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Introduction The assessment of vegetation productivity is especially important in Mongolia where drought and winter disasters (dzud) that deplete vegetation resources represent a major risk confronting herders. During the period from 1999 to 2001, as much as 35% of the nation's livestock was lost to these two disaster events. To help address these challenges to livestock production in Mongolia, a livestock early warning system was implemented with the objective of developing a forage monitoring system that provides near-real time spatial and temporal assessment of current and forecasted forage conditions. As part of this effort, we sought to assess 1) the ability of the PHYGROW forage simulation model to accurately predict forage biomass at selected sites across the landscape using near-real time climate data, and 2) the feasibility of using geostatistical interpolation methods that combine forage model output with Normalized Difference Vegetation Index (NDVI) to produce landscape level maps of forage production.

Materials and methods Using the protocols described by Stuth *et al*. (2005) for implementing livestock early warning systems, 297 monitoring sites were established in 8 provinces in the Gobi region of Mongolia during May 2004 to September 2007. During the first visit to each site, vegetation, soil, and grazing data were collected to parameterize the PHYGROW forage production model (Stuth *et al*. 2005). PHYGROW was driven by near real-time climate data acquired from the National Oceanic & Atmospheric Administration's (NOAA) CMORPH system (Joyce *et al*., 2004). To verify the PHYGROW model, forage biomass was collected at each of the monitoring sites 2 to 4 times after the initial visit. The clipped biomass was statistically compared to the predicted biomass from PHYGROW. For validated sites, the forage model outputs were coupled with NDVI data using the geostatistical method of cokriging to create interpolated maps of forage biomass. Cross validation (Isaaks and Srivastava 1989) was used to assess the performance of cokriging for mapping biomass.

Results For the majority of the monitoring sites, we found a very good correspondence between forage biomass clipped at the monitoring sites and that predicted by the PHYGROW model ($R^2 = 0.69$). The standard error of prediction for the validation was 83.6 kg/ha which was less than the overall standard error associated with the clipped biomass (115.3 kg/ha) indicating that the variability associated with validation was much less than the variability of the field collected data across all sites. The model had a tendency to slightly under-predict at higher biomass and slightly over-predict at low biomass conditions.

Maps of forage biomass were produced every 15-16 days (to match the NDVI image availability) during the growing season (May to September) for 2005 and 2006 using cokriging. The cross validation of model-predicted forage biomass and the cokriged estimates of forage biomass resulted in reasonable estimates of mapped biomass ($R^2 = 0.71$). The standard error of prediction for cross validation was 111.74 kg/ha which was very similar to that seen for the clipping data (115.3 kg/ha), indicating that the cokriging procedure variability was similar to that encountered with the field clipping data.

Conclusions The results of this study indicate that the use of the PHYGROW forage simulation model would be useful for predicting forage biomass on a near real-time basis in the Gobi region of Mongolia. The forage model output, when combined with NDVI using geostatistics, results in the production of reasonably accurate maps of forage biomass. These maps provide both a spatial and temporal assessment of forage conditions that can assist herders, as well as local and regional governments, in decision making for livestock in the face of drought or winter disaster.

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