Grazinglands Research Laboratory

RESEARCH REPORTS 2006

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GRAZINGLANDS RESEARCH LAB FORT RENO

This publication is dedicated to Dr. Herman Mayeux, who served as Laboratory Director of the Grazinglands Research Laboratory from 1999 to 2006. The research report was conducted under his leadership. We gratefully acknowledge his leadership and support, and wish him a fulfilling and productive retirement.

USDA-ARS

GRAZINGLANDS RESEARCH LABORATORY

Reports of Research Projects and Research in Progress on

CLIMATE AND NATURAL RESOURCES

LIVESTOCK PRODUCTION

FORAGE PRODUCTION

Edited by Charles T. MacKown and Jurgen Garbrecht

September, 2006

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Introduction

The Grazinglands Research Laboratory conducts research across a broad range of scientific disciplines, but each component of the program is designed to increase profitability and reduce economic and environmental risks by providing new technology and management strategies for Southern Great Plains agriculture. We focus a large component of our research on more efficient approaches to forage production and utilization, especially the elimination of those periods during the year when forage production is not adequate for grazing needs in the stocker calf component of the Nation's beef production system. We also focus on developing knowledge for sound stewardship of the soil and water resource base that supports agricultural as well as other critical community needs, enhancing understanding of climate variability and its impacts on agriculture, and developing decision support technologies that incorporate climate forecasting, hydrologic and agronomic modeling, and remote sensing. At the same time, with the help of our supporters, our Congressional delegation, and the Agency's leadership, we are implementing new projects, such as forage-based biofuels production, which may diversify farm and ranch income and enhance environmental quality in agricultural settings

While the Grazinglands Research Laboratory is staffed and operated primarily by USDA's Agricultural Research Service, we are fortunate to have many partners who help us achieve our goals. Cooperators with Oklahoma State University, the Oklahoma State Experiment Station and Oklahoma Cooperative Extension Service, have been members of the research team at El Reno for over 50 years. We also place a high value on our relationship with Langston University, where a portion of our staff is assigned. Other institutions, such as the Oklahoma Climate Survey, U.S. Geological Survey, Oklahoma Water Resources Board, University of Oklahoma's Health Sciences Center, the University of Central Oklahoma, the Noble Foundation, the Natural Resources Conservation Service, and Redlands Community College, participate with the Laboratory staff in a variety of research projects and activities. These partnerships greatly enrich our research programs.

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GRAZINGLANDS RESEARCH LABORATORY

Research Program

The USDA, Agricultural Research Service has operated the Grazinglands Research Laboratory on the 6,700 acres of Fort Reno lands since 1948. The **Laboratory's Mission** is to provide new technology and management strategies which increase profitability of forage and livestock production, reduce risk, promote sustainability, and conserve the productivity of grazinglands resources in the southern Great Plains. We emphasize development of sustainable forage/livestock production system for the stocker calf component of the U.S. beef cattle industry, and assessment of effectiveness of conservation programs of the USDA to enhance the environment in agricultural watersheds.

The research is conducted by 17 scientists and 34 support personnel, divided into two units.

The objectives of the **Forage and Livestock Production Research Unit** are to:

- Minimize periods during the year when high-quality forage is unavailable, requiring producers to import purchased feeds at high cost, by developing new varieties of forage grasses and better management techniques for existing forages;
- Increase the profitability of beef cattle production by resolving constraints to rapid weight gain by stocker cattle and developing beef cattle finishing systems that utilize more forages in the diet; and
- Identify, develop, and evaluate biomass/bioenergy crops which will diversity agriculture in the southern Great Plains and reduce dependence on imported petroleum.

Objectives of the **Great Plains Agroclimate and Natural Resources Research Unit** are to:

- Evaluate and adapt seasonal climate forecasts developed by NOAA's Climate Prediction Center for agricultural applications and incorporate them with other information about variability in climate and weather into risk-based decision and management tools;
- Quantify environmental effects of agricultural conservation at a watershed scale, using long-term climatic and hydrological data bases from the Little Washita Experimental Watershed and the Fort Cobb Reservoir watershed to define interactions among climate, land use and management, and hydrologic processes;
- Develop new technology to monitor soil water content and forage characteristics using remote sensing (satellite imaging technology); and
- Document changes in soil organic carbon content in response to management and shifts in land-use, to define rates of carbon sequestration.

The Forage and Livestock Production unit maintains staff at Langston University, Langston, OK, to address problems unique to small, low capital farms, with emphasis on low-input forage and livestock production and natural resource conservation.

The facilities include laboratories for physical, biological, and chemical analyses, greenhouses, instrumented watersheds, and experimental herds of cattle (usually about 1,000) and sheep (600), and 200 acres of irrigated alfalfa, 900 acres of cropland in wheat, 2,000 acres of improved grass varieties, and almost 3,000 acres of native tallgrass prairie, all grazed and used to conduct farm-scale research projects.

UTILITY OF SEASONAL PRECIPITATION FORECASTS IN CENTRAL OKLAHOMA

Jeanne M. Schneider and Jurgen D. Garbrecht

RATIONALE

A primary characteristic of weather and climate in the southern Great Plains is extreme variability. This translates into a large natural risk factor in agricultural production and management of water resources. Any reliable ability to forecast future weather and climate has the potential to reduce weather and climate related risks for producers and managers. The National Oceanic and Atmospheric Administration (NOAA) has been issuing seasonal climate forecasts (average temperature and total precipitation) for overlapping 3-month periods out to a full year ahead for more than 9 years now, and the forecasts have been reported to have some skill. However, it has not been clear where and when the forecasts are dependable, or if the dependable forecasts have any utility in real-world management decisions.

OBJECTIVE

Determine the potential utility of the NOAA climate forecasts of 3-month total precipitation in central Oklahoma for agricultural and water resource managers.

METHODS

The forecasts are probabilistic – they represent a statement of odds for different amounts of precipitation falling during a certain period, rather than a prediction for a specific amount of precipitation. This means that no single forecast is "right" or "wrong", and any assessment of dependability has to be made over a large number of forecasts to determine whether or not the forecasters got the odds right. Our assessment was conducted over 82 forecasts, issued for January-February-March 1997 through October-November-December 2003, at the shortest possible lead time, which is two weeks ahead of each 3-month forecast period.

As we began the forecast dependability assessments, we discovered that most of the forecasts for central Oklahoma have been equal to historical odds for precipitation, or essentially non-forecasts. Since most management systems in agriculture and water resources already take historical climate conditions (climatology) into account, we perceive the small number of bold forecasts to be a serious shortcoming. In other words, the forecasts need to be for conditions significantly different from average for managers to consider adjusting their established management practices to account for a different climate. We determined the number of forecasts that differed from climatology by some minimum percentage, and call this measure usefulness. We used thresholds of ± 5%, ±10%, and ±15% away from average.

We then sorted the forecasts into wetter or drier conditions than average, applied the thresholds of usefulness, and counted how often the potentially useful forecasts "hit" (matched what actually occurred in terms of wetter or drier than average). If the forecast odds are correct, then the forecasts should "hit" in about half of the cases; if they do, we call them "dependable".

RESULTS

The results for central Oklahoma are shown in **Table 1**. The usefulness measure indicates that almost one-quarter of the forecasts (19 out of 82) have been for shifts in odds significant enough to imply an increase or decrease in average precipitation of at least 5%. If the threshold is raised to 15%, only four out of 82 were potentially useful. Clearly, we should not expect frequent bold forecasts in central Oklahoma at this time.

For the 5% and 10% thresholds, the forecasts for wetter than average conditions were dependable (the forecasts got the odds right) during 1997 through 2003. At the 15% threshold, there were too few forecasts that passed the threshold (three) to draw any conclusions.

For the drier than average forecasts at all threshold levels, none of the forecasts "hit"; these dry forecasts are clearly not dependable at this time. A manager could have done better by using the historical record as a forecast.

Overall, the utility of the seasonal precipitation forecasts in central Oklahoma is limited, with few forecasts for conditions significantly different than average, and only wet forecasts showing any dependability. The wet forecasts were issued only for the fall through mid-winter seasons (September-October-November through December-January-February). For all other seasons and for dry forecasts, managers would have a higher rate of success using historical odds for precipitation.

