Degradation in Mongolia's Gobi Desert: not as straight forward as assumed

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Short title: How applicable are degradation assumptions to Mongolia's Gobi Desert?

Abstract

Assumptions about the levels and causes of rangeland degradation in Mongolia have become embedded amongst a range of stakeholders. This paper explores the applicability of five such 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) goats have proportionally increased and this is causing desertification; iii) rainfall is declining; iv) there is less pasture now; and v) Mongolian rangelands are degraded. Biophysical and quantitative social data from the Dundgobi and Omnogobi desert-steppe areas suggest not all of these assumptions are supported mechanistically all of the time, and that the information upon which these assumptions are based is more complex than is commonly recognised. Caution in designing policy and programmes based on current understandings of rangeland condition is necessary.

Additional keywords: rangeland, Gobi Desert, livestock, goats, climate

Introduction

Rangeland theory and the understanding of causal mechanisms behind rangeland dynamics have changed significantly over the last century. The largely static 'climax community' of Clementsian succession (Clements 1916) has been replaced by ideas of more dynamic multiple stable and non-equilibrium states (Holling 1973; Noy-Meir 1975), thresholds (Friedel 1991), and states and transitions models (Westoby *et al*. 1989). Dynamic socio-political and cultural values have additionally informed, and been informed by, how we understand rangelands.

Much of the literature around how changing value systems can intersect with changing rangeland science to facilitate a 'misreading of the landscape' has come from colonial and post-colonial Africa (e.g. Ellis and Swift 1988; Behnke 1992; Fairhead and Leach 1996). Any landscape that has become rapidly exposed to externally-derived systems of thought appears vulnerable to a 'misreading' however. In the context of arid areas of Asia, Robinson *et al.* (2003) compared Soviet and western methods of 'reading' the rangelands, and discussed their relative applicability to the Kazakh rangelands. They highlighted the vagaries of understanding rangeland condition when past and present assessments are underpinned by false assumptions imported from elsewhere, methodologically inconsistent or do not include field-based assessment. Yang *et al.* (2005) also criticised the use of significantly different methodologies in the assessments of desertification in China, some of which relied upon satellite imagery or questionnaires of perceived degradation levels with no ground-truthing, or did not differentiate between climatic 'deserts' and 'areas undergoing desertification.' These issues compound the difficulties of understanding change in landscapes that are inherently biophysically variable and prone to stochastic disturbances.

It is widely assumed by a range of stakeholders – policy-makers, non-government organisations (NGOs), academics and the media – that the rangelands of Mongolia are degraded (e.g. Batjargal 1997; Johnson *et al*. 2006; Mau and Dash 2007; United Nations Development Programme 2007; Enkh-Amgalan 2008; The World Bank 2009; Hess *et al*. 2010; Mongolian Society for Rangeland Management 2010; Usukh *et al*. 2010). An increase in the number of livestock, particularly goats, is commonly cited as a major contributing cause of landscape degradation (e.g. United Nations Development Programme 2007; Bayanmonkh 2007; Index Based Livestock Insurance Project Implementation Unit 2009; Sheehy and Damiran 2009; Whitten, 2009; Hess *et al.* 2010; Sternberg 2010). 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). Policy responses and programme designs, such as the draft Pasture Law (United Nations Development Programme 2008; Dorligsuren 2010) and NGO-facilitated pasture user/pastoralist groups (e.g. Schmidt 2006; United Nations Development Programme 2007; Hess *et al*. 2010; Usukh *et al.* 2010; The World Bank 2011) have been, or will be, applied across landscapes based on some of these assumptions.

Despite the influence of these assumptions on policy design and prescriptions, the status of Mongolia's rangelands is neither as well documented nor agreed upon as is often believed (Sternberg 2009). A number of organisations have landscape-scale forage production monitoring and forecasting programmes (e.g. Texas A & M University *et al*. 2011; Institute of Meteorology and Hydrology 2003). Mongolia does not have a nationally recognised rangeland monitoring system, however, although one is currently in development (Mongolian Society for Rangeland Management, personal communication, 2010). This has resulted in conflicting understandings of rangeland condition and condition trend at the national level as 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) quote Chognii (2001) as stating that 30% of Mongolia's rangeland area was degraded. Mau and Dash (2007) put this figure at 80%, whilst Bayankhishig (2009) stated that 77.2% was degraded to some extent. Sneath (1998) quotes 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).

Peer-reviewed, English language literature increasingly foregrounds rainfall patterns 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; Wesche *et al*. 2008; Ronnenberg *et al.* 2008; Wesche *et al*. 2010; Sasaki *et al.* 2009). Empirical research assessing the effect of grazing pressures on vegetation dynamics over a number of seasons increasingly recognises that the current pastoral system may have a low impact on rangeland condition in desert steppe areas (Wesche and Retzer, 2005; Wesche *et al*., 2010; Cheng *et al.,* 2011). This raises the question of how robust at a finer spatial scale are the national scale rangeland condition assumptions that have underpinned the creation of policy/programmes.

This paper uses a case study to review the applicability of common Mongolian degradation assumptions to the more localised spatial and temporal scales of the Gobi Desert. We examine 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 Gobi.

Materials and methods

Site description: The Gobi Desert

The Gobi Desert occupies the basin of Central Asia, including northern parts of the People's Republic of China and southern *aimags* (States) in the Republic of Mongolia (Figure 1). Broadly undulating with occasional rocky rises, the Gobi Desert is located on a relatively high plateau. The northern part of the Mongolian Gobi Desert, with its higher annual precipitation, increased vegetation cover and dominance of perennial forbs and grasses, is generally referred to as 'desert steppe.' More southern areas are often referred to as 'true desert' or 'hyper-desert,' with a more rocky subsurface and increased dominance of sub-shrubs (Lavrenko and Karamysheva 1993).

