GLOBAL LIVESTOCK CRSP

A Satellite-Based Technology Predicts Forage Dynamics for Pastoralists

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The Livestock Early Warning System Project (LEWS) has created a technology suite of products to predict forage conditions on the ground in pastoralist regions of East Africa. The system monitors the impact of emerging weather events on forage supply for livestock. The PHYGROW model is the foundation of the LEWS toolkit. Primary inputs for the model include: soil parameters, plant community characteristics, and livestock management decision rules. These inputs are driven by satellite-based gridded weather data for a particular location, simulating daily forage available for livestock and wildlife. Regular verifications are conducted to ensure that PHYGROW's simulation output of available forage agrees with observations in the field. LEWS scientists sampled 81 of over 300 monitoring sites scattered across Ethiopia, Kenya, Tanzania, and Uganda throughout the entire vegetation production cycles of 2001 and 2002. The zonal teams estimated the total forage standing crop (kg/ha) for 50 plots in each of the 81 grids, based on pre-established reference quadrats. The field data collected by the zonal teams was highly correlated with the simulated model output (R^2= 0.96 and SEP = 161 kg/ha). The methodology was judged effective in providing large-scale estimates of forage dynamics on the ground, offering a low-cost mechanism for translating weather data into forage over large regions. Satellite-based weather data, coupled with a robust biophysical model like PHYGROW, is a viable base to support early warning efforts in developing countries.

Background

For the past five years, the LEWS project has conducted research and developed a Livestock Early Warning System for the pastoral communities in Ethiopia, Kenya, Tanzania, and Uganda. The project explored an array of technologies and their applications in developing countries, including access to satellite-based weather data and computer simulation models of plant growth and spatial techniques linked with NDVI greenness data. The algorithms needed to derive satellite-based rainfall and temperature data have been extensively tested by Xie and Arking (1998), Grimes et al (1999), and Funk et al. (2003). Similarly, the use of NDVI satellite data has been well established (Tucker et al., 1991). However, the effectiveness of linking the satellite-based weather and NDVI data with PHYGROW, the biophysical model used in the LEWS program, had not been extensively tested in East Africa. The LEWS project found PHYGROW to be an effective model in predicting forage on-offer to livestock over a wide array of East African ecosystems.

PHYGROW is a hydrological-based plant growth model used to simulate daily available forage. The model uses soil parameters, plant community characteristics, livestock movement/destocking decision rules, and weather data for a particular location to simulate daily available forage. The initial characterization of the modal plant communities is based on a sample at a specific location, carefully selected to be as representative as possible of a corresponding 8 x 8 km satellite weather/ NDVI grid. The model is run with long-term weather (1961-2002) to test its true stability. During stabilization, a modeler examines both the input and the output parameters for reasonableness and inadvertent errors. Subsequently, the model is placed in a web-based automation process to report daily forage conditions, percentile ranking of forage on-offer, deviations from a long-term average, and projections for the next 90 days on a near real-time basis with minimum human interference (http://cnrit.tamu.edu/aflews). Various geostatistical methods and GIS techniques are employed to produce surface maps of available forage using the point data generated through the automation process. These techniques allow the estimation of forage yield for large areas of non-sampled locations, offering a cost-effective and timely way to monitor forage in vast areas of developing countries.

There are currently over 300 LEWS monitoring points distributed over Ethiopia, Kenya, Tanzania, and Uganda (Figure 1). To set up and parameterize PHYGROW for each of these sites, the host-country scientists led field teams to selected sites representing 8 X 8 km weather and NDVI grids. The teams made 500 observations of basal area of the grasses, frequency of the forbs, and effective canopy cover of the woody species for each site