Table 1. Summary of analysis results for forecast utility in central Oklahoma for 1997 through 2003. Threshold refers to the difference between the forecast average and historical average precipitation.

Threshold	Usefulness†	Wetter than average‡	Drier than average‡
5%	23.2%	6/12	0/7
10%	8.5%	3/6	0/1
15%	4.9%	3/3	0/1

† Calculated as the number of forecasts meeting the threshold, divided by the total number of forecasts (82), as a percentage.
‡ The total number of "hits", divided by the total number of forecasts meeting the threshold.

SEPARATING THREE-MONTH SEASONAL PRECIPITATION FORECASTS INTO ONE-MONTH FORECASTS

Jeanne M. Schneider and Jurgen D. Garbrecht

RATIONALE

We would like to use seasonal climate forecasts issued by the NOAA Climate Prediction Center in crop models to produce forecasts of forage or grain yield up to a year in advance. But most crop models require daily weather as input, either from historical records or generated from a computer program called a weather generator. Weather generators require 1-month climate data as input, but seasonal climate forecasts are issued for over-lapping 3-month periods. These climate forecasts need to be separated into 1-month periods before they can be used by weather generators to produce forecasts of daily weather (**Fig. 1**). Previous attempts to disaggregate seasonal forecasts have not been successful, so a new approach is needed.

OBJECTIVE

To develop a method to separate the overlapping 3-month seasonal precipitation forecasts into a sequence of 1-month forecasts. The method must produce physically realistic results, and do a good job of matching the total precipitation indicated by the forecasts.

METHODS

The forecasts produced by NOAA's Climate Prediction Center specify both statistics from 30 years of observed data and statistics for the forecast. A suite of 3-month forecasts is issued every month for 102 forecast regions covering the contiguous U.S. (**Fig. 2**). Only one statistic from the forecasts will be disaggregated: the difference between the mean of the forecast precipitation, and the mean of the 30-year historical precipitation. To obtain a value for a single month, our method uses a heuristic approach to separate the overlapping 3-month forecasts, using historic 1-month data to decide how to distribute the precipitation.

We chose actual monthly precipitation data from 1971-2000 to evaluate the performance of the separation method. The historical monthly data were summed into overlapping 3-month periods to use as input for the method. Results from the separation method were then compared to the historical 1-month data. This is a rigorous

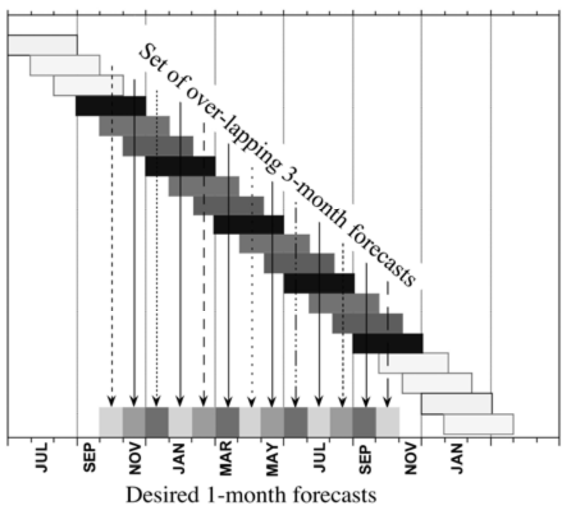


Fig. 1 Sketch illustrating the disaggregation problem. Forecasts are issued for 13 overlapping 3-month forecasts, in this example covering September-October-November of one year through the same period the following year (15 total months). Crop and hydrologic models need individual 1-month forecasts instead.

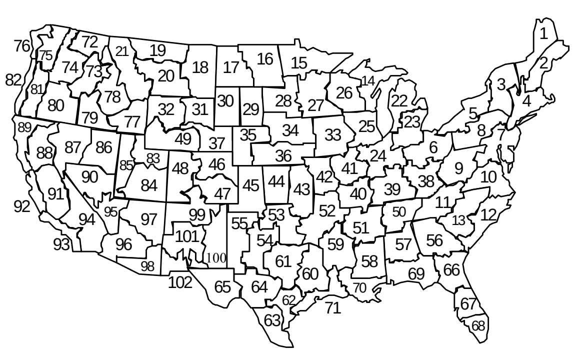


Fig. 2. Map defining the NOAA/CPC forecast divisions.test of the method, since historical precipitation varies more than the 3-months forecasts.

RESULTS

Fig. 3 shows an example of results for the Central Oklahoma forecast division. The separated monthly departures do a good job of following the pattern of sustained (multi-month) variations in precipitation, but usually underestimate the size of the largest 1-month variations. This is reasonable, since the method works from the 3-month values.

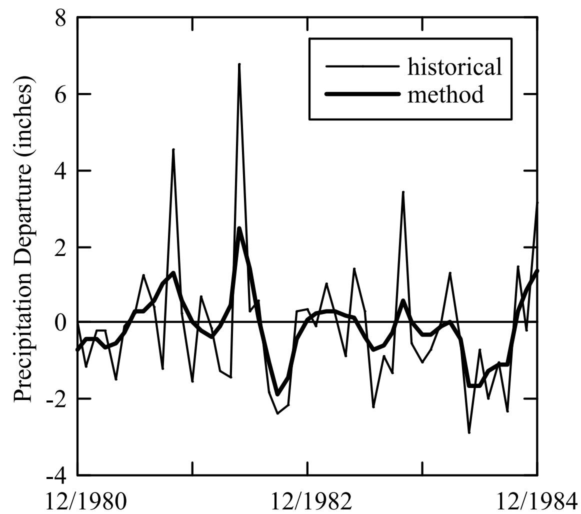


Fig. 3. An example of method results for central Oklahoma (FD 53). The historical monthly precipitation data is labeled “historical”; the result of the separation method is labeled “method”.

o get a numerical evaluation of method performance, the separated 1-month values and sums of those 1-month values over three months and one year were plotted against historical values. Linear regressions were then calculated. **Fig. 4** shows an example of the scatter plots and linear regressions of the monthly, quarterly, and annual sums of data for central Oklahoma. The slope of the regression line for the 1-month values is 0.39, indicating that the method tends to produce 1-month departures that are smaller than the test data. This quantifies the underestimation shown in **Fig. 3**. But the magnitudes of the departures match better in sums over longer time periods, as one would expect. The slopes of the regression for quarterly sums is larger than that for monthly sums, and the slope for

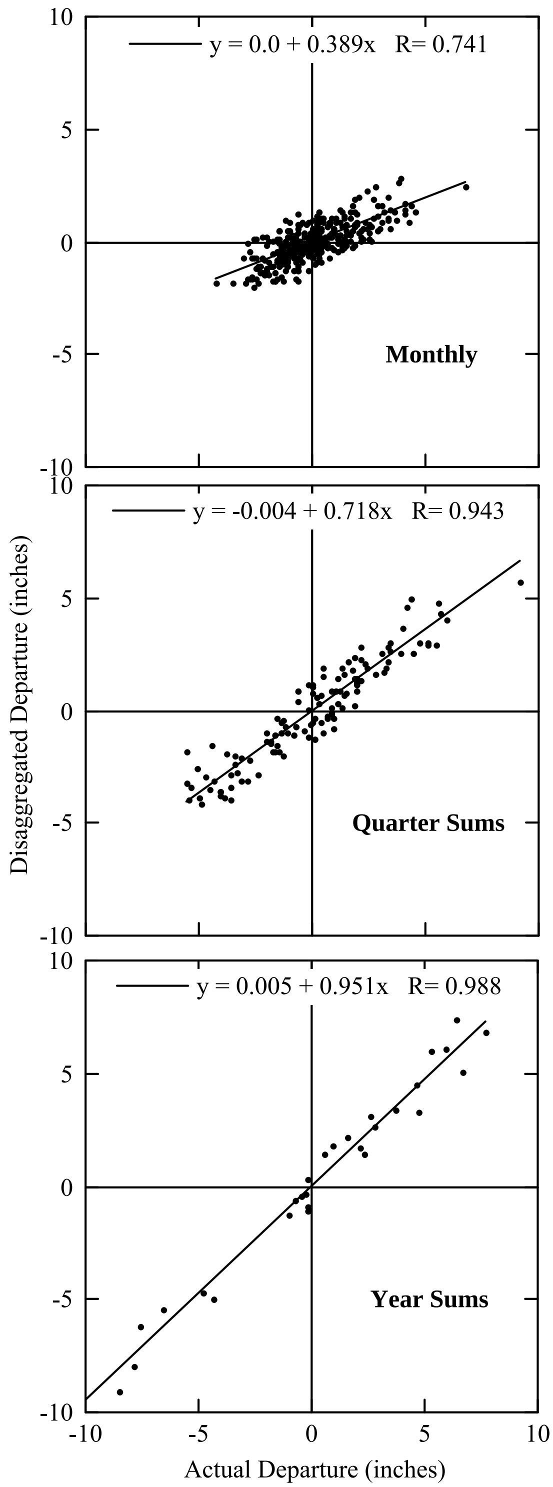


Fig. 4. Scatter plots and linear regression of method results vs. test data for 1-month values and sums over quarters and years for central Oklahoma; method results are labeled "Disaggregated Departure", while the historical test data are labeled "Actual Departure".

annual sums is even larger at 0.95. This means that the method does a good job of generating 1-month values that add up to a sum that is close to the forecast total precipitation over 3 months or longer.

