Journal of Arid Environments 109 (2014) 88–91

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Short communication

Herding strategies during a drought vary at multiple scales in Mongolian rangeland

Kaoru Kakinuma [a,*], Tomoo Okayasu [b], Undarmaa Jamsran [c], Toshiya Okuro [b], Kazuhiko Takeuchi [b]

[a] Department Civil Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology, 2-12-1-M1-6 Ookayama, Meguro-ku, Tokyo 152-8552, Japan
[b] Department of Ecosystem Studies, Graduate School of Agricultural and Life Science, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan
[c] Center for Ecosystem Study, Mongolian State University of Agriculture, 210153 Ulaanbaatar, Mongolia

ARTICLE INFO

Article history:
Received 21 February 2014
Received in revised form
27 May 2014
Accepted 28 May 2014
Available online 19 June 2014

Keywords:
Drought
Key resource
Local knowledge
Non-equilibrium model
Pastoralism
Rangeland management
Variable environments

ABSTRACT

Grazing-induced degradation is an important issue in semi-arid and arid regions, particularly in key resource areas where livestock concentrate during droughts. However, this concentration assumes a single nomadic strategy, and in practice, pastoralists employ multiple mobility patterns in response to environmental and socioeconomic factors. We surveyed pastoralists to detect variation in herding strategies during a drought, such as key resource selection and travel distance. We defined two groups of strategies: small herds moved a short distance and used key resources; large herds moved a long distance and moved to areas with more abundant rain and plants instead of using key resources. These variations relate to the cost of long-distance travel, and suggest that grazing-induced degradation can occur at multiple scales; degradation of key resources in the study area may occur at a small scale, corresponding with the travel distance for small herds. Our study suggests that interactions between resource spatial heterogeneity and herding strategies at multiple scales should be considered when assessing grazing-induced degradation in highly variable environments.

1. Introduction

Grazing-induced degradation in highly variable environments is an important challenge for sustainable rangeland management (Briske et al., 2003; Vetter 2005). Several theoretical models have focused on the relationships between variable resources and pastoralist herding strategies to predict the impact of grazing on rangeland conditions. Non-equilibrium models assume that pastoralist mobility is opportunistic; they track patchy resource distribution, and the occurrence of frequent multi-year droughts increases livestock mortality and prevents livestock numbers from reaching carrying capacity (Behnke et al., 1993; Coughenour 1991; Ellis and Swift, 1988). Although many empirical studies have examined non-equilibrium models (e.g., Dorji et al., 2010; Fernandez-Gimenez and Allen-Diaz 1999; Fynn and O'Connor, 2000; Todd and Hoffman, 2009), results have been inconsistent, and there is no consensus about whether and how livestock numbers should be controlled in highly variable rangeland systems.

Previous studies suggested that equilibrium models and non-equilibrium models are not mutually exclusive. Illius and O'Connor (1999) emphasized that pastoralists take advantage of spatial resource heterogeneities (i.e., the existence of key resources) that result from topographic and environmental variation to mitigate the effects of climatic variability. They predicted that animal numbers are regulated in a density-dependent manner by the limited forage availability in key resource areas. Key resources are defined in terms of the key factor that determines livestock populations – usually survival through the season of plant dormancy – and thus, the factor that determines the availability of forage, particularly during a drought (Illius and O'Connor, 1999; Vetter, 2005). The importance of their prediction was widely recognized, and empirical research and review papers have supported their prediction (e.g., Kakinuma et al., 2013; von Wehrden et al., 2012).

However, the prediction of Illius and O'Connor (1999) assumed the use of a single herding strategy in the prediction of rangeland dynamics (i.e., that pastoralists use key resource areas during

* Corresponding author. Tel.: +81 3 5734 2190; fax: +81 3 5734 3577.
E-mail addresses: kakinuma.k.aa@m.titech.ac.jp, k.kakinuma0214@gmail.com (K. Kakinuma).

http://dx.doi.org/10.1016/j.jaridenv.2014.05.024
0140-1963/

droughts). Actual herding strategies are more flexible (e.g., McCarthy and Di Gregorio, 2007). Different variations emerge from a balance of the costs and benefits of mobility. Long-distance, frequent mobility has costs (McCarthy and Di Gregorio, 2007), such as weight loss by livestock and greater labor demands (Turner, 1999), and has benefits, such as a chance to obtain more forage. Strategies during a drought may therefore not be uniform and should vary, depending on the resource availability and on pastoralist socioeconomic conditions.

Although herding strategies and resource distribution are tightly related, previous studies did not consider the possibility of variable herding strategies. If herding strategies vary during a drought, degradation of key resources would not occur at a single spatial scale, but would exhibit spatial patterns that correspond to the herding patterns. We therefore examined whether herding strategies vary, and the effects on degradation of key resources in a highly variable environment.

