GLOBAL LIVESTOCK CRSP

Verification of Simulation Model and Landscape Map Results for Near Real Time Forage Monitoring in the Gobi Region of Mongolia

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Research Brief 08-03-GOBI January 2008

Assessment of vegetation productivity on rangelands using conventional methods such as clipping can be very time consuming and expensive, and becomes very impractical to do on a near real time basis. Near real time information is critical for timely decision making in the face of drought and other disasters, especially in the Gobi Region of Mongolia. In this study we sought to assess the ability of a forage simulation model (PHYGROW) to accurately predict forage standing crop at 300 sites, and whether the output from the simulation model could be combined with satellite greenness data to produce landscape maps of forage production on a near real-time basis. The assessment required 3 main steps: 1) model calibration, 2) model validation, and 3) map cross-validation. For model calibration and validation, we found that the PHYGROW model generally did a good job of predicting forage biomass at the monitoring sites with the variability in model predicted biomass to be less than the error associated with actual clipping for biomass production. An assessment of the cross-validation for the landscape maps found a good relationship between forage model biomass and the map interpolated biomass, thus indicating that the forage model outputs can be useful for creating near-real time maps of forage production. These technologies will provide timely information on forage conditions to increase lead time for making risk mitigation decisions by herder groups and policy makers in Mongolia.

Background

The ability to characterize the vegetation productivity over large landscapes can be an important component in the assessment of drought impacts, natural resource management options, environmental degradation, and economic impacts of changing technologies. For pastoralists, an understanding of the vegetation productivity in the surrounding landscape can assist in determining whether to move, buy, or sell animals, and assess the level of risk for decision making. However, the time and resources required to conduct accurate assessments of vegetation productivity over large landscapes are prohibitive, and in many areas such as Mongolia, the infrastructure and funding does not exist to do large-scale characterization. Another complicating factor is that decisions regarding livestock movement and stocking/de-stocking may require near real-time information, especially in the face of drought. Vegetation productivity assessment is almost impossible to conduct over large land areas on a near real-time basis, thus the information needed for livestock related decisions is not always available when it is needed most. The inability to make decisions at critical times could lead to vegetation overuse, which in turn, could lead to environmental degradation.

Improvements in computing power and capacity, along with near real-time production of climate data and remote sensing imagery offer the opportunity to develop near-real time systems for monitoring vegetation on rangelands. Improved computing power and capacity has also increased the use of simulation modeling for agriculture systems, including rangelands. A limitation of many rangeland simulation models is that most provide simulation output for a specific point. Ideally, one would want to simulate as many points (or sites) as possible to represent a region or landscape, especially for the determination of vegetation productivity across the landscape. However, the amount of effort and cost for model parameterization on a large number of monitoring points can be prohibitive. An alternative approach is to conduct simulations for a select number of points and then use geostatistical interpolation methods such as cokriging to create maps of simulation output for a region or landscape (see Stuth et al. 2003; Stuth et al. 2005). These surface maps can then be used represent spatially explicit vegetation production allowing users to monitor conditions and to improve decision making.

As an interpolation method, cokriging can provide estimates for unsampled points using information provided by the cross relationship between a primary variable (in our case, forage model output) and a secondary variable. The secondary variable is usually sampled more frequently and regularly, thus allowing estimation of unsampled points using both variables. Satellite derived vegetation indices (i.e., greenness

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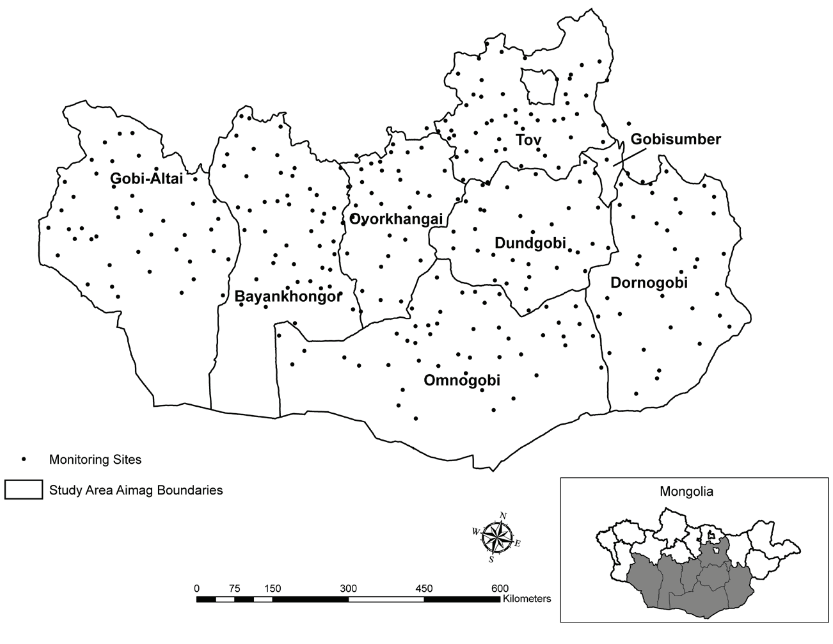
indices), most notably the Normalized Difference Vegetation Index (NDVI), have been found to be correlated to vegetation productivity, therefore making this products useful as a secondary variable in cokriging of vegetation productivity.