In summary, the method presented here produces physically realistic sequences of 1-month forecasts, and does a reasonable job of producing the forecast total precipitation. The method's performance is a bit weak for the 1-month individual values, underestimating the variations in some individual months. But those errors begin to balance out when the 1-month values are summed over quarters, and disappear when the values are summed over 1-year periods. This means that sequences of 3 or more disaggregated months will have realistic total precipitation, and should be useful in crop modeling spanning a growing season. The method performs equally well across widely different climates, and does a reasonable job reproducing the sudden onset of strong seasonal variations such as the southwest U.S. monsoon. All that is needed is the 30-year record of monthly precipitation for the location or area of interest to be able to disaggregate the 3-month forecasts.

A FORECAST WEATHER-GENERATION TOOL

Jurgen D. Garbrecht, Jeanne M. Schneider, and John X. Zhang

RATIONALE

Recent advances in our knowledge of the global climate have led the Climate Prediction Center of the National Weather Service to issue seasonal climate forecasts for 102 regions in the continental Unites States. These forecasts are for precipitation and average air temperature, for overlapping three-month periods, out to 1 year in advance. Each forecast region is about 35,000 square miles in size. These seasonal climate forecasts offer the potential to reduce economic risk and increase profitability of agricultural enterprises. While these forecasts provide us with a likely climate trend, the forecasts are for areas too large, and time periods too long, to accurately determine their impact on agricultural production or water resources. Regional forecasts must be expressed at watershed, county or farm scales, and in terms of daily precipitation and air temperature before they can be used in practical agricultural applications. The problem of expressing forecasts over smaller areas or single locations, and for single months, has been solved and detailed in other reports. The transformation of monthly forecasts to daily values is addressed here by way of stochastic weather generation. Weather generation refers to the simulation of daily weather patterns by use of a computer program, and stochastic means that a random element in daily weather outcomes is considered. For this research, an existing and popular weather generation model developed by the Agricultural Research Service was modified to generate daily precipitation and air temperature that represent seasonal climate forecasts. This modified weather generator is called SYNTOR, for SYNthetic weather generaTOR. Generated weather data are often used in agricultural models to determine the impacts of weather patterns on crop production and water resources availability.

OBJECTIVE

The objective of this research was to pro duce a daily weather generator that incorporates the Climate Prediction Center seasonal climate forecasts and generates daily weather values for agricultural models, in support of the climate impact and risk reduction research conducted at the Grazinglands Research Laboratory.

RESULTS

A wet forecast generally implies more rainy days over the forecast period and more rainfall on days when it rains. For a dry forecast the opposite holds true: fewer rainy days, and less rainfall on days when it does rain. Statistical procedures have been used to estimate the change in the number of rainy days per month, and the amount of rain on rainy days due to a wet or dry forecast. These statistical procedures have been incorporated into the synthetic weather generator so that it generates daily weather for forecasted monthly climate conditions. Here, the ability of the synthetic weather generator to reproduce historical weather conditions and a wet forecast is illustrated for weather conditions at Weatherford, Oklahoma. The seasonal climate forecast used as an example was issued by the Climate Prediction Center in November 1997 and covers the months of December through May. This forecast was selected for illustration because it was one of the stronger wet forecasts issued for central Oklahoma.

The observed daily rainfall amount on rainy days is shown in **Fig. 1** (solid line) as an "exceedance frequency" curve for the month of February from 1907 through 2003. An "exceedance frequency" curve defines the odds that a particular daily rainfall is exceeded. For example in **Fig. 1**, a daily precipitation amount of 0.5 inches is exceeded on about 15 percent of all rainy days, whereas daily precipitation amount equal to less than 0.5 occurs on about 85 percent of all rainy days. The dotted line in **Fig. 1** represents the "exceedance frequency" for the generated daily precipitation. Daily precipitation was randomly generated from the fitted distribution of the observed daily precipitation. The solid and dotted lines are very similar and indicate that the synthetic weather generator reasonably duplicates the actual record. The distributions of monthly total precipitation for the month of February are shown in **Fig. 2**. Monthly totals are obtained by summing the daily precipitation for each month. In **Fig. 2** the solid line again represents the monthly precipitation calculated from the observed daily precipitation and the dotted line the monthly precipitation calculated from the generated daily precipitation. Both **Figs. 1 and 2** demonstrate that the synthetic weather generator can accurately reproduce the observed daily and monthly precipitation.

The 1997 Climate Prediction Center seasonal climate forecast predicted higher odds for wet conditions for December 1997 through May 1998. The Climate Prediction Center provides forecasted precipitation as a distribution, but for illustration purposes only the mean of the precipitation distribution is considered here. In **Table 1**, the historical mean precipitation, the Climate Prediction Center forecasted mean precipitation and the generated mean precipitation are shown for the months December 1997 through May 1998. For example, the historical mean precipitation for February is 1.08 inches, and the Climate Prediction Center calls for a forecasted amount of 1.49 inches, a 38%

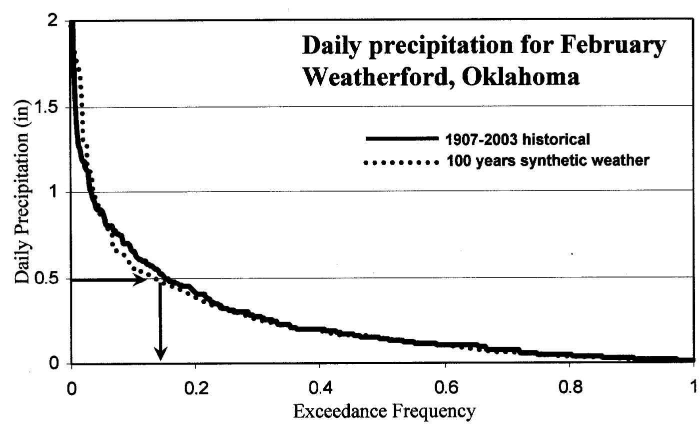


Fig. 1. Exceedance frequency of observed (1907-2003) and generated daily precipitation for the month of February at Weatherford, Oklahoma.

