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Emerging Near-Real Time Forage Monitoring Technology with Application to Large Herbivore Management in Mongolia

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Emerging Near-Real Time Forage Monitoring Technology with Application to Large Herbivore Management in Mongolia

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Abstract

Large herbivore livestock and wildlife in Mongolia depend almost entirely for substance on forage standing crop produced each year on natural pastureland. Consequently, both livestock and wildlife are continuously subject to environmental risk, especially drought and severe winter storms, while livestock are also subject to financial risk. As consumption-based livestock production changes to commercialized livestock production, steps taken by the livestock herder to avert both environmental and financial risk to livestock can increase environmental risk to large wild herbivores. A realistic and workable pastureland and risk management system will be critical for conservation of large herbivore habitat. New technologies are becoming available to facilitate understanding of risk and resource allocation. Texas A&M University has developed a suite of innovative technologies that facilitate resolving risk and resource allocation issues. A pre-parameterized rangeland model (i.e., PHYGROW) provides daily estimates of forage available to a mixed-population of herbivores. Near Infra-Red Spectroscopy (NIRS) allows prediction of diet quality of free-ranging large herbivores via fecal scans which, when coupled with advanced nutritional management software (i.e., NUTBAL), can predict performance of animals. Oregon State University has developed a computerized multi-criteria decision-making tool (i.e., KRESS) that can take landscape parameters and determine the suitability of each cell or unit of the landscape for use by large herbivores. Emerging near real-time technologies can help clarify habitat needs, identify habitat improvements, and enable better management of large herbivore wildlife and livestock.

Key words: risk, herbivores, wildlife, livestock, habitat, technologies, models

Introduction

Extensively managed livestock production in Mongolia is currently based on and dependent almost solely on forage produced during annual cycles on natural pastureland. Large wild herbivores also are dependent on forage produced annually on natural pastureland. Management of these resources is required, especially management of the human use to maintain resources in the best condition possible. Although simple in concept, management of natural resources to ensure sustainable use is a complex process that warrants consideration as Mongolia begins to commercialize agriculture and privatize access to natural resources.

Especially important to both wild and domestic large herbivores is managing the “risk” associated with livestock production. Risk management in livestock production involves two major sources of risk: environmental risk which primarily involves weather, with positive or negative impacts on agricultural production, and financial risk which is related directly to costs of production, prices received for agricultural products, and indirectly to environmental risk and access to resources and inputs needed for efficient production. Environmental risk also interacts with agricultural production at two different scales: a national/regional scale that affects production by altering access to natural resources (drought and dzud), and at a scale directly affecting the production system i.e., crop failure or livestock mortality).

Large wild herbivores are also subject to the same risks. Environmental risk such as drought and dzud can directly affect productivity and viability of wild herbivores similar to domestic herbivores. An obvious direct conflict may be competition for forage and habitat between wild and domestic herbivores using the same pasture resources. However, steps taken by the livestock producer to avert both environmental and financial risk can have an even greater negative impact on sustainability of large wild herbivore populations. Infrastructure development to mitigate risk in livestock production (e.g., well development, fencing of pastureland, higher animal stocking rate, etc.) or facilitate utilization of natural resources (e.g., roads, railroads, mining developments, etc.) that does not consider needs of large wild herbivores may, over time, have even greater adverse consequences to sustaining viable populations of wild herbivores.

Development of an effective and functioning national pasture and risk management program is critical to sustainable use of Mongolia's natural resources and improving livelihoods of its citizens. It is especially critical to develop a realistic and workable pastureland and risk management system for large wild and domestic herbivore management as extensively managed pastoral livestock production systems become commercialized. To do this, Mongolia urgently needs to:

- Resolve its position on land privatisation and water resources management so investment can take place, pastureland resource exploitation can be controlled, and conflict over natural resource allocation can be resolved.
- Resolve resource and social issues, especially those related to land and water use, possession, and ownership since privatization is happening although the form of privatization is still to be decided.
- Realize that risk, and the reduction of risk as it affects livestock production, is commonly recognized as an important attribute and concern of wild herbivore management.
- Assess how pastureland management and risk reduction link with the overall objectives for large herbivore management in commercialized agricultural production systems.
- Determine the institutional needs, training needs, and hardware needs that will be required to develop and institutionalize an effective and functioning pastureland and risk management system.
- Assess how to develop or adapt technologies to improve pastureland management and planning activities, herbivore early warning systems, drought and dzud surveillance systems, and risk assessment mechanisms.

Forage Monitoring Technology

Texas A&M University has developed an innovative suite of automated technologies that address the above issues and can facilitate our understanding of, and capacity to resolve issues related to risk and resource allocation. These technologies allow the acquisition of satellite based weather data from NOAA to feed minimum/maximum temperature, precipitation and solar radiation daily into a pre-parameterized rangeland model (PHYGROW) to provide daily estimates of forage on offer to a mixed population of herbivores.

