Final Report

Title: Drought Prediction Model Development and Dissemination in Wyoming

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Abstract:

A useful predictor of forage yields for the upcoming growing season has been lacking for Wyoming and this region. Available data from three long term sites where native forage yields had been harvested annually were analyzed for the relationship of the yield to seasonal precipitation. Realizing that precipitation zone, elevation, and ratio of cool to warm season grasses might make a realistic early season predictor unlikely, 19 sites around the state in a variety of regions were established to provide the infrastructure for the development of locally realistic predictors. As this effort was started during a drought and state government realized that there was no relevant soil moisture information, the Wyoming Dept of Agriculture and Governor's office funded the installation of soil moisture monitoring equipment at all the sites of forage yield sampling.

The optimum predictor of forage yield from the highest elevation site was precipitation during one week in April. Subsequently lower elevation sites had windows of precipitation that were longer and started earlier, running from mid March into June. These sites we hypothesized to thaw and start growing earlier. They had more warm season grasses that require warmer temperatures to grow. A generalized model for the state may not provide a sufficiently early date with a reliable predictor.

Problem and Research Objectives:

Timely, locally relevant, within year drought prediction tools for each major land resource area within Wyoming were not available. The few sites with existing data were not developed or extent of their geographic relevance examined. The overall goal of this research was to develop a timely, locally relevant, within year drought prediction tool for each major land resource area within Wyoming, focusing on the relationships of precipitation variables and annual forage production on rangeland by accomplishing the following objectives.

1. Cooperatively with CES and land management agencies, establish herbage yield and quality measurement sites representative of the predominant soils and precipitation pattern/amounts in major land resource areas in Wyoming and continue sampling the existing long-term forage production harvest site near Saratoga.
2. Locate and access existing annual forage production data from agency files within Wyoming.
3. Obtain and summarize relevant precipitation records for reporting stations nearest to vegetation sampling sites.
4. Analyze relationships of monthly and seasonal precipitation with annual peak standing crop forage yields and quality.
5. Provide cooperators with sampling and analysis tools for each to continue to strengthen predictive capabilities for their site.
6. Widely disseminate to the broad constituency of land managers and users in Wyoming, the most useful drought prediction methods resulting from this study.

Methodology:

Cooperating agencies were canvassed concerning volunteering to establish vegetation production sampling sites in different land resource areas in Wyoming near their weather site or existing weather recording stations. Inquiries were made of NRCS, CES, CD's, BLM, ARS, and USFS.

Existing sources of long term vegetation production/weather records were sought. These included those from Cheyenne, USDA-ARS-HPGRS and records of Natrona County collected by BLM. A 17 year record of productivity and weather data from a site near Saratoga was continued.

Simple linear regression analysis for each of the three sites with long term data was used iteratively to examine all possible combinations of precipitation summed over date intervals within 1 January to harvest date to discover regressions (step 1 models) with slopes greater than "0" . Coefficient of correlation, r 2, was noted for each to indicate date intervals with highest prediction for that site. A second step involved validating these step 1 models with data from the other locations around Wyoming. The precipitation summed over the date interval in the model was used to predict forage yields. The output of this procedure was correlated with observed values to discover those step 1 models with outputs correlated to the observed values. Those step 1 models with slopes greater than "0" when correlated with observed data were referred to as step 2 models. In the third step, the date intervals were converted to categories of short, medium, and long intervals occurring early or late in the year relative to the forage harvest date. Step 2 models were used with these date categories to predict herbage yields. Those models with relatively high r 2 when the output was correlated with observed values from validation sites were categorized as step 3 models. In step 4, the step 3 models were examined for reliance on a single data point, linearity, and equality of variances of residuals. In step 5, those models passing step 4 were sequentially examined for stability by removing each data point in turn and determining if the regression slope remained significantly greater than "0". The five models passing the step 5 test were retained.

An analysis goal was to identify a weather variable existing early enough in the year for livestock producers to respond to predicted forage production by making relevant stocking level adjustments before financial hardship or resource damage are probable. Results will be disseminated through the CES web site and county offices statewide. Other print and visual/audio media will also be used. The Wy State Climatologist will utilize model results to publish a map of projected forage yield categories.

Principal Findings and Significance

A graduate assistant in Renewable Resources has conducted sampling and analysis duties. The student funded by this project will be graduating with an MS this year in December. Additionally five Renewable Resource undergraduate students have participated in field sampling.

A major thrust of this research was to establish cooperatively managed forage yield data collection sites in major land resource areas (or ecoregions) broadly distributed within Wyoming. These regions included 10-14" ppt. Southeast High Plains, 15-17" ppt. Southern Plains, 10-14" ppt. Northern Plains, 15-19" ppt. Blackhills, 5-9" ppt. Bighorn Basin, 5-9" Wind River Basin, 7-

9" ppt. Green River/Great Divide Basins, and two of the several 10-14" ppt. Foothills zones in western Wyoming.

