GOBI FORAGE – Forage Monitoring Technology to Improve Risk Management by Herders in the Gobi Region of Mongolia

Narrative Summary

The GOBI FORAGE project represents an expansion of the existing LINKS/GLCRSP project which is applying forage and animal monitoring technology developed in the LEWS phase of the program to pastoral communities in another country: Mongolia. The project addresses rural business development by adapting proven LEWS/GLCRSP monitoring technologies so that they can be used by Mongolia's livestock producers. These technologies will provide timely information on forage conditions to increase lead time for making risk mitigation decisions by herder groups and policy makers. Nutritional profiling to assess and manage livestock performance will be integrated with the forage monitoring technology via other funding sources (Mercy Corp-USDA) to enable herders to make business decisions that enhance profitability within an array of livestock enterprises. Formation of herder alliances for marketing will be pursued in collaboration with Mercy Corp. The USAID Mission supported GOBI II initiative run by Mercy Corp will form the umbrella under which this project will function.

Research

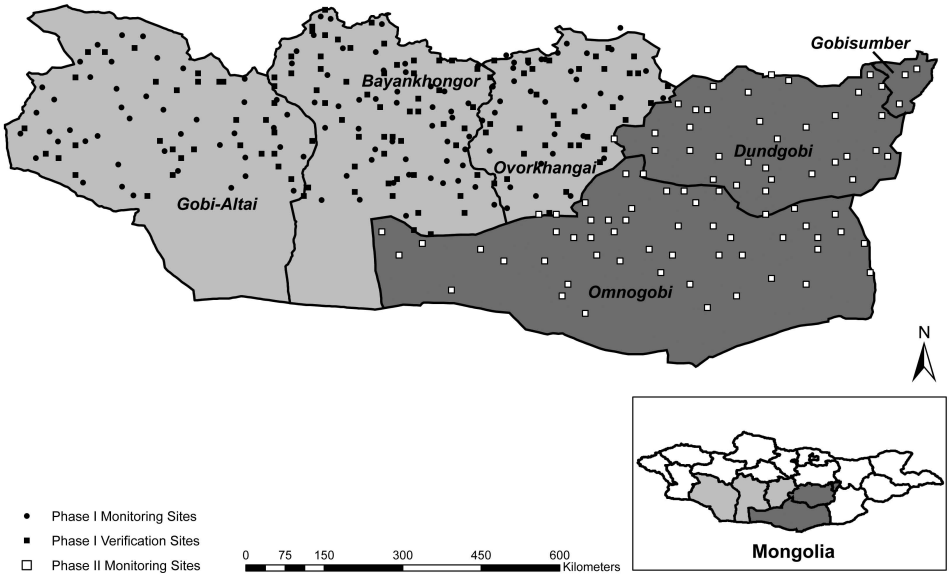
Activity One: Infusion of Forage Monitoring Technology

Problem Statement and Approach. Drought and winter disasters represent a major risk confronting herders in Mongolia. During the period from 1999 to 2001, as much as 35% of the Nation's livestock have been lost to these two disaster events. To help address these challenges to livestock production in Mongolia, a livestock early warning system is being pursued. Our objective is to develop a forage monitoring system that provides near-real time spatial and temporal assessment of current and forecasted forage conditions for Mongolia livestock producers.

Progress. After completion of training in use of the PHYGROW and LEWS technology, two trips were conducted, one in June and the other in August, where the USA team and Mongolian team conducted field verification measurements of vegetation and established a series of new monitoring sites in the Dundgobi, Gobisumber, Omnogobi aimags with new verification sites added in. To date 127 monitoring sites have been established in the Gobi Altai, Banyonhongor and Uvurhangai aimags along with an additional 120 randomly selected verification sites (Phase 1 sites, Figure 1). A subset of the verification sites were monitored during this fiscal year. The remaining sites will be monitored during the next fiscal year. In the Dundgobi, Gobisumber, Omnogobi aimags, 90 sites have been established (Phase 2 sites, Figure 1). All of these sites were characterized during June to September 2005.

