Is Overgrazing A Pervasive Problem Across Mongolia? An Examination of Livestock Forage Demand and Forage Availability from 2000 to 2014

W Gao[1], J.P. Angerer[2], M.E. Fernandez-Gimenez[3], R.S. Reid[4]

[1]Ecosystem Science and Management, Texas A&M University, College Station, TX, 77840-2138 USA, <gao1991@tamu.edu>
[2]Blackland Research and Extension Center, Texas A&M University, Temple, TX, 76502 USA, <jangerer@brc.tamus.edu>
[3]Forest & Rangeland Stewardship, Colorado State University, Fort Collins, CO, 80523-1472 USA, <Maria.Fernandez-Gimenez@colostate.edu>
[4]Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO, 80523-1476 USA, <Robin.Reid@colostate.edu>

ABSTRACT

Pastoral livestock production is considered a pillar of the Mongolian economy. Since the early 1990's, Mongolia has transitioned to a market economy, and livestock numbers have trended upward. Recent remote sensing studies have indicated widespread overgrazing; however, to date, no studies have examined grazing pressure on a national scale to assess the pervasiveness of overgrazing. We conducted a spatial and temporal analysis of grazing pressure by analyzing the relationship between livestock forage availability and forage demand across soums during 2000 to 2014. To estimate livestock forage demand (kg/ha/yr), we converted soum livestock densities to sheep forage units and calculated forage intake on an area basis. Forage availability was estimated using a regression relationship between herbaceous biomass and 250-m resolution MODIS NDVI (r^2 = 0.70). The regression was applied to yearly maximum NDVI images to create surfaces of available forage (kg/ha/yr). Percent use (PU) of forage, which is the ratio of forage demand to forage available, was used as an indicator of grazing pressure. 50% use is generally recommended on rangelands for promoting forage regrowth and soil protection. Thirteen percent of the rangeland across Mongolia had PU that exceeded 50% during the entire time series, while 37% had 10 or more years with >50% use. Grazing pressure was higher in the central and western aimags, and lowest in the eastern aimags. Dzuds (winter disasters) in 1999-2002 and 2010 resulted in 35% and 22% reductions in livestock numbers nationwide. Grazing pressure exceeded 50% in over half of the country prior to and during dzuds due to the effect of summer drought on forage availability and high animal numbers. Grazing pressure was lowest after dzuds due to lower livestock numbers and forage response to higher rainfall. Our results indicate that heavy stocking (>50 PU) appears to be pervasive in about 32% of the country and consistent overgrazing (>=10 years with PU>=70) occurs on approximately 11% of the land area. During individual years, land areas having overgrazing are variable due to extreme climate events and linear increases in livestock numbers, regardless of forage availability, during periods between dzuds. The spatially explicit and temporal nature of these results will aid in disentangling effects of changing climate and management, and assessing the resilience of these rangeland systems in Mongolia.

Keywords: overgrazing, forage demand, forage availability, Mongolia

INTRODUCTION

In Mongolia, pastoral livestock production is considered a pillar of the economy and a large portion of the rural population depends on livestock production for their livelihood. Livestock producers are generally semi-nomadic herders who extensively graze their animals in surrounding regions during the spring, summer, and fall, then return to protected camps for the winter months (Bedunah and Schmidt, 2004). Sheep and goats are the predominant kinds of livestock, followed by cattle, horses, yaks and camels. Since 1991, Mongolia has been transitioning to a market economy and livestock numbers during this period have generally increased each year with the exception of 1999-2002 and 2010 where large-scale drought and winter disasters (Fernández-Giménez et al., 2012) resulted in 35% and 22% reductions in livestock numbers nationwide (National Statistical Office of Mongolia, 2015).

Recent remote sensing studies, using proxies for vegetation biomass such as the Normalized Difference Vegetation Index (NDVI), have indicated that widespread overgrazing and changing climate in Mongolia are leading to land degradation (Liu et al., 2013; Hilker et al., 2014). In these studies, overgrazing was generally attributed to increases in animal numbers; however, no evaluations were conducted to assess whether the vegetation could support the number of animals measured in annual statistical surveys, and numbers for each species of livestock were not converted to a common forage intake unit (e.g., a sheep) to account for forage intake differences across species so that forage demand and grazing pressure could be interpreted correctly. To date, no studies in Mongolia have examined grazing pressure on a national scale to assess temporal and spatial trends in overgrazing over a period of 10 or more years. An understanding of these trends is important for evaluating how changing climate and livestock management influence vegetation change and resilience in these systems. For this study, our overall goal was to conduct a spatial and temporal analysis of grazing pressure by analyzing the relationship between livestock forage availability and livestock forage demand across soums (similar to districts) in Mongolia during the period from 2000 to 2014. Our objective was to define land areas having grazing pressure indicative of overgrazing, and to examine trends in grazing pressure over time to identify areas that have had prolonged overgrazing that could result in rangeland degradation.