An opportunity developed because of funding (approximately $20,000) from Wyoming Dept of Agriculture, the Governors Office, BLM, and USFS to augment the vegetation sampling sites with soil moisture monitoring equipment. These TDR based units (Campbell Scientific CR 616 probes with CS 200 data logger)are placed to measure water content in the top 1 ft., 2^{nd} ft., and 3^{rd} ft. of the soil profile. Data loggers record data daily. Data is downloaded and forwarded to the State Climatologist at 1-2week intervals. Cooperator production sites (18) were established including the following counties-cooperators, Albany- CES, CD, Converse-CES and USFS, Laramie-CES, ARS (HPGRS), Cambell-CES, Johnson-CES, Washakie-TNC, Sublette-CES,BLM, Sweetwater-BLM, Park-Meeteetsee CD, Goshen Co-CES, Crook Co-CES, Natrona Co-BLM, Carbon Co-NRCS/CD AND BLM, Fremont- BLM, CES, CD, Hot Springs- CES. The site in Carbon County near Saratoga, maintained for 18 years jointly by UW and Saratoga Cons. Dist., was again sampled. In aggregate, these sites provide a geographic dispersion oriented largely toward east of the continental divide where effective precipitation for forage growth largely comes in spring. We assisted cooperators with aid in sampling and weighing materials as needed. Long term data sets recruited for this effort in addition to the data from the Saratoga site, includes a 21 year set from HPGRS near Cheyenne and a 18 year sets from BLM Casper area. Conservatively estimated in kind resources dedicated to the collection of soil moisture and productivity information on an annual basis are $12,000 for an indefinite period into the future.

Analysis of data of all sites and from the Saratoga site indicates, as has previous treatments of Saratoga data, that winter precipitation is not an effective predictor of growing season productivity. Normal winter precipitation wets the upper few centimeters of the soil providing moisture for early growing species. Precipitation received in April (Fig. 1), particularly 12-19 April, produces the highest level of correlation with forage yields of the site/months/season tested. May and June precipitation are less effective predictors of growth but are valuable in extending the green season and maintaining higher forage quality. Soil moisture in May is also an effective predictor, however an end of April decision point for stocking decisions related to predicted forage production, is better for economically effective decisions for most managers.

Additional analysis of Saratoga data indicates that there is a distinct window of time in April (Fig. 1) that produces the highest level of correlation between precipitation and summer forage yields. HPGRS data (Fig. 2) indicates an earlier starting, wider window, 23 March-21 June, extending into summer. Casper area data (Fig. 3) are less definitive but have a window of 5 March-25 May. Beginning of the predictive period appears to be related to elevation and associated temperatures.

The apparent differences between these sites include elevation and vegetation community composition. Elevations are Saratoga 7200 ft., Cheyenne 6100 ft., and Casper 5100 ft. The plant communities are all largely cool season species, however there is a larger C-4, warm season species, component at Cheyenne and Casper. We hypothesize that since elevations are influential to temperature and subsequently in how early the soil thaws in spring, plants start growth sooner at successively lower elevations. Since the relatively higher precipitation months continue into June, the window of influence is also wider at the lower elevation sites where warm season species occur. Snow may be wetter and melt faster at the lower elevations with warmer temperatures, reducing the snow blowing and sublimation that reduces the effectiveness of winter snow for plant growth.

Current analyses suggest that relatively effective predictive models may be developed for a geographic locale. However, the differences in the dates when precipitation begins to effectively predict, and the length of time in the window producing the best prediction suggests that universally applicable models may not be possible with the limited data we had from the cooperator locations.

The validation models that survived five screening steps have relatively lower r^2 than the "best" models from individual sites and respond to relatively late season precipitation. Four were based on models of Cheyenne productivity while one was from Saratoga data. The "best" of these models has been demonstrated to be related to the observed data from sites withing the state (Fig. 4). It was based on Cheyenne data and explained 52% of the variation in observed productivity. The validation models undoubtedly suffered from the high level of variation encountered in the sites across Wyoming.

Unfortunately, the validation model does not provide sufficiently early warning of impending drought conditions. In a drought environment most of the plant growth would have ended by the time precipitation needed for this model occurs. Although the "best" relationships from individual sites may not be as robust as the validation model, they provide notice of impending drought conditions sufficiently early that economically effective decisions can be made regarding destocking, increased stocking, or finding alternative forages during an agricultural drought. In addition, assessing precipitation during the critical period for plant growth will permit discrimination of whether agricultural drought or hydrologic drought is the issue for the season.