A web site has been established at http://glews.tamu.edu/mongolia that provides access to the model output for those sites that are fully functional and tested. Several new vegetation condition and forage condition indices have been tested as well as linkage to the CMORPH rainfall data from NOAA FEWS NET. The vegetation condition indices have been tested include the Vegetation Condition Index (VCI) and the Forage Condition Index (FCI). The VCI is an index derived entirely from Normalized Difference Vegetation Index (NDVI) data. The current NDVI is scaled according to the historical minimum and maximum for a pixel and the index reflects where the current pixel falls along this scale. Current pixels that are scaled very close to the minimum are defined as severe drought. The FCI

Figure 1. Location of the monitoring sites in the Phase I and Phase II aimags in the Gobi Region of Mongolia. Phase I indicates sites initially monitored in fiscal year 2004 and Phase II sites are sites monitored in fiscal year 2005.



is calculated using the same logic as the VCI and values of livestock forage that fall close the historical minimum are considered severe drought.

Forage mapping using geostatistical methods has been conducted for the Phase 1 sites. Initial mapping using cokriging was not successful due to problems with low forage conditions during the early part of the growing season, so alternative mapping techniques were examined. The most promising method was a pixel based regression technique built from the time series of NDVI and forage for pixels containing the monitoring sites. As the growing season progressed, statistics for cokriging improved and this method was used. However, another problem was identified in that the CMORPH rainfall data appeared to be over predicting rainfall in portions of the region, especially in the higher elevation areas. We are currently working with the Mongolia Institute of Meteorology and Hydrology and NOAA to better understand this issue and to resolve it using bias correction techniques.

Activity Two: Infusion of the NIRS/NUTBAL Nutritional Management System

Problem Statement and Approach. In addition to drought and winter disasters, herders in Mongolia have no information on nutritional deficits or opportunities for inputs of supplements to help them transfer from a subsistence to entrepreneurial system of production. The major limitation is the lack of monitoring technology for them to make this transition to understand how to best graze forage resources and input strategic nutrients. Our specific objective for this activity is to develop a nutritional monitoring system for sheep, goats, cattle, yak and horses that provides assessment of nutritional balance, changes in body conditions and optimal fodder interventions for Mongolia livestock producers.

Progress. This activity was funded by monies provided to Mercy Corps via USDA Wheat Monetization funds. Our proposed study area is still under advisement from Mercy Corps and USDA, but discussions have focused on working with a private NGO on intensive dairies north of Ulaanbaatar and with cattle, sheep, goats, horses and yak in the region north of the aimags associated with the GOBI forage region. We plan to have some overlap with the GOBI Forage regions.

We have initiated testing a portable NIRS spectrophotometer from Ocean Optics both laboratory and filed settings, and a potentially

portable system from Perten in the laboratory. Mercy Corps has agreed to purchase a second Ocean Optics NIRS systems to help us cover more geography with the portable NIRS lab concept. Sheep calibration equations were successfully re-created on both the Ocean Optics (CP: RSQ = 0.97, SEP 1.20, DOM: 0.92, 1.25 respectively) and Perten (CP: RSQ = 0.97, SEP 0.77, DOM: 0.87, 1.24 respectively) instruments.

The NUTBAL PRO software package's multiple language database has been provided to the Mongolian team and is translated so that the package can be used in the Mongolian language. The material has been incorporated into an updated version of the metric NUTBAL PRO software that was successfully tested in the LEWS/GLCRSP project in east Africa.

Activity Three: Forage Monitoring Information Delivery and Outreach

Problem Statement and Approach. Develop an information and communication infrastructure and analysis delivery system to provide herders with information on current and forecasted forage conditions that will assist them to make timely and specific management decisions in the Gobi Initiative Project region of Mongolia.

Progress. We initiated talks with Mercy Corps Rural Business News personnel and mapped out how we are going to deliver the GOBI forage information to the herder groups. A DVD with 3, 5-minute segments on the nature of disasters facing Mongolian herders, the GOBI forage technology package and herder alliance has been designed and filming started. We were able to work with the Mercy Corps information group to prepare the design for distribution and narration of the DVD that will be in English and Mongolian. Mercy Corps is primarily responsible for this activity with GOBI Forage assisting in data flow and data presentation issues.

We also met with personnel in the Mercy Corps Arvaiheer office in the Overhungai aimag. These personnel will be conducting training and outreach activities for Gobi Forage products within this aimag during the coming fiscal year. A training program was outlined and a plan of implementation was discussed. Design of maps and situation reports was discussed so that templates could be built for use by the aimag offices in disseminating the information to local herders.