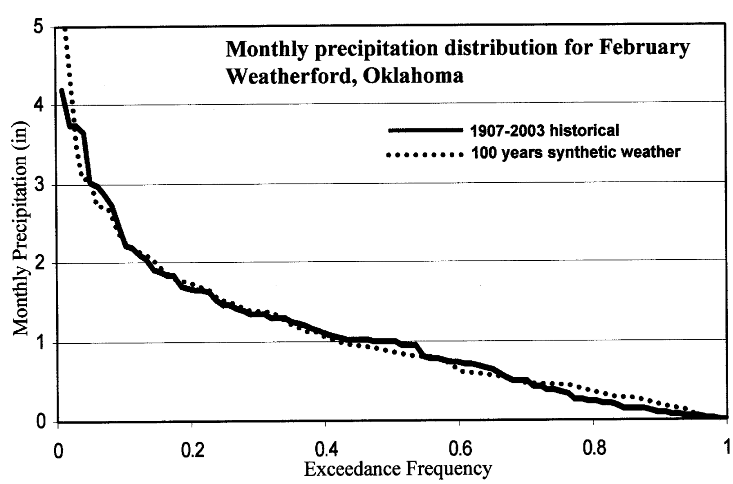


Fig. 2. Exceedance frequency of monthly precipitation, based on observed (1907-2003) daily precipitation and generated daily precipitation representing observed conditions, for the month of February at Weatherford, Oklahoma.

increase. The mean precipitation for February based on the generated precipitation data is 1.57 inches, within 0.8 inches or about 5% of the Climate Prediction Center forecasted value. The average discrepancy between the Climate Prediction Center forecasted and generated monthly precipitation was 3.1%. Finally, the historical and forecasted mean precipitation for the months of December through May are plotted in **Fig. 3**. This figure and the values in **Table 1** demonstrate that the synthetic weather generator can accurately simulate the forecasted monthly mean precipitation and Climate Prediction Center forecasted precipitation for December

Overall, the synthetic weather generator demonstrated good ability to generate daily precipitation sequences that sum up properly to historical and forecast conditions. Thus, the synthetic weather generator is a daily weather generator tool that can effectively support computer simulations of crop productivity and water resources under forecasted climate conditions.

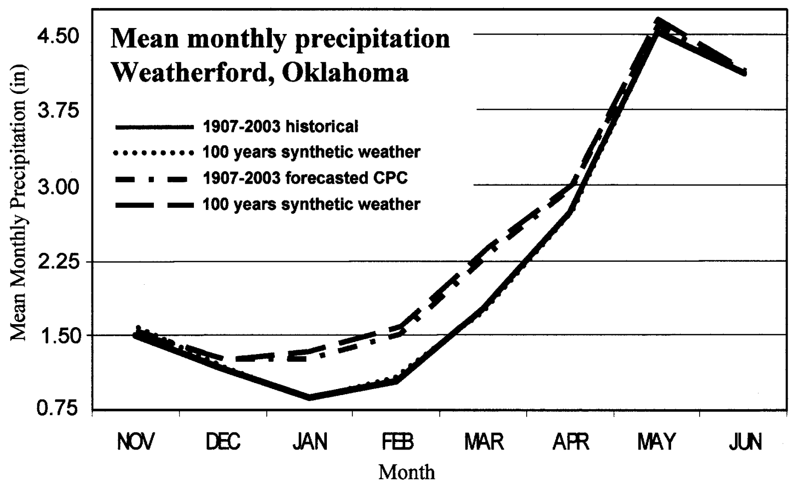


Fig. 3. Mean of the distribution of monthly precipitation based on observed (1907-2003) and generated daily precipitation for December through June, and for forecasted (1997-1998) precipitation for Weatherford, Oklahoma.

Table 1. Mean of the distribution of historical precipitation from 1997 through May 1998, and corresponding mean based on generated daily precipitation.

Date	Historical	Forecasted	Generated	Difference
	inches			%
Dec. 1997	1.18	1.25	1.26	0.8
Jan. 1998	0.90	1.23	1.35	9.8
Feb. 1998	1.08	1.49	1.57	5.4
Mar. 1998	1.79	2.28	2.33	2.2
Apr. 1998	2.71	2.94	2.95	0.3
May 1998	4.50	4.62	4.62	0.0
				Mean 3.1

PRECIPITATION AND RUNOFF TRENDS IN OKLAHOMA WATERSHEDS

Jurgen D. Garbrecht, Jeanne M. Schneider, and Michael W. Van Liew

RATIONALE

Surface runoff generally mirrors variations and trends in precipitation at time scales from seasons to centuries. Variations in seasonal and inter-annual precipitation and surface-runoff occur commonly, and reservoirs built over the last century help water resource managers cope with short-term droughts, low flows and periods of flooding. On the other hand, precipitation and surface runoff trends lasting 5 years or longer (decade scale) have the potential to greatly surpass short-term variations in their societal, economic and political impacts. Even though decade-scale trends are more subtle than inter-annual variations, it is the cumulative effects of sustained departures from average conditions that may lead to greater impacts. The recent sustained drought and depletion of reservoirs in the western United States are examples of cumulative drought effects on the water resources system.

Above average precipitation has been observed in Oklahoma during the 1980's and 1990's. **Fig. 1** illustrates this precipitation trend for south-central Oklahoma. This increasing precipitation trend appears to have reversed itself since the mid 1990's. From the water resources planning and management point of view, this decline in precipitation, if sustained, may lead to a water shortfall that could have tangible impacts on a society and an economy that have come to rely on an ample supply of water. To assess the vulnerability of the water resources system to decade-scale precipitation trends, the sensitivity of watershed runoff to precipitation trends was investigated. In this study, impacts of decade-scale trends in precipitation on surface runoff were examined for several mid-size agricultural watersheds in Oklahoma.

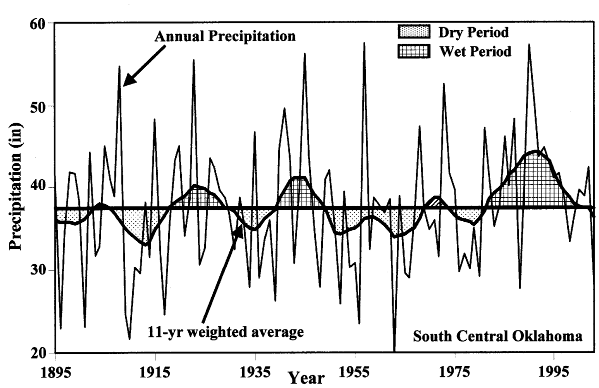


Fig. 1. Precipitation trends in central Oklahoma from 1895 to 2003.

OBJECTIVE

The objective of this study was to identify the sensitivity, magnitude and range of changes in watershed runoff resulting from observed decade-scale precipitation variations. Findings were expected to provide insights and guidance on impacts of precipitation trends on surface water resources, and provide climate-trend information to support long-term planning and management of water resources.

RESULTS

Runoff from seven watersheds in Oklahoma that have mostly natural unregulated streamflow was analyzed. The watersheds ranged in size from about 300 sq mi to 2000 sq mi, land use was primarily grass and cropland, and long-term average annual precipitation ranged from 28 inches for watersheds in south-west Oklahoma to 44 inches for watersheds in eastern Oklahoma. The locations of the watersheds are shown in **Fig. 2**. Streamflow data for each watershed were obtained from the U.S. Geological Survey, and estimates of monthly precipitation over each watershed were developed from precipitation data published by the National Climatic Data Center. Decade-scale trends in precipitation and streamflow were highlighted by smoothing the annual values with an 11-year moving average.

The smoothed annual precipitation and streamflow showed a surprisingly high level of correlation, as illustrated in **Fig. 3** for Baron

Fork, Mud Creek, and Chickaskia River. Both precipitation and streamflow were depressed in the 1950's, 1960's and 1970's and elevated in the 1980's and 1990's. Also, since the mid 1990's, precipitation trends for Baron Creek and Mud Creek declined gradually from the high values observed in the late 1980's. The streamflow mirrored this decline, which was typical for watersheds in southern and eastern Oklahoma. In southern Kansas and north central Oklahoma, the precipitation trend had leveled off in 2000, and began to decline in 2001.

The sensitivity of streamflow to variations in precipitation was greater than one, implying that a change in precipitation always lead to a disproportionately larger change in streamflow. For example, a 13% increase in precipitation for Baron Creek resulted in a 45% increase in streamflow. This sensitivity could be a concern for water resources managers, because even small, but sustained, trends in precipitation can lead to substantial change in reservoir inflows.

On a seasonal basis, the precipitation increases in the 1980's and 1990's were primarily during fall, winter and spring, with little or no change during the warm summer months. The lack of significant change in summer precipitation suggests that low streamflow values during summer will persist despite the observed increase in annual precipitation. Thus, summer water supply will continue to rely primarily on water storage capacity, and may continue to experience shortfalls during the later summer, as it has in the past.

Overall, this investigation demonstrated that watershed runoff in Oklahoma is sensitive to decade-scale precipitation trends, and that reservoir storage which relies on surface runoff for recharge could be vulnerable to declining precipitation, more so in the south and west than in the northeast. Incorporation of potential impacts of precipitation trends into water management may be necessary to help ensure a reliable water supply and to meet the growing demand for water for domestic, industrial, environmental and recreational purposes.