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 standing crop of forage at selected sites across the landscape using the near-real time rainfall data, and 2) the feasibility of using forage model output and NDVI in geostatistical interpolation to produce landscape level maps of forage production.

Major Findings

To assess the ability of the simulation models to produce reliable vegetation productivity estimates as well as the reliability of landscape maps of forage production, we employed a 3 step process. The steps were as follows: 1) model parameterization and calibration, 2) model validation, and 3) map cross validation. Each of these will be described below along with the results of these assessments.

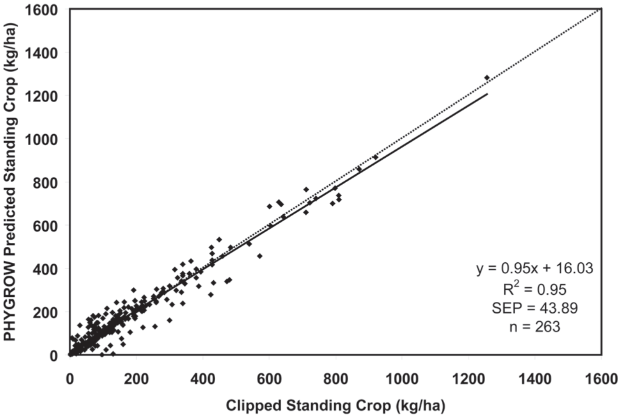
Figure 1. Location of the monitoring sites within the Gobi Region of Mongolia.

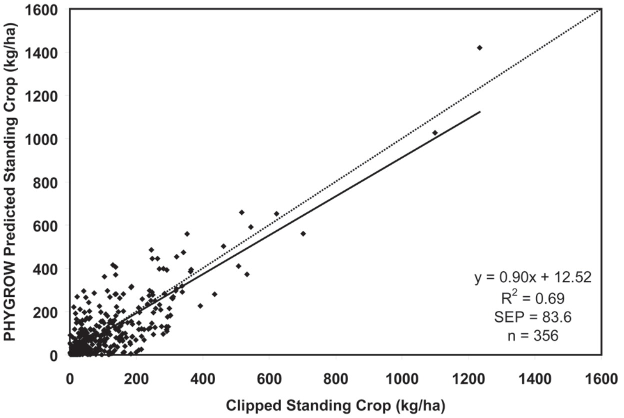


Model parameterization and calibration entailed collection of vegetation composition data to parameterize the PHYGROW model, and measurement of vegetation productivity to calibrate the model. In Mongolia, approximately 300 monitoring sites were established in 8 aimags (provinces) across the Gobi region during the period from May 2004 to October 2006 (Figure 1). At each monitoring site, vegetation composition data were collected along fixed length transects and used to parameterize the model. Vegetation productivity was measured by clipping forage biomass from quadrats of known size and converting the biomass values to kg/ha after air drying and weighing. Calibration of the model for each site involved slight modifications of PHYGROW parameters such as leaf turnover and growth rate to allow the model predictions of biomass to converge at or near the forage biomass measured when the transect was established. For the majority of the monitoring sites, we found a very good correspondence between forage standing crop clipped at the monitoring site and that predicted by the model (R2 = 0.95; Figure 2). However, we had 37 problem sites that we were not able to completely calibrate. We believe these problems may be associated with a mischaracterization of soil at the site, stocking rates that are greater than those reported for the monitoring site, or data collection errors. The majority of these problem sites were located in higher elevation steppe and forest steppe areas, which had high plant diversity and highly variable soils. These sites will require some additional soil sampling to improve our model parameters at these higher elevation areas.

Model validation provides and indication of the calibrated model's performance in predicting the forage biomass without further model adjustments. In subsequent years after transect establishment, the monitoring sites were visited again to collect vegetation productivity data to validate the model output for each site over time. Vegetation productivity was again measured using quadrat methods and the presence/absence of species encountered during the transect establishment were noted. Each site was visited at least once after establishment and some were visited up to 4 times. The results of the validation indicated that the PHYGROW model estimates of forage biomass had reasonable correspondence with that clipped at the monitoring sites (R2 = 0.69; Figure 3). The standard error of prediction for the validation was 83.6 kg/ha which was less than the overall standard error

Figure 2. Model Calibration: results of regression analysis of the clipped standing crop versus the PHYGROW forage model standing crop for the first year samples used for calibration of the PHYGROW model at the monitoring sites within the study region.





associated with the clipping data (115.3 kg/ha) indicating that the variability associated with validation was much less than the variability of the clipping data across all sites.

