Rangeland Degradation in Mongolia – Using State and Transition Models to Help Understand Rangeland Dynamics

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Key words: rangeland ecology; land degradation; Mongolia; STM; vegetation dynamics

Abstract

Rangeland degradation and soil erosion pose constant challenges to the management of natural resources in Mongolia. Large increases in livestock numbers since the early 1990s, together with increasing temperatures and higher frequency of extreme weather events have led to widespread degradation of rangeland resources, to the extent that today, nearly 57% of rangelands in Mongolia are considered degraded to some degree. New ways of understanding the dynamics of rangeland ecosystems and guidelines to conserve healthy and productive rangelands are urgently needed. The application of State and Transition Models (STMs) in ecosystem management has shown promise to understand the mechanistic processes behind rangeland degradation and to suggest appropriate interventions for maintaining the health or restoring degraded rangelands. The Green Gold-Animal Health project funded by the Swiss Development Agency in Mongolia was the first initiative aimed at developing and applying STMs to Mongolian rangeland management. Here we describe the development of STMs for the most common rangeland types in Mongolia, including the definition of reference and alternative rangeland states and "recovery classes", based on the timelines and management actions needed to recover a reference state. Our results show that STMs are effective tools for analysing and interpreting rangeland health monitoring data and provide a scientific basis for planning and implementing resilience-based rangeland management. Furthermore, STMs facilitate synthesis of available knowledge and help identify areas where more information is needed. In summary, STMs have the potential to serve as a valuable tool for better communication of rangeland health assessments and decision making to facilitate appropriate management.

Introduction

Mongolian rangelands represent about 2.5% of the world's total grassland area (White et al. 2000) and support the traditional livelihoods of nomadic pastoralists and other sectors of society (Shagdar 2002). Mongolian rangelands have degraded considerably within the last twenty years following an increase in the number of livestock and changed management. Therefore, overgrazing and rangeland degradation are becoming primary environmental concerns in Mongolia (Hilker et al. 2014, Densambuu et al. 2018b). Differences in sampling methodology and criteria for determining degradation can create confusion and lead to disagreements about rangeland health trends. Inaccurate rangeland health assessments can lead to flawed prescriptions that lead to misplaced management efforts, for example, by reducing livestock numbers where reductions are not needed, or by allowing management practices that allow degradation to continue. The causes and persistence of rangeland degradation are not well understood (Addison et al. 2012). This situation calls for new tools for rangeland management based on ecological knowledge, including knowledge on land condition, land potential and the underlying ecosystem functions.

A powerful tool to organize our understanding of how an ecosystem works are conceptual frameworks. They can help structure the state of knowledge and as such, they are a fundamental part of successful adaptive monitoring and long-term research programs (Lindenmayer and Likens 2009). State and Transition Models (STMs) are one such conceptual frameworks that have been extensively used in rangelands worldwide. STMs describe plant community change pathways under certain sets of disturbances (Stringham et al. 2003). STMs consist of possible alternative states which are connected by transitions and indicate opportunities to restore degraded states to healthy ones (Westoby et al. 1989).

In Mongolia, the National Agency for Meteorology and Environmental Monitoring (NAMEM) and the Green Gold-Animal Health project of SDC collaboration with Jornada Experimental Range, USDA, launched a

pioneer project in 2009 aimed at understanding rangeland degradation and informing rangeland management based on the use of a solid ecological conceptual framework, including STMs. The project aimed at developing technical capacity and tools for interpreting rangeland health data, to make management recommendations.

STMs are currently used as an interpretation tool in two nationwide monitoring systems in Mongolia. First, the long-term rangeland health monitoring system at the National Agency for Meteorology, Hydrology and Environmental Monitoring (NAMEM), updated in 2011, which monitors 1516 plots across Mongolia to report on national rangeland health. NAMEM's rangeland health monitoring system can provide national rangeland health reports in every four years, trends in rangeland indicators over time, maps and summaries of ecological states and recovery classes for each year. Secondly, the grazing impact assessment and monitoring at the Agency for Land Management, Geodesy and Cartography (ALMGC) is responsible for land management planning, its implementation and monitoring of management impacts nationally.