Activity Four: Nutritional Monitoring Information Delivery and Outreach

Problem Statement and Approach. Develop an information and communication infrastructure and analysis delivery system to provide herders with information on nutritional status of livestock and potential interventions to meet production goals.

Progress. The outreach program was designed to allow integration with Mercy Corps and their work in some of the more productive livestock regions of Mongolia. Dr. Udval Gombosuren, was provided training in outreach issues with GANLAB during her training at Texas A&M University. She translated several of the information sheets that were felt useful for communicating the NIRS/NUTBAL system to herders.

Activity Five: Linking the GLCRSP Technology to the Herder Associations

Problem Statement and Approach. Linking the GLCRSP technology to the herder associations, which are seen as viable structures, to insure institutionalization of both the forage and nutritional monitoring technology in Mongolia after the end of the Project.

Progress. A 15-minute DVD video has been designed, filming completed and first draft finished which incorporates three topics covering the nature of disasters facing Mongolian herders, the GOBI forage NIRS and early warning technology and the formation of herder marketing alliances. We were able to acquire the services of Dr. Dennis Sheehy who worked with Mercy Corp to design the video and initiate the filming process. GOBI Forage will be a member of a team headed by Mercy Corps that will be working on design and functionality of these alliances.

Gender

The project is organized to allow a good mix of well experienced scientists and young emerging scientists. The two project officers coordinating the forage and nutrition component are highly skilled women in their respective fields, reflecting a gender mix typical of professionals in the region (two older women scientists and one young male scientist). Over half of the outreach officers are women which work closely with all members of the participating herder groups.

The technology being delivered to the Mongolian herders will be supplied via radio, newspaper, and situation reports that will allow uniform accessibility for all gender and age classes. Training and outreach will be designed to insure that both male-headed and female-headed households are targeted since the number of female-headed households appears to be growing in Mongolia. The information disseminated by outreach activities will attempt to be gender responsive so that the needs of both men and women head of households will be addressed.

Working with Mercy Corps communication and outreach group, GOBI Forage will conduct a rapid appraisal of how the information being generated and delivered to the herder groups is used by the families and determine who in the family acts upon the information and the dynamics of the gender and age relationships so that dissemination and outreach products can be tailored to have the greatest impact across genders and age groups.

Policy

The Gobi Forage project is part of a large initiative of USAID called the GOBI II initiative which has key government organizations intertwined in the project. The herder associations that will be an integral part of the project will provide a direct feed back to the best design of information programs, interventions and government action resulting from the warnings provided to the communities. Policy makers of each of the critical institutions in the Ministry and the key Universities are involved in the overall planning process of the GOBI II project and are part of the information flow process in the GOBI Forage project. Our in-country project coordinator Mr. Sean Granville-Ross, works closely with the USAID Mission, the Ministry of Agriculture and the World Bank Sustainable Livelihoods program that directly advises the government on policy issues in the country insuring a direct conduit into government for policy relevant issues emerging within the project.

Outreach

Mercy Corp has an extensive outreach infrastructure as part of the Gobi Initiative with weekly radio shows, monthly newspapers and monthly television shows. They are planning on using our computer derived reports to move them into the communications network. During the past fiscal year, Texas A&M scientists met with Gobi Initiative personnel to discuss the best methods for displaying Gobi Forage output and maps and to develop templates for situation reports and maps. Discussions were conducted on the development of training manuals for training of herders in the use of Gobi Forage information in daily decision making for livestock. Discussions were also conducted on how GOBI Forage information will be incorporated into weekly news items reported in both the radio shows and newspapers currently used by the Gobi Initiative.

As reported, a video has been designed, filming completed and first draft finished which incorporates three topics which include the nature of disasters facing Mongolian herders, the GOBI forage NIRS and early warning technology, and the formation of herder marketing alliances. This video will be used to introduce herders to the need for technology like that being used by Gobi Forage, how the technology can be used to reduce effects of drought and cold winter (dzud) conditions on livestock, and how herder alliances could be used as a conduit for livestock decision making and marketing.

A Gobi Forage website (http://glews.tamu.edu/mongolia) has been developed where results and maps can be viewed along with general information about the project. The site has been partially translated into Mongolian and the remainder of the translation will be completed in the coming year.