The technology relies on establishment of a series of carefully selected monitoring sites where vegetation measured from those sites are reflected in a rangeland production model. The vegetation is then characterized in terms of basal area of the grass species, frequency of the forb species and effective canopy cover of the woody species. The data is input into the PHYGROW model along with soil surface and horizon characteristics of the monitoring sites and the grazing rules derived from interviews with range users and specialists in the immediate area of the monitoring grid.

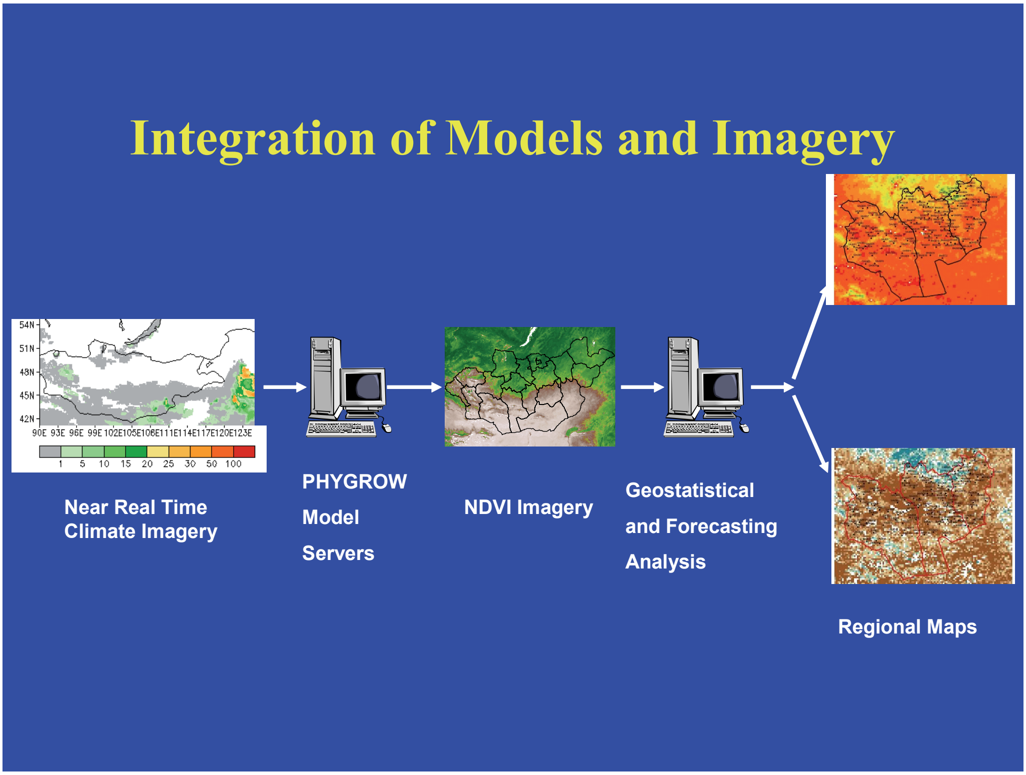

Fig. 1: Integration of near-real time imagery using geostatistical analysis to predict regional forage growth.

The computation of forage loss as a percent deviation or percentile ranking requires a geographical rich source of weather data with sufficient statistical variation to reflect a wide variety of likely forage responses in the region. A climatic surface is developed which takes known reporting stations within the county and surrounding area and splines the monthly average maximum/minimum temperature and precipitation values as adjusted for elevation and proximity to mountains and large bodies of water. A matching technique is used to assign known historical weather data with the newly created weather climate surfaces.

The associated weather is then subjected to statistical analysis to create a weather generator coefficient file for that station. Once this is completed, the surface climate values for a specific grid replace the surface climate monthly means in the station and the weather generator produces 50 years of weather data using the probability distributions of temperature and precipitation events, coupling of sequences of rainfall and likely solar radiation. This generated 50-year weather set forms the foundation for comparing current forage conditions in terms of percent deviation and percentile ranking at each selected grid location. The key to success of this technique is to locate and properly match historical weather data with the selected grid in terms of behaviour of events in a selected locale (i.e., absolute monthly average min/max temperatures or precipitation, the occurrence of ice or snow storms and their duration, the pattern of drought, etc.).

Each site is then run for the 50 years and daily percent deviation and percentile ranking is determined for each day based on a "day of year" average standing crop of forage usable by a target herbivore (e.g., cattle, sheep, goats, horses, khulan, gazelle, etc.) PHYGROW accounts for differential preferences of mixed populations of livestock and models growth of individual plant species or functional groups of species competing for resources under selective grazing.