The Gobi's precipitation is relatively low, with the vast majority falling in summer as rain. Annual precipitation over the last 20 years for this paper's study sites varies from 132mm (Bulgan *soum*) to 67.5mm (Sevrei *soum*). Precipitation is spatio-temporally variable, and as such is often referred to as being 'at disequilibrium' (Ellis and Swift 1988; Wesche and Retzer 2005; Fernandez-Gimenez and Allen-Diaz 2001; Marin 2010). Co-efficients of variation (CVs) for annual precipitation are moderate to high, with minimum and maximum CVs at study sites of 26% (Bulgan *soum*) and 49% (Tsogtseggi *soum*) over the last 20 years, respectively. Variability increases when precipitation falls as rainfall, with minimum and maximum rainfall CVs of 30% (Bulgan *soum*) and 53% (Sevrei *soum*), 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, Sheehy *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, limiting pastoral production) add a level of unpredictability to the pastoral landscape.

The area has been used for grazing for many hundreds of 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 service provision to pastoralists, devolving the management of much of the climatic risk back to the individual. Whilst finer scale patterns of mobility have changed through time, the general pattern of mobility of Gobi Desert pastoralists in both socialist and post-socialist periods has involved shifting frequently during summer/autumn months, with more permanent winter/spring camps.

Rangeland condition

Fifty rangeland sites were assessed for indicators of rangeland condition across thirteen *soums* (second smallest administrative districts) in central and northern

Omnogobi *aimag*, and southern Dundgobi *aimag*. These assessments were carried out between June and October, 2010. Whilst encompassing a range of soil-types, these sites were all classed as desert steppe (Lavrenko and Karamysheva 1993). Precipitation patterns prior to the survey resulted in the majority of herders classing the season as ‘fair’ to ‘good’. A broad, landscape-scale approach to sampling was taken to maximise spatial representativeness. Sites were generally located at least one kilometre from a livestock waterpoint to minimise any localised piosphere effect (Sasaki *et al.* 2009). Unrepresentative features in the landscape, such as mountain-tops, or areas relatively close to settlements, were avoided.

Interpreting indicators assessed by temporally one-off rangeland condition assessments can be difficult. For this reason, soil-based and perennial vegetation indicators were used as a more reliable indicator of rangeland condition than vegetation clipping or diversity surveys that reflect shorter term fluctuations in vegetation cover and composition. Species presence and phenology was recorded. The 50 surveys were done over three separate time periods. Although each site was only assessed once, the spatial spread of sites meant that different sampling periods assisted with understanding temporal vegetation dynamics at the landscape scale, and allowed for cross-checking with pastoralists’ accounts.

A 50m line transect was laid parallel to the identified main erosive vector at each site. Wind was assessed as 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 an adapted version of Landscape Function Analysis (LFA) (Tongway 2008). Perennial species were identified at species level if known, or genus level if not. In the few instances where the genus was not identifiable, the functional type was recorded. Patch/interpatch lengths were recorded along each transect until seventy patch or interpatch responses were recorded. Whilst this method was generally suitable for assessed landscapes, 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 1cm diameter was recorded as a patch (according to LFA methods), the patch/interpatch sample size grew extremely quickly, reaching the required replicate number (of seventy) over a very short distance (e.g. <5m). The alternative to this, defining 'patches' at the vegetation community level, would have meant transects tens of kilometres long.

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 during site recording, they were recorded separately to non-geophytic perennials.

Five 1m^2 quadrats were laid equi-distance along the LFA transect. This quadrat size is the maximum commonly used in Mongolian desert steppe areas (Sheehy and Damiran 2009; Sasaki *et al*. 2009; MercyCorps Mongolia and Texas A & M University personal communication, 2009). 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 were noted. The percentage of each quadrat covered by litter cover, whether this litter was incorporated into the soil or not, and whether the litter was spatially local or foreign in origin was visually assessed. Percentage projected cover was visually assessed, and the presence/absence of a biological crust was recorded. Field texture, slake-ability of a soil ped and crust-brokenness were categorised using LFA methods (Tongway 2008). Major erosive features encountered along the transect were also assessed for breadth and length.

Indicators of local pasture utilisation were recorded at each site. The presence/absence of vegetation utilisation by livestock, plant species consumed and qualitative severity of utilisation were noted at either the quadrat or site scale. Utilisation indicators are likely to be more useful at estimating relative grazing pressures than livestock pads or relative dung density, although these were also recorded. This is because Gobi Desert herds are more likely to 'fan' rather than create distinct pads, and pastoralists collect dung for fuel.

Interviews

Fifty pastoral households were interviewed with the help of a translator in nine *soums* between August and October 2010. Whilst the sole reliance on semi-structured interviews do not provide the in-depth insights of a more complete ethnography, relatively short (1 – 2 hour) interviews and a reasonable sample size were necessary for gaining landscape-scale perspectives.

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

Pastoralists were directly approached at their *gers* (mobile tents). Basic demographic information was elicited. 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 then transcribed into English if consent was given. A second transcriber was used to cross-check a subset of interviews.

