0–4 (0 = cannot slake, 1 = slakes within seconds, 4 = intact)	1.3 (0.8)	1.0 (0.2)	1.6 (0.5)	1 (1.8)
Crust brokenness	Score of 0–4 (0 = no crust, 1 = extremely broken, 4 = intact)	1.5 (1.9)	0.9 (1.7)	0 (0)	0 (0.8)
Texture	Score of 1–4 (1 = clay, 4 = sand)	2.8 (0.7)	3.2 (0.9)	2.0 (0)	3.2 (4.0)
Deposited materials	Score of 1–4 (1 = >50%, 4 = <5%)	3.7 (0.8)	3.8 (0.7)	4.0 (0)	4.0 (3.6)
Erosion extent	% of sites	11 (9.1)	13 (7.0)	11 (4.8)	0 (0)
Erosion severity	Score of 1–4 (1 = least severe, 1 = most severe)	1.3 (0.8)	1.0 (0.2)	1.6 (0.5)	0 (0)
Erosion type	Rilling/pedestals/hummocking/sheeting/terracettes/scalding/gullying	H, S	H	–	–
Topsoil intact	% of sites	90 (30.5)	94 (23.4)	87 (35.2)	100 (80.0)
Topsoil eroding	% of sites	1 (12.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mobile sandy deposits	% of sites	3 (17.7)	1 (12.0)	0 (0.0)	0 (20.0)
Depositional mobile sand	% of sites	9 (28.3)	4 (19.6)	13 (35.2)	0 (0.0)
Bare	%	47 (18.6)	49 (20.2)	37 (21.4)	40 (33.0)
Fine gravel	%	40 (20.8)	38.9 (18.7)	52 (21.2)	28 (50.0)
Coarse gravel	%	12 (11.4)	11 (9.1)	12 (5.6)	32 (7.2)

erosion, including rills, pedestals, hummocks, sheeting, terracettes, scalding or gullying were largely absent at the quadrat (1 m^2) or site (up to 50 m) scale (Table 4). Most sites had an intact surface, except for a few sites with depositional features. The high percentage of gravel lag found on sites may have an armouring effect, accounting for the lack of erosional features despite the inherently unstable soils.

Utilisation

Five of the fifty sites (10%) surveyed showed signs of vegetation utilisation by livestock at the site scale. At most sites, only one of the subsamples were utilised. Higher than usual livestock mortality rates associated with the 2009–10 *dzud* may partially explain the low levels of utilisation.

Allium mongolicum Rgl. was the primary plant species grazed. However, *Allium polyrrhizum* or *Stipa* spp. were often grazed preferentially to *Allium mongolicum*. In subsamples where grazing was apparent, visual assessments revealed that plants had been selectively 'picked' with fully intact individuals mixed in with those grazed, and a relatively small proportion of the plant's aboveground biomass generally was grazed. Three sites were located within sight of a *ger* or permanent water point but showed no sign of utilisation by livestock at all.

Livestock dung was noted at 26% of sites, in one or more of the site's five subsamples. None of the 250 subsamples showed any sign of roots excavated by any type of livestock. Hoof marks were noted on 4% of sites. An additional 4% of sites were traversed by a livestock pad.

Changes in the rangeland

The primary respondent of households interviewed had spent an average of 22 years herding (min. 8, max. 30). Fifty-one percent of all interviewed households had at least one female respondent. The average household size was 4.8 (min. 2, max. 8). Each household had an average of 297 head of livestock (min. 1, max. 1000), primarily goats and sheep. The average livestock number should be treated with some caution, however, due to socio-cultural factors that may affect the willingness of pastoralists to cite accurate figures (see, for example, High 2008). In a pastoralist defined 'good' year, a typical household moved an average of 17 km to reach new pastures at any one time. The maximum distance a household moved during a good year was 30 km (min. = 0, max. 160). In a pastoralist-defined 'bad' year, the average distance moved was 39 km, and the average maximum was 61 km (min. = 0, max. = 230). Establishing the average total number of moves was made difficult by the tendency of pastoralists to exclude small, frequent summer movements from counts.