Associated soils, grazing rules and satellite-based weather data is used to produce daily estimates of forage production, deviation from normal forage on offer and associated percentile ranking. Advanced geo-statistics coupled with NDVI greenness data is used to map areas of forage deficiencies and excesses as well as provided 90 day forecasts updated weekly.

The resulting forage standing crop as subjected to grazing density rules derived from resource users is compared with a 50-yr historically generated weather dataset for a geographic area and the percent deviation in forage on offer from “normal” and the percentile ranking determined. The predicted forage standing crop is then co-regressed with NDVI satellite greenness data corresponding to the site to predict the likely weekly forage conditions over a 90-day window updated weekly.

This same technology allows indexing of where forage conditions are relative to historical response (percentile and percent deviation from average grazed standing crops). These indices could be incorporated into forage loss insurance policies, which provide livestock producer’s access to cash in a timely manner to help stimulate early actions to mediate emerging drought. When coupled with disaster insurance associated with ice and snow in the winter and drought in summer, this policy and technology package could be integrated with other programs focused on development of markets, water, roads, and providing options to help formulate policy instruments to better protect habitat of wild and domestic herbivores.

To map forage on a regional basis, a predetermined number of monitoring sites reflecting the variety of landscapes and climate conditions are established across the selected region to help provide feedback on the emerging conditions and serve as communication node for moving information into pastoral communities. The location and number of sites is determined with experts in the region and analysis of prior response information.

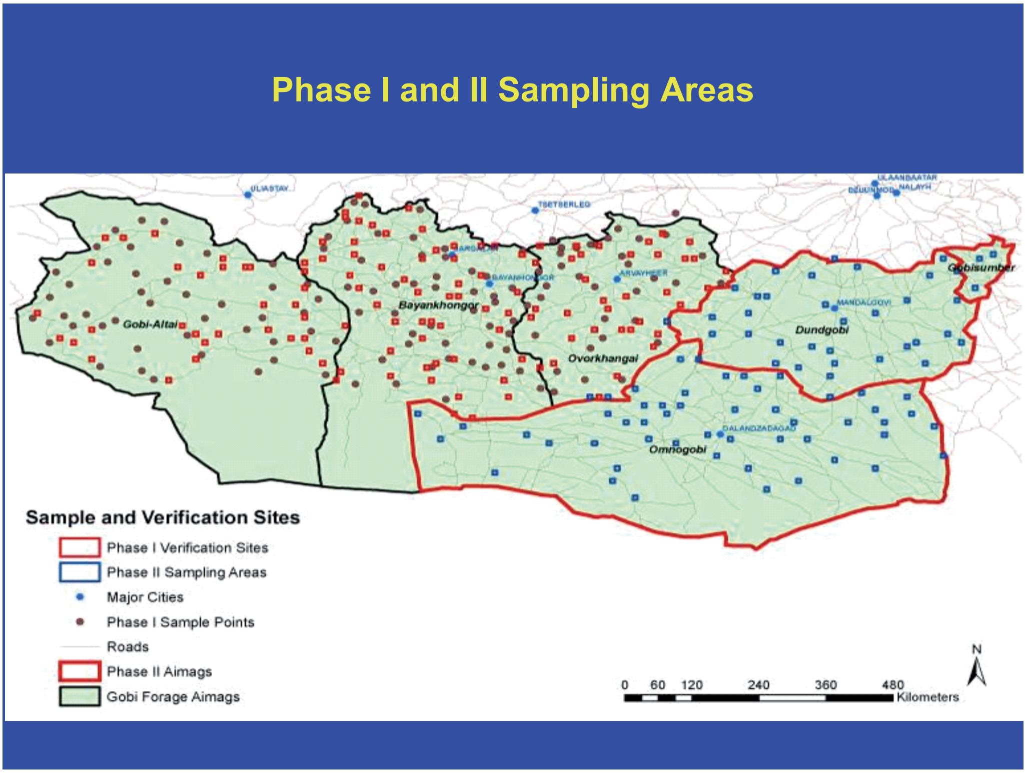

Fig. 2: Randomly selected forage monitoring sites in the Gobi Region of Mongolia.

Establishment of these sites provide information on current conditions, past conditions and their trends, and likely emerging conditions with updates every 7 to 10 days and new projections being made. Over time as the system is fine-tuned and human resource skills are established, the computerized automation technology can then be mirrored on computer systems in Mongolia without disruption of information flow.

NOAA currently places a global 4x4 km satellite weather data product that covers Mongolia on their FTP site each day. The Texas A&M University LEWS team has access to this data. Information includes daily rainfall, temperature and solar radiation. Wind, snow cover and relative humidity are other products that could be packaged. TAMU –LEWS has the skills to automate acquisition and use of this sort of data not requiring large investments in technique development.

The forecasting technique uses the ARIMA forecasting techniques in SAS with detrending and wavelet spectral analysis to condition the signal NDVI and biophysical model data prior to analysis.