Secondary data

Livestock, rainfall and temperature data were sourced from local officials. The official annual number of animals, by type, between 1960 and 2008, were sourced for all fourteen *soums* in Omnogobi as this was the longest time series available. Livestock census data was collected twice a year, but the timing of data collection was unknown for this dataset. 2009 and 2010 livestock numbers were additionally sourced from local officials or extrapolated from stated mortality rates from five Omnogobi *soums* within the research area. Only November 2009 and April 2010 numbers, by livestock type, were able to be sourced for Ulziit *soum*, Dundgobi. These figures 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). Precipitation and temperature data were sourced for each month since 1990 in seven *soums* from the Mongolian Academy of Science's Institute of Hydrology and Meteorology in Ulaanbaatar, and/or local *soum* Institute branches. Maximum yearly, non-grazed, livestock available biomass for six *soums* within the desert-steppe area, was also sourced from the Mongolian Academy of Science's Institute of Hydrology and Meteorology. The methodology of assessment of biomass data was described by Munkhtsetseg *et al.* (2007). The cost of sourcing longer time periods for all data was prohibitive.

Data analysis

Means and standard deviations of rangeland condition indicators were calculated. The palatability of recorded 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 Incorporated 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 Incorporated 2003) for regression analysis.

Results

Rangeland condition

Vegetation-based indicators

Stipa spp. constituted about 32% (Table 1) of all patches recorded between June and October 2010. Over 50% of individual plants were preferred or desirable species for sheep, goats and camels, all year round; approximately 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 during 2010. In many areas that pastoralist accounts suggested had received winter/spring precipitation but not substantive spring/summer rainfall, *Allium* species had flowered/seeded but *Stipa* spp. desiccated before reaching full maturity. *Cleistogenes* sp. was rarely noted on any site.

Both basal and projected perennial cover was low, recording about 6% and 12% respectively (Table 2).

Soil-based indicators

Soils were relatively unstable (as assessed by the slake test), and there was an apparent lack of mechanical or biological crusts. The amount of litter was low (Table

2). The origin of the litter was spatially local, and it had not yet begun physical or chemical breakdown.

Despite apparent inherent instability and the presence of a strong erosive vector, there were very few signs of current accelerated erosion found on study sites. Signs of erosion, including rills, pedestals, hummocks, sheeting, terracettes, scalding or gullying were largely absent at the quadrat ($1m^2$) or site (up to 50m) scale (Table 2). Most sites had an intact surface, except for a few sites with depositional features.

Utilisation

Five of the fifty sites surveyed showed signs of vegetation utilisation by livestock (10%) at the site scale. Only one of the five replicates at each site were utilised at most sites, meaning that only between 2 and 10% of the 250 replicates had one or more individual plants grazed.

Allium mongolicum Rgl was the primary plant species grazed. *Allium polyrrhizum* Turcz. et Rgl. or *Stipa* spp. was often grazed preferentially to *Allium mongolicum* Rgl, however. In replicates where grazing was apparent, plants had been selectively ‘picked’ with fully intact individuals mixed in with those grazed. Less than half the plant’s above ground biomass was generally grazed. At least three sites were located within sight of a *ger* or permanent water point but showed no sign of utilisation by livestock.

Livestock dung was noted at 26% of sites, in one or more of the five replicates. None of the 250 replicates showing 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.

Interviews

Fifty one percent of households included a female respondent. The average herd size was 297 head per household (min 1, max 1000). The average number of head per household member was 62 (min 11, max 500), and the average number of years spent herding was 22 years (min 8, max 30).

Changes in the rangeland

The response of pastoralists to the question 'Has there been any change in the pasture since you started herding?' generally depended upon whether they understood 'change' to mean that pasture had changed as would, or would not, be expected with typical precipitation patterns (Table 3). No pastoralist directly associated livestock grazing pressure with changes in rangeland condition, with one specifically stating that:

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

The most cited change, 'no/less rain,' was not supported by monthly precipitation totals over the last 20 years (Table 3). 'Lack of summer rain' was only significantly supported by Ulziit *soum* rainfall trends although a non-significant decline was found in all *soums*. 'Late rain' and 'more moisture from snow, less from rain' were not supported by trends in monthly precipitation records in selected *soums* (Table 3). 'More windy rain now,' 'torrential rains so water doesn't penetrate soil' and 'decline in number of rainy days' cannot be tested using the secondary data obtained for this research.

Pastoralists who responded that there had been no change generally suggested that vegetation attributes were primarily rainfall dependent:

'*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)

'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 [Achnaterum splendens (Trin.) Nevski] have almost become absent. This year we saw some ders for the first time after years of drought*.' (Tsogtseggi *soum*, Omnogobi *aimag*, 25 years herding)

Of the changes in vegetation that pastoralists noted since they had begun herding, 50% 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 amongst both *Stipa* spp. and *Artemisia* spp. (5%). There were two phenological changes (changes in flowering patterns) noted with *Caragana* spp. and *Artemisia* spp. (5%).

Goats and rangeland condition

Two pastoralists were specifically asked about the likelihood of goats 'digging the roots of plants, killing them'. The first respondent replied:

'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).

Another responded:

'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)

A third pastoralist stated that livestock digging plant roots contributed to decline in rangeland condition, but did not specify the livestock type.

Secondary data

Livestock numbers

Livestock numbers significantly increased in five of the seven assessed Gobi *soums* since 1960 (Table 4) but none of the five *soums* showed a significant increase in the recorded total SFU. Khanbogd, Tsogtseggi, Manlai and Tsogt-ovoo *soums* in Omnogobi showed a significant decline in total SFU since 1960. Herd compositional changes in the five *soums* showed that goat numbers have significantly increased since 1960 in all seven Gobi Desert *soums*.

Officially recorded herd sizes have been more volatile in all assessed *soums* since the socio-political reform processes of the 1990s (Figure 2). Annual SFU coefficients of variation were between 41% (Bulgan *soum*) and 340% (Tsogtovoo *soum*) greater in the post-1990 period than prior to 1990. Total SFU first declined, and then built throughout the 1990s before crashing during the *dzuds* of the late 1990s/early 2000s. A similar increase developed subsequently, followed by major livestock losses in the 2009/2010 *dzud*.