In this paper we describe the development of STMs for Mongolian rangelands and discuss the usefulness of this approach to help interpreting rangeland health data and recommend management strategies.

Methods

To develop STMs for Mongolia, we conducted a literature review, held workshops with local experts, and compiled inventory data (Figure 1). Inventory data was collected between 2009-2014 at >600 sites across Mongolia and was initially analysed to classify ecological site types based on soil properties. These ecological sites represent areas with distinctive climate and soil conditions, and require specific assessment and interpretation of monitoring data. Ecological sites were then grouped to 22 ecological site groups (ESGs) according to similarities in vegetation and landscape position, season of grazing, and land classification, concepts already used by herders and scientists. Relatively healthy rangeland conditions that are observed within an ecological site were used as a reference for assessing rangeland health. For each ESG, we developed a STM that described the reference and alternative states (Densambuu et al. 2018a). We characterized the dominant plant species for each ecosystem state and tools to aid in the identification of states. Using the inventory data to describe variations measured in the field, workshops were conducted in 2012 in each eco-region of Mongolia to gather local knowledge about land classification and reference conditions, the presumed causes of vegetation change, and to identify informative sites for additional inventory. Field visits and interviews with US and Mongolian rangeland management specialists were used to propose management recommendations, especially regarding the timing of grazing, grazing deferment, and grazing rest periods, based on local and international studies.

STMs are being tested using the long-term vegetation monitoring program of NAMEM, and the monitoring data interpreted according to STMs are periodically published in the National Report of Rangeland Health of Mongolia. These procedures were officially approved by the Research Institute of General and Experimental Biology of Academy of Sciences, NAMEM and ALAGAC in 2015 (Figure 1).

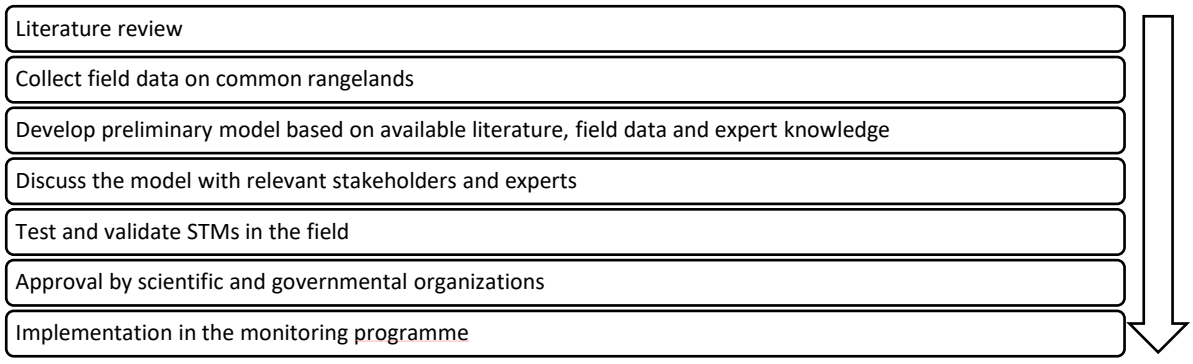

Figure 1. Development process of STMs for Mongolian rangelands

Results

In each ecological zone of Mongolia between three to five ESGs were recognized and STMs were built. A total of twenty-two STMs were developed for the most common rangeland types. For each, we defined reference and alternative rangeland states and their "recovery classes" that are based on the timelines and management changes needed to recover the corresponding reference state (Figure 2). The reference states of

related steppe STMs featured dominance by perennial grasses of the genus *Stipa* spp. alongside a high diversity of other perennial grasses and forbs. Frequent, high grazing utilization of perennial grasses initially caused a thinning of overall cover with increased bare ground and, eventually, pronounced reductions in formerly dominant grasses and increases in less palatable plants, particularly subshrubs of the genus *Artemisia* and upland sedges (*Carex* spp.). In some cases, gully erosion can occur. Feedbacks reinforcing state changes are initially due to reproductive limitations and possibly by resource pre-emption when certain subshrubs become dominant. Most transitions are postulated to be reversible with grazing management alone from 3-10+ years, but the degree of hysteresis associated with thresholds between states is poorly understood.

