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Piospheres and Pastoralists: Vegetation and Degradation in Steppe Grasslands

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Abstract The Mongolian plateau in East Asia is part of a new hotspot of land cover change. Recent human activity and natural forces have degraded grasslands in northern China with the southern Mongolia steppe similarly vulnerable. Investigating vegetation patterns at piospheres (the area around water points) can identify herder influence on pasture conditions. Through fieldwork and remote sensing this paper examines plant density and species richness at water sources to establish land cover patterns in two Mongolian provinces where overgrazing is thought to be the major cause of degradation. In contrast to standard piosphere patterns, vegetation was greater near water points and decreased with distance. This suggests that livestock are not concentrated at water points in Mongolia and that piosphere dynamics are more influenced by precipitation, edaphic factors and potential distinctive processes in cold drylands. It implies that pastoralism, with mobile livestock management, is a suitable adaptive strategy to the low forage capacity of steppe grasslands.

Keywords Piosphere · Degradation · Mongolia · Steppe vegetation · Pastoralism · Water point

Introduction

The enduring limitation of water in arid zones defines human interaction in such environments (Zhou *et al.* 2011). In grasslands climate, biophysical traits and human activity determine ecological resources across spatial and temporal scales. For communities in developing regions the focus is on water sources, vegetation productivity and landscape services that contribute to livelihoods and agro-pastoralism. Range management is a challenge in drylands as livestock grazing and human activity can impact vegetation dynamics and lead to ecosystem degradation (Mortimore 2009). This is a particular concern at water points (piospheres) where livestock concentration can negatively affect ecological functioning and exacerbate land cover change (Andrews 1988; Todd 2006; Sasaki *et al.* 2012).

Whilst degradation has received much attention in African rangelands (Thomas *et al.* 2000; Todd 2006; Reed and Dougill 2010) Asia is now identified as the hotspot of land cover change (Lepers *et al.* 2005). The vast Inner Asian grasslands are ecologically fragile and sensitive to climate change yet there are limited reports on land system alteration in the cold drylands of Mongolia and northern China (Jun Li *et al.* 2007; Zhang *et al.* 2007; Keshkamat *et al.* 2012). The Gobi steppe region provides an unusual study site as landscape and human dynamics contrast with more commonly studied arid regions. Continued mobility and severe winters (to −40 °C) result in livestock grazing in snow or ice conditions several months per year. Past patterns of development–communism and collectivisation – have transitioned to market-oriented systems with altered herding practices and government policies influencing ecological productivity and increasing the risk of grassland damage (i.e. crossing desertification thresholds) (Yang *et al*. 2005; Sasaki *et al*. 2012; Regdel *et al.* 2012).

In arid and semi-arid environments like the Gobi Steppe livestock grazing can modify ecosystems and is considered a major cause of land degradation (Nangula and Oba 2004; Okayasu *et al.* 2007; Lin *et al.* 2010). Potentially negative impacts center on overgrazing, fragility vs. resilience in dryland ecosystems, persistence of "irrational" traditional herding practices and whether human activity (stocking strategies) or natural conditions define grassland productivity (Mortimore

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2009). In Mongolia rangeland degradation rates >70 % are cited though little research has attempted to define current conditions at a localized scale (UNCCD 2002; Regdel *et al.* 2012). Communal land stewardship, resource restraints and weak rural governance means pastoralists determine their environmental interactions – deciding stocking rates, livestock composition, location and mobility patterns. Efficacy and impact of this laissez-faire approach to rangeland is unclear and contrasts markedly to the government-structured intensified system of grassland use in China that has made it one of the world's most desertifed counties (Li *et al.* 2006; Normile 2007; Zhang *et al.* 2007). A decline in rangeland functionality and an increase in desertification in East Asia makes understanding vegetation dynamics at a local scale a prerequisite to addressing regional environmental conditions (Yang *et al.* 2005; Yoshihara *et al.* 2010).

In rangelands water points are the fundamental organizational structure. Studying piospheres – the zone of ecological impact around livestock watering points - can differentiate the long-term effect of livestock on vegetation from that of other environmental factors around water sources (Andrew 1988). Previous piosphere findings in dryland regions show livestock impact to be greatest near water points with influence diminishing with distance from water source (Fernandez-Gimenez and Allen-Diaz 2000; Nangula and Oba 2004). The piosphere effect can create a 'sacrifice zone' immediately surrounding the water point where grazing and trampling result in bare ground. Changes in ground cover and plant composition may result from water-centered grazing and have potentially severe consequences as piosphere development can be the first stage of the desertification process (Andrew 1988; Landsberg *et al.* 2003; Yamaguchi 2011). This study hypothesized that the common global pattern of a water point being 'the center of its own little desert' would occur in Mongolia. Vegetation cover at piospheres was investigated along a transect gradient to determine grazing impact on pasture conditions (Todd 2006). Field surveys and remote sensing techniques were employed to identify vegetation cover and assess the role of grazing as a proximate cause of degradation in the steppe ecosystem. Measuring plant density and species richness evaluated cover patterns and forage palatability whilst integrating remote sensing and ecological data provided an historical perspective on range productivity in two grassland regions.