Changes in rainfall patterns

Annual precipitation did not change significantly over the last 20 years in any of the *soums* assessed (Table 4). The seasonality of precipitation in all *soums* did not significantly change except in Ulziit, where summer rainfall significantly declined. Other *soums* showed declining rainfall in summer although this trend was not significant at the 0.05 level. Changes in the timing of the onset of precipitation as rainfall was not examined here as monthly rainfall statistics are 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*).

Change in pasture biomass

Official biomass figures sourced in non-grazed areas across six *soums* (Table 4) show a significant decline in livestock available biomass for five of the six since 1990. In all *soums*, livestock available biomass was significantly greater between 1990 and 1999 than between 2000 and 2009.

Discussion

There are too many animals

The assumption that there are too many animals can not be supported in the desert steppe areas if assessed using the average trend in SFUs since the 1960s as the primary indicator.

The socio-political reform processes of the early 1990s are sometimes used as a temporal reference point for assessing livestock trends (e.g. Hess *et al.* 2010). The temporal variability of livestock numbers has increased since 1990. This makes it difficult to interpret the effect of livestock numbers on rangeland condition if only two static points in time since the 1990s are compared, particularly when short-term livestock numbers are not considered together with short-term forage availability.

The 1990s socio-political reference point may not reflect the temporal scale at which grazing pressures cause significant biophysical change, particularly as pastoralism has existed in the desert steppe for hundreds of years at largely unknown grazing pressures. Biophysical change may be dependent upon temporally non-linear mechanisms, such as the 'demographic inertia' and 'grazing catastrophe' mechanisms described by Westoby *et al*. (1989). The temporality of episodic *dzuds* on both livestock dynamics and vegetation reproduction are likely to be particularly important in contributing to rangeland condition.

There is also evidence from other similar landscapes that areas grazed for a long time have far greater levels of resilience to grazing (Cingolani *et al*. 2005). There is some evidence that Mongolian steppe areas are resilient to high grazing pressures and that grazing is in fact needed to maintain functionality in the desired vegetation community (Lavrenko and Karamysheva 1993). The Gobi desert steppe may show similar responses. Piospere studies suggest that high grazing pressures can, and do, cause significant vegetation change in the certain desert steppe landscapes (Sasaki *et al*. 2005). The timing and intensity of grazing pressures required to cause such a change, and whether this change is permanent or not, however, is unclear. These responses should be considered before assuming a significant relationship between current official livestock numbers and rangeland condition.

Comparing pre-1990 and post-1990 livestock numbers may complicate attempts to link livestock numbers and rangeland condition. Livestock numbers since the 1990s may have a greater impact on the vegetation per SFU than during socialist times because socialist collectives (*negdel)* buffered much of the climatic risk inherent in the region through the importation of fodder. Fernandez-Gimenez (1999) reported an 'abuse' of emergency fodder resources in the Gobi Desert that may have contributed to livestock numbers, particularly of cattle, that were unsustainable once this resource was removed. As one pastoralist told us:

'During the negdel they supported everything… the authorities supplied all fodder for free, as much as we needed' (Tsogtseggi *soum*, Omnogobi *aimag*, herding for 25 years)

It is also possible that official livestock numbers were inflated during the socialist era to indicate nation-building, or deflated in more recent years as pastoralists underreported numbers to avoid the livestock ‘foot’ tax. Other changes in livestock productivity may also confuse comparisons between socio-political periods. There is some evidence that average live weights have declined since the socialist period (Batimaa and Batnasan 2009), for example, meaning that vegetation consumption per SFU may be less now, with one SFU during socialist times having a different impact on rangeland condition than one SFU today. The relative ecological impact of the more consistent total grazing pressure during *negdel* times compared to the more dynamic pressures of recent years is also unclear. Given these complexities, the sole reliance of perceived gaps between ‘carrying capacity’ estimates and livestock numbers to assess degradation, a practise that Robinson *et al.* (2003) highlighted as existing during soviet periods in other parts of arid Asia, should be avoided.

Goats have proportionally increased and this is causing desertification

The proportion of goats has increased in all selected *soums* since 1960. The specific impact that this increase has on rangeland condition in the desert steppe is unclear, however. Goats have higher dietary plasticity than sheep (Devendra 1989). When goat grazing pressures are low or moderate, this broader diet means that the pressure that goats have on preferred, palatable species may be less than sheep at the same SFU. In the *Acacia aneura* shrublands of Western Australia, for example, sheep at the same moderate SFU as goats had more impact on the average annual plant recruitment and mortality rates of palatable plants than goats (Fletcher 1991).

High dietary plasticity may contribute to landscape degradation during droughts or when goat grazing pressures are high in landscapes where vegetation strategies for avoiding drought (e.g. geophytic behaviour) do not also allow them to escape grazing. The drought impact of goats cannot be assessed directly from the 2010 survey. Given the proportion of flowering/seeding species, the abundance of palatable perennials (Table 1) and the lack of evidence that goats 'dig the roots' of plants, there was no evidence that the risk of severe degradation associated with high grazing pressures of goats was realised during the moderate to good levels of soil moisture in the 2010 survey.