To map the region's forage status, a geo-statistical technique is used to "co-krig" the relationship between predicted forage supply and NDVI values of known points and predict conditions where only NDVI data is known. The resulting map of forage supply and deviation is a provided on an 8x8 km grid for the entire region.

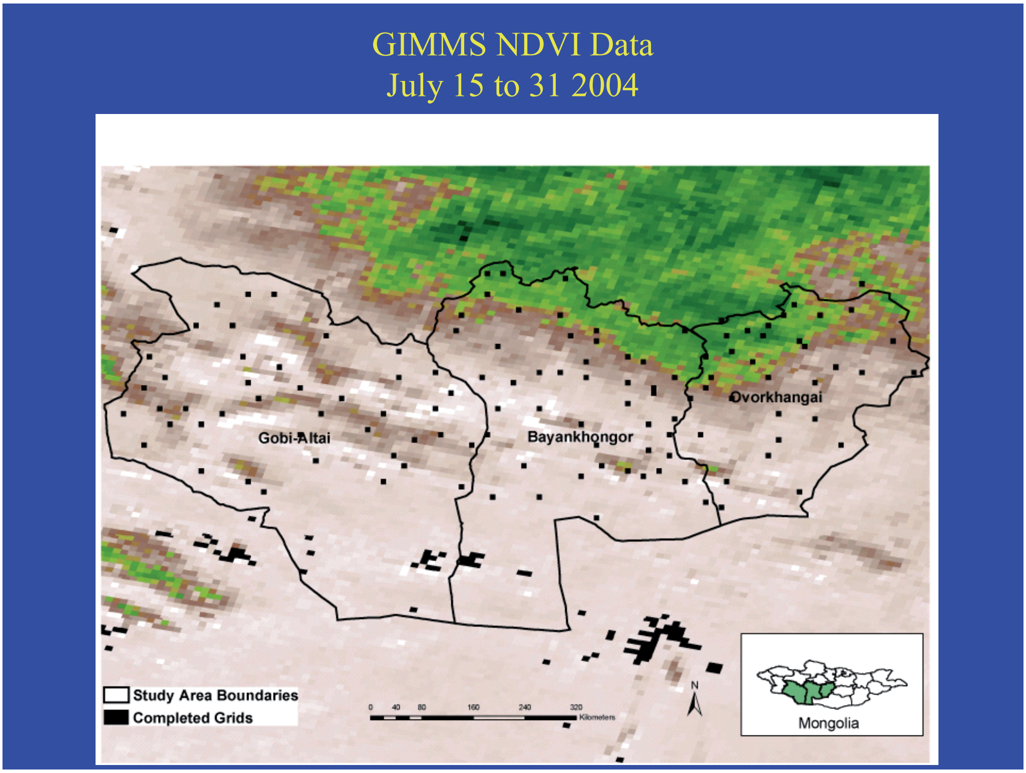

Fig. 3: NDVI image covering three provinces in the Gobi Region of Mongolia.

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Timely issuance of reports on forage conditions relative to expected long-term averages updated every 7 to 10 days with 90-day forage forecasts and projected probabilities of precipitation and temperature issued monthly would provide a new dimension to monitoring that currently does not exist in Mongolia.

Once the analysis is completed each 10 days, a web site is updated automatically and all the data from 1998 to present are made available to the public, NGO’s and other interested organizations.

The web site is http://cnrit.tamu.edu/aflews. The Center for Natural Resource Information Technology at Texas A&M University provides the analysis hub for the automation site.

