International Grassland Congress Proceedings
21st International Grassland Congress / 8th International Rangeland Congress

Monitoring of Inner Mongolian Grassland Using Sustainable Roundtable Indictors

Mengli Zhao
Inner Mongolia Agricultural University, China

Guodong Han
Inner Mongolia Agricultural University, China

Mingjun Wang
Inner Mongolia Agricultural University, China

Xiaoyu Wang
Inner Mongolia Agricultural University, China

Chunli Li
Inner Mongolia Agricultural University, China

See next page for additional authors

This document is available at https://uknowledge.uky.edu/igc/21/4-1/2

The 21st International Grassland Congress / 8th International Rangeland Congress took place in Hohhot, China from June 29 through July 5, 2008.

Proceedings edited by Organizing Committee of 2008 IGC/IRC Conference

Published by Guangdong People's Publishing House

Presenter Information

Mengli Zhao, Guodong Han, Mingjun Wang, Xiaoyu Wang, Chunli Li, Zhongwu Wang, Dennis Chlld, Lakhdar Benkobi, and Walter D. Willms

Monitoring of Inner Mongolian grassland using sustainable roundtable indictors

Mengli Zhao[1], Guodong Han[1], Mingjun Wang[1], Xiaoyu Wang[1], Chunli Li[1], Zhongwu Wang[1], Dennis Child[2], Lakhdar Benkobi[2], Walter Willms[3]

[1] College of Ecology and Environment, Inner Mongolia Agricultural University, Hohhot, P.R. China. E-mail: menglizhao@yahoo.com. [2] Forest Rangeland and Watershed Stewardship, Colorado State University, USA. [3] Lethbridge Research Centre, Agriculture and Agri-Food Canada, T1J 4B2

Key points:
1. Four distinct seral stages (early to late) were identified in Meadow steppe, typical steppe and desert steppe of Inner Mongolia.
2. The key plants in each grassland site are different. These key plant species as variables can be used to indicate the grassland trend and they played different roles at individual seral or successional stages.
3. Knowledge of the seral stages can be used to guide rangeland management in Inner Mongolia.

Key words: series stage, indicators

Introduction

The world's rangelands occupy about 70% of the total land area (Holechek et al., 2003). Monitoring is one of the important necessary steps for better management of natural resources (Ludqig et al., 2000). For grassland, we have to understand the condition of the resource base, and how and when the grasslands change and the grassland trends. In northern China, rangelands are being monitored as a means of managing livestock production (Li, 1997). However, grassland monitoring is conducted only within exclosures and not on grazed lands for which we lack suitable methods. Traditionally, Chinese scientists used quadrats to estimate species composition and bare soil to predict degradation. This paper uses multivariate analysis to monitor the rangeland dynamics and to classify the seral stages under grazing in the Meadow Steppe, Typical Steppe and Desert Steppe vegetation types of Inner Mongolia. The study evaluated indicators that could be used to monitor the changes in seral states to determine sustainable rangeland management for these grassland types.

Materials and methods

Site description

Grassland monitoring measurements were conducted at three sites: Meadow Steppe, Typical Steppe and Desert Steppe, located in Xiwu Banner, Keshiketeng Banner, and Siziwang Banner, respectively, in Inner Mongolia (Figure 1). These sites are the main zonal grassland types in Northern China.

The Meadow Steppe site is in the northeastern Xiginguole grassland with average annual air temperature of 1.2℃ (average lowest temperature of -7.8℃ in March and highest temperature of 17.7℃ in August) and average annual accumulated heat units (base temperature of 0℃) of 2556 growing degree days (GDD). Average annual precipitation was 342 mm with 99 days rain and 37 days snow. The seasonal precipitation allocation was 38, 236, 49, and 19 mm in spring, summer, autumn, and winter, respectively. The average annual evaporation is about 1768 mm. The soil is black chestnut soil with 35.6 g kg^{-1} of organic matter and 1.85 g kg^{-1} of nitrogen. This soil is one of the richest soil types in China's northern grasslands. The vegetation is dominated by *Leymus chinensis* (Trin.) Tzvel., *Stipa baicalensis* Roshev., and *Filifolium sibiricum* (L.) Kitam. with other species, such as *Achnatherum sibiricum* (L.) Keng, *Thymus serphyllum* L., *Allium tenuissimum* L., *Leontopodium leontopodioides* (Willd.) Beauv., *Stellera chamaejasme* L., *Artemisia pubescens* Ledeb., and *Melilotoides ruthenica* (L.) Sojak. The average aerial coverage ranged from 59 to 77% in the Meadow Steppe with high plant biodiversity and forage production.