Developmental Impact

Environmental impact. Early marketing and movement decisions resulting from reactions to the livestock early warning system and ultimate organization of marketing alliances will transform grazing pressure to reduce the impact on stability of ecosystems and retention of higher order grasses in these extensive production systems. Dissemination of information about forage amounts on a regional basis will provide more knowledge about where animals can be moved during drought or dzud conditions, thus reducing localized overgrazing. This in turn will assist in reducing soil erosion and improve rangeland recovery after drought.

Currently, very little information exists among herders about the actual carrying capacity or potential diet quality of the land where they graze. There has been an increased tendency since the droughts and dzuds of 1999 to 2001 for herders to increase the numbers of animals in their herds as a hedge against animal losses in the event of future droughts and dzuds. Informed stocking rate and diet quality/animal nutrition decisions by herders could be used to maintain fewer animals of higher body condition going into drought or winter, thus reducing death loss and increasing individual animal productivity while providing for greater ecological sustainability. Knowledge of forage quantity and quality are the foundation for identifying the economic threshold where individual animal versus unit area of land production meet. The information from Gobi Forage, along with training, outreach, and formation of herder alliances will help herders understand that this strategy of over stocking as a hedge against drought or dzud is not sustainable and can lead to long-term degradation of the system.

Contributions to U.S. agriculture. The technology being applied involves the first use of the CMORPH weather satellite technology for extensive grazinglands. If successful, this technology can be transferred back to the USA to serve the livestock industry by improving the emerging livestock early warning system in the USA. The CMORPH precipitation and US Air Force SNOW/ICE depth data also has application in USDA Risk Management Agency risk management tools for the ranching industry. A proposal will be submitted to USDA RMA to determine the effectiveness of the CMORPH data for biophysical indexing stocking rates. The Portable NIRS technology developed in this project could be used to provide rapid, near real-time monitoring tools for animal nutrition and rangeland health.

Agricultural sustainability. One of the major problems facing livestock production is the flight from extensive grazinglands to urban centers and large interest in peri-urban livestock agriculture. At issue is reduction of herder risk. The Mongolian LEWS system is being designed in such a way that the data is acquired and reported through the existing communication systems with limited continuing costs. TAMU has committed to a near-real time computing capacity to service decision making with fully automated computational systems that have very low maintenance needs. This has proven to be a very sustainable form of technology delivery thus allowing the host country to pursue outreach and capacity building. Organized marketing coupled with integration of new risk management tools, should offer a viable mechanism to allow herder groups to raise their livestock in a more sustainable manner and yet protect the fundamental production capacity of the resource.

Contributions to the host country. Since 1999, Mongolia has experienced a series of droughts and severe winters that has lowered the national livestock herd by approximately 30%. During this same period, the USAID funded GOBI Initiative Project managed by Mercy Corps has been actively forming herder cooperatives in six aimags. These cooperatives will act as a legal entities and will conduct business and financial transactions with the goal of improving enterprise diversification and augment existing enterprises. This will enhance their ability to sell products in a market chain and improve the business climate for herder families. One of the greatest sources of risk to livestock herders in Mongolia is drought, particularly in the spring, and winter ice/snow disasters. The technology developed by the GOBI Forage Project in the Global Livestock CRSP, should provide early warning of emerging short falls in forage supplies and development of areas with extensive snow coverage and depth to

create crisis situations where government can focus energies on priority areas where forage supply was low going into winter and ice/snow conditions are too extensive to escape their effects through movement of livestock. Simultaneously, the scientists in the GOBI Forage project will be building the capacity within key institutions in Mongolia to allow assessment of animal nutrient balance for the first time in remote regions and explore least cost feeding interventions via the use of fecal profiling technology with near infrared reflectance spectroscopy (NIRS) and computer simulation models. When coupled with the proposed Marketing Alliance organizations these technologies could strengthen the livestock sector and help spawn development of new industries such as processed feeds. Based on a PRA conducted prior to implementation of the project, we interviewed 10 herder groups involving over 120 families and over 200 individuals to determine if they would find the information generated by the GOBI Forage Project useful to their decision making. In all cases, the herder groups we interviewed identified the need for early warning and improved nutrition as major decision support needs in their respective grazing areas, regardless of the ecosystem that we were visiting.