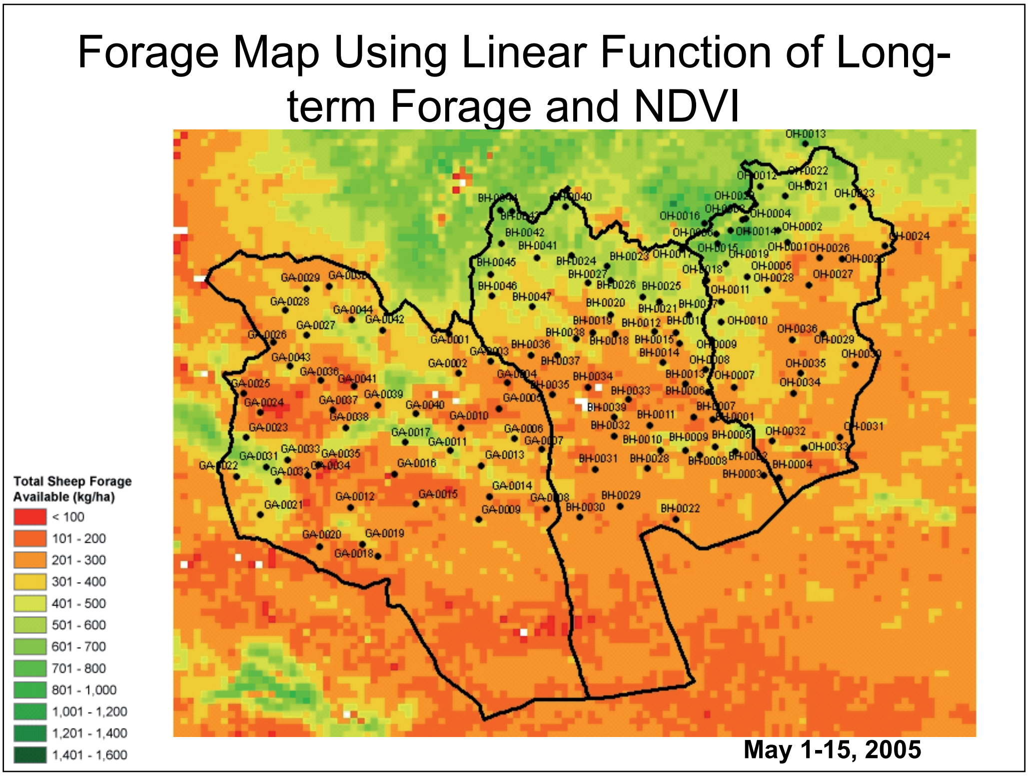

Fig. 4: Bi-weekly forage growth map produced by the PHYGROW forage forecasting model.

Nutritional Management System

Another important technology developed by Texas A&M University that should be interjected into this matrix is the creation of a NIRS laboratory that allows prediction of diet quality of free ranging large herbivores via fecal scans. Near infrared reflectance spectroscopy has been used to predict dietary crude protein and digestible organic matter of livestock in the USA, Kenya, Ethiopia, Uganda, Tanzania, Argentina, Japan, Hungary and Australia. When fecal profiling is coupled with advanced nutritional management software (i.e., NUTBAL), performance of animals can be predicted with high accuracy and least cost feed inputs determine to mediate nutrient deficiencies. The concept of monitoring herds and providing advisories to livestock producers would allow rangeland users to have a direct connection between their animals, the land and their decision making process.

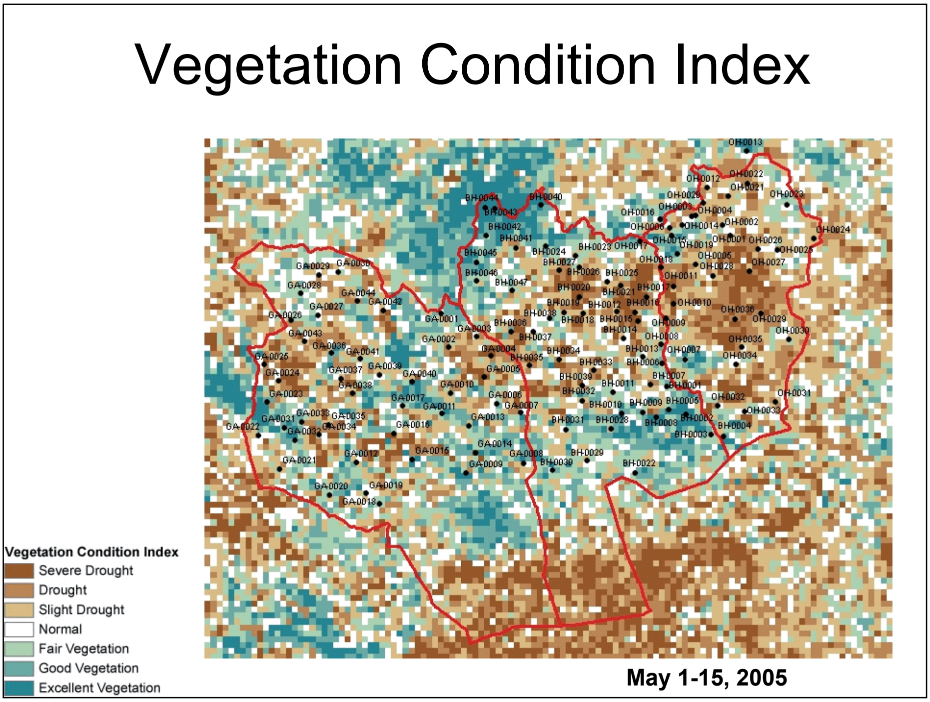

Fig. 5: Bi-weekly vegetation condition index produced by the PHYGROW forage forecasting model.