All the *soums* in which livestock numbers were sourced before and after the 2009/2010 *dzud* had slightly higher adult goat mortality rates over winter/spring than average livestock mortality rates. Pastoralists suggested this pattern was typical, as:

"*Sheep have better survival ability than goats because it is very cold in Mongolia's winter time… Goat's fat coagulates very easily and that is the main reason why they do not survive in a cold winter.*" (Ulziit *soum*, Dundgobi *aimag*, >30 years herding)

Whilst goats are considered better able to withstand drought than sheep, the higher *dzud* mortality rates for adult goats in extensive desert steppe systems may at least partially replace drought as an environmental check on herd size. If this check occurs before spring temperatures are high enough to trigger plant germination, the relatively high soil moisture levels after high precipitation *dzuds* with follow-up rainfall may allow key species like *Stipa* sp. to germinate and seed before flock recovery. If this is the case, goats would probably only pose a greater risk to rangeland condition than other livestock types at the same SFU in the desert steppe pastoral system if their quicker recovery times (Mongolian Society for Range Management, 2010) circumvented this environmental check.

Rainfall is declining

There is a partial conflict between pastoralist accounts of changes in precipitation and quantitative records. Quantitative records show that total precipitation, and total precipitation by season, has not significantly declined since 1990 apart from a consistent, sometimes significant decline in summer rainfall. Livestock available biomass has significantly declined despite this. Both Von Wehrden *et al.* (2010) and Liang *et al.* (2002) 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. Vegetation community responses may be more fine-tuned to rainfall temporally than the rough classification of seasonal rainfall/temperature done here.

It may be the most vegetation growth-effective form of precipitation that pastoralists, and others, believe 'is less now.' The perceived decline in precipitation and later rain in summer/autumn of interviewees was also recorded by Marin (2010) in slightly more northern parts of Dundgobi. As Marin (2010) noted, it is possible that pastoralists have a more nuanced understanding of changes in weather patterns than is detectable by the temporal scale of weather statistics. Similarly, pastoralists' perceptions may additionally be based upon more short-term events than was the intention of survey questions.

There is less pasture now

Maximum livestock-available biomass has significantly declined since 1990. This supports the 'less pasture now' assumption at a 20 year temporal scale. It is possible that the 1990 – 1999 period had higher than normal biomass, rather than the 2000 –

2009 period having lower than normal biomass, however. Whilst the average maximum biomass in the six *soums* assessed was less in the 2000 to 2009 period, the earlier 1971 – 1978 period at a similar desert steppe site (Lavenko and Karamysheva 1993) was also less than the 1990 to 1999 period. A 20 year dataset may not have been long enough to capture longer term trends in precipitation, and therefore vegetation production, variability. This highlights the risks of detecting trends through the use of short-term dataset in environments that are temporally variable.

Vegetation production is closely coupled with annual precipitation in Mongolia’s desert steppe areas (Von Wehrden and Kesche 2007). Given that vegetation production has significantly declined, the lack of a widespread significant decline in spring, summer and autumn precipitation (Table 4) over the last 20 years is surprising. Apart from the timing in rainfall events, changes in temperature may be important. The significant increase in temperatures in either summer or winter of four of the six *soums* may at least partially account for this mis-match, with Munkhtsetseg (2007) and Liang *et al*. (2002) suggesting that vegetation growth can be highly sensitive to variations in the region’s temperature. It is also possible that the significance of temperature increases and rainfall decreases in the primary growing period needs to be considered together.

Mongolian rangelands are degraded

The term ‘degradation’ is rarely temporally or spatially defined. It usage rarely questions what resource users are ‘managing’ for, or their ability to ‘manage’ at all. This makes interpreting rangeland condition indicators very difficult. The declines in vegetation production discussed above may have interacted with the post-socialist peaks of high SFUs without external fodder provision to facilitate overgrazing. Fine-scale livestock grazing pressures were not assessed by the 2010 survey and it is anyway unclear what utilisation levels over what time period in the desert steppe have a significant impact on vegetation, particularly given the relatively short growing period. Nevertheless, utilisation levels in 2010 were far lower than the 50% utilisation level often assumed to be sustainable in rangelands elsewhere (reviewed by Frost *et al*. 1994). There were relatively high proportions of palatable species, reproductive plants and low numbers of erosive features at the site scale. Pastoralists linked pasture conditions with rainfall events rather than grazing pressures. These indicators conflict with assumptions of severe and recent grazing-facilitated degradation that significantly reduces the ability of pastoralists to maintain their resource base in the long-term.

The belief of some pastoralists that grazing pressures do not affect rangeland condition conflict with observations by Sasaki *et al*. (2005) and Addison (pers. obs.) of low levels of vegetation cover and/or a dominance of unpalatable species around permanent water points and winter/spring camps in desert steppe areas. However, there is also increasing quantitative evidence that the current pastoral system does not have a consistent, significant, negative impact on rangeland condition across broad landscapes. Tsogtbaatar and Baasandorj (2009) documented an increase in the number of palatable *Stipa* sp. and *Allium* sp. in a $100m^2$ desert steppe plot from 11 to 19 between 1981 - 82 and 2001 - 2005, although they did not compare rainfall dynamics in each of those time periods. Ronnenberg *et al*. (2008) found that excluding livestock had no effect on *Stipa krylovii* Roshev. or *S. glareosa* P. Smirn. germination rates in Bulgan *soum*, Omnogobi. The data of Wesche *et al*. (2010) suggested that whilst grazing did have effects on both soil nutrients and vegetation floristics in southern/central Omnogobi between 2003 and 2005, '*neither did our observations* *support the idea that typical grazing leads to severe degradation'* (p 240) The assumed ability of pastoralists to significantly 'manage' or 'mismanage' vegetation in the desert steppe by reducing current livestock numbers, and the design of policies/programmes based on such a premise, need to be re-examined in light of such research.