(Jama et al., 2002). Soils were characterized based on soil surveys (where available) or actual soil sampling at the site. Livestock densities and movement rules were acquired via interviews with local pastoralists using the grid selected as a monitoring site. A minimum of 30 years of daily weather data is needed to drive the model and set up a baseline, or long-term normal, for each site. The weather variables needed are: minimum and maximum temperatures (C), rainfall (cm), and solar radiation (Langley). Baseline weather data was derived from the 1961-1997 CHARM rainfall data set up by Funk et al. (2003) coupled with the RFE/NOAA CPC weather dataset for Africa (1998 to present). Temperature and solar radiation through 1997 were generated by the WXGEN weather generator. For the period of 1998 to present, weather data was acquired at the following sites:

<u>Maximum Temperature</u>
ftp://ftp.ncep.noaa.gov/pub/cpc/fews/daily_gdas_avgs/tmax/
<u>Minimum Temperature</u>
ftp://ftp.ncep.noaa.gov/pub/cpc/fews/daily_gdas_avgs/tmin/
<u>Rainfall</u>
ftp://ftp.ncep.noaa.gov/pub/cpc/fews/newalgo_est/

The resultant PHYGROW model outputs for selected sites were ground-truthed by LEWS zonal teams, based on rapid field appraisal of the standing crop of grazed forage (Haddock and Shaw, 1995). When a test of the PHYGROW model's predicted results indicated a good agreement with the field data, the model was judged both to adequately track the real conditions on the ground and to be eligible for automation. Continuing field verification of model-simulated available forage is an integral part of the Livestock Early Warning System development process. Confidence in model output is necessary to provide credible information to stakeholders and decision-makers.

Preliminary Findings

Over the period of 2001 through 2002, the LEWS zonal teams selected 81 sites across the region for intensive sampling. Fifty 0.5 m^2 quadrats were sampled at each monitoring site using a comparative yield method, where forage biomass is visually estimated on all quadrats using a ranking method. Of the 50 evaluated, 15 quadrats were clipped and used in the development of a regression equation (Haddock and Shaw, 1975). The regression equation is used to convert the rankings into actual forage values. Since PHYGROW estimates grazed forage for each of the target herbivores, only forage available to livestock was measured in the field. The sites were re-sampled if the field sampler's visual estimate and associated clipped samples resulted in R^2 values less than 0.80. More training was provided to the field enumerators having difficulty estimating standing forage values.

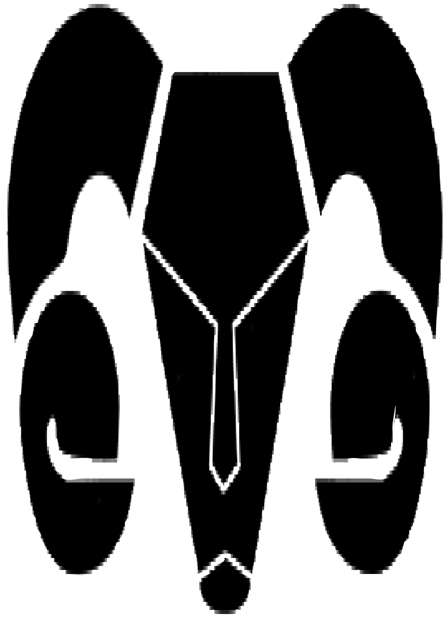

Figure 1: Location of the LEWS monitoring sites and verification sites in East Africa.

Results indicate that PHYGROW accounted for 96% of the observed variation in herbaceous forage on- offer with a standard error of prediction of 161 kg/ha. Mean difference in sampled and predicted forage on-offer was 15 kg/ha. When parameterized properly, the PHYGROW model performed well for the level of analysis required for the LEWS program in East Africa. Committed in-country field staff, trained in LEWS field methodology, was vital to the successful implementation of the model.