No pastoralist directly associated livestock grazing pressure with changes in rangeland condition (Table 5). Most pastoralists who gave an affirmative response to the interview question 'Has there been any change in the pasture since you started herding?' attributed the cause to changes in the quantity or nature of precipitation. The following comment by one interviewee encapsulates a widespread view:

> 'Herders can not have any influence [on the pasture]' (Tsogttsetsii *soum*, Omnogobi *aimag*, 25 years' herding).

The change in precipitation most commonly cited by pastoralists – 'no/less rain' (Table 5) – was not supported by monthly precipitation totals over the last 20 years (Table 6). 'Lack of summer rain' (Table 5) was only significantly supported by Ulziit *soum* rainfall trends although a non-significant decline was found in all *soums*. 'Late rain' was not supported by trends in monthly precipitation records in selected *soums* for the 1990–2010 period if a decline in spring–summer precipitation and an increase in autumn precipitation is the indicator used. 'More moisture from snow, less from rain' was not supported if an increase in winter precipitation and decline in non-winter precipitation is used. 'More windy rain now,' 'torrential rains so water doesn't penetrate soil' and 'decline in number of rainy days' could not be tested using available secondary data.

Pastoralists who gave a negative response to the question 'Has there been any change in the pasture since you started herding?' also commonly suggested that vegetation attributes were primarily rainfall dependent, for example:

> 'Depending on the condition of the year, the quality [of the pasture] is different. In good years it is good. [There is] no change' (Tsogt-ovoo *soum*, Omnogobi *aimag*, 15 years' herding); and 'The [forage] quality is the same, [but] the amount is less because there is less rain.' (Bulgan *soum*, Omnogobi *aimag*, 25 years' herding)

Of the pastoralists who said there had been change, most referred to changes in the quantity or quality of forage available, for example:

> 'The grass has changed a lot. Mongol [*Stipa* spp.] was here in the past but doesn't grow anymore. *Khazaar* [*Cleistogenes* sp.] has not been growing in the last few years. *Khazaar* and *ders* [*Achnatherum splendens* (Trin.) Nevski] have almost become absent. This year we

Table 5. Reasons cited by pastoralists for change in the rangelands

Cause and effect as defined by current western rangeland science was rarely differentiated. % = percentage of total responses by pastoralists. Data rounded to the nearest whole number

			%
Climate variability	Quantity of rain	No/less rain	33
	Changes in nature of rain	Chinese rain-seeding program	2
		More 'windy rain' now	2
		Late rain	7
		Torrential rains so water does not penetrate the soil	9
		Lack of summer rain	2
		Decline in number of rainy days	7
		More moisture from snow, less from rain	2
Biophysical change	Vegetation	The roots are dead	2
	Soil	Dust-storms and/or sandstorms and/or dust	7
		More sand	7
		Reduced soil fertility	2
Not pastoralist-mediated		More roads creating dust	7
		Mining (or a named mine), often 'digging the topsoil'[A]	7
		The democratic revolution	2
Pastoralist-mediated	Grazing	Animals eating grass roots	2
	Not grazing	Some grasses stop growing when we cut them for hay	2

[A] 'Digging the topsoil' is understood by some Mongolians to cause significant environmental damage at a spiritual level, above and beyond localised biophysical effects (Humphrey (1978).

Table 6. Trends in key rangeland related variables in study *soums*

P-values are derived from climate data are from 1990 to 2009 and livestock data from 1960. Attributes with trends that are not significant are not shown. (↓) = significant decline over time, (↑) = significant increase over time. SFU = sheep forage units, ppt = precipitation, temp. = temperature. n.a. = data not available. n.s. = relationship not significant. $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$. Spring = March, April, May. Summer = June, July, August. Autumn = September, October, November. Winter = December, January, February