Biomass and compositional changes in the vegetation of Gobi's desert steppes are highly dependent upon short-term rainfall events (Lavrenko and Karamysheva 1993; Von Wehrden and Kesche 2007; Cheng *et al*. 2011; Wesche *et al*. 2010). 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 two or more favourable years for pasture growth. Whilst *Cleistogenes songorica* (Roshev.) is a more dominant desert steppe Cleistogenes species, Shinoda *et al*. (2010) found that *Cleistogenes squarrosa* (Trin.) Keng has a higher sensitivity to drought than *Stipa krylovii* Roshev. Sodnomdarjaa and Johnson (2003) suggested that the genus requires long wet periods for reproduction. Given the spatio-temporal variability of summer rainfall in desert steppe areas, it is therefore not surprising that sexually mature *Stipa* sp. and *Cleistogenes* sp. were not frequently found during the 2010 survey. Their short-term absence cannot necessarily be interpreted as degradation. Comparisons in time between vegetation communities that are then explained by 'overgrazing' without consideration of rainfall events are inappropriate. Indeed, the practise of using productivity or species compositions to create 'carrying capacities' or to assess rangeland condition in Mongolia's desert steppe without acknowledging precipitation variability (e.g. Toriyama 2009), has been criticised internationally (Scoones 1989; Leeuw and Tothill 1990; Bartels *et al.* 1993).

There is a disconnect between the presence of spring sand-storm deposits recorded as far away as the United States (Heald *et al*. 2006) and the absence of accelerated erosion features observed during this assessment. The lack of litter incorporation also suggests that older litter had been utilised by livestock, disintegrated rapidly or was removed through wind or water to sink zones outside the assessed desert steppe area. One explanation is that accelerated erosion or deposition occurred in areas deliberately not targeted for assessment because they were 'unrepresentative' – that is, large gullies, internal drainage depressions or steep slopes. The spatial scale of rangeland condition assessments used here may not match the scale of the erosive vectors. However the quadrat size ($1m^2$) was typical of most pasture assessments conducted in the Gobi, and the site sampling regime was designed to be representative at the landscape scale. The limitations of single assessments of rangeland condition, without recognising the effect of erosive vectors at the landscape scale has been identified as an issue in other arid rangelands (Friedel 1994; Pringle and Watson, 2006). Small-scale, plot-based assessments based upon vegetation indicators have been over-relied upon in Mongolia's desert steppe areas. Rangeland condition indicators that are less susceptible to short-term precipitation patterns and more appropriate to the scale of stochastic events like sandstorms would provide more useful information upon which to base policy/programmes in the Gobi Desert.

CONCLUSION

It can be tempting to transplant known methodologies and causal effects of change from other landscapes or cultural settings. Arid rangelands are dynamic, and it is important that policies and programmes address change that is not merely 'noise' and instead can be managed. In Mongolia, claims of decline in rangeland condition are not a new thing, and neither is debate around their causal effects (e.g. Lattimore 1938). Our analysis shows that not all common rangeland condition assumptions in Mongolia universally apply in the Gobi Desert all of the time - and the biophysical mechanisms upon which these assumptions are based is more complex than is commonly recognised. Policy responses to degradation assumptions, such as requiring Gobi Desert herders to destock, would have substantial, negative impacts on their sometimes already marginal livelihoods. A more precautionary approach to designing policy and programmes applied to the Gobi Desert may be necessary given current understandings of rangeland condition.

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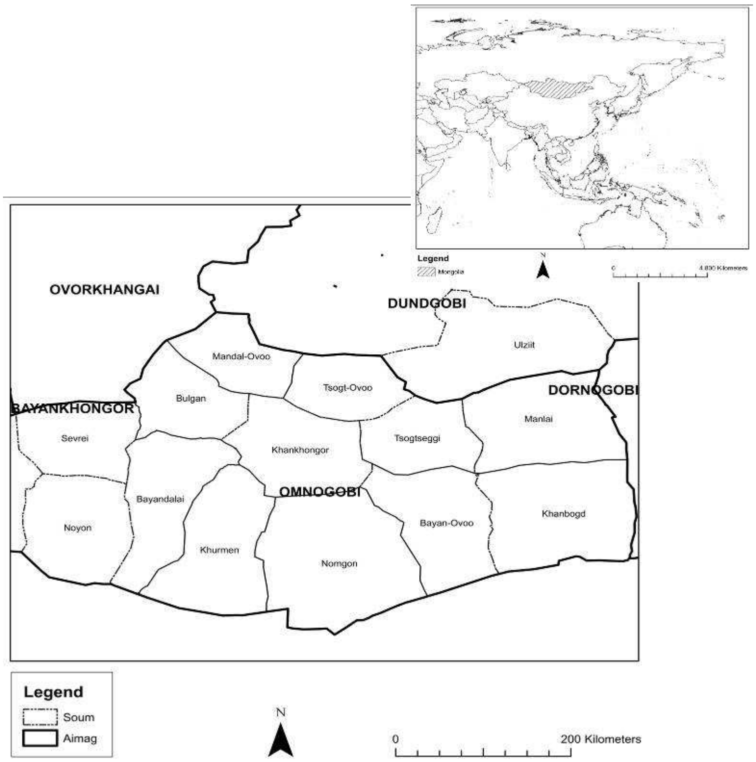


Fig. 1. Mongolia and the Gobi Desert *aimags* (States) and *soums* (second smallest administrative areas) selected for analysis.

Table 1. The 10 most abundant perennial species along transect lines.