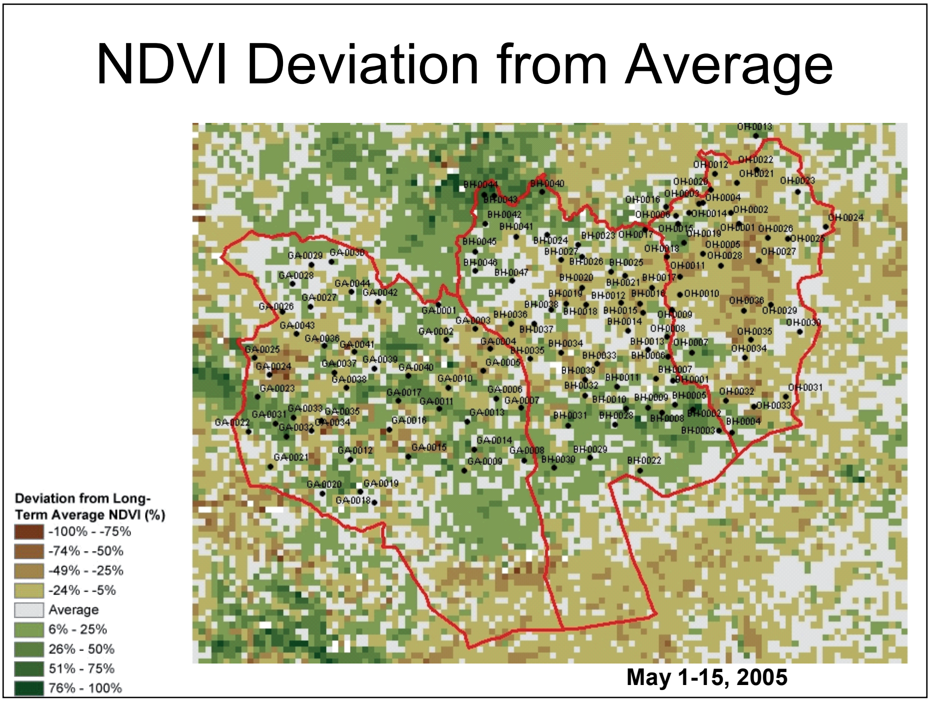

Fig. 6: Bi-weekly forage deviation index produced by the PHYGROW forage forecasting model.

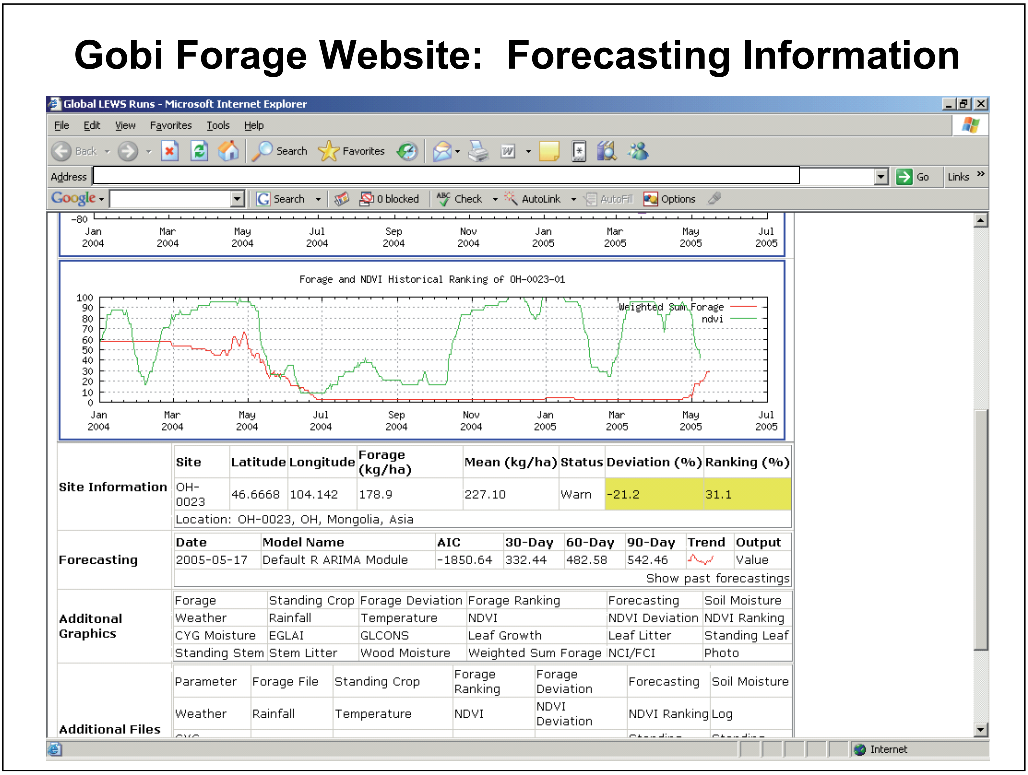

Fig. 7: Forage forecasting website.