Soum	Total SFU	Total livestock number	Total goats	Summer Ppt (mm)	Summer Temp. (°C)	Winter Temp. (°C)	Annual biomass (kg ha^{-1})
Khanbogd	n.a.	n.a.	n.a.	n.s.	n.s.	0.000***(↑)	n.s.
Bulgan	n.s.	0.000***(↑)	0.000***(↑)	n.s.	0.000***(↑)	n.s.	0.003**(↓)
Bayandalai	n.s.	0.000***(↑)	0.000***(↑)	n.s.	0.005**(↑)	n.s.	0.00***(↓)
Sevrei	n.a.	n.a.	n.a.	n.s.	0.003**(↑)	n.s.	0.028*(↓)
Ulziit	n.a.	n.a.	n.a.	0.013**(↓)	n.s.	n.s.	0.00***(↓)
Tsogttsetsii	0.036*(↓)	0.035*(↑)	0.000***(↑)	n.s.	n.s.	n.s.	0.00***(↓)
Manlai	0.012*(↓)	0.042*(↓)	0.000***(↑)	n.a.	n.a.	n.a.	n.a.
Tsogt-ovoo	0.000***(↓)	n.s.	0.000***(↑)	n.a.	n.a.	n.a.	n.a.

saw some *ders* for the first time after years of drought.' (Tsogttsetsii *soum*, Omnogobi *aimag*, 25 years' herding)

Fifty percent of the 39 changes cited by pastoralists involved a decline in the abundance or distribution of an individual plant species. Twelve species were reported to have declined, with *Stipa* spp. and *Cleistogenes* sp. the most reported. Thirteen percent of reports involved increases in abundance or distribution, notably *Nitraria* sp. Twenty-six percent of responses referred to a change in the spatial distribution of plant species, with *Allium polyrrhizum* reported six times. Temporal distribution changes were also noted among both *Stipa* spp. and *Artemisia* spp. (5%). There were two phenological changes (changes in flowering patterns) noted with *Caragana* spp. and *Artemisia* spp.

Goats and rangeland condition

No pastoralist interviewee spontaneously identified goats as the cause of pasture changes during the period that they had been herding. Three were specifically prompted about the likelihood of goats 'digging the roots of plants, killing them' as time was available for an extended discussion. Of these three, one stated that livestock digging plant roots contributed to decline in rangeland condition (Table 5), but did not specify the livestock type. The second replied that:

> 'On the television they say that goats are bad but I disagree. The goats don't eat the plant roots. Horses are far worse. They eat really low to the ground, and dig the roots. They are less efficient. . .I am glad we are a democracy now and I can say such things that disagree! (laughing)' (Ulziit *soum*, Dundgobi *aimag*, more than 30 years' herding); with the third stating that 'Goats don't dig roots in the Gobi. Hungry horses will, though, gazelle also. Pasture changes are not because of the goats, just less rain.' (Tsogt-ovoo *soum*, Omnogobi *aimag*, 25 years' herding)

Secondary data

Livestock numbers

Total livestock numbers significantly increased in three of the five assessed Gobi Desert *soums* between 1960 and 2010, and significantly declined in one *soum* (Table 6). None of the five *soums* showed a significant increase in the recorded total SFU, with Tsogttsetsii, Manlai and Tsogt-ovoo *soums* showing significant declines as the number of large livestock declined. Bayandalai *soum* had the largest increase in mean total SFU between the 1960–90 and 1991–2010 periods, with an increase of 10%. Tsogtovoo *soum* declined by an average of 23% total SFU between these two periods. Herd compositional changes in the five *soums* showed that goat numbers significantly increased between 1960 and 2010 in all five Gobi Desert *soums*. Goat numbers in the five selected soums increased by between 148 and 185% between the periods 1960–90 and 1991–2007.

Officially recorded herd sizes were more volatile in all assessed *soums* between 1990 and 2010 than during the previous three decades. There were large declines following two separate *dzud* periods, the most recent being the winter immediately before the survey period (Fig. 3). Annual SFU CV were between 41 (Bulgan *soum*) and 340% (Tsogtovoo *soum*) greater in the post-1990 period than before 1990. Total SFU first declined, and then built throughout the 1990s before crashing during the *dzuds* of the late 1990s/early 2000s. Numbers again built during the 2000s, followed by a sharp decline due to major livestock losses in the 2009–10 *dzud*.