				Palatability as per Damiran (2005)			
Species	**Count**	**%**		**January - March**	**April - June**	**July - September**	**October - December**
Stipa sp	229	32.25	Goats	P	P	P	P
			Sheep	P	P	P	P
			Camels	P	P	P	P
Allium polyrrhizum	152	21.41	Goats	D	P	P	D
			Sheep	D	P	P	D

Turcz. et Rgl.			Camels	D	P	P	D
Anabasis	58	8.17	Goats	D	P	P	D
brevifolia			Sheep	D	P	P	D
			Camels	D	T	C	D
Allium	50	7.04	Goats	C	P	P	C
mongolicum			Sheep	C	P	P	C
Rgl			Camels			-	
Unknown							
shrub	35	4.93				-	
Salsola sp	25	3.52				-	
			Goats	D	P	P	D
Artemesia			Sheep	D	P	P	D
frigida	24	3.38	Camels	D	P	P	D
Unknown forb	23	3.24				-	
Cleistogenes	22	3.10	Goats	P	P	P	P
sp			Sheep	P	P	P	P
			Camels	C	C	C	C
Unknown							
grass	18	2.54				-	

Palatability for sheep, goats and camels has been selected as the first to apply the greatest grazing pressure in the area, and camels occupy proportionally higher grazing pressure during/after extreme *dzuds* when feed gaps are likely to be most severe. Dashes indicate data missing from this source. P = preferred. D = desirable. T = toxic. C = consumed but undesirable.

Table 2. Site stability descriptions.

Indicator	Description	N	Mean (standard deviation)
Litter cover	%	250	1.34 (1.53)
Litter incorporation	Not incorporated = 1, Incorporated = 0	250	1 (0)
Litter source	Local = 1, Foreign = 0	250	1 (0)
Projected cover	%	250	11.55 (8.58)
Slake test	Score of 0 – 4 (0 = can't slake, 1= slakes within seconds, 4 = intact)	250	1.27 (0.72)
Crust brokenness	Score of 0 – 4 (0 = no crust, 1 = extremely broken, 4 = intact)	250	1.63 (1.87)
Texture	Score of 1 – 4 (1 = clay, 4 = sand)	250	2.85 (0.76)
Deposited materials	Score of 1 – 4 (1 = >50%, 4 = <5%)	250	3.71 (0.72)
Biological crust	Presence = 1, Absence = 0	250	0 (0)
Erosion extent	Presence = 1, Absence = 0	250	0.09 (0.29)
Erosion severity	Score of 1 – 4 (1 = least severe, 1 = most severe)	250	0.15 (0.45)
Erosion type	Rilling, pedestals, hummocking, sheeting, terracettes, scalding, gullying	250	Hummocking (6.8%), scalding (1.2%)
Topsoil intact	%	250	91.02
Topsoil eroding	%	250	0.41

Mobile sandy deposits	%	250	2.45
Depositional mobile sand	%	250	6.12
Landscape organisation index	Patch: interpatch	250	0.21
Patch proportion	%	1750	17.13
(Perennial vegetation)	%		5.85
(Rocks)	%		6.78
(Other)	%		6.78
Interpatch proportion	%	1750	82.87
(Bare)	%		54.8
(Rocky bare surface)	%		4.32
(Rocky surface)	%		18.49
(Sandy surface with rocks)	%		5.02
(Other)	%		0.22

Surface erosive type classifications modified from Friedel *et al.* (1993); landscape organisation and indicators other than non-vegetative cover types modified from Tongway (2008). N = number of replicates.

Table 3. Pastoralist reasons for changes in the rangeland.

			%
Climate variability	Quantity of rain	No/less rain (total quantity)	33.3
	Changes in nature of rain	Chinese rain-seeding programme	2.2
		More 'windy rain' now	2.2
		Late rain	6.7
		Torrential rains so water doesn't penetrate the soil	8.9
		Lack of summer rain	2.2
		Decline in number of rainy days	6.7
		More moisture from snow, less from rain	2.2
Biophysical change	Vegetation	The roots are dead	2.2
	Soil	Dust-storms and/or sandstorms and/or dust	6.7
		More sand	6.7
		Reduced soil fertility	2.2
Not pastoralist-mediated		More roads creating dust	6.7
		Mining (or a named mine), often 'digging the topsoil'*	6.7
		The democratic revolution	2.2
Pastoralist-mediated	Grazing	Animals eating grass roots	2.2
	Not grazing	Some grasses stop growing when we cut them for hay	2.2

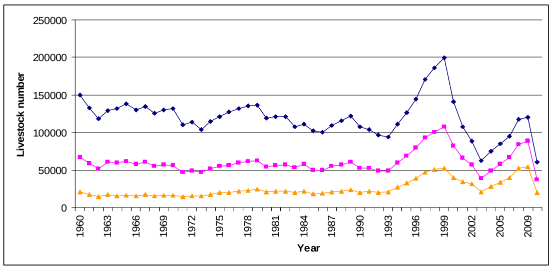
Pastoralists did not often differentiate between grazing facilitated changes in rangeland condition and a lack of rain. Cause and effect as defined by current western rangeland science was rarely differentiated. * 'Digging the topsoil' is understood by some Mongolians to cause significant environmental damage at a spiritual level, above and beyond localised biophysical affects (Humphrey 1978).

Table 4. Trends in key rangeland indicators in study soums.