When fully implemented, a large majority of the grazinglands will be covered by the GOBI Forage system and information will reach 85% of the herder community in the country via the rural business news network already in place.

The primary impact indicator will be the number of people aware of the early warning system and a measure of how they have changed their management practices to improve their financial status. Mercy Corps has collected an excellent baseline survey of all herders participating in GOBI II initiative and we will build upon this survey to quantify the impacts or contribution of the GOBI Forage project to the well being of the herders in the study. In the long term, we will use the number of herder alliances formed and length of time they are active as another measure of impact.

The Texas A&M team has trained two Mongolian scientists in the use of the Gobi Forage models and tools. This was the first phase of the program where scientists were brought to the US for advanced training and would then go back to Mongolia to train and mentor others in the use of the models and tools. Training of these two scientist and several others will continue during the next fiscal year. The Research Institute of Animal Husbandry and the World Bank Global Environmental Facility Lake Hovsgol Project have expressed interest in having personnel from their institutes travel to the US (at their expense) for future training sessions. We have also had discussion with the Director General of the Research Institute of Animal Husbandry for an internship program where undergraduate students from their program would work as summer interns to learn field sampling techniques for the forage sampling activities and to train in the use of NIRS for livestock diet quality analysis.

A drying oven and sample mill is being sent to the High Mountain Research Station in Ihktamir to facilitate cattle and yak feeding and NUTBAL validation trials in that region. These trials will be implemented with both station personnel and animals and with cooperation from local herders.

Linkages and networking. The primary linkages in this project is with the Mercy Corps, World Bank Sustainable Livelihoods Program, the USAID Mission, USDA, the Research Institute of Animal Husbandry of the Mongolia Agriculture University, the Mongolia Institute of Meteorology and Hydrology, and the World Bank Global Environmental Facility Lake Hovsgol Project.

Texas A&M and Mercy Corps currently have an MOU with the Research Institute of Animal Husbandry to conduct feeding trials for the NIRS equation development. The Institute through this arrangement also provides housing for a drying oven purchased by Gobi Forage as well as the lab facilities for the portable NIRS development.

In an August meeting with the Mongolia Institute of Meteorology and Hydrology an agreement was made to develop an MOU for sharing of forage production data collected by Gobi Forage and rainfall data collected by the Institute. The forage data will allow the Institute to have additional information for their annual assessment of livestock forage production for the country and the rainfall data will allow Gobi Forage to examine correspondence of the CMORPH rainfall data with

data collected at soum centers in the study area.

Collaboration with international centers and CRSPS. There are no major international center activities in the country. However, we will be collaborating with the SANREM CRSP on modeling interaction of forage conditions and potential disease spread between domestic livestock and wildlife, using the output of the GOBI Forage LEWS technology.

Meetings were held with personnel from the Bank Global Environmental Facility Lake Hovsgol Project to discuss areas of collaboration. The Lake Hovsgol project is collecting a large array of vegetation, soil, and climate data as part of their assessment of the effect of climate change on vegetation and herders in the Lake Hovsgol area of Mongolia. Although this project is outside of the region of study for Gobi Forage, the data being collected by the Lake Hovsgol project can be useful for further validation of the models being used in Gobi Forage. An agreement has been made to share data and to pursue avenues for funding a collaboration between the two projects.

Other Contributions

Support for free markets and broad-based economic growth. This project is directly targeted toward reducing risk and forming new marketing structures to help herders move to a free-market, entrepreneurial form of livestock production.

Contributions to and compliance with Mission objectives. The USAID Mission is a critical partner in this project and we are addressing their specific needs for the Gobi II Initiative via coordination with Jeff Goodson.

Concern for individuals. The technology being developed, outreach programs and improved marketing alliances will lead to opportunities for individuals to pursue personal development and accumulated of wealth that is independent of government mandates.

Support for democracy. Although GOBI Forage is not explicitly addressing democracy, the formation of marketing alliances allows a very local form of self-governance to emerge where they can market their goods and services as a unit independent of government.

Humanitarian assistance. Provision of early warning and affording herders and their families an opportunity to react to life threatening events can be considered a near-real time "humanitarian assistance" program.