STUDY SITE

Mongolia is a landlocked country in east-central Asia. The political administration in Mongolia is divided into 21 *aimags* (similar to provinces), which are further sub-divided into *soums.* Each year, the National Statistics Office of Mongolia conducts surveys in each soum to determine the number and species of livestock.

METHODS

In order to assess grazing intensity over time, we compared the forage demand (based on livestock density and herd composition) to forage availability during the 2000 to 2014 period. Livestock census data, by *soum*, were acquired from the National Statistics Office of Mongolia for the period from 2000 to 2014 (National Statistical Office of Mongolia, 2015). Livestock species numbers we converted to sheep forage units (SFU) using conversion factors of 1, 0.9, 6, 7, and 5 sheep forage units for sheep, goats, cattle, horses, and camels, respectively (Bedunah and Schmidt, 2000).

Forage demand was calculated by multiplying the SFU densities in each district by the forage intake of an individual SFU (i.e., 365 kg of forage intake/yr) (Bedunah and

Schmidt, 2000). The forage demand for each district was then divided by the total hectares in each district to derive livestock forage demand per hectare for each year.

Forage availability was estimated using a linear regression relationship between herbaceous biomass and the 250-m Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) (Huete et al., 2002). The herbaceous biomass data were collected from plots that were clipped along vegetation transects as part of a forage monitoring study conducted in Mongolia during 2004 to 2010 (Angerer, 2012). Transect locations were collocated with NDVI pixels and NDVI values were extracted from MODIS scenes for the time periods when biomass data were collected. The resulting regression had an r^2= 0.70 and a root mean square error of 164 kg/ha. The regression was used to predict herbaceous biomass for the maximum NDVI that occurred for each 250-m pixel within the district boundaries for each year (2000 to 2014). Spatial statistical tools were used to calculate the total herbaceous biomass in each *soum*. The total herbaceous biomass was divided by the number of hectares in the *soum* to derive forage available for livestock per hectare.

Percent use (PU) of forage was used as an indicator of grazing pressure. PU was calculated as the forage demand divided by the forage available multiplied by 100. Because grazing is not always efficient and vegetation is lost through trampling, soiling, insects, and natural senescence (Smart et al., 2010), a loss factor of 20% of the available forage was included in the calculation of percent use. As a general rule, PU values of 50% will leave enough standing forage biomass to protect the soil and allow plants to regrow; however, research in arid and semi-arid regions of the United States indicate that percent use values of 25 to 45% are need to prevent overuse in these areas, whereas values of 50 to 60% are reasonable in more humid areas or annual grasslands (Holechek, 1988). For this analysis, PU values exceeding 50% were used to indicate heavy stocking, and values exceeding 70% use were used to indicate overgrazing. Values approaching 100% can indicate removal of all forage biomass.

RESULTS

Total SFUs approached 64 million in 2000 and declined in both 2001 and 2002 to 45 million due to drought and winter disasters (dzud). After 2003, SFUs increased steadily each year until 2010, when drought conditions in 2009 and dzud in early 2010 resulted in a 21% decrease in SFUs. Since 2010, SFUs have increased more than 10% each year, and in 2014, SFUs approached 85 million.

Using PU values exceeding 50% as an indicator of vegetation overuse or heavy stocking rate, 13% of the rangeland across Mongolia had PU that exceeded 50% during the entire time series, while 37% of the rangeland area had 10 or more years with >50% use. Total land area in Mongolia that could be classified as overgrazed (>=70 PU) varied by year in the time series with the lowest percentage occurring during 2003 and the highest percentages occurring during 2007 to 2009 and in 2014. Land areas that had consistent overgrazing during the 15 year period totaled only 3%; however, this increased to 11% of the total land area if 10 years or more were included.

Grazing pressure was generally higher in the central and western *aimags*, and lowest in the eastern *aimags* (Figure 1a, b). Grazing pressure was lowest after dzuds due to lower animal numbers and an increase in forage production in response to higher rainfall in the year following the dzuds (Figure 1a). Within ecological zones, land area within zone boundaries classified as overgrazed was greatest for the mountain steppe zone, followed by the steppe zone and mountain forest steppe zone. Percent of overgrazed area varied over time, but was generally lowest for all ecological zones in 2003 and highest in 2014 (Table 1).