The Typical Steppe site is in the Keshiketeng Banner located northwest of Chifeng City Prefecture in central Inner Mongolia, China. The climate is continental with significant diurnal temperature variability, cold winters, and frequent windy periods. The following attributes apply throughout the area: Mean annual temperature of about 2℃, annual accumulated heat units (base temperature of 10℃) ranging from 1,300 to1,700℃, mean annual total sunshine ranging from 2,700 to 2,900 ,hours, annual radiation of 57-58 J cm^{-2}, annual precipitation ranging from 310 to 350 mm with the growing season ranging from 60 to 80 days (April-September). The soil is a Kastanozem (Mollisols in World References Base for Soil Resources). The surface soil (0-20 cm) throughout the study area was classified as loamy texture with sand content at 59.6±0.6%, silt at 23.8±0.4% and clay at 16.7±0.4% (based on 45 soil samples). The typical pH in the 0 to 5 cm profile varied from 7.32 to 7.79 and soil bulk density was 1.16±0.07 g m^{-3}. Soils freeze to a maximum depth of about 1,9 m during winter. The vegetation is dominated by *Leymus chinensis* (Trin.) Tzvel., *Stipa grandis* P. Smirn. and *Cleistogenes squarrosa* (Trin.) Keng. The primary associate species are *Artemisia frigida* Willd., *Potentilla acaulis* L. and *Carex duriuscula* C. A. Mey. *A. frigidia* is a sub-shrub while the other plant species are all herbaceous plants.

The Desert Steppe site is in Siziwang Banner in the mid-west of Inner Mongolia. This site is dry and windy in spring and hot in summer. The weather is characterized by a colder winter and a warmer summer with an annual mean temperature of 2.8℃ and growing season temperature (May to October) of 17.3 ℃. The soil is Kastanozem (FAO soil classification) or Brown Chermozem (Canadian Soil Classification) and soil texture is loamy sand. Vegetation is very short (average to about 8 cm in height) with canopy cover varying from 17 to 20% with relatively few species (about 20). The dominant species are *Stipa breviflora* Griseb., *Artemisia frigida* Willd. and *Cleistogenes songarica* (J. F. Gmel.) while associated species were *Convolvulus ammannii* Desr, *Heteropappus altaicus* (willd.) Novopokr, *Neopallasia petinata* (Pall.) Poljok., *Kochia prostriata* (L.)Schrad., *Caragana stenophylla* Pojark and *Leymus chinensis* (Trin.) Tzvel.