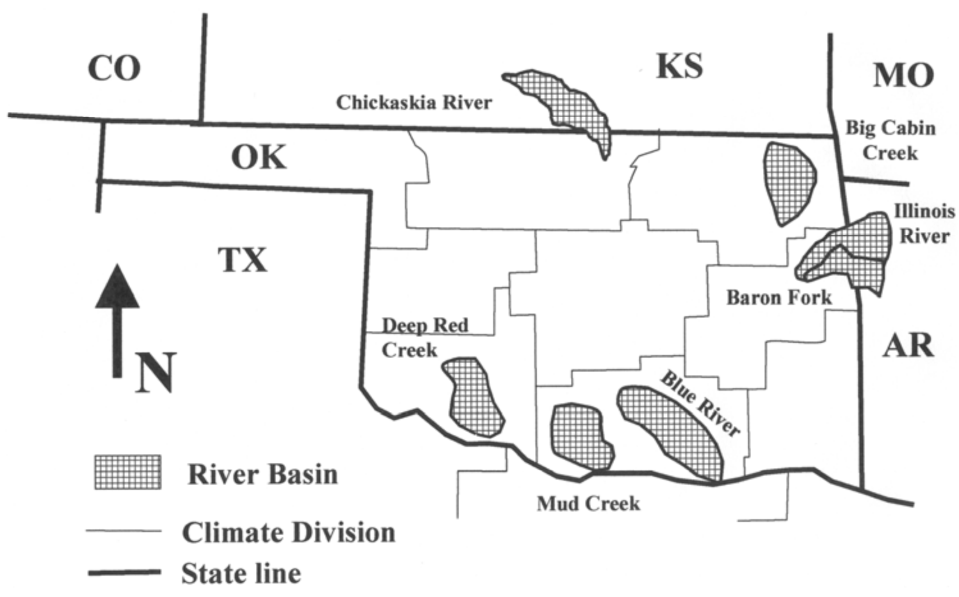


Fig. 2. Location of the watersheds.

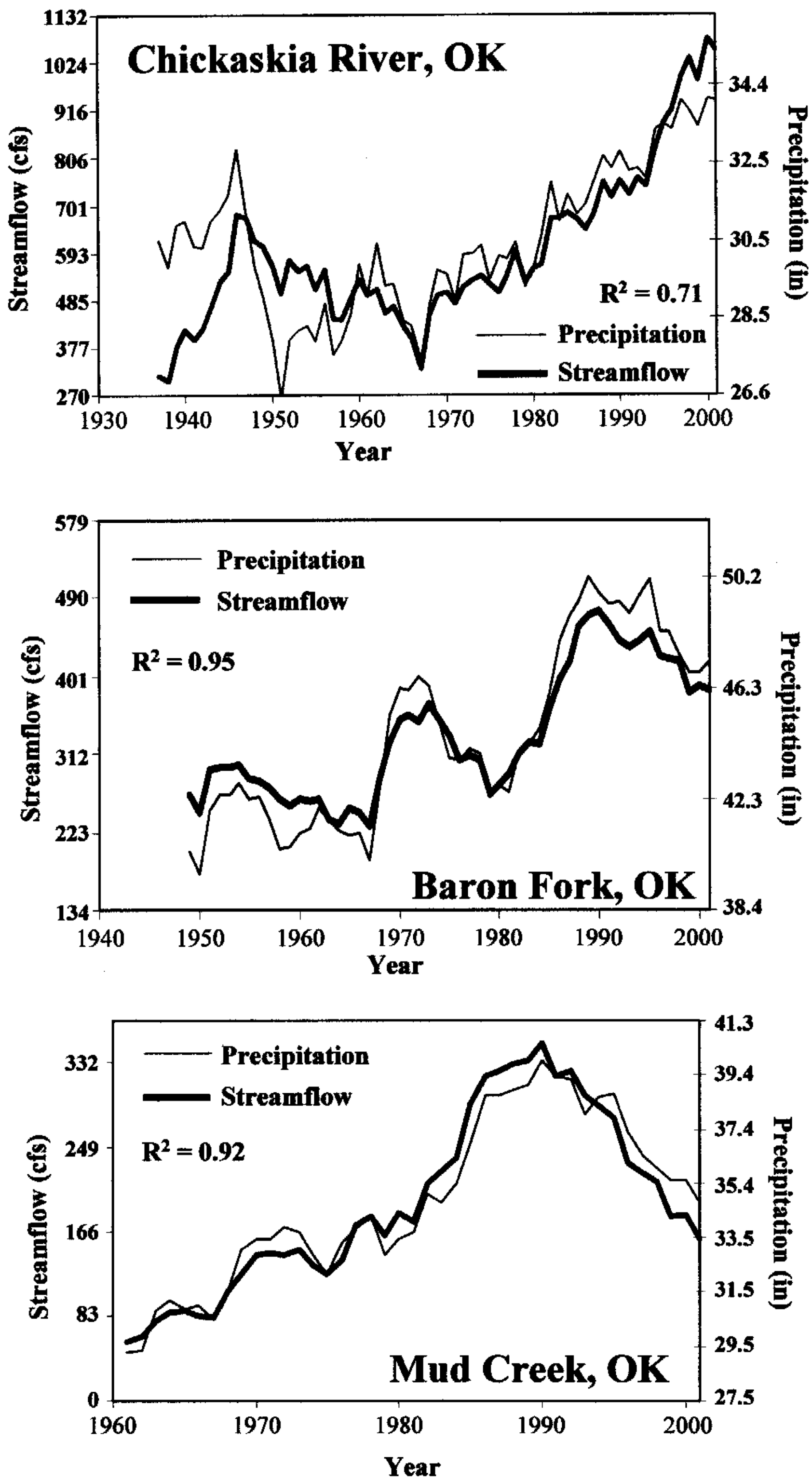


Fig. 3. The 11-yr moving averages of annual precipitation and streamflow for Mud Creek, Baron Fork, and Chickaskia River. Streamflow units are cubic feet per second (cfs), and precipitation units are inches (in.).

Downscaling Monthly Projections to Simulate Impacts of Climate Change on Soil Erosion and Wheat Production

X.-C. John Zhang, Jurgen D. Garbrecht, and Jean L. Steiner

RATIONALE

Climate change can substantially affect agricultural production and soil and water conservation efforts. Knowledge of potential impacts of climate changes on natural resources and agricultural production is needed to develop new production systems or modify existing ones in response to climate changes. Great efforts have been undertaken to simulate future climate changes due to increases in greenhouse gases in the atmosphere, such as CO_2. General Circulation Models are computer programs that simulate global climates. Most General Circulation Models projected that globally averaged temperature and precipitation would increase in the future with increased greenhouse gases. The potential for such changes to increase the risk of soil erosion and related environmental consequences is clear, but the impacts for particular regions need to be assessed. Assessment of the climatic impacts is complex due to the interactive effects of climate and other components in the agricultural systems, and may be best investigated using agricultural simulation models (i.e., computer programs). These models, which mimic the whole agricultural system, require daily weather data as input. Thus, monthly General Circulation Model projections must be downscaled to daily weather values before agricultural systems models can be used to simulate the impacts of climate change.

OBJECTIVES

This study was to (i) develop a method for downscaling monthly climate projections to daily weather data while preserving means and variability of precipitation and temperature of monthly forecasts using a weather generator called CLIGEN, and (ii) evaluate, as an example, responses of soil erosion and wheat yield to climate change scenarios projected for the 30-year period of 2056-2085 for El Reno, Oklahoma, using the Water Erosion Prediction Project model, which is a computer program simulating surface hydrology, soil erosion, and plant growth.

METHODS

Three instrumented watersheds located at the Grazinglands Research Laboratory were used for the study. Each watershed is 4 acres in size. The watersheds were in the annual winter wheat-summer fallow rotation having contrasting management and tillage systems including conventional tillage, conservation tillage (crop residue left on surface), and no-till from 1980 to 1995. Precipitation, surface runoff, and sediment loss were recorded between 1985 and 1995, and wheat yields and soil moisture were intermittently measured during the period. These measurements were used to calibrate the WEPP model.