DISCUSSION

Changes in livestock numbers over time appeared to follow a boom-bust cycle with drought and dzud events reducing animal numbers nationally with linear increases in animal numbers following these events. There was no correlation between livestock numbers and forage availability indicating that herders were not adjusting herd size based on climatic factors such as rainfall. Land area classified as consistently overgrazed (>70 PU for 10 or more years) generally occurred in the steppe and the mountain and forest steppe ecological zones in the central and western portions of Mongolia (Figure 1b, Table 1). These zones are generally some of the most productive rangeland areas in Mongolia; therefore long-term overgrazing in these zones could lead to reduced productivity, irreversible degradation, and/or loss of resilience. A recent study of long-term vegetation trends in mountain steppe, steppe and desert steppe ecological zones in south-central Mongolia indicated that the interaction of climate and grazing pressure resulted in degradation in these zones, and that mountain steppe zones were most susceptible to degradation; however, their results indicated that the degradation was reversible and not permanent (Khishigbayar et al., 2015).

Results from this study do not show the degree of overgrazing indicated by recent remote sensing studies. Hilker et al. (2014) stated that their analysis of MODIS NDVI decline from 2002 to 2012 revealed widespread degradation across Mongolia and increases in animal numbers during this period were the primary cause of this decline. Results from this study indicated that only 11% of the total land area in Mongolia experienced overgrazing for 10 years or more, and 37% of the land area could be considered heavily stocked (> 50% PU); therefore, overgrazing would not be considered as widespread across Mongolia. In a study using MODIS Leaf Area Index data to assess vegetation productivity and use during the period from 2000 to 2006, Sekiyama et al. (2014) reported that overgrazing occurred over large portions of Mongolia in 2000 and 2001 due to low biomass availability. However, during the period from 2002 to 2006, overgrazing was limited to *soums* having increases in animal numbers, especially goats. Our analysis identified areas of heavy forage use in 2000 to 2001 similar to Sekiyama et al.; however, the area that we classified as overgrazed was much smaller.

Our results also indicate that opportunities for vegetation recovery do exist during periods after dzuds when forage demand is lower due to reduced animal numbers and higher rainfall that promotes vegetation growth. Additional research is needed to evaluate rates of recovery after reductions of livestock numbers in these regions.

IMPLICATIONS

The spatially explicit and temporal nature of these results provide a basis for identifying areas that are experiencing overgrazing and that may be on a trajectory for loss of productivity and resilience. These areas could be targeted by local community based rangeland management groups or aimag government for programs to reduce animal numbers and for conducting long-term rangeland health monitoring programs to identify changes in vegetation and soil conditions to avoid irreversible degradation. At the national level, the spatial analysis of grazing pressure and livestock numbers would be beneficial in developing pasture guidelines for stocking rates, determining the potential economic impacts of dzud, and for dzud disaster response. Lastly, the ability to define the degree of grazing pressure across Mongolia can aid in disentangling effects of livestock management and changing climate in assessing the resilience of these rangeland systems.