Experimental design and measurements

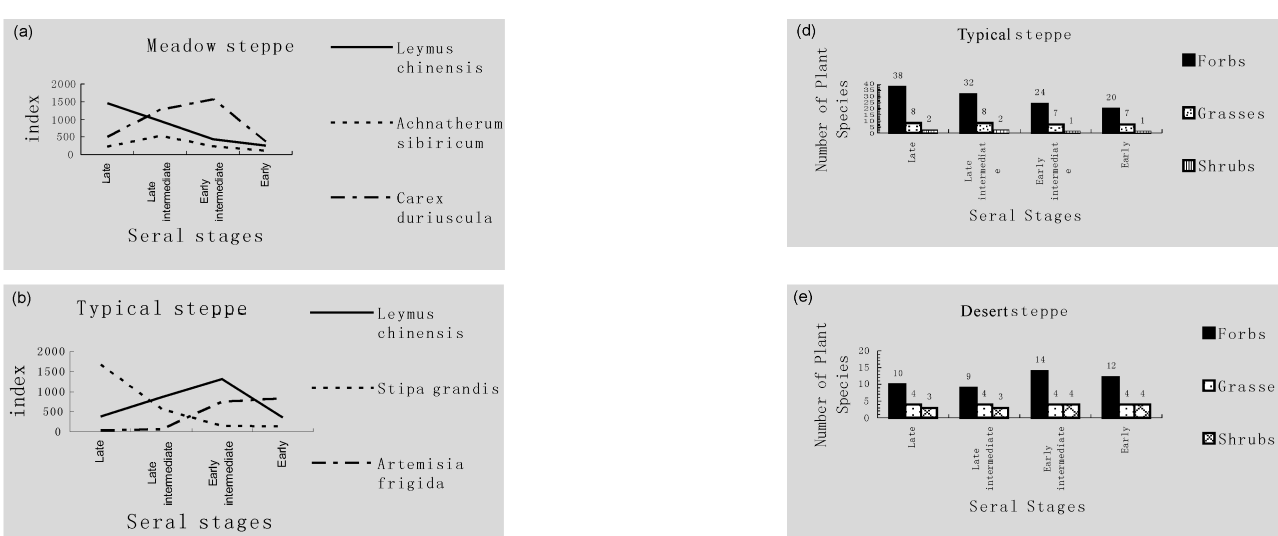
At three different locations within each grassland site, we monitored range condition from 2005 to 2007 along three transects that followed a gradient of decreasing grazing pressure from a focal source (water/corral). The transects were partitioned into three grazing intensity classes while an ungrazed exclosure at each location represented the control. Plant cover by species were measured in each grazing intensity class on single 50 m subtransects that were arranged perpendicular to the transect or randomly distributed within the exclosure. This resulted in 3, 50-m subtransects for each grazing intensity class on each ranch for a total of 12. Plant cover was estimated every 2-m along the subtransects and the biomass of functional groups, such as grass, forbs, shrub and litter, every 5 m. All measurements were made in 20×50 cm quadrats. The measuring points were recorded with GPS and repeated every year.

Data analysis

Data analyses followed Uresk (1990) at each grassland site. Average canopy cover (%) was multiplied by frequency of occurrence (%) of all plant species to produce an index value for the final analyses (Uresk 1990). A non-hierarchical clustering procedure, ISODATA (Ball and Hall 1967), grouped the gazing gradients into 4 distinct clusters (seral stages). Then stepwise discriminant analysis at the 0.05 entry level selected 3 plant species as the best predictive variables to be used for seral stage classification and monitoring in each grassland site.

Results

Four distinct seral stages (early to late) were identified along the gradient, which included the exclosure, in each steppe. The Stepwise Discriminant Analysis showed significantly differences among all the seral stages ($P < 0.05$). The model is of 3 plant species (variables) and 4 Fishers discriminant functions that define the seral stages in all grassland sites (Table 2) The key plants in each grassland site are different. The key plants are *Leymus chinensis*, *Achnatherum sibiricum*, and *Carex duriscula* in Meadow Steppe, *Leymus chinensis*, *Stipa grandis*, and *Artemisia frigida* in Typical Steppe and *Stipa breviflora*, *Artemisia frigida* and *Cleistogenes songorica* in Desert Steppe. These key plant species as variables can be used to indicate the grassland trend and they played different roles at individual seral or successional stages. For example, the index value of *Leymus chinensis* is the highest in the late seral stage and lowest in the early stage of the Meadow Steppe but the highest in the early intermediate stage in the Typical Steppe. Also, the index value of *Artemisia frigida* is the highest in the early stage in the Typical Steppe and in the early intermediate stage of the Desert Steppe (Figure 2). These seral-stage dynamics are related to the cover and frequency of the selected plant species (Table 3) and define grassland condition. The percentage of total transects in late, late intermediate, early intermediate and early was 16.1%, 12.1%, 24.2%, and 47.6%, respectively in the Meadow Steppe site. The percentage of total transects by class was 54.4%. 24.2%, 10.3%, and 11.1%, respectively in the Typical Steppe site, and 53.2%, 17.1%, 9.9%, and 11.2%, respectively, in the Desert Steppe site.



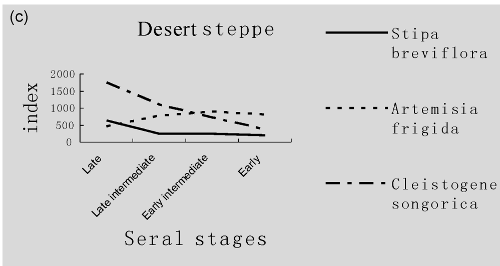


Figure 2 *Key plant species with index values [canopy cover(%)× frequency of occurrence (%)] distributed throughout all seral stages in Inner Mongolia grasslands.*