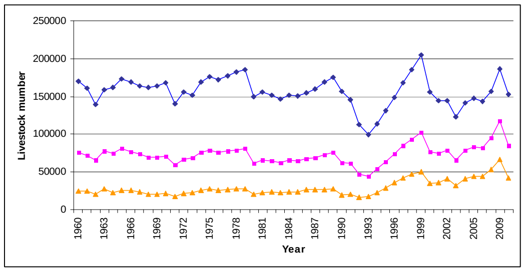
				Annual		Spring		Summer		Autumn		Winter		
	Total SFU	Total livestock number	Total goats	Ppt (mm)	Temp (ºC)	Ppt (mm)	Temp (ºC)	Ppt (mm)	Temp (ºC)	Ppt (mm)	Temp (ºC)	Ppt (mm)	Temp (ºC)	Annual biomass (kg ha^{-1})
Khanbogd	**0.000*****	**0.013***	**0.000*****	0.623	0.524	0.237	0.831	0.903	0.922	0.445	0.323	0.676	**0.000*****	0.067
	-	+	+	+	-	+	-	-	+	+	-	-	+	-
Bulgan	0.063	**0.000*****	**0.000*****	0.202	0.809	0.845	0.93	0.101	**0.000*****	0.477	0.805	0.355	0.735	**0.003****
	-	+	+	+	+	-	+	-	+	-	+	+	+	-
Bayandalai	0.892	**0.000*****	**0.000*****	0.392	0.956	0.97	0.937	0.265	0**.005****	0.686	0.837	0.58	0.384	**0.00*****
	-	**+**	**+**	-	-	+	-	-	+	+	+	-	-	-
Sevrei	0.453	**0.000*****	**0.000*****	0.369	0.813	0.807	0.998	0.521	**0.003****	0.386	0.925	0.651	0.701	**0.028***
	+	+	**+**	-	-	-	-	-	+	-	-	-	-	-
Ulziit	ND	ND	ND	0.05	0.261	0.907	0.141	**0.013****	0.867	0.789	0.566	0.317	0.866	**0.00*****
	ND	ND	ND	-	-	-	-	-	+	+	-	+	+	-
Tsogtseggi	**0.036***	**0.035***	**0.000*****	0.093	0.439	0.934	0.878	0.212	0.051	0.531	0.317	0.247	0.689	**0.00*****
	-	+	+	-	-	-	-	-	+	-	+	+	-	-

Manlai	**0.012****	**0.042****	**0.000*****	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	-	-	+	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tsogt-ovoo	**0.000*****	0.938	**0.000*****	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	-	-	+	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

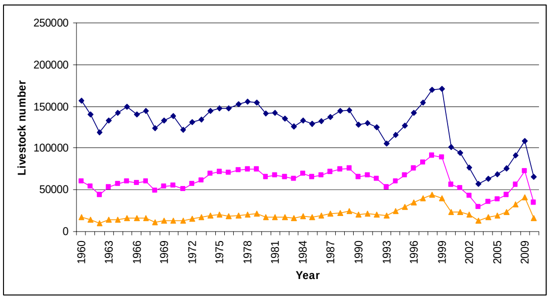
p-values are derived from climate data are from 1990 to 2009 and livestock data from 1960. All *soums* are in Omnogobi except for Ulziit *soum*, which is in southern Dundgobi. - = decline over time, + = increase over time. ND = no data available. Ppt = precipitation. $^{***}p<0.001$, $^{**}p<0.01$, $^{*}p<0.05$.



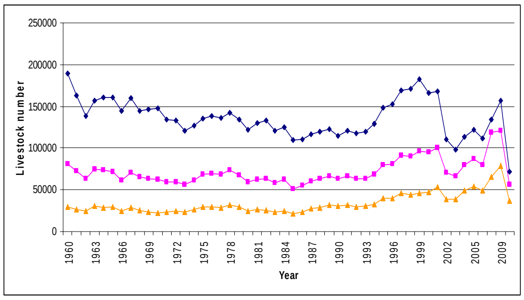
2a. Tsogtseggi *soum*



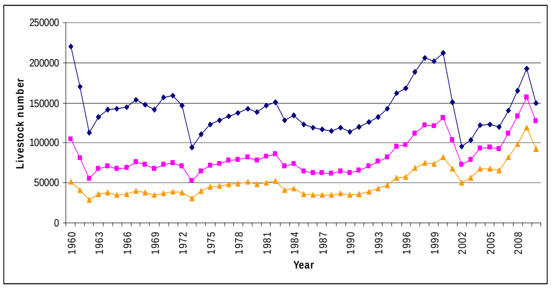
2b. Manlai *soum*



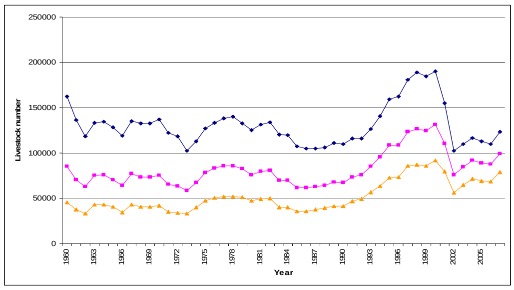
2c. Tsogtovoo *soum*



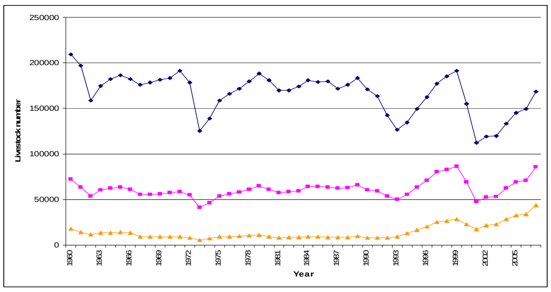
2d. Bulgan *soum*



2e. Bayandalai *soum*



2f. Sevrei *soum*



2g. Khanbogd *soum*

Fig. 2. Changes in livestock numbers since 1960. ◆ = total SFU, ■ = total livestock, ▲ = goat. Bulgan and Bayandalai *soum* 2009 figures are extrapolated from the growth in the previous 3 years. 2010 figures assume a 53.8% herd loss (the soum-wide loss) for Bulgan *soum* (pers comm., Bulgan *soum* Food, Agriculture, Trades and

Services Officer, 2010), and a loss of 30000 head (*soum*-wide) for Bayandalai *soum* (pers comm., Bayandalai *soum* Food, Agriculture, Trades and Services Officer, 2010).

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