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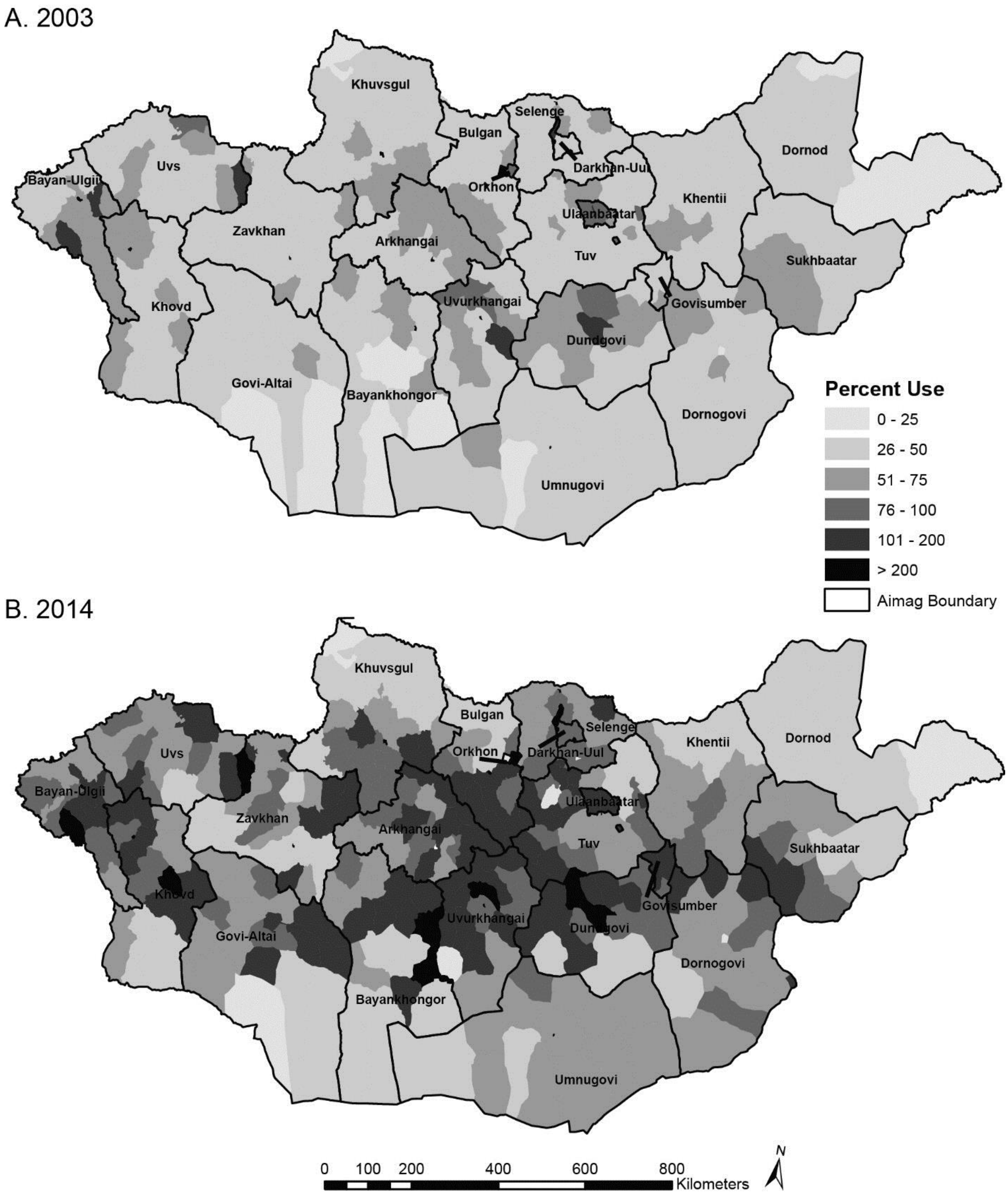

Figure 1. Percent use of forage by livestock within *soums* and *aimags* in Mongolia during 2003 (A) and 2014 (B).

Table 1. Percent of total land area, by year, within ecological zone classes having greater than 70% use of forage. Ecological zones boundaries were acquired from the from the Mongolia Information and Computer Center (ICC) Environmental Database vegetation map. http://www.eic.mn:8080/geonetwork/srv/eng/main.home)

		Year (%)							
Ecological Zone Class	Hectares	2000	2001	2002	2003	2004	2005	2006	2007
Desert	25,283,265	9.2	14.0	4.7	1.3	6.2	7.3	5.5	9.5
Desert steppe	34,123,871	18.8	19.4	9.4	3.8	13.6	15.3	13.5	21.7
High Mountain	7,192,755	18.0	15.1	6.9	4.5	8.3	10.0	14.1	31.9
Mountain desert steppe	2,690,406	12.3	11.3	4.3	1.6	6.3	8.0	7.4	33.1
Mountain forest steppe	33,413,359	15.8	13.6	10.3	3.7	9.4	10.2	12.8	31.3
Mountain steppe	8,426,857	25.0	29.8	15.4	6.3	21.9	26.4	28.8	50.9
Steppe and dry steppe	24,725,573	22.3	22.1	10.4	6.7	16.4	18.6	18.4	39.6
		2008	2009	2010	2011	2012	2013	2014	
Desert	25,283,265	13.2	26.3	3.6	3.8	3.6	19.9	16.7	
Desert steppe	34,123,871	23.9	33.0	9.9	10.8	11.4	28.2	36.5	
High Mountain	7,192,755	29.0	30.7	11.8	12.4	20.0	24.6	44.6	
Mountain desert steppe	2,690,406	18.1	27.5	8.2	6.1	10.2	14.7	30.4	
Mountain forest steppe	33,413,359	22.9	28.3	13.6	14.9	16.9	24.0	44.1	
Mountain steppe	8,426,857	39.7	42.2	21.8	18.1	22.2	34.2	54.8	
Steppe and dry steppe	24,725,573	31.3	35.7	18.1	16.7	20.4	32.3	48.9	