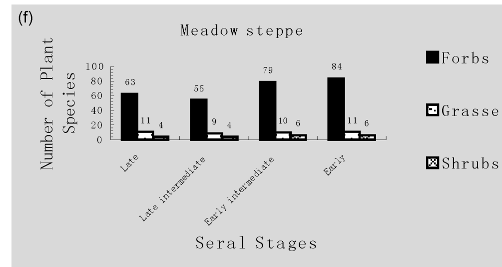


Figure 3 *Number of plant species by category throughout all seral stage in Inner Mongolia grasslands.*

Discussion

The classification of grassland seral stage was based on the ecological concept of plant community succession (Clement 1916; Dysterhuis 1949; Daubenmire 1968). Cluster analysis and discriminant analysis with cover-frequency index was used to examined all the plant species and ISODATA (Ball and Hall 1967) was used to group the transects efficiently into seral stages similar to that of Uresk study(Uresk 1990). This is a practical way to classify the seral stages quantitatively when monitoring grassland.

Three key plant species were selected with discriminant analysis as the indicators for grassland trend in each monitoring site, we can continue to use them when monitoring every year reducing the monitoring time and cost. In general, the Typical Steppe and Desert Steppe are in good condition because of the high percentage of the late and late intermediate stages, and the Meadow Steppe is in poor condition because of the higher percentage of the early and early intermediate stages(Table 2). Therefore, the low stocking rate of grazing management will be applied to the Meadow Steppe site, and improved livestock distribution will be applied to the Typical and Desert Steppe sites.

Table 1 *Fisher's discriminant coefficiencts for classification of seral stages in Inner Mongolia grasslands.*

Meadow Steppe site				
Species	Seral stages			
	Late	Late Int.	Early Int.	Early
Leymus chinensis	0.023	0.015	0.006	0.004
Achnatherum sibiricum	0.009	0.013	0.006	0.004
Carex duriuscula	0.003	0.015	0.015	0.003
Constant	-19.656	-24.860	-15.216	-2.801
Typical Steppe site				
Species	Seral stages			
	Late	Late Int.	Early Int.	Early
Leymus chinensis	0.008	0.004	0.005	0.008
Stipa grandis	0.017	0.016	0.005	0.017
Artemisia frigida	0.010	0.027	0.042	0.010
Constant	-21.111	-29.353	-27.900	-21.111
Desert Steppe site				
Species	Seral stages			
	Late	Late Int.	Early Int.	Early
Stipa breviflora	0.012	0.003	0.027	-0.008
Artemisia frigida	0.008	0.024	0.001	0.039
Cleistogenes songorica	0.008	0.008	0.032	0.011
Constant	-9.104	-23.830	-36.014	-55.450

Table 2 *Canopy cover and frequency of occurrence for key plants throughout the defined seral stages in Inner Mongolia grasslands.*

Meadow steppe site				
Seral stages		*Leymus chinensis*	*Achnatherum sibiricum*	*Carex duriuscula*
	n	Canopy cover (%)		
Late	5	15.33±3.99A	3.05±2.40A	10.03±12.60A
Late intermediate	4	10.75±3.27A	6.15±4.11A	15.99±7.68A
Early intermediate	8	4.69±2.62B	2.78±1.77B	20.61±13.92A
Early	16	3.18±1.86B	1.72±1.60B	12.89±13.97A
	n	Frequency of occurrence (%)		
Late	5	94.31±6.60A	50.92±29.98B	53.65±42.22AB
Late intermediate	4	87.64±6.89A	75.34±23.28A	60.95±3.60B
Early intermediate	8	82.40±16.41A	76.23±23.72A	90.39±14.53A
Early	16	70.35±26.81A	43.26±31.94B	56.97±30.41A
Typical steppe				
Seral stages		*Lymus chinenses*	*Stipa grandis*	*Artemisia frigida*
	n	Canopy cover (%)		
Late	20	11.69±3.13A	7.15±2.05A	1.65±0.68B
Late intermediate	9	6.46±2.00B	7.32±2.94A	2.00±1.20B
Early intermediate	4	4.54±1.06B	7.56±1.47A	3.57±1.31A
Early	4	2.52±0.29C	6.31±1.39B	2.93±0.46A
	n	Frequency of occurrence (%)		
Late	20	46.92±7.69C	47.49±8.62B	17.30±2.71C
Late intermediate	9	71.13±6.77A	70.48±17.85A	22.73±7.39A
Early intermediate	4	62.39±9.30B	73.42±5.14A	26.64±8.37A
Early	4	78.16±3.60A	80.19±8.99A	20.31±0.67B
Desert steppe				
Seral stages		*Stipa breviflora*	*Artemisia frigida*	*Cleistogenes songorica*
	n	Canopy cover (%)		
Late	12	6.23±2.49B	15.45±2.88A	8.47±3.14B
Late intermediate	10	3.28±1.99C	25.24±7.19A	12.90±3.92B
Early intermediate	5	4.92±2.35B	6.96±4.23B	13.97±1.61A
Early	9	5.60±3.47B	6.08±3.21B	8.52±1.82A
	n	Frequency of occurrence (%)		
Late	12	68.40±15.83B	86.80±8.85A	91.20±7.50A
Late intermediate	10	40.80±7.69B	85.60±10.04A	92.00±7.48A
Early intermediate	5	56.00±9.38B	60.44±15.55B	97.33±3.46A
Early	9	63.00±14.28B	72.67±12.40B	87.00±8.38A