The climate change scenario used in this study was projected on the assumption that atmospheric CO_2 concentration would increase by 50% over the present level by the year 2070 (B2a emissions scenario). Since this study tests a new downscaling method, the particular emissions scenario is not so important.

The monthly precipitation and mean monthly temperatures projected for the periods of 1950-1999 (hindcast) and 2056-2085 (future) for the grid cell covering the majority of Oklahoma were used to calculate relative climate changes between the two periods. Mean monthly temperature rise, percent monthly precipitation change, relative changes in monthly precipitation variability and monthly temperature variability between the two periods were calculated variability is measured in standard deviations. Those relative changes were used to modify the present climate statistics derived from the observed daily data at El Reno during 1950-1999. Changes in mean temperature were additive, and changes in precipitation mean as well as in temperature and precipitation variances (a measure of variability) were multiplicative. Changes in rainfall probability were linearly interpolated between dry and wet months. The modified statistics were input into the climate generator, and 100 and 500 years of daily weather data were generated for the changed climate.

RESULTS

Observed mean monthly precipitation at El Reno during 1950-1999 and projected mean monthly precipitation for 2056-2085 at El Reno are shown in **Fig. 1**. The projected monthly precipitation would decrease below historical levels in April, July, and August. The proposed method satisfactorily reproduces the projected monthly precipitation totals. To evaluate the ability of the proposed method to reproduce precipitation variability of General Circulation Model monthly projections, generated daily precipitation amounts were summed to obtain monthly precipitation amounts. Relative changes in variability of monthly precipitation were calculated using the summed monthly values. The relative changes in monthly precipitation variability calculated using 100 years of generated daily precipitation agreed relatively well with the General Circulation Models projected change in monthly precipitation (**Fig. 2**); however, the agreement was improved when 500 years of generated daily precipitation were used. The overall agreement indicates that the approach is adequate, and provides a viable means of transferring variability of monthly precipitation to daily precipitation.

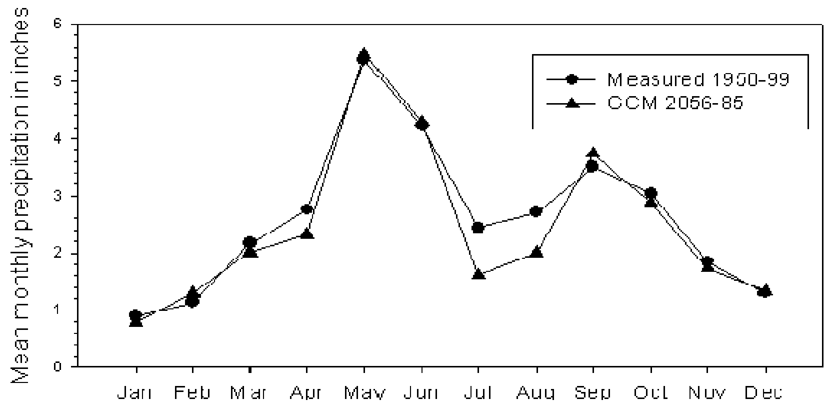


Fig. 1. Measured monthly precipitation during 1950-1999 and General Circulation Model (GCM) projected monthly precipitation for the period of 2056-2085 at El Reno, Oklahoma.

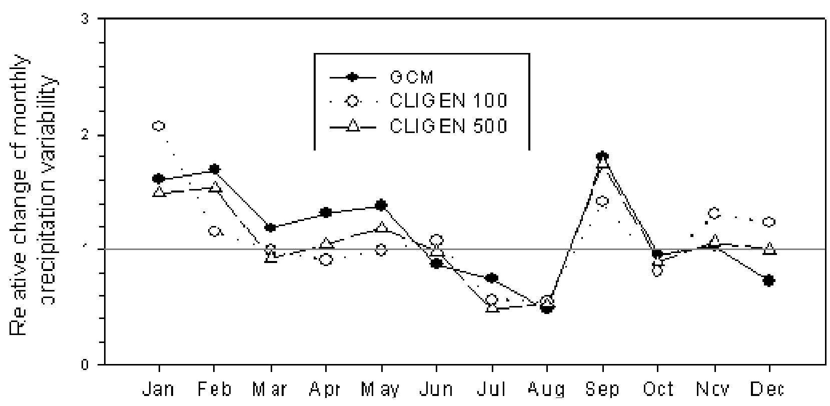


Fig. 2. General Circulation Model (GCM) projected and climate generator (CLIGEN) generated relative changes of monthly precipitation variability between 1950-1999 and 2056-2085 for El Reno, Oklahoma. Greater than 1 indicates an increase in precipitation variability, and less than 1 a decrease in variability.

General Circulation Model projected increases in monthly mean temperatures at El Reno during 2056-2085 are shown in **Fig. 3**. Projected temperature increased in all months, but it increased more in summer months. This is because the projected climate in summer months was drier during 2056-2085.

Relative changes in variability of monthly mean temperatures calculated from generated daily values are plotted in **Fig. 4**. The relative changes of General Circulation Model projected monthly variability were reproduced well by the climate generator using the proposed method for maximum temperature, but not so well for minimum temperature. The lesser agreement for minimum temperature resulted from inadequate generation of minimum temperature in the climate generator. The overall results show that the proposed method is acceptable as a first approximation for downscaling monthly mean temperature to daily temperature.

The Water Erosion Prediction Project simulated surface water runoff, soil loss, and wheat yield for the changed climate and their relative changes under the same tillage as presently used are shown in **Table 1**. The projected average annual precipitation, compared with the present climate, would decrease by almost 4% during 2056-2085. The increased variability in precipitation (**Fig. 2**) leads to more frequent occurrence of large storms, and as a result, the projected average annual runoff would increase by 3 to 8%, depending on the tillage systems. Soil loss would increase by approximately 11% in the conventional and conservation tillage, with no change in the no-till system. Projected average wheat grain yield would decrease by 11%, because the negative effects of rising temperature (**Fig. 3**) on wheat production outweigh the positive effects of increasing atmospheric CO_2 on wheat growth.

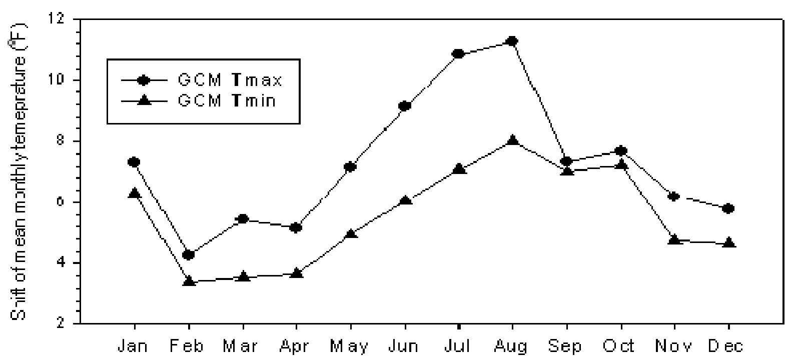


Fig. 3. General Circulation Model (GCM) projected monthly average increases of maximum temperature (Tmax) and minimum temperature (Tmin) between 1950-1999 and 2056-2085 for El Reno, Oklahoma.

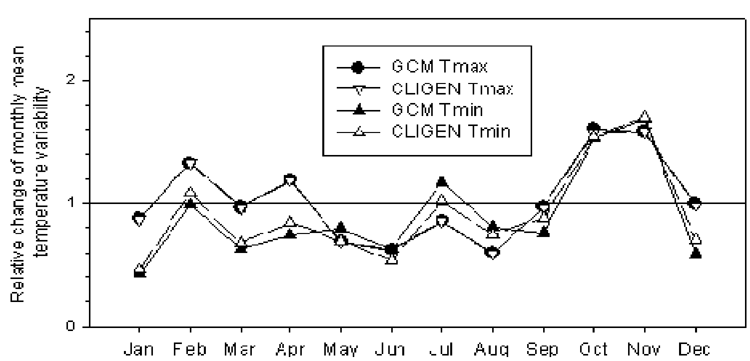


Fig. 4. General Circulation Model (GCM) projected and the climate generator (CLIGEN) generated relative changes of monthly temperature variability between 1950-1999 and 2056-2085 for El Reno, Oklahoma. Greater than 1 indicates an increase in temperature variability, and less than 1 a decrease in variability. (Tmax = maximum temperature, Tmin = minimum temperature)

Table 1. Simulated average annual precipitation, surface water runoff, soil loss, and wheat yield for a climate scenario for the period of 2056-2085, and their percent changes under the same tillage as presently used at El Reno, Oklahoma.