Other mitigation strategies are needed to reduce large herbivore risk. Issues of fodder conservation and distribution schemes, water development, breeding, strategic application of concentrate nutrients for managing body condition and above all others management of stocking levels that insure that the resource is sustained and the animal's body condition is at an optimal level should be pursued within the context of this program. Careful analysis of other organizations addressing these issues must be made to insure that coordination is taking place and scare funding is applied with maximum impact.

Evaluation of Landscapes

The KRESS Modeler is a computerized multi-criteria decision-making tool developed by Oregon State University. It is the outgrowth of work that was done by a series of projects that evaluated the suitability of various locations across a landscape for use by domestic livestock. It is a software package that can take landscape parameters, determine the suitability of each cell or unit on the landscape for use by animals based upon decision-making rules, and determine the accuracy of the model or map produced based on actual observations of animals.

The general suitability of a specific location for an animal is dependent upon what the animal is doing and how well the site supplies the animal's needs. During feeding periods we would expect to find animals in areas with the highest amounts of forage. If temperatures are extreme, we would expect to see grazing animals in thermally neutral areas with greater standing forage, gentler slopes and close to water. The relationship between suitability of a location on the landscape is mediated via mathematical models (rules) that are created by researchers or managers who have extensive knowledge about a landscape and the animal species being modeled.

Once a model is built, it can be saved and applied to a new pasture or landscape. We have programmed a model evaluation routine that uses data gathered from animal GPS collars. The GPS information is read and, if desired, a random selection is taken from it. The frequency of animal presence in each cell on the landscape is determined and compared to a random distribution model using a relative operating characteristics (ROC) analysis.

The KRESS Modeler was programmed in Visual Basic and C++. It uses raster landscape information in an ASCII Raster Format. Users input data about the environment of the pasture or landscape as: 1) Digital Elevation Model (DEM), 2) Soils Classification Maps, 3) Range Site Maps, 4) Vegetation Maps, 5) Distance from Water, 6) Distance from Trails, and 7) Point data for attributes such as temperature or wind speed. The KRESS Modeler program has the capability to derive data layers such as slope and aspect maps from a DEM and to attribute class layers such as standing crop from range site maps. Interpolation between point data can be done either as a single set of values to produce a single map or as a series of maps generated on time-steps from sequential data collected by data loggers at fixed locations.

Once data has been entered into the computer, it is scaled so that all factors have the same data range. Data scaling allows us to think of each factor in terms of its relative importance for influencing animal spatial positioning. For example, forage standing crop would be ranked from 0 (the lowest amount existing on a cell in the pasture) to 255 (the highest amount existing on a cell in the pasture). Slope likewise would be ranked from 0 (the shallowest slope present) to 255 (the steepest slope present). Once scaled these two factors could be evaluated as to their relative importance in determining herbivore position.

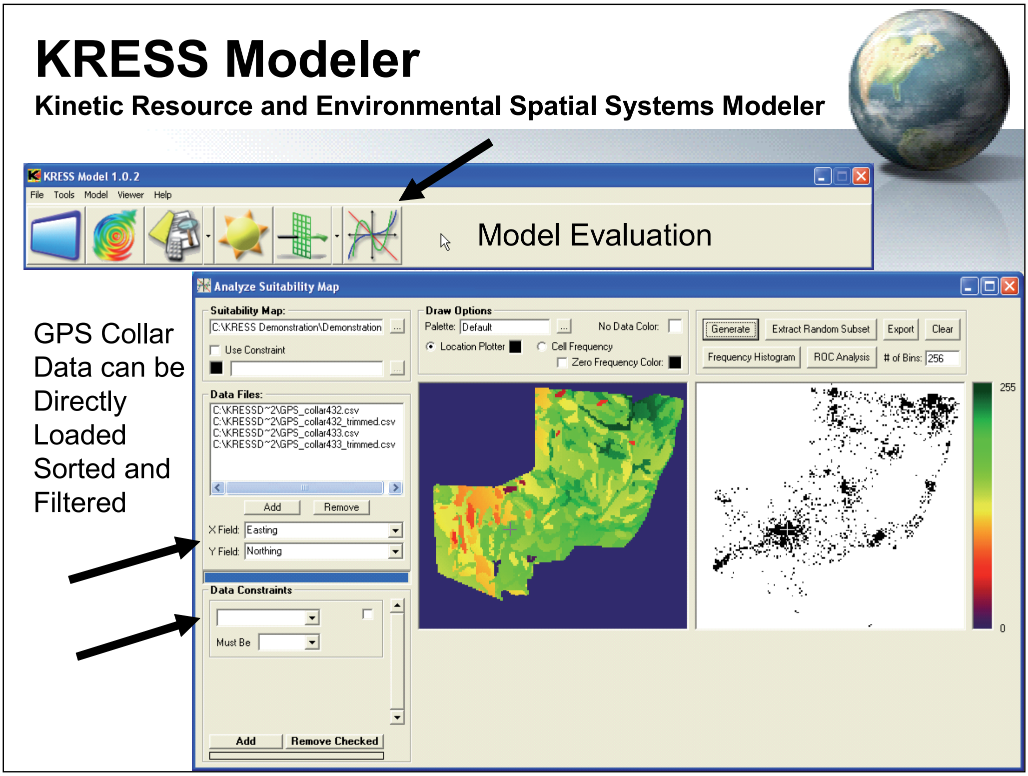

Fig. 8: Animal movement and vegetation site data used by the KRESS modeler.