Multivariate vegetation analysis provided an accurate method for assessing ecological seral stages (Uresk 1990), and can be used for rangeland monitoring purposes. However, more continuous monitoring sites need to be established to provide data for the development of grassland models for Inner Mongolia.

Conclusions

A monitoring tool was developed from gradients of grazing intensity in Inner Mongolia using the plant succession approach and three key plant species indicators. The species were identified using multivariate statistical methods. The index value of cover and frequency measurements can be used in Inner Mongolia grasslands for the range condition assessment at management unit scale . Knowledge of the seral stages can be used to guide rangeland management in Inner Mongolia .

Acknowledgments

We gratefully acknowledge for the National Key Fundamental Research and Development Fund (No .2007CB106800) and Research Award Program for Outstanding Young Teachers in Higher Education Institutions of MOE , P .R . China , National Natural Science Foundation of China (30590382) , and the Technology Support Plan (2006BAD16B01 , 2006BAD04A16-4) for provide the funding for t this study .

References

Abdel-Magid , A .H . , Schuman , G .E . , Hart , R .R . , 1987 . Soil bulk density and water infiltration as affected by grazing systems . J . Range . Manage . 40 , 307-309 .

Amundson , R .G . , Trask , J . , Pendall , E . , 1988 . A rapid method of soil carbonate analysis using gas chromatography . Soil Sci . Soc . Am . J . 52 , 880-883 .

Bauer , A . , Cole , C .V . , Black , A .L . , 1987 . Soil property comparisons in virgin grasslands between grazed and nongrazed management systems . Soil Sci . Soc . Am . J . 51 , 176-182 .

Bilotta , G .S . , Brazier , R .E . , Haygarth , P .M . , 2007 . The impacts of grazing animals on the quality of soils , vegetation , and surface waters in intensively managed grasslands . Adv . Agron .94 , 237-280 .

Burke , I .C . , Lauenroth , W .K . , Vinton , M . , Hook , P .B . , Kelly , R .H . , Epstein , H .E . , Aguiar , M .R . , Robles , M . D . , Aguilera , M .O . , Murphy , K .L . , Gill , R .A . , 1998 . Plant-soil interactions in temperate grassland .Literature cited

Holechek , J .L . , R .D . Pieper , C .H . Herbel , 1989 . Range Management : principles and practices . Pp10 .

Ludwig , J .A . , G .N . Bastin , R .W . Eager , R . Karfs , P . Ketner , G . Pearce , 2000 . Monitoring Australian rangeland sites using landscape function indicators and ground-and remote-based techniques . Environmental monitoring and assessment . 64 : 167-178 .

Ren , J Z . 1998 . Research Methods of Grassland Science . China Agricultural Press . Beijing , China .

Li , B . Grassland degradation and prevention in Northern China . Journal of Agriculture Sciences of China .30(6) :1-9 .

Ball , **G .** H . ; D . J . Hall . 1967 . A clustering technique for summarizing multivariate data . Behavioral Sci . 12 : 153-155 .

Uresk , Daniel W . 1990 . Using multivariate techniques to quantitatively estimate ecological stages in a mixed-grass prairie . Journal of Range Management . 43 : 282-285 .