Changes in precipitation and temperature

Annual mean precipitation did not change significantly between 1990 and 2010 in any of the *soums* assessed. The seasonality of precipitation in all *soums* did not significantly change except in Ulziit, where summer rainfall significantly declined (Table 6). There was a non-significant trend to declining summer rainfall in many other *soums*. Changes in the timing of the onset of precipitation as rainfall was not examined here as monthly rainfall statistics were not at a suitable temporal scale. Maximum temperatures showed more significant change, with increases in summer (trends in all six *soums*, significant at the 0.05 level in three *soums* and nearly significant in an additional *soum*) and winter (significant in one *soum*). In *soums* where temperature/precipitation data was available, the 2009–10 winter was far colder for a longer period of time than other years.

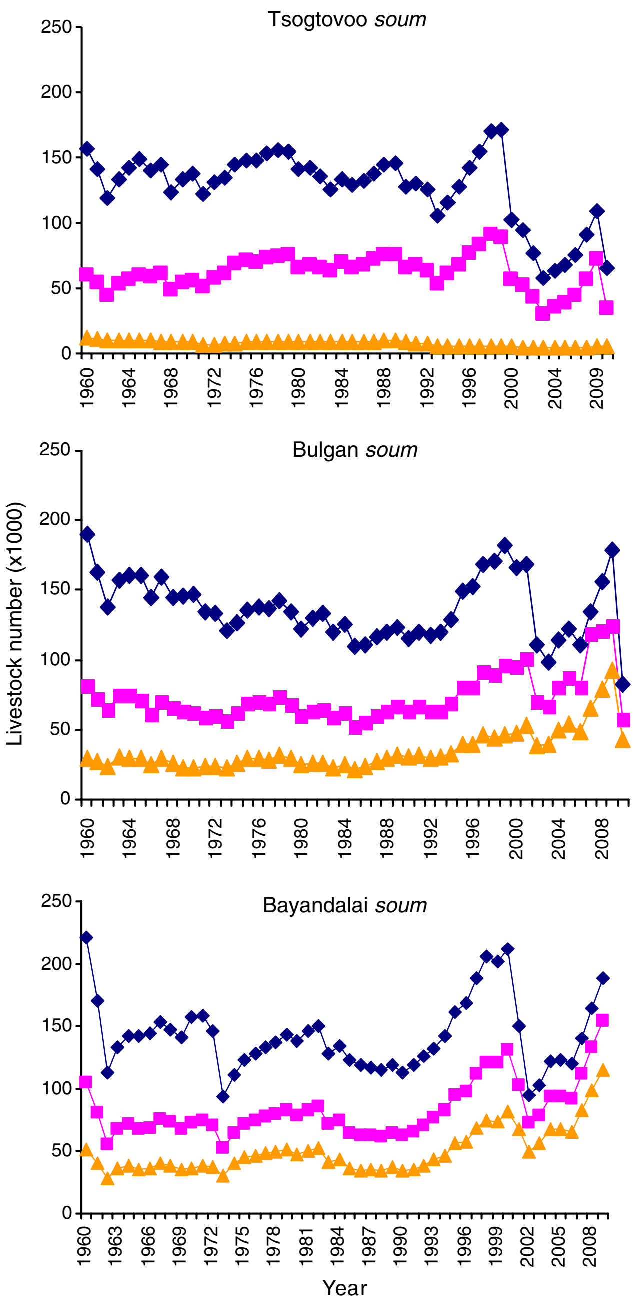

Fig. 3. Changes in livestock numbers since 1960. Only *soums* with at least one significant increase/decrease in one of the livestock attributes are shown. Livestock numbers are in thousands of head. ◆ = total SFU, ■ = total livestock, ▲ = goat. Only *soums* with significant trends (Table 6) are shown. Bulgan and Bayandalai *soum* 2009 figures are extrapolated from the growth in the previous 3 years. The 2010 figures assume a 53.8% herd loss (the *soum*-wide loss) for Bulgan *soum* (Bulgan *soum* Food, Agriculture, Trades and Services Officer, pers. comm., 2010), and a loss of 30 000 head (*soum*-wide) for Bayandalai *soum* (Bayandalai *soum* Food, Agriculture, Trades and Services Officer, pers. comm., 2010).