These validation results provided us with confidence that the calibrated PHYGROW model performed well in predicting forage biomass at the monitoring sites over time. We then used the geostatistical procedure of cokriging (see Isaaks and Srivastava 1989 for a discussion of cokriging) to produce landscape maps of forage production using the model output for each site and satellite greenness (NDVI) data. Satellite greenness data is produced by the National Aeronautic and Space Administration (NASA) every half month. The forage model output was averaged for each half month period to match the production of the NDVI during the growing season (May to September) in 2005 and 2006 when vegetation biomass sampling was conducted in Mongolia. The cokriging procedure not only uses the positive relationship between the forage biomass and the NDVI, but also accounts for spatial autocorrelation (i.e., items closer together in space are generally more similar than those farther apart) to create interpolated maps of forage biomass. To assess how well cokriging predicted forage biomass, we employed a procedure called cross-validation. Cross-validation involves dropping out data for one of the monitoring points and then running the cokriging procedure and predicting the forage value for the point that was left out. This procedure is then repeated for all the monitoring points and then the observed and predicted values can be compared via regression to assess statistically how well the cokriging procedure performs for estimating unsampled points. The results of this exercise indicated that the cokriging procedure generally did a good job of predicting forage biomass (R2 = 0.71). The cokriging procedure had a tendency to slightly overpredict forage biomass and to underpredict forage at higher biomass conditions. 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. Like the validation data set, there was a tendency for underprediction of forage biomass in the maps when compared to that predicted by the forage simulation model.

Practical Implications

The results of this study indicate that the use of the PHYGROW forage simulation model would be useful for predicting forage production on a near real-time basis in the Gobi region of Mongolia. The forage model output, when combined with satellite greenness measurements using geostatistics, results in the production of reasonably accurate maps of forage biomass for the Gobi Region. 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. Since movement of animals is generally the first response of Mongolian herders in times of drought, the regional maps can allow herders to determine areas where they might move their animals or assist them in determining the number of animals they may need to destock. In times of above average forage conditions, this near real-time information can assist in determining the number of animals that the herder could purchase to take advantage of additional forage.

For local and regional governments in Mongolia, the regional maps of forage biomass could assist in determining carrying capacity and stocking rates. During periods of drought/dzud, the maps could be useful in coordinating herder movement to areas where forage amounts are adequate to sustain the additional numbers of animals. At the national level, the maps can indicate “hot spots” where drought or dzud is most severe, thus providing information to help coordinate disaster relief efforts and pinpoint areas where fodder may need to be delivered.

The collection of data at 300 monitoring sites for model parameterization can become part of a larger database for monitoring rangeland health in region. The transect data collection provides important baseline data to monitor changes in species composition and abundance over time. The use of near-real time forage maps in short term decision making by herders can have long-term benefits to rangeland health if properly used. Timely decision making in the face of drought can reduce environmental degradation and lead to overall improvements in rangeland health and condition.

Further Reading

Isaaks E.H. and R.M. Srivastava. 1989. *Applied geostatistics*. New York: Oxford University Press.

Stuth J.W., J. Angerer, R. Kaitho, A. Jama, and R. Marambii. 2005. “Livestock Early Warning System for African Rangelands.” In Boken V. K., A.P. Cracknell, and R.L. Heathcote (eds.), *Monitoring and predicting agricultural drought : a global study*, p. 472. New York: Oxford University Press.

Stuth J.W., J. Angerer, R. Kaitho, K. Zander, A. Jama, C. Heath, J. Bucher, W. Hamilton, R. Conner, and D. Inbody. 2003. *The Livestock Early Warning System (LEWS): Blending technology and the human dimension to support grazing decisions.* University of Arizona, Office of Arid Lands Studies. Available from http://cals.arizona.edu/OALS/ALN/aln53/stuth.html (accessed 10/1/2006).

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The GOBI FORAGE project was initiated in 2004 to adapt Livestock Early Warning System (LEWS) technologies developed by the GL-CRSP in east Africa for Mongolia to improve risk management by herders and other stakeholders in the Gobi Region of Mongolia. The project is a partnership between the Global Livestock CRSP, the USAID-Mongolia Mission, Texas A&M University, Mercy Corps Mongolia, and USDA Rural Agribusiness Support Program, and is managed by Jay Angerer. Email contact: jangerer@cnrit.tamu.edu

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in West and East Africa, Central Asia and Latin America.

This publication was made possible through support provided by the Office of Agriculture, Bureau of Economic Growth, Agriculture and Trade, under Grant No. PCE-G-00-98-00036-00 to University of California, Davis. The opinions expressed herein are those of the authors and do not necessarily reflect the views of USAID.

Design by Susan L. Johnson