Practical Implications

Forage monitoring is becoming increasingly important in East Africa, as frequent recurring droughts affect large areas of the region. Determining forage production over large regions poses a problem of logistics and cost for rangeland monitoring systems in developing countries. This limitation has resulted in reduced capability to determine potential stocking rates for rangelands. Also reduced is the ability to determine the effects of vegetation loss within the context of rangeland monitoring, assessment programs, and livestock early warning systems. The technique of linking the PHYGROW model with satellite-based weather data offers a major breakthrough in establishing a point-based sampling system of large landscapes. When coupled with rich NDVI satellite imagery, PHYGROW can be used to create maps of forage dynamics in vast and remote regions of the world with limited resource monitoring infrastructure. The resulting methodology is the foundation of the first livestock early warning system applied in East Africa. This system allows pastoral communities, district officers, NGOs, and relief/development decision-makers to be proactive in implementing appropriate management practices or interventions to protect the natural resource base and livelihoods of people using fragile rangelands.

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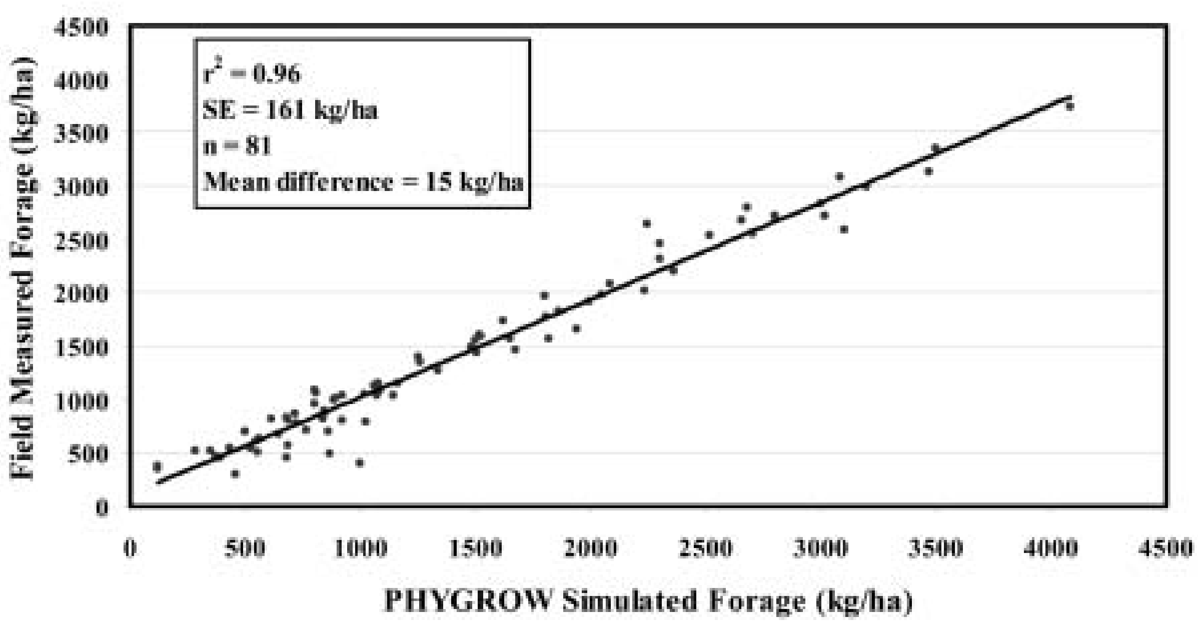
Figure 2: Relationship between sampled standing crop of forage on offer in selected LEWS monitoring sites and available forage predicted by the PHYGROW model.



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http://cnrit.tamu.edu/aflews - Analysis Portal for Livestock Early Warning System for East Africa.

http://cnrit.tamu.edu/rsg/rainfall/rainfall.cgi - Weather Access Portal for African Weather Data Used in the LEWS Program.

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The GL-CRSP Livestock Early Warning System Project (LEWS) was established in 1997 and conducts research, training, and outreach in an effort to provide proactive information on emerging forage conditions and quality to assist pastoralists, NGOs, district officers, and national food security agencies in coping and mediating emerging drought and excess rainfall conditions. The project is led by Dr. Jerry W. Stuth, Texas A&M University. Email contact: jwstuth@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 East Africa, Central Asia and Latin America.

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