Study Area

Mongolian Rangelands

Grasslands cover approximately 80 % of Mongolia's 1.56 million km^2 where mobile pastoralism continues to be an effective manner of harvesting forage resources in the dry, cold, low-fertility steppe environment (Fig. 1) (Fernandez-Gimenez 1999; Yu *et al.* 2004). Climate is characterized by short hot summers and long cold winters with unimodally distributed precipitation (224 mm annually) concentrated in summer (Yu *et al.* 2004). Drought and *dzud*, a condition when snow and ice prevent livestock from obtaining adequate forage, are the country's worst natural disasters (Sternberg *et al*. 2009). Surface water is scarce in the southern half of the country with groundwater the principal source; since 1990 the number of working wells in the country has fallen in half (Tanaka *et al.* 2005). An increase from 24 to 44 million livestock between 2002 and 2009 led to livestock intensification at water points (Regdel *et al.* 2012). Mearns (2004) identified vegetation degradation at wells and Okayasu *et al.* (2007) stressed the difficulty of data collection prevented accounting for the effect of well sites in their efforts to address land degradation in Mongolia. Concern about potential overgrazing, land degradation, and desertification have prompted efforts to

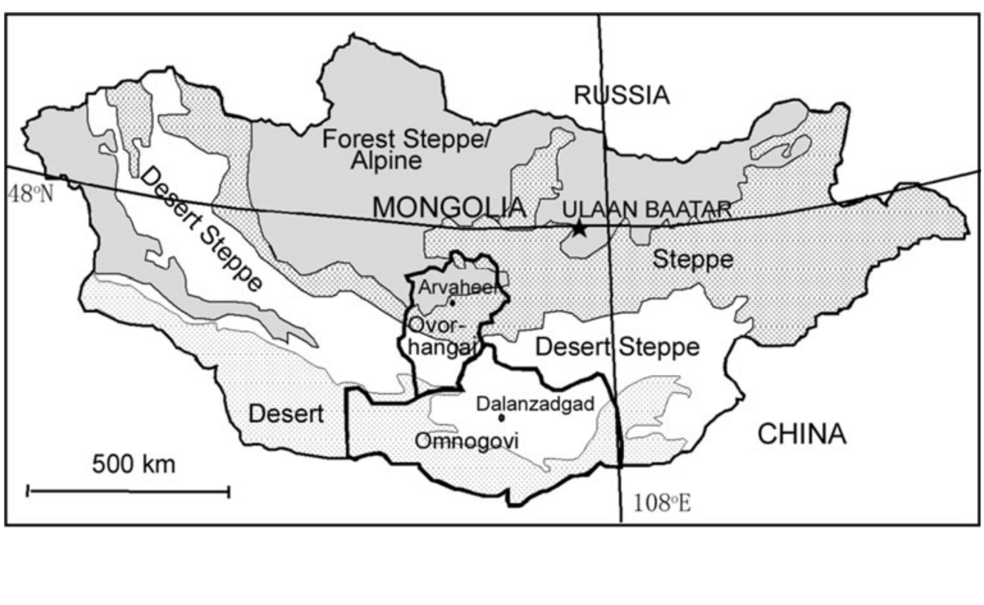

Fig. 1 Map of Mongolia with vegetation zones

identify pasture and vegetation conditions through field research (Stumpp *et al.* 2005; Sternberg *et al*. 2010).

Ovorhangai and Omnogovi Provinces were selected as research sites that encompass semi-arid and desert-steppe terrain in Mongolia (Table 1). The steppe grassland has high precipitation variability and low soil fertility that suggests edaphic and abiotic factors strongly influence plant growth and livestock communities (Munktstsetseg *et al.* 2007). Ovorhangai's precipitation Coefficient of Variation (CV) is 27 %, Omnogovi's CV=34 %, with their summer growing season monthly CV at 58 % and 72 % respectively, suggesting non-equilibrium environments (Fig. 2) (Begzsuren *et al.* 2004). Past study identifies that inter-annual precipitation variability can lead to considerable fluctuation in vegetation cover in Mongolia (von Wehrden *et al.* 2006).

Methods

Degradation of vegetation cover is considered to be a main form of desertification, usually evident as a decline in vegetative cover, increased erosion or decreased biomass (Huang and Siegert 2006; Keshkamat *et al.* 2012). Additionally, grazing can affect vegetation spatial distribution in drylands; knowledge of species composition and plant palatability are important factors in evaluating degradation (Lin *et al.* 2010). Local concern in desert-steppe regions is that the loss of vegetation cover will leave soils vulnerable to wind erosion, a process that reduces productivity and leads to dust storms with region-wide impact (Akata *et al.* 2007). Previous study in Mongolia found total vegetative cover the most consistent response to grazing, and that nomadic herders primarily use cover to assess pasture conditions (Fernandez-Gimenez and Allen-Diaz 2000). To investigate degradation two methods of assessment were undertaken to establish vegetation parameters and provide verification of coverage and potential change (Okayasu *et al.* 2007). Applying methods pioneered in African drylands, we employed the line-transect method to examine vegetation dynamics along a 1 km gradient (Thomas *et al.* 2000; Todd 2006). In this study 110 transects across Ovorhangai and Omnogovi Provinces were surveyed to identify piosphere vegetation dynamics in Mongolia's steppe and desert-steppe regions. The extensive spatial and numerical scales were selected to increase the study applicability and expand pasture knowledge across a substantial grassland area.