Change in pasture biomass

Five of the six *soums* for which official livestock-available biomass data from sites protected from grazing were sourced showed a significant decline between 1990 and 2010 (Table 6). In all six *soums*, the mean annual livestock available biomass was significantly greater between 1990 and 1999 than between 2000 and 2009.

Discussion

This study investigated the evidence for five widely held assumptions about degradation in the Mongolian Gobi Desert. These assumptions are discussed below.

(i) There are too many animals

The assumption that there are 'too many animals [now]' was not supported if the average trend in total SFU since the 1960s is used as the indicator. This is not to say that declining rangeland condition through overgrazing at the landscape scale could not still have occurred. There are likely to be spatial or temporal differences in vulnerability to overgrazing, and changes in pastoralist mobility that have a positive impact on some pastures (e.g. areas far from permanent water) while having negative impact on other pasture types (e.g. spring pastures).

The socio-political reform processes of the early 1990s are often used as a temporal reference point for assessing livestock trends (see, for example, Leisher *et al.* 2012). However, the increased temporal variability of livestock numbers since 1990 (Fig. 3) makes it difficult to interpret the effect of livestock numbers on rangeland condition due to short-term fluctuations in forage availability. *Soum* level livestock numbers also ignore the high porosity of *soum* boundaries, changing patterns of use in seasonal pastures and the growing influence of mining on mobility patterns since the early 1990s.

Comparing numbers between socio-political periods is also a potentially inaccurate method for comparing grazing pressures between the two periods. Livestock numbers since the 1990s may have had a greater impact on the vegetation per SFU than during socialist times when socialist collectives (*negdels*) buffered much of the climatic risk inherent in the Gobi through the importation of fodder (Fernandez-Gimenez 1999). Official livestock numbers may been inflated during the socialist era to indicate nation-building, or deflated in more recent years as pastoralists under-reported numbers to avoid the livestock 'foot' tax. Changes in liveweights (Batimaa and Batnasan 2009) and other production factors may also have changed vegetation consumption per SFU, and therefore the relative impact of each SFU on rangeland condition.

Piospere studies that assess vegetation communities at varying distances from permanent waterpoints suggest that high grazing pressures can, and do, cause significant vegetation change in at least some desert steppe landscapes (Sasaki *et al.* 2009*b*). The timing and intensity of grazing pressures required to cause such a change, and whether this change is permanent or not, is not certain. Such biophysical and socio-political complexities should be considered before assuming a significant relationship between current official livestock numbers and rangeland condition.

(ii) The relative increase in goat numbers has led to desertification

The proportion of goats has increased in all selected *soums* since 1960. The specific impact that this increase has had on rangeland condition in the desert steppe is unclear, and has not been documented by empirical evidence in the English language, peer-reviewed literature. It is possible that goats do contribute to overgrazing. For example, the high dietary plasticity of goats (Devendra 1989) may contribute to overgrazing in windows of time when goat grazing pressures are high but the forage resource is declining, particularly among plant species that do not have the strategies for avoiding drought or freezing temperatures that also allow plants to quickly escape, rather than persist through, grazing.

Conversely, it is also possible that goats do not overgraze disproportionately to other livestock types in rangelands that are not overstocked. The strategies of most plants in the Mongolian Desert that allow them to persist through winter and drought periods also allow them to avoid grazing during these same periods (see Table 3). Dietary plasticity in goats may additionally mean sheep at the same moderate SFU as goats have more impact on the average annual plant recruitment and mortality rates of palatable plants than goats, as has been documented elsewhere (e.g. Fletcher 1991). What 'moderate' versus 'high' goat densities are in relation to rangeland condition in the desert steppe remains untested. The proportion of flowering/seeding species during our survey together with the abundance of palatable perennials (Table 3), the lack of physical evidence that goats 'dig the roots' of plants, and that no pastoralists cited goats as a mechanism of degradation suggests that the risk of severe degradation associated with high grazing pressures of goats was not being realised during the moderate to good levels of soil moisture in the 2010 survey. Our data and the review of the peer-reviewed, English language literatures suggest that it cannot be automatically assumed that goats are inherently more likely to cause degradation than other livestock types.