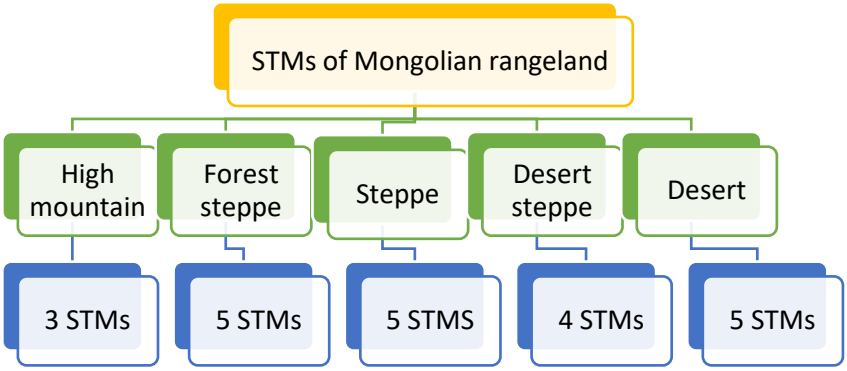

Figure 2. The classification of ecological site groups and state and transition models in Mongolia.

For all STMs, we characterized the dominant plant species for each ecosystem state and included tools to aid in the identification of states. The description of STMs was developed in two formats, a detailed account including species composition, abundance, average biomass and carrying capacity estimation, and a simplified photo version for easier field implementation (Figure 3). The geographical distribution of ecological site groups is described as well (Densambuu et al. 2018a).

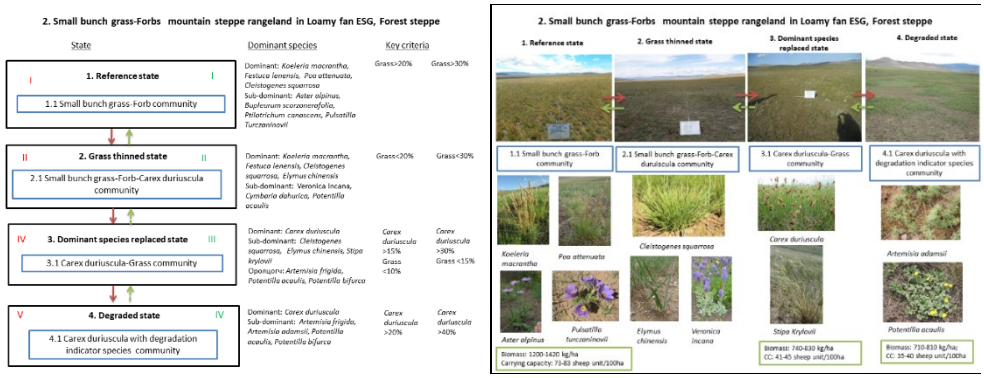

Figure 3. The description of the State and Transition Models (STMs) for each ecological site was provided in two formats: a detailed STM description with plant cover information of dominant and subdominant species (left), and a simplified photo version of STMs for easier implementation in the field (right).

Conclusions

Robust implementation of theoretical frameworks can help our understanding of rangeland dynamics and the processes that lead to rangeland degradation. STMs are effective tools for analysing and interpreting rangeland health monitoring data and provide a scientific basis for planning and implementing resilience-based rangeland management. STMs provide a scientific basis for planning and implementation of resilience-based rangeland management in Mongolia and allow summarization of the large amount of knowledge available to date, while allowing for the identification of areas where more information is needed (Bestelmeyer et al. 2017). In summary, STMs have the potential to serve as an essential tool for better communication on the state of rangeland health and facilitating management planning in Mongolia.

Acknowledgements

This research is supported by Green Gold-Animal Health project, SDC in Mongolia. Funding to attend IRC/IGC 2021 was provided by the GRÓ LRT programme (https://www.grocentre.is/lrt).

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