Within a 1° latitude by 2° longitude field area (46°N, 103°E to 44°N, 104°E) in each province sites were randomly selected to encompass spatial and ecosystem variability. Water points were located through visual inspection and in consultation with local herders. All sites were currently used by livestock, determined by fresh dung at the piosphere, adequate source-water availability, tent dwellings in the vicinity and herder confirmation when possible. Fieldwork was carried out during the April to October plant growth season in 2006–2007. At each water point data were collected along 1 km transects. To ensure sampling randomness all piosphere transects were due north except when visible barriers (terrain, abodes) prevented this. Vegetation measurements were taken at 25, 50 100, 200, 500, and 1,000 m from the water source to identify cover as a function of distance from a piosphere. At each distance three 30-m sections were examined, each separated by a 30 m interval with sections located to the left, center, and right of the transect (Fig. 3). Percentage of plant basal cover for each meter along the line was recorded as a measure of plant density. At each site all plant species growing along the

Table 1 Physical and social characteristics in Ovorhangai and Omnogovi Provinces

Province		Ovorhangai	Omnogovi
Sites		55	55
Rangeland		Steppe–Desert Steppe	Desert Steppe
GPS		N 45.7–46.7, E 102.1–104.2	N 43.4–44.5, E 103.2–105.3
Elevation (meters)	Average	1,678	1,533
	Range	1,389–2,095	1,092–2,067
Mean annual precipitation	mm	235	121
	Min-max	119–378	51–235
Mean temperature	January	−14.4 °C	−13.9 °C
	July	16.3 °C	21.9 °C
Water point	% well/surface	87–13	93–7
Herders	% population	57 %	49 %
Livestock	Type	Sheep, Goat, Horse, Cattle	Goat, Sheep, Camel, Horse
Livestock numbers	2002	1,665,000	909,000
	2006	2,623,300	1,155,700

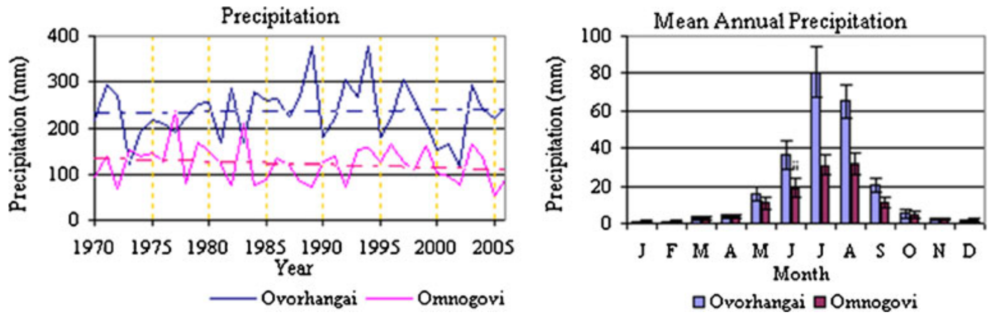

Fig. 2 Average annual precipitation (**a**) 1970–2006 in Ovorhangai (r^2–0.001) and Omnogovi Provinces (r^2= −0.03); average monthly precipitation (**b**)1970–2006 in Ovorhangai and Omnogovi Provinces with standard error

transects were collected to establish species composition and richness by water point. Plants were dried for later identification in the Geo-Botany lab of the Mongolian Institute of Geography. At each piosphere latitude and longitude, elevation and temperature were recorded to analyze with vegetation data. Analysis was done with SPSS 14 (SPSS Inc. Chicago, Il.).

Remote sensing was employed to provide an historical perspective on vegetation cover at study sites. Multi-temporal SPOT-4 satellite imagery was used to assess Normalized Differential Vegetation Index (NDVI) at each piosphere. NDVI is a commonly used vegetation index derived from remotely sensed measurements that is a normalized ratio of the NIR and red bands $NDVI = NIR\text{-Red}/NIR + \text{Red}$ where *NIR* and Re*d* are the spectral reflectance in near-infrared and red wavelength respectively (Zhou *et al.* 2011). Research has established that NDVI, sensitive to vegetation density and photosynthetic capacity, is highly correlated with biophysical parameters such as vegetation coverage and biomass (Yu *et al.* 2004). Thirty-day images were used from 1 April through October 30, 1998–2006 time series of observations. The months were selected to encompass the potential growing season and peak precipitation period. Similar to other regional studies, a 1 km spatial resolution was used to generate pixel values on a scale equivalent to the line transects (Huang and Siegert 2006; Okayasu *et al.* 2007). Data were used to derive NDVI monthly and annual coverage values at each piosphere throughout the time period. To verify the relationship between groundcover and NDVI we matched fieldwork data with NDVI findings at each site so that two methods assessed vegetation cover in field locations. Though NDVI is an inexact measurement it provides an approximation of land coverage over time. Use of several years' data it gives an historical perspective to vegetation coverage and change in the region.