Tillage system	Precipitation		Runoff		Soil loss		Wheat yield	
	Depth	Change	Depth	Change	Amt.	Change	Amt.	Change
	inch	%	inch	%	ton/acre	%	bu/acre	%
Conventional	30.5	-3.8	3.5	2.9	2.9	11.5	32.3	-11.4
Conservation	30.5	-3.8	3.2	6.7	1.1	10.0	32.3	-11.8
No-till	30.5	-3.8	2.7	8.0	0.1	NA†	31.9	-9.7

† NA = not appropriate.

INTEGRATING REMOTE SENSING AND MODELING TO PREDICT SOIL MOISTURE OVER LARGE AREAS

Patrick J. Starks and Gary C. Heathman

RATIONALE

Soil water content in the root zone is a key variable for agricultural, hydrological, and meteorological research. These research areas require tools and techniques to quantify soil water reserves over large land areas. Such tools could also be used to help manage water resources and watersheds. Unfortunately, point-based measurements of soil water content, although very accurate, cannot be obtained in a timely, cost-effective manner over large land areas. Passive microwave remote sensing, a technique that measures naturally-emitted microwaves, can be used to provide timely measurements of soil water content over large areas; but these measurements only reflect the water content of the top 2 inches of the soil. One of the most promising approaches to estimating root zone soil water content over large areas is through integration of microwave remote sensing and soil water simulation models. However, soil water simulation models often require pre-determined input values that are not readily available for large land areas.

OBJECTIVE

The objective of this research report is to summarize findings from recently completed investigations that use remote sensing and soil water simulation models to estimate water content in the root zone. One experiment used the ARS Root Zone Water Quality Model to investigate the amount of soil property data needed to produce reasonable estimates of water content in the root zone. Two other experiments were conducted to determine if providing remotely sensed estimates of surface soil water directly into soil water models improved model simulations of soil water content beyond the top 2 inches of the soil profile.

METHODS

All experiments were conducted with data collected from the Little Washita River Experimental Watershed, located in southwest Oklahoma (**Fig. 1**). The Little Washita River Experimental Watershed is about 236 mi^2 in size, and contains a meteorological network (Micronet) of 45 stations distributed every 5 miles. The Micronet stations measure air temperature, relative humidity, rainfall, incoming solar radiation, and soil temperature. At selected Micronet sites, soil water content is measured with a Soil Heat and Water Measurement System.

Soil cores were collected at most Micronet locations and selected soil properties were determined to a depth of 24 inches in 6-inch intervals. Each soil core was divided into two 3-inch long sub-samples. One sub-sample was used to determine soil texture. The second sub-sample was used to determine bulk density and water content at various imposed air pressures to determine the soil's water retention properties (also known as the soil water characteristic). Field experiments were also conducted to determine the soil water characteristic under natural drainage conditions.

Surface soil water content was measured over the Little Washita River Experimental Watershed during the summer of 1997 using an aircraft-mounted microwave remote sensing system. Other spatial data of the Little Washita River Experimental Watershed used in the study included soil type (from the Natural Resources Conservation Society) and land cover developed from LANDSAT satellite imagery.

Three experiments were conducted. In the first experiment, soil properties were supplied to the Root Zone Water Quality Model to determine the effect of varying detail on model simulations of root zone soil water content. The type of soil information ranged from soil texture class, from which the Root Zone Water Quality Model selects statistical averages of soil physical/hydraulic properties, to a more detailed set of data based on laboratory and field measured soil water characteristics. Saturated hydraulic conductivity, a measure of soil permeability, was also measured in the field. This value, when

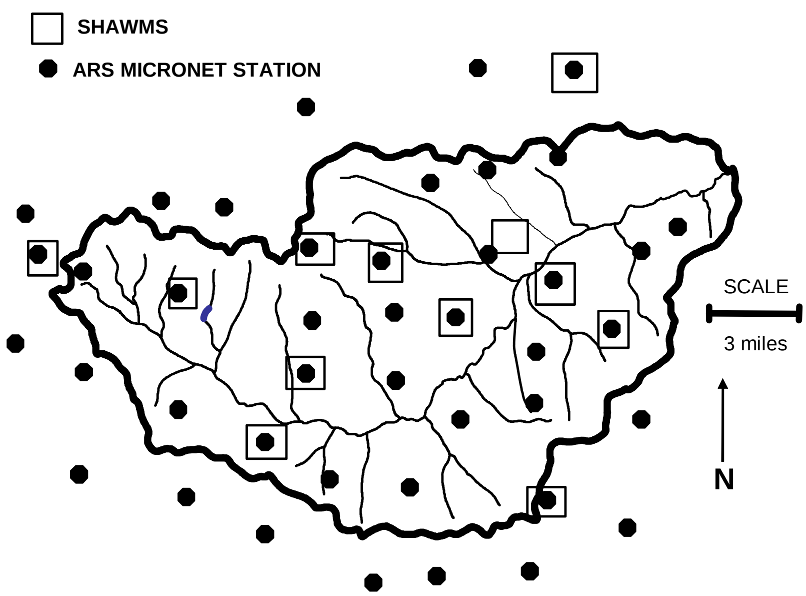


Fig. 1. Little Washita River Experimental Watershed showing the location and distribution of ARS Micronets and Soil Heat and Water Measurement System.

used in conjunction with the field measured soil water characteristic, enables the Root Zone Water Quality Model to calculate the necessary parameters to fully describe the properties of the soil horizons. This range of detail resulted in six modeling scenarios (**Table 1**). Model simulations were compared to measured soil water at selected Soil Heat and Water Measurement System down to a depth of 24 inches.

In the second experiment, soil texture, land cover, rainfall (derived from the Micronet) and microwave remote sensing estimates of surface soil water content were integrated into a simple soil water budget model. Model simulations with and without integration of remotely sensed soil water were compared to total soil profile water content measured at selected Soil Heat and Water Measurement System sites.

In the third experiment, measured surface soil water at selected sites were used in the Root Zone Water Quality Model to determine the depth at which simulations of root zone soil water content could be improved over those simulations without integration of surface soil water content. Measured soil water content was used as a surrogate for remotely sensed data, thereby providing the best case scenario for what may be obtained using remotely sensed data.

RESULTS

Experiment 1 revealed that "average" soil properties supplied to the Root Zone Water Quality Model enabled simulations of root zone soil water content that matched measurements as good as or better than simulations based on laboratory- or field-measured soil physical/hydraulic properties. This finding is important because presently available soil data bases may provide all the soil property data needed for adequate simulation of root zone soil moisture. Experiment 2 revealed that integration of remotely sensed surface soil water content into the simple soil water budget model improved soil water estimates in the soil profile (**Fig. 2**). Experiment 3 showed that the major improvement in soil water simulation in the top 12 inches of the profile was achieved by integrating surface soil water content into the Root Zone Water Quality Model.

The combined experimental results imply that if texture or some other simple soil property can be obtained by remote sensing, that large-area assessments of soil water may soon be realized. Such soil water assessments would be helpful to individuals and agencies as a tool to better manage watersheds and water resources.

Table 1. Soil property input data for each modeling scenario in experiment one.

Scenario	Soil texture	Bullk density	Soil water characteristic	Saturated hydraulic conductivity	Full description
RZS1	✓				
RZS2	✓	✓			
RZS3	✓	✓	✓†		
RZS4	✓	✓	✓‡		
RZS5	✓	✓	✓‡	✓	
RZS6	✓	✓	✓‡	✓	✓

†Measured in the laboratory on soil cores.
‡Measured in the field under natural conditions.