Leveraged Funds and Linked Projects

The value of leveraging for GOBI Forage during 2005 was USD $765,339.

Dept Homeland Security – 503056, Resource Informatics for Defending Against Foreign, Animal & Zoonotic Diseases, Jerry Stuth, 10/2004-9/2005, $524,662.

USDA NRCS – 503093, Grazingland Spatial Analysis Tool, Jerry Stuth, 10/2004-9/2005, $100,000.

Kelleher Professorship, Resource Informatics for Ranching, Jerry Stuth, 10/2004-9/2005, $ 12,000.

Texas A&M University, Ann Zhang Stipend - Enhance Phygrow, Jerry Stuth, 10/2004-9/2005, $ 13,677.

Mercy Corps, Enhanced Nutritional Management For Herders in Mongolia, Jerry Stuth, 10/2004-12/2005, $115,000.

Training

Non-degree

Training in use of IPAQ GPS, ARCPAD and field sampling for PHYGROW, June 10-17, 2004 in Ulaanbaater, Mongolia. Facilitated by Doug Tolleson and Jay Angerer. Attended by 2 participants (2 female).

Training in conduct of diet-fecal pair studies, August 2005 in Ulaan Baator and Ikhtamir Mongolia. Facilitated by Doug Tolleson. Attended by 1 female participant.

Collaborating Personnel

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Publications

Kidane, N. 2005. Fecal Near-Infrared Reflectance Spectroscopy Calibrations for Predicting the Diets Quality and Intake of Donkeys. Ph.D. Dissertation. Texas A&M University, College Station, TX.

Tolleson, D.R. and J.W Stuth. 2005. Near infrared spectroscopy of feces to predict diet quality in grazing animals: Development of a portable system. Proceedings of the XX International Grassland Congress, Dublin, Ireland

Angerer, J.P., Stuth, J.W., Tsogoo, D., Tolleson, D., Sheehy, D., Gombosuren, U., and Granville-Ross, S. 2005. Forage Monitoring Technology to improve risk management decision making by herders in the Gobi region of Mongolia. Proceedings of the XX International Grassland Congress, Dublin, Ireland

Jama, A.A, Tolleson, D.R. and J.W Stuth. 2005. A decision support system for monitoring livestock diet quality and performance: Verification Study on Cattle, Adami Tulu, Ethiopia. Proceedings of the XX International Grassland Congress, Dublin, Ireland

Abstracts and Presentations

Tolleson, D.R. and J.W. Stuth. 2005. Nutritional monitoring of grazing cattle: Application at the ranch, regional, or national scale. Abstract of paper presented at the Society for Range Management Meetings, Fort Worth, Texas.

Angerer, Jay. 2005. GOBI FORAGE: Forage Monitoring Technology to Improve Risk Management by Herders in the Gobi Region of Mongolia. Mongolia Institute of Meteorology and Hydrology, Ulaan Baatar, Mongolia.

Angerer, Jay. 2005. The GOBI FORAGE Project. Mongolia Ministry of Agriculture, Ulaan Baatar, Mongolia.

Tolleson, D.R.; Stuth, J.W. 2006. Near infrared reflectance spectroscopy of fresh feces and plant tissue under field conditions. Society for Range Management meetings, Vancouver, BC.

Dittmar R., Tolleson D., Prince S., Banik K, Gallino J. Gombosuren U., and Stuth J. 2006. Crude protein of diet and feces in goats: Forward and reverse process prediction via near infrared reflectance spectroscopy. Journal of Animal Science 84 (Suppl. II).

Li H., D. Tolleson, J. Stuth, K. Bai, F. Mo, S. Kronberg. 2006 Fecal near infrared reflectance spectroscopy to predict dietary protein and digestibility of sheep. (Small Ruminant Research, In Press).

Tolleson, D.R. 2005. Principles and Practices of NIRS in Range and Animal Sciences. Research Institute of Animal Husbandry, and State Agricultural University of Mongolia. Ulaan Baatar, Mongolia.

Tolleson, D.R. 2005. Principles and Practices of NIRS in Range and Animal Sciences. Research Institute of Animal Husbandry, High Mountain Research Station. Ikhtamir, Mongolia.

Tolleson, D.R. 2005. Portable NIRS Software Development for Natural Resource Applications. Huston-Tillotson University, Austin, Texas.

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