Due to remoteness and limited research there is one unrelated study that combines field data with remote sensing to assess land cover in Mongolia (Javzandulam *et al.* 2005). Previous vegetation studies relating to water points in Mongolia focused on plots (Fernandez-Gimenez 1999; Wesche and Retzer 2005) and line-transects. In Omnogovi Stumpp *et al.* (2005) examined soil characteristics along 5 transects while Sasaki *et al.* (2007) reviewed plant composition in plots along a single transect.

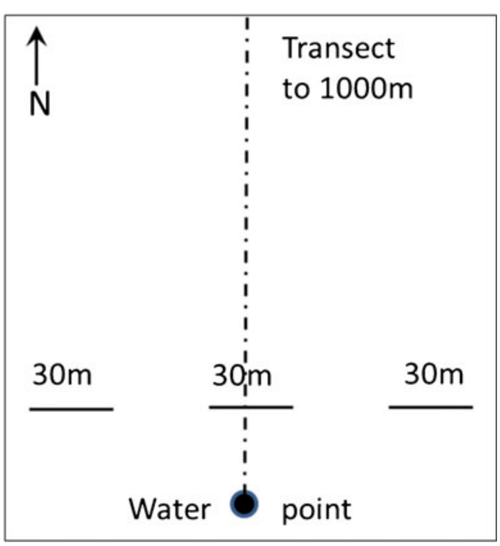

Fig. 3 Vegetation collection at three 30 m intervals along transect line

Results

Water points studied demonstrated no 'piosphere effect' of increased ecological impact from livestock around water sources in the Mongolian steppe and desert-steppe environment. Transect measurement showed vegetation density decreased with distance from the water point in both provinces (Fig. 4a). Though plant density differed between the two provinces species richness was similar (Fig. 4b); composition was dominated by perennial grasses and forbs. Satellite imagery from 1998 to 2006 reflected low vegetation density and both inter- and intra-annual variability in land cover. Site factors, such as elevation and latitude, were predictors of vegetation dynamics. The inverted vegetation density, where lowest values were furthest from the water point, suggest piosphere overgrazing does not strongly influence plant coverage or species richness.

Plant density in Omnogovi declined at each measurement with distance from water points. Average coverage ranged from 4 % at 25 m to 2 % at 1,000 m (r^2=0.98), much sparser

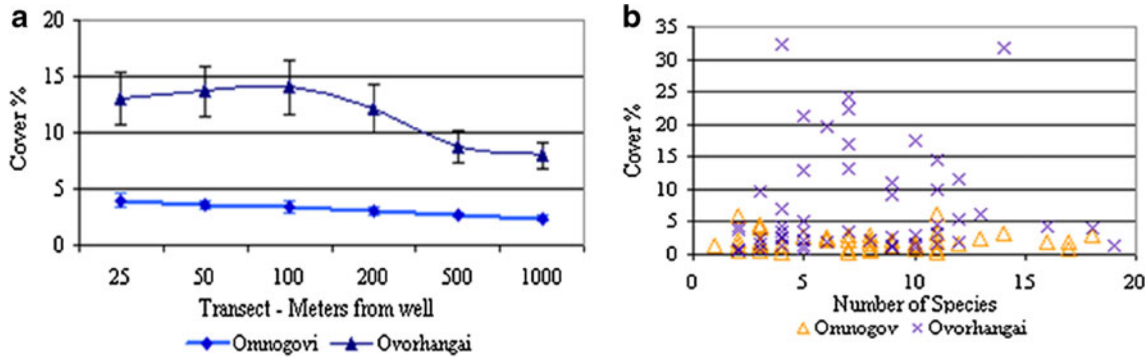

Fig. 4 Field-measured vegetation coverage by distance from water point with standard error (**a**), and species richness (**b**) at each site in Ovorhangai and Omnogovi Provinces

than previously recorded in the desert steppe region (Fernandez-Gimenez and Allen-Diaz 2000). In Ovorhangai vegetation coverage increased slightly from 25 m to 50 m, peaking at 100 m distance from the water point. Cover then decreased at 200 m and 500 m, with 1,000 m having the lowest vegetation density. Maximum average coverage in Ovorhangai was 14 % at 100 m and minimum was 7.8 % at 1,000 m (r^2=0.74). Coverage was significantly correlated (P=0.01) with elevation and NDVI throughout the study. It tracked latitude (P=0.01), mirroring the steppe to desert steppe gradient of the region. Species richness was similar in both provinces, ranging from 2 to 19 plant types per site in Ovorhangai, with an average of 7.9, and 1 to 18 species with an average of 7.8 in Omnogovi. Species richness was not correlated with vegetation coverage but was strongly associated with elevation (P=0.01). Richness and NDVI were significantly related (P=0.01) in Omnogovi but not in Ovorhangai.