2. Materials and methods

2.1. Study area

Our study area was the Saintsagaan district, which includes Mandalgovi City (45°46′N, 106°16′E) in Mongolia's Dundgovi Province. Mandalgovi lies in a desert-steppe ecological zone. The main livestock are sheep, goats, horses, and camels. The climate is arid and cold, with a short summer. The annual precipitation from 2000 to 2010 averaged 112.0 mm, with a coefficient of variation (CV) of 35.7% (Institute of Meteorology and Hydrology of Mongolia, unpublished data). Our study area had a highly variable environment according to Ellis' (1995) criteria. Ellis predicted that non-equilibrium dynamics would predominate in areas such as ours with mean annual precipitation less than 250 mm and CV > 33%. Our study took place from July to August in 2009 and 2010. The total and growing season (June and July) precipitation in 2009 were 84.6 and 26.9 mm, respectively, versus 98.4 and 50.5 mm in 2010. The growing season precipitation from 2000 to 2010 averaged 48.6 mm; thus, 2009 and 2010 were drought and normal years, respectively. Pastoralists in this region move frequently and over long distances compared with those in northern Mongolia, where precipitation is greater and more stable (Humphrey and Sneath, 1999).

2.2. Interviews

We interviewed 52 pastoralists who stayed within Saintsagaan district from July to August 2011. We visited their homes, which are traditional *gers*, and performed semi-structured interviews. The homes were dispersed throughout the district and often moved, so we needed help from village leaders to find them. We interviewed pastoralists who lived at our study sites during our study. In the study area, village leaders are responsible for gathering information on the number of livestock belonging to each household and reporting this data to the government. Therefore, they have good knowledge about the local pastoralists' mobility strategies and the number of livestock they own. The leaders also helped us during the interviews. We interviewed one respondent per household from 52 households. The average age of the respondents was 46.1 (range: 20–77). Interviews were carried out in the Mongolian language, through an interpreter, and took around 30 min per respondent. To investigate the grazing strategies during a drought, we asked the following questions: first, we asked how many livestock they had during the drought summer (2009). Second, we asked them where they traveled during the drought summer and the normal summer (2010). We then asked each respondent whether they used key resources during the drought. Our previous study (Kakinuma et al., 2013) showed that plant communities dominated by the perennial tussock-forming graminoid *Achnatherum splendens* were key resources during a drought. In this study, we interviewed key informants (village heads) in our study area to learn more about the key resources and the other forage resources. They told us that pastoralists in the study area used four plant communities (*Caragana microphylla*, *Allium polyrrhizum*, *A. splendens*, *Reaumuria soongorica* dominant communities) during a normal summer so long as the communities contained the small graminoids that were highly palatable to livestock, but that during a drought, few of these graminoids were available. During a drought, the pastoralists therefore often used the *Achnatherum* community. *A. splendens* is highly tolerant of dry conditions, and the cover of this species in the study area remains high during a drought, even when other species disappear (Sasaki et al., 2009). The *Achnatherum* community is usually found at the margins of salt marshes in the bottoms of valleys, where the groundwater is close to the surface (Grubov, 1982), and its distribution is therefore smaller than those of other plant community types (Kakinuma et al., 2013). Thus, the *Achnatherum* community is a key resource, and we asked pastoralists whether they used this resource during a drought.

2.3. Data analysis

We converted livestock numbers into sheep units (Bedunah and Schmidt, 2004) and summed them per household. We used the following conversions: cow = 6 sheep, horse = 7 sheep, and goat = 0.9 sheep.

We categorized the herd destinations in 2009 and 2010 for three travel distance groups: within Saintsagaan district (short; less than about 20 km), outside of Saintsagaan district but within Dundgovi Province (medium; more than about 20 km, but less than 100 km), and outside Dundgovi Province (long; more than about 100 km). We divided resource selection by the pastoralists into two groups based on whether they did or did not use key resources.

To classify pastoralists based on their herding strategy, we performed hierarchical clustering analysis using Ward's method (Ward, 1963). As inputs, we standardized the four mobility variables (livestock number, travel distance during a drought, travel distance during a normal summer, and utilization of key resources) by using the results of a principal-components analysis (PCA; PC1–4). We calculated the mean, standard deviation, and range of all the mobility variables for each pattern. We then used the chi-square test to identify significant differences between the mean values of the mobility variables for each mobility pattern.

All statistical analyses were performed using the R software (version 2.9.2, http://www.R-project.org).

3. Results

The cluster analysis revealed two mobility patterns (Fig. 1) that differed for all mobility variables. The number of livestock, which is often used as an indicator of household economic conditions (Butt, 2011), differed significantly between the two mobility patterns in 2009 ($P < 0.01$: Fig. 2): hereafter, we have called these groups "large" and "small" herds accordance with their herd size. Large herds moved significantly longer distances than small herds during a drought ($P < 0.01$; Table 1). Half of the large herds moved within Saintsagaan district and the remainder moved out of the district, whereas all of the small herds stayed within the district during the 2009 drought. In contrast, the distance did not differ significantly in the normal summer of 2010 ($P = 0.05$; Table 1). The resource selection also differed significantly during the drought ($P < 0.01$;