Locally developed relationships between precipitation and herbage yields appear to be preferred to the statewide model based on the dates found to produce the "best" models and the relatively low r^2 of the statewide model. Additional sites have been added to the network of sites across Wyoming to determine annual herbage yields, bringing the number to 19 locations and soil moisture monitoring equipment at each location has been installed. Future assessment of data from these locations will permit each geographic area to have a locally effective predictor of herbage yields and opportunity to improve the state wide model will be apparent.

This research can be viewed as successful on several fronts. Relevant models of herbage yields based on antecedent precipitation predict herbage yields sufficiently early for economically effective decision making in Wyoming. Infrastructure for the development of locally relevant models is in place across much of the state. The project has been used to leverage the installation of soil moisture stations in the same locale as the herbage yield sites. The models developed to date have been used to develop statewide prediction maps for herbage yields in the upcoming growing season. These maps provide real time tools for BLM and rancher's planning of grazing strategies for the upcoming season.

Publications:

Smith, M. A., T. L. Thurow, and D. Legg. 2005. Predicting herbage standing crop on Wyoming rangeland from winter and spring precipitation. Abstracts 58th Annual Meeting Society for Range Management. Abst. #.

The Wyoming state map describing the predicted forage crop on rangeland was disseminated on the state climatologist's web page ( )twice, early and late April 2005. Annually at the end of April this map will be published.

Cooperative Extension Service publications will be developed within the year to provide producers, land management agencies, and CES field staff results of this research. This document will be available on the CES publications web page and limited hard copies.

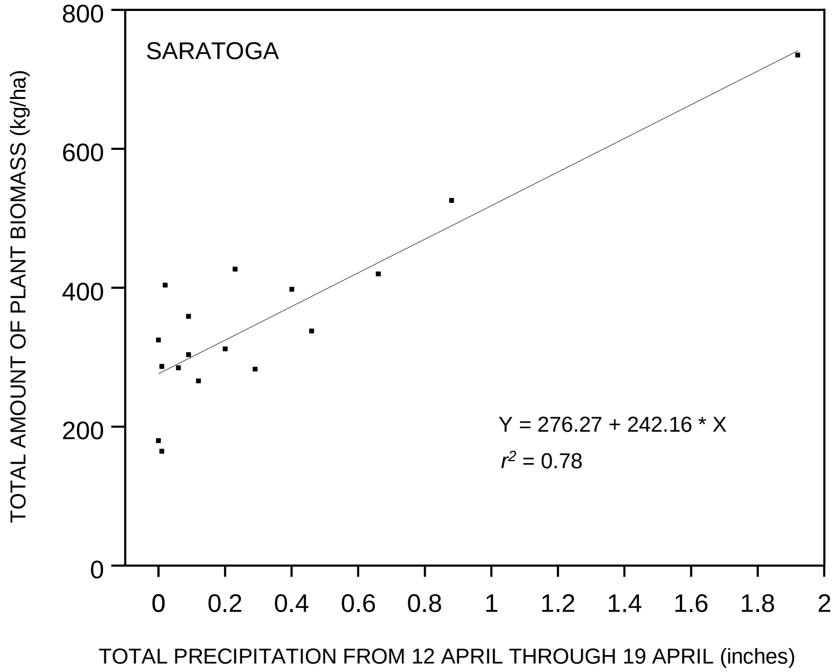

Fig. 1 Relationship of precipitation to herbage yield, Saratoga, Wy.