Piosphere NDVI for 1998 to 2006 had low annual coverage values of between 39 to 51 in Omnogovi and 63 to 83 Ovorhangai (digital number scale = 0–255). NDVI trends illustrated the variability of the steppe environment and ongoing land cover change. Average province-wide intra-annual variability was 40 % and 27 % respectively, with inter-annual fluctuation of ≥30 % in both provinces (Fig. 5). At individual sites there was great variability between and within years, >400 % in Omnogovi and >300 % in Ovorhangai. Such pronounced change points to the role of precipitation affecting land cover, reflected in the significant correlation (P=0.01) between NDVI and observed vegetation cover at the sites. This link between cover and NDVI enabled an historical land cover perspective. Examining 4 year intervals found 1998 was a wet year, reflected in higher NDVI values. 2002 was a severe dry year with the low land cover values, resulting in a 35 % decrease in NDVI. By 2006 precipitation rebounded to slightly above normal, seen in a 38 % NDVI rise over this period, though this was still 11 % below 1998 levels. Figure 6 identifies decreasing coverage, suggesting reduced pasture resources over the 9-year timespan. NDVI was also correlated with

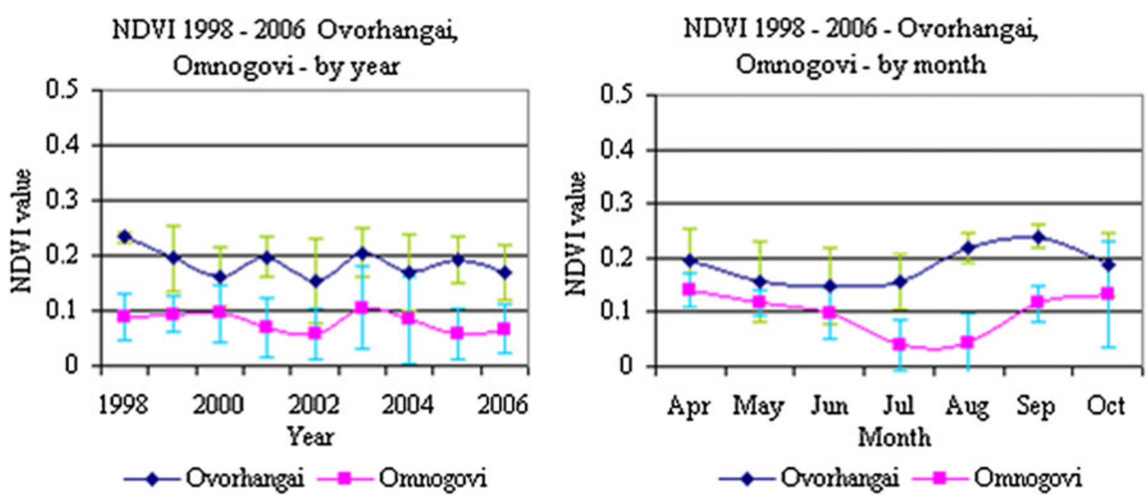

Fig. 5 1998–2006 province average annual NDVI (**a**) and average monthly NDVI values (**b**) for Ovorhangai and Omnogovi, with standard deviation

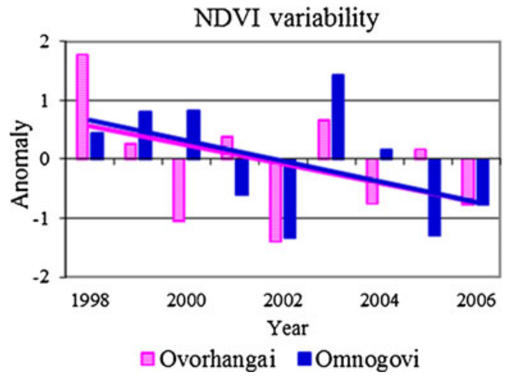

Fig. 6 NDVI trends from 1998 to 2006 (Ovorhangai r^2=0.19; Omnogovi r^2=0.23)

elevation (P=0.01), reflecting increased coverage in interspersed mountainous terrain, and was similarly related to latitude (P=0.01).

The relationship between NDVI and climate data was assessed in the two provinces. This found that in both provinces precipitation was concentrated in summer, with >67 % in June, July and August and >85 % from May through September, mirroring the short plant growth season of 90–130 frost-free days (Begzsuren *et al.* 2004). Rainfall records and NDVI had a significant correlation (P=0.01) in Omnogovi whereas the two factors were not strongly related in Ovorhangai. Temperature was not correlated with NDVI.

The vegetation survey recorded 86 plant genera and 120 species at the field sites. Species composition was dominated by forbs and perennials with distribution following: *growth* – grass 22 %, forbs 60 %, shrub – 18 %; *life form* – annual – 14 %, biennial – 8 %, perennial – 60 %, shrub – 18 %; *palatability* – 78 %. In both provinces less than half (45 %) of the genera were at >2 sites; several species had single site distribution – 33 % in Ovorhangai and 39 % in Omnogovi (Table 2). The major plant species (31) comprised 69 % of the total presence and represent a cross-sample of steppe vegetation (Table 3).