(iii) Rainfall is declining

There is a partial conflict between precipitation records and pastoralist accounts of changes. Quantitative records show that total precipitation, and total precipitation by season, has not significantly declined since 1990 apart from a spatially consistent, sometimes significant tendency for a decline in summer rainfall. Livestock available biomass has significantly declined despite this. Pastoralists consider summer rainfall to be the most vegetation growth-effective form of precipitation and it may be that they believe that this component 'is less now.' Indeed, the decline in precipitation and later rain in summer–autumn reported by many interviewees has also been recorded by Marin (2010) in slightly more northern parts of Dundgobi. von Wehrden *et al.* (2010) and Liang *et al.* (2002) additionally suggest that the absence of suitable rain at a key point at the beginning of the Inner Asian growing season may be important in determining vegetation dynamics. Change in precipitation patterns may therefore be more nuanced than is suggested by the generality that 'rainfall is declining'.

(iv) There is declining pasture biomass

Maximum livestock-available biomass at ungrazed sites has significantly declined since 1990, a trend that is largely supported by pastoralist accounts. This supports the 'declining pasture biomass' assumption at a 20-year temporal scale. While the average maximum biomass in the six *soums* assessed was less in the 2000–09 period than the previous decade, the earlier 1971–78 period at a similar desert steppe site (Lavrenko and Karamysheva 1993) was also less than the 1990–99 period. This suggests a 20-year dataset may not have been long enough to capture longer term trends in the variability of vegetation production. This highlights the risks of determining trends through the use of short-term dataset in environments that are temporally variable. 'Declining pasture biomass' claims therefore need careful defining in terms of temporality.

Vegetation production is closely coupled with annual precipitation in Mongolia's desert steppe areas (von Wehrden and Wesche 2007). Given that vegetation production has significantly declined since 1990, the lack of a widespread significant decline in spring, summer and autumn precipitation (Table 6) over the last 20 years is surprising. Shifts in the temporality of key precipitation events, discussed earlier, may have been important. Changes in the seasonal distribution of rainfall may also have been important (Liang *et al.* 2002; Munkhtsetseg *et al.* 2007), particularly with the significant increase in temperatures in either summer or winter of four of the six *soums*.

(v) Mongolian rangelands are degraded

Fine-scale livestock grazing pressures were not assessed by the 2010 survey. It is anyway unclear what impact different utilisation levels during, or over different time periods, have on vegetation in the desert steppe, particularly given the relatively short growing period. Ungrazed analogues are somewhat of an artificial construct in a landscape with such a long grazing history, and differentiating long-term grazing mediated change from natural variability in arid and semiarid systems is difficult.

Grazing pressures during the post-*dzud* 2010 assessment were relatively light, however. There were relatively high proportions of palatable species (Damiran 2005), and these were often found to be reproducing. This suggests that pre-*dzud* grazing pressures had not totally compromised the ability of palatable plant species to reproduce when soil moisture was adequate (as was the case after the 2009–10 *dzud*). There were low numbers of erosive features at the site scale. These indicators conflict with assumptions of severe, widespread and current grazing-facilitated degradation that significantly reduce the ability of pastoralists to maintain their resource base in the long term.

Variation in the definition of 'degradation' may at least partially account for the mismatch between widespread degradation assumptions and what was observed during the 2010 survey. The term 'degradation' has both spatial and temporal dimensions. Given the change in temporal and spatial mobility patterns of Mongolian pastoralists since the transition to the market economy, and the variability of precipitation and vegetation patterns common in arid and semiarid landscapes, it becomes important that the scale of rangeland condition assessments and assumptions are well defined (Prince 2002).