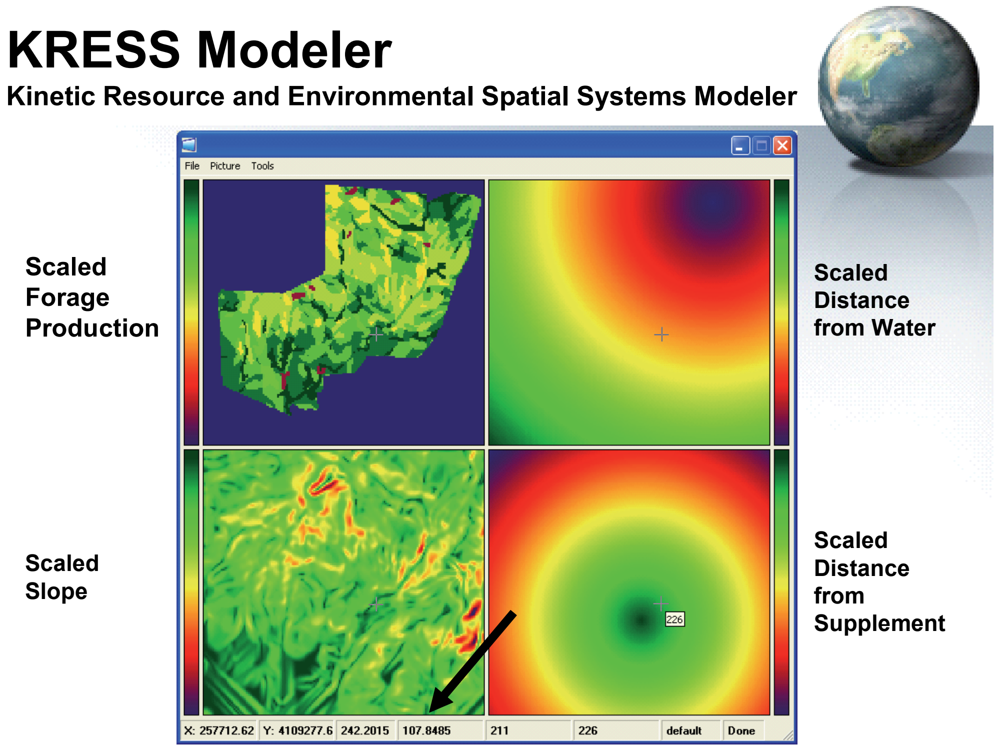

Fig. 9: Scaled output information generated by the KRESS modeler.

Once data layers of importance have been prepared and scaled the user can build one of four model types: 1) single pass linear, 2) single pass non-linear, 3) time-step linear, or 4) time-step non-linear. Below is an example of a single-pass linear model.

We believe that the KRESS Modeler can be a useful tool for identifying and evaluating factors that influence animal distribution on landscapes. Because it quantifies desirability of a location contrasted with other locations in a pasture, we think that it can also be used to predict how large herbivore distribution patterns change when the position of water, supplement and other factors are changed on a rangeland.

Application to Large Herbivore Management

The importance of the Gobi environment to the conservation of Khulan and other threatened wildlife is undeniable. At the present time, Mongolia is anticipating development of a commercialized agricultural sector that could easily cause greater intrusion of human activities in the Gobi environment than current pastoral livestock production. Development of other sectors of the Mongolian economy, especially mining and road and railroad construction, could also impact environmental security in general and habitat needs of the Khulan and associated wildlife in the Gobi environment in particular. Natural weather factors such as drought and severe winter weather, combined with anthropomorphic factors, can substantially increase conflict between humans and khulan. Water in the Gobi Desert Region of Mongolia is a critical resource for human occupation, livestock production, and a key component of wildlife habitat.

Ensuring sustainable khulan populations requires additional knowledge on basic khulan ecology and developing meaningful and pragmatic management recommendations to protect important khulan habitat, mitigate khulan-human conflicts, and guarantee the long-term survival of the species in Mongolia. The emerging near-real time technologies presented can help clarify to what extent the khulan competes with domestic livestock for water, forage, and habitat. On the basis of these findings, habitat needs of khulan and livestock can be determined, habitat improvement can be identified, and better management of both wild and domestic herbivores can be initiated.

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