Table 2 Genera and species total and presence by province

	Genus	Presence	Species
Ovorhangai	61	Total	82
	28	≥3 sites	46
	13	2 sites	13
	20	1 site	23
Omnogovi	61	Total	85
	27	≥3 sites	47
	10	2 sites	12
	24	1 site	26
Provinces	86	Total	120
	34	Shared	38

To examine basic vegetation patterns and relate them with environmental and site factors correspondence analysis was used where the lengths of a particular axis gives an estimate of diversity (Fernandez-Gimenez and Allen-Diaz 2000). Eigenvalues of the two main axis were 0.383 and 0.229, explaining 61.2 % of community variance. Examining all sites the first axis explained 4.1 % of species variability with the axis correlated with site characteristics (r^2=0.87) (Fig. 7). The second axis added 2.4 % species variance; combined the axes explained 6.5 % of species variability. The general distribution suggests an ongoing variation in species distribution and therefore not distinctly defined vegetation types in the data. The provinces reflected similarly disparate composition trends with Ovorhangai having greater variance along a main axis (to 3.5) than Omnogovi (to 0.75). Omnogovi's species distribution was not along a single dominant axis.

Discussion

Study results indicate that piosphere vegetation cover on the steppe is greater near water points and decreases with distance, suggesting that grazing is not concentrated around water sources to the detriment of the environment. High variation in NDVI, land cover and precipitation also suggests climate factors have greater impact on vegetation dynamics in southern Mongolia than managed livestock grazing. Findings infer that degradation is an inappropriate term around piospheres and that extremely low cover values are endemic in the Gobi steppe region. NDVI values question if thresholds have been crossed – the great fluctuation in land cover may reflect natural forces, particularly precipitation, as wet episodes enable areas devegetated in dry periods to recover sufficiently to be productive. Additionally, livestock, through urine and faeces deposition, may elevate soil nutrients and affect vegetation composition and density around a water source (Fernandez-Gimenez and Diaz 2000). The idea of pasture continuity is supported by increasing provincial livestock numbers over the study period despite variegated land cover values.

Results from this study contradict the prevalent "overgrazing causes desertification" school of thought on the Mongolian plateau (Gunin *et al.* 1999; Zhao *et al.* 2005; Kawamura *et al.* 2005; Lise *et al.* 2006). Greater vegetation density within 100 m of piospheres than at 500 m or 1,000 m suggests that herders are not overusing accessible areas around water points, findings that differ from several studies in Africa (Todd 2006; Nangula and Oba 2004). In contrast, findings support the hypothesis that in this arid ecosystem grazing may have a marginal effect on piosphere vegetation cover and species richness; high palatability rates inferred suitable animal forage at field sites. It questions the concept that pastoralism has a negative impact on environmental

Table 3 Major plant species by growth, form, livestock palatability, # sites, and province, and relative presence (total sites = 110–55 each province)

Plant species	Growth	Life form	Palatability	Sites	Ovorhangai	Omnogovi	Presence %
Caragana pygmaea	Shrub	Shrub	Palatable	47	34	13	42.7
Achnatherum splendens	Grass	Perrenial	Palatable	39	15	24	35.5
Chenopodium album	Forb	Annual	Palatable	34	18	16	30.9
Iris bungei	Forb	Annual	Palatable	33	22	11	30.0
Peganum nigellastrum	Forb	Perennial	None	32	6	26	29.1
Agropgron christatum	Grass	Perennial	Palatable	31	27	4	28.2
Convolvulus ammanii	Forb	Perrenial	Palatable	30	17	13	27.3
Potentilla bifurca	Forb	Perennial	Palatable	29	29	~	26.4
Artemisia frigida	Shrub	Shrub	Palatable	22	13	9	20.0
Erigrostis minor	Grass	Biennial	Palatable	22	6	16	20.0
Allium pollyrrhizum	Forb	Perennial	Palatable	21	~	21	19.1
Bassia dasyphylla	Forb	Biennial	Palatable	20	2	18	18.2
Artemisia sp.	Shrub	Shrub	Palatable	17	13	4	15.5
Panzeria lanata	Forb	Perennial	None	15	11	4	13.6
Trisetum sibiricum	Grass	Perennial	Palatable	14	6	8	12.7
Artemisia sericea	Forb	Perennial	Palatable	14	~	14	12.7
Axyris hybrida	Forb	Annual	Palatable	14	5	9	12.7
Allium mongolicum	Forb	Perennial	Palatable	13	~	13	11.8
Anabasis brevifola	Forb	Perennial	Palatable	13	~	13	11.8
Ptilotrichum canescens	Forb	Perennial	Palatable	13	5	8	11.8
Artemisia macrocephala	Forb	Annual	Palatable	11	3	8	10.0
Cleistogenes squarrosa	Grass	Perennial	Palatable	11	11	~	10.0
Cleistogenes soongorica	Grass	Perennial	Palatable	11	~	11	10.0
Salsola passerina	Shrub	Shrub	Palatable	11	~	11	10.0
Thymus gobicus	Shrub	Shrub	None	11	11	~	10.0
Stipa krylovii	Grass	Perennial	Palatable	10	9	1	9.1
Artemisia santolinifolia	Forb	Perennial	Palatable	10	4	6	9.1
Chenopodium sp.	Forb	Annual	None	9	2	7	8.2
Heteropappus hispidus	Forb	Biennial	None	9	6	3	8.2
Crepis crocea	Forb	Perennial	None	9	9	~	8.2
Artemisia adamsii	Forb	Biennial	None	9	9	~	8.2