The importance of defining spatiality is illustrated by the disconnect between the presence of large-scale spring dust-storm deposits believed to originate in the Gobi Desert that have been recorded as far away as in the United States

(Heald *et al*. 2006), and the absence of accelerated erosion features observed at the site scale during this assessment. One explanation is that desert steppe areas of the Mongolian Gobi are not a significant source zone for these duststorms. Another is that accelerated erosion or deposition occurred in areas deliberately not targeted for assessment because they were 'unrepresentative' of grazed areas – that is, large gullies, internal drainage depressions or steep mountain slopes. The spatial scale of rangeland condition assessments used here may not target the scale of the erosive vectors, as was found to be the case in other arid or semiarid rangelands (Friedel 1994; Pringle *et al*. 2006). Perhaps highly dynamic vegetation indicators in small-scale plots have been too relied upon in assessments of Mongolia's desert steppe areas. Rangeland condition indicators more appropriate to the spatial scale of stochastic events like sandstorms, such as the remote sensing of the expansion or contraction of erosion source and sink zones, might provide further information upon which to base policy/programs in the Gobi Desert.

Temporality may have also been neglected by stakeholders seeking to understand rangeland condition. Biomass and compositional changes in the vegetation of the Gobi Desert's desert steppes are highly dependent upon short-term rainfall events (Lavrenko and Karamysheva 1993; von Wehrden and Wesche 2007; Wesche *et al*. 2010; Cheng *et al*. 2011). Ronnenberg *et al*. (2008) found that *Stipa glareosa* P. Smirm. seedlings in Bulgan *soum*, Omnogobi, needed at least 20 mm of rainfall to germinate, an event that did not occur in several years of a germination experiment. Lavrenko and Karamysheva (1993) reported 7–10-year cycles of sexual maturity in *Stipa gobica* Roshev, and that survival of seedlings and juveniles is rarely possible, except when there are 2 or more favourable years for pasture growth. The data of Wesche *et al*. (2010) suggested that while grazing had effects on both soil nutrients and vegetation floristics in southern/central Omnogobi between 2003 and 2005, '[their] observations [did not] support the idea that typical grazing leads to severe degradation' (p. 240). The lack of a clear distinction between the 'normal' effects of low and variable levels of precipitation, temporary and reversible grazing effects and permanent 'degradation' in desert steppe areas may partially account for why grazing-induced degradation assumptions have become widespread.

Conclusion

The majority of assumptions about declining rangeland condition were either not supported by the social or biophysical data in this paper, require reexamination in terms of scale, or are more complex than is often acknowledged by stakeholders. Our analysis suggests that not all common assumptions about rangeland condition in Mongolia apply across the Gobi Desert, all of the time.

The biophysical mechanisms upon which these assumptions are based have spatial and temporal dimensions that may be under-recognised. Assumptions like 'too many animals' and 'rainfall is declining' ignore the dynamics of climate, how these dynamics may affect vegetation patterns, and how they may interact with variable grazing pressures. The transition to a market economy has also changed spatial and temporal land-use patterns (Fernandez-Gimenez and Batbuyan 2004), generating an additional level of complexity to understanding grazing-facilitated degradation. The spatial and temporal 'patchwork mosaic' that both biophysical and socioeconomic factors create makes extrapolation across space and time, or differentiating between manageable and non-manageable changes in rangeland condition, very difficult.

Given such complexity, it can be tempting to transplant known methodologies and causal effects of change from other landscapes or cultural settings. Claims of decline in rangeland condition are not new to Inner Asia. Nor is debate around their causal effects. As far back as the 1930s, Lattimore (1938) gave a succinct example of how a 'recently fashionable theory' developed in a different landscape can be misapplied to that of Inner Asia:

> 'the spectacular development of a huge dust-bowl in Western America and Canada has made the phenomenon of "man-made deserts" so popular that it is even being used in attempts to override theories of desiccation in regions that are old favourites of those who believe in "climatic pulsation".' p.4.

A better understanding of the local pastoral context and the utilisation of a wider variety of both land-use and biophysical indicators for measuring change may minimise the risk of misapplying such 'fashionable theories.' The risk of mistaking correlation for causation or attributing causal mechanisms to confounding factors may be similarly minimised. Requiring Gobi Desert herders to destock to fixed notions of carrying capacities, restricting mobility through changing land tenure policies or mistaking a dry season for degradation could have substantial, negative impacts on already marginal livelihoods. A more precautionary approach to understanding change in the Gobi Desert, and designing policy and programs based on such an understanding, is necessary.

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