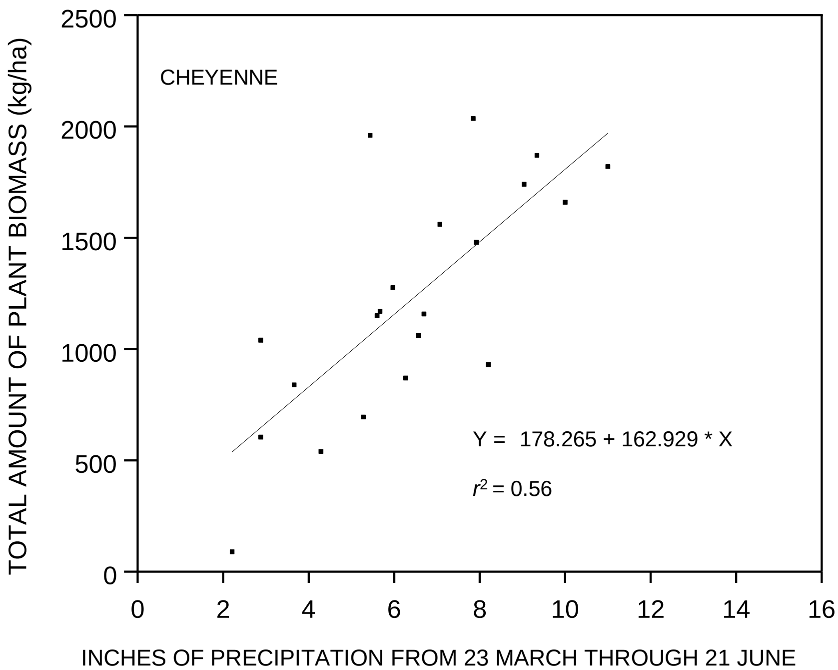

Fig. 2, Relationship of precipitation to herbage yield, Cheyenne, WY

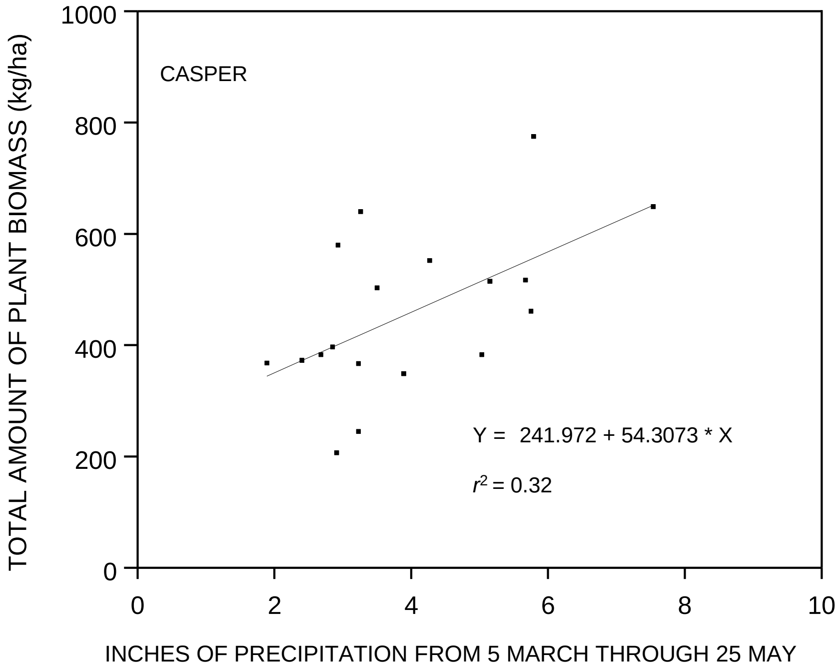

Fig. 3. Relationship of precipitation to herbage yield ,Casper, Wy.

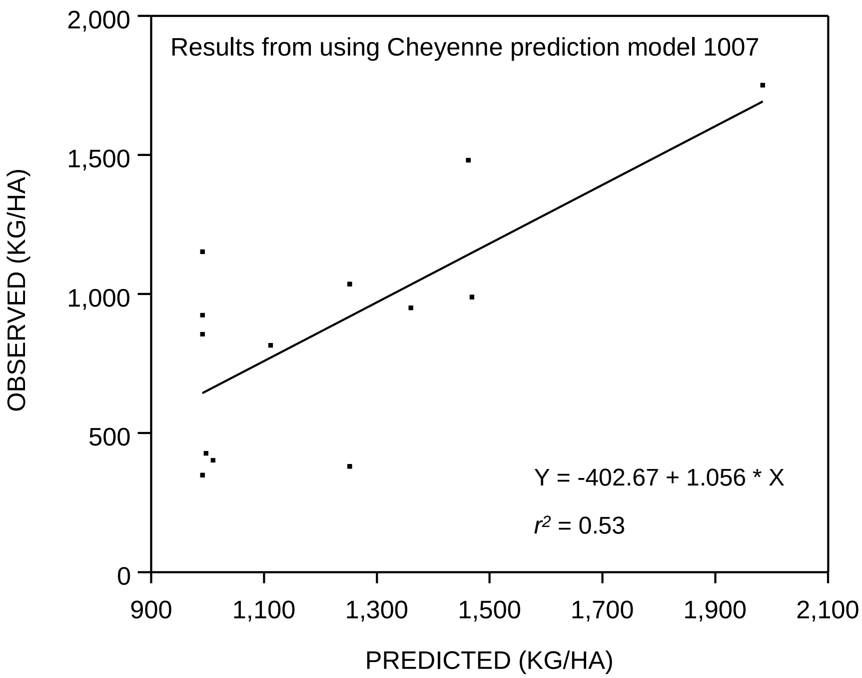

Fig. 4, Statewide model prediction of herbage standing crop compared to yields at cooperator sites