productivity and suggests customary usage patterns that maximize low pasture resources through extended livestock forage areas, limited concentration around water points and access to several different pastures are appropriate. A more non-equilibrium focus suggests that climatic variability, environment and edaphic factors characterize ecological systems and control land cover. This is exemplified in the study by variable precipitation and fluctuating NDVI values that separate vegetation coverage patterns from livestock and piosphere sacrifice zones. Study outcomes leave the herder, through insight, tradition, or limited alternatives, operating in a manner that is sustainable given environmental constraints. Findings postulate that in Mongolia overgrazing, and thus herder pasture usage and decision-making, is not the cause of low vegetation coverage or species richness around steppe piospheres.

The difference between study findings in a cold grassland and vegetation cover in warm drylands presents an opposite piosphere effect and suggests divergent range processes may occur. Conventional interpretations could be that a) overgrazing, trampling and compaction has less impact on a northern steppe environment, b) plant composition near water points are comprised of less palatable species and thus are underutilised by livestock, c) soil nutrients/fertility may vary with climate regimes with processes in cold regions sufficient to counter degradative processes associated with livestock. A more in-depth assessment would evaluate how piosphere dynamics may differ between cold and warm environments.

Several potential scenarios specific to cold grasslands may affect piospheres. Snow often provides sufficient moisture for animals in winter, decreasing the need for a water point, thus reducing movement and trampling around piospheres in cold months (Fernandez-Gimenez 1999). In winter livestock forage for vegetation or are in shelters to protect from the wind and weather. Further, springs and

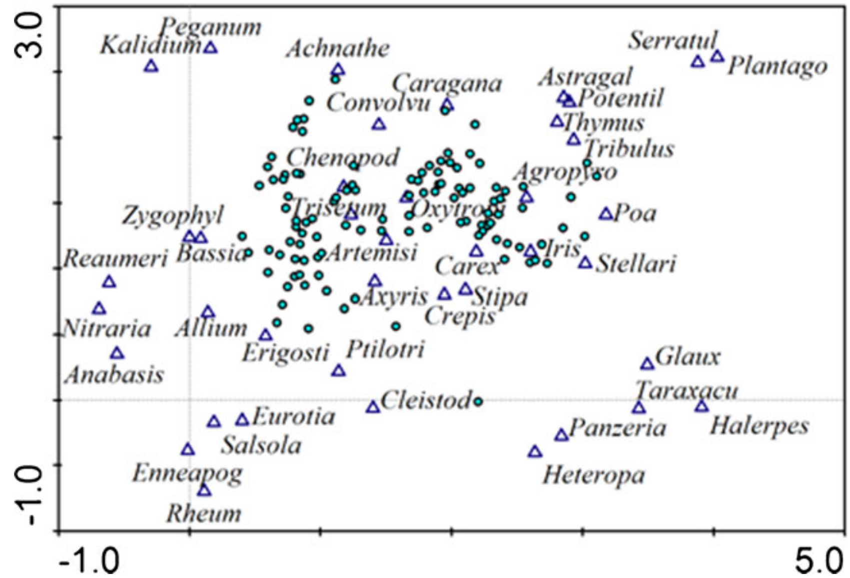

Fig. 7 Major species (genera) and sites distribution at all sites (o = Omnogovi; Δ = Ovorhangai)

water in wells are frozen for extended periods so animals cannot access water without herders present, processes that discourage livestock from assembling at water points. Additionally, snow or ice cover on the ground may provide surface cover that reduces trampling impact on vegetation and soil, decreasing compaction. In the cold season forage resources may not be driven by scarcity but more by access – winter disaster occurs when snow becomes too thick (>10 cm) or covered in ice that prevents foraging (Sternberg *et al.* 2009). Thus diverse processes occur; 1) animals do not concentrate at water points, instead preferring more sheltered lands, such as in protected foothills as opposed to open land, 2) livestock may not need to use water points, getting adequate moisture from snow cover, and 3) open grazing (non-fodder based) regimes in winter mean that animals expend time and energy foraging in challenging conditions rather than concentrating at a water source. These varied processes differ from animal behavior in hot drylands and may reduce grazing impact at steppe piospheres.

Vegetation cover at the two field areas differed, reflecting a zonal shift between a steppe ecosystem in the north (Ovorhangai) to a desert steppe environment to the south (Omnogovi) with sparse plant cover. Species richness was similar throughout the survey though composition varied −60 % of the genera and 68 % of the species were unique to a province. Piosphere communities were dominated by a limited number of plants – the top 10 accounted for 45 % of species presence. Plant distribution was not widespread – in Omnogovi 72 % and Ovorhangai 63 % of species were present only once or twice, <4 % of surveyed sites. Ordinations showed Omnogovi had notably scattered species composition patterns and less plant association than Ovorhangai. Plant patterns are limited by soil productivity and moisture regimes, including depth of water penetration. Grazing intensity is also known to affect species composition with historic livestock use potentially forming plant communities. This is indicated by the dominance of forbs over grasses, which has been noted as a response to livestock pressure (Fernandez-Gimenez and Allen-Diaz 2000). Long-term grazing and human impact are intertwined with vegetation presence on the steppe (Hilbig 1995).

Recent studies on the Chinese side of the Mongolian plateau have attempted to establish degradation criteria for the region. Desertification thresholds begin at <50 % vegetation coverage, with between 10 and 30 % vegetation cover considered severe and <10 % very severe desertification (Li *et al.* 2006; Huang and Siegert 2006). According to these standards study sites in Mongolia are severely degraded. However, this rating does not adequately consider the sparse vegetation conditions extant in Mongolia's drylands. All distances surveyed were within these levels yet low cover alone is not proof that ecosystem productivity has declined or lacks the resilience to remain stable or improve as abiotic factors change. NDVI data identifies systemic fluctuation over time, therefore to conclude Mongolia has been desertified, as opposed to experiencing ongoing dryland conditions, is incorrect. What is identified as degradation in China's human-modified system may be part of normal variance within Mongolia's more traditional pastoral approach.

Unlike some rangelands that have not had long-term exposure to grazing, such as Australia, the Mongolian environment has evolved with domesticated livestock over centuries (Fernandez-Gimenez 1999; Yoshihara *et al.* 2010). This posits that continual interaction between livestock and vegetation may have contributed to today's landscape where grazing, limited water supply, stable species richness, and variable plant distribution patterns coexist. Sasaki *et al.* (2007) and Li *et al.* (2008) suggest that due to a long history of livestock use Mongolia's vegetation is relatively resistant to grazing. Few places have had such longstanding human/

nature interactions that make a distinction between the two either impossible or inappropriate (Dearing 2006). A phenomenon that perhaps looks random, and thus in China is labeled desertification, is in Mongolia incorporated into pastoral vegetation dynamics. To expand this study's implications other natural zones of the country should be surveyed and species composition differentiated within piosphere transects to determine the community structure relationship with distance from a water point. Additionally, expanding small-scale mining at water sources that has a deleterious impact on the range environment has not been adequately investigated.

While China's varied land management and usage patterns over the last 50 years have stressed a move away from transhumanence, Mongolia's pastoralists continue traditional patterns that have provided basic sustenance and range sustainability over a long time. Rather than causing degradation, herder interaction with the steppe environment extracts benefit for the livestock without lasting damage to the land. Recent articles on desertification emphasize the nomad's effective use of natural resources, opportunistic grazing strategies, and the importance of mobility in arid and semi-arid herding (Veron *et al.* 2006). Zhang *et al.* (2007) state that Mongolian nomadic culture stresses sustainable utilization and ecological stewardship of land which generally prevents desertification; Wesche and Retzer (2005) found that the nomadic lifestyle was a "crucial" aspect of sustainable land use in southern Mongolia. Absence of sacrifice zones and higher coverage values near the piosphere suggests pastoralist grazing strategies on the steppe are not harmful to the ecosystem and that the role of transhumance in Mongolia is an ongoing adaptation to limited forage potential and an effective means to extract benefit from the sparse environment. Zhang *et al.* (2007) argue nomadic culture should have a leading role in China; it has that "deserved position" in Mongolia – because of mobility and adaptation to a harsh, dry environment with limited precipitation and low forage resources.

This shifts local land use debate from mitigating the harm of indigenous practices (Jun Li *et al.* 2007) to how customary livestock grazing pratterns can be maintained, a process that may be applicable to other dryland regions. In Mongolia the essentials are distributed water points in productive grasslands and the ability to migrate to areas with adequate forage. Management and development that stresses adaptability to fluctuating grassland and climatic conditions will limit anthropogenic impact on the environment. This can enable herders to continue present livelihoods without sacrificing future opportunities or incurring high ecological costs.

Conclusion

In contrast to piosphere studies in other dryland regions this paper found vegetation cover was greater near water points in Mongolia. Limited other productive land uses beyond livestock raising, such as agriculture or industry, suggests that customary herding patterns continue to be an effective practice and that mobile pastoralism is one of few, perhaps the only, enduring land use strategy in Mongolia's steppe and desert steppe. Pastoralism can be considered as a way to combine communal land stewardship, low external supports, and individually-determined land management and tenure as a viable livelihood approach in an otherwise difficult environment. Across the Mongolian plateau the Chinese development arc has industrialized livestock production with fodder, fencing, transport, and intensified land use, but at a cost to the environment that is not seen in the survey ecosystem in Mongolia. To continue the ecologically-suited Mongolian approach more water points and movement appears warranted, with policies that encourage dispersed livestock grazing rather than concentration around fewer water points (Li *et al.* 2008). The steppe has limited productivity with human impact often long-term, as exemplified by degradation incurred from past management policies and intense land use in adjacent areas in China that require extensive rehabilitation (von Wehrden *et al.* 2006; Jun Li *et al.* 2007; Normile 2007). In Mongolia it is prudent to maintain a naturally resilient transhuman system rather than replace it with models from elsewhere, even across the border in China, that may have dubious or detrimental effects on the environment.

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