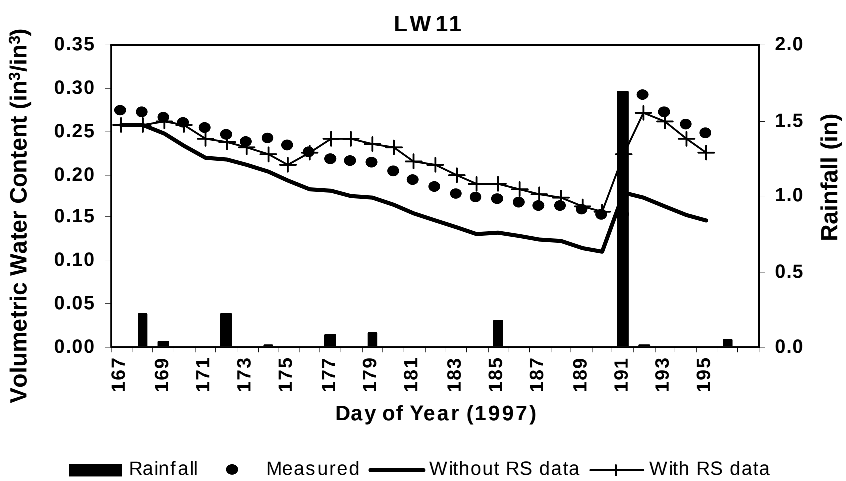


Fig. 2. Comparison of volumetric water content simulations of the soil profile with and without remotely sensed surface soil moisture integrated into the soil water model. Note that the model simulation that includes the remotely sensed data matches measurements more closely than the simulation without the remotely sensed data.

Using an Automated Approach to Calibrate a Watershed-Scale Model on USDA-ARS Experimental Watersheds

Michael W. Van Liew, Tamie L. Veith, David D. Bosch, and Jeffrey G. Arnold

RATIONALE

Computer simulation models are used routinely to determine the effects of changes in land use or climatic conditions on water resources in a watershed. Understanding how these changes affect water resources is important to help address issues related to downstream water supply, water quality, flood control, and low-flow management. Computer models used for such studies contain mathematical terms referred to as parameters. Parameters are used to describe watershed properties such as vegetative cover, soil characteristics, and landscape features that influence runoff. They must be assigned specific values to accurately simulate runoff from a particular watershed. Parameter values can be adjusted to better match the runoff simulated by the model with the runoff that has been measured on the watershed. This process is referred to as model calibration. In recent years the increasing complexity of simulation models has led to the development of automatic calibration techniques that use computers to match model simulations and measured data. Although an automated approach to model calibration may provide substantial savings in labor on the part of the modeler, there is a possibility that values of the calibrated parameters are not realistic for the watershed characteristics. In addition, the calibrated model may not necessarily provide acceptable values for certain ranges in runoff that are simulated.

OBJECTIVE

To better understand the strengths and weaknesses of an automated model calibration, an investigation was conducted to evaluate the performance of a newly developed autocalibration tool for a watershed-scale hydrologic model. The Soil and Water Assessment Tool for a range in climatic, soils, topographic and land use conditions throughout the United States.

METHODS

The Soil and Water Assessment Tool is a hydrologic simulation model that operates on a daily time step. It can be used to predict the impact of land management practices on the amount of water, sediment and agricultural chemicals leaving large watersheds. In this study, the model was used to simulate runoff from five USDA-ARS experimental watersheds throughout the United States. Watershed locations included the Mahantango Experimental Watershed in Pennsylvania, the Little River Experimental Watershed in Georgia, the Little Washita River Experimental Watershed in Oklahoma, the Walnut Gulch Experimental Watershed in Arizona, and the Reynolds Creek Experimental Watershed in Idaho (**Fig. 1**). A long record of climatic and streamflow data was used to calibrate the Soil and Water Assessment Tool on each of the watersheds. To account for spatial variability of topography, soils, and land use conditions, each watershed was divided into two or three subwatersheds. The completion of a given calibration, therefore, resulted in two sets of model parameters for the Mahantango, Little River, and Little Washita watersheds, and three sets for the Walnut Gulch and Reynolds Creek watersheds. Eleven parameters that control watershed surface and subsurface response in the model were calibrated on the three southern watersheds, and an additional five parameters that control accumulation of snow and snowmelt runoff were calibrated on the two northern watersheds.

To calibrate each watershed using the autocalibration tool in the Soil and Water Assessment Tool, it was necessary to specify the lower and upper range in values for each model parameter. An understanding of model algorithms and watershed conditions was helpful in selecting appropriate values for these upper and lower ranges. After thousands of simulations were

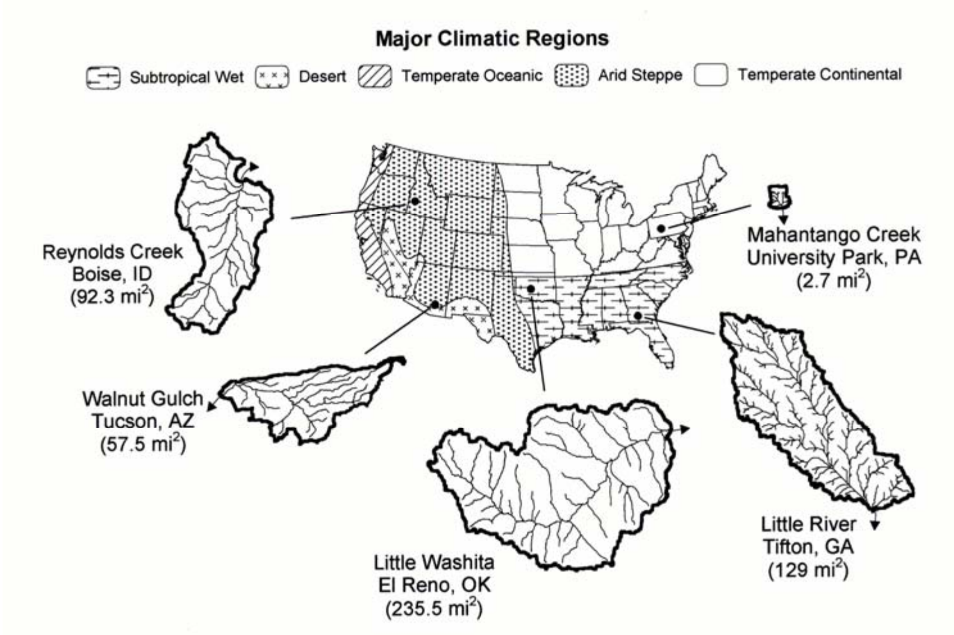


Fig. 1. Location of the five USDA ARS experimental watersheds.

made to test various combinations of the model parameters, the autocalibration tool selected the best parameter set that most closely matched the simulated runoff response of the model to the measured response observed in the field.

RESULTS

Fig. 2 illustrates the comparison of average monthly measured and simulated runoff rates for calibration periods on four of the ARS subwatersheds. Results show that for the most part, the Soil and Water Assessment Tool did a good job reproducing the month-to-month variations in runoff for Mahantango Creek and Reynolds Creek. For the Little River, however, the Soil and Water Assessment Tool tended to underestimate flows during the winter months and overestimate flows during the summer and fall months. For Walnut Gulch, the Soil and Water Assessment Tool performed well in reproducing surface runoff from high intensity rainstorms during the summer months, but consistently overestimated subsurface flows for the remainder of the year.

Displays of day-to-day changes in runoff, referred to as daily hydrographs, provide another means of comparing simulated results against the measured record. Selected daily hydro graphs that compare measured and simulated runoff for six of the ARS subwatersheds are presented in **Fig. 3**. Test results show that for Mahantango Creek and Little Washita River, the Soil and Water Assessment Tool simulated the time to reach the highest runoff rate from a storm (referred to as the time to peak), the peak runoff rate, and the shape of the hydrograph following the peak with reasonable accuracy. Simulation results were not as good on Little River, in that the time to peak was two or three days too early and the low flow portion of the hydrograph was overestimated. **Fig. 3** also illustrates that for the most part, the Soil and Water Assessment Tool did a good job simulating not only short duration, ephemeral flows resulting from high intensity rainstorms in the desert of Arizona (Walnut Gulch), but also the longer term runoff response to snowmelt from the mountainous watershed in Idaho (Reynolds Creek).

Results of this study suggest that the newly developed autocalibration tool in the Soil and Water Assessment Tool is a labor saving tool that can be used to provide reasonable runoff simulations for a range of climatic, soil, topographic, and land use conditions. However, on a case by case application, manual adjustments following autocalibration may be necessary to improve the simulated water balance and the range in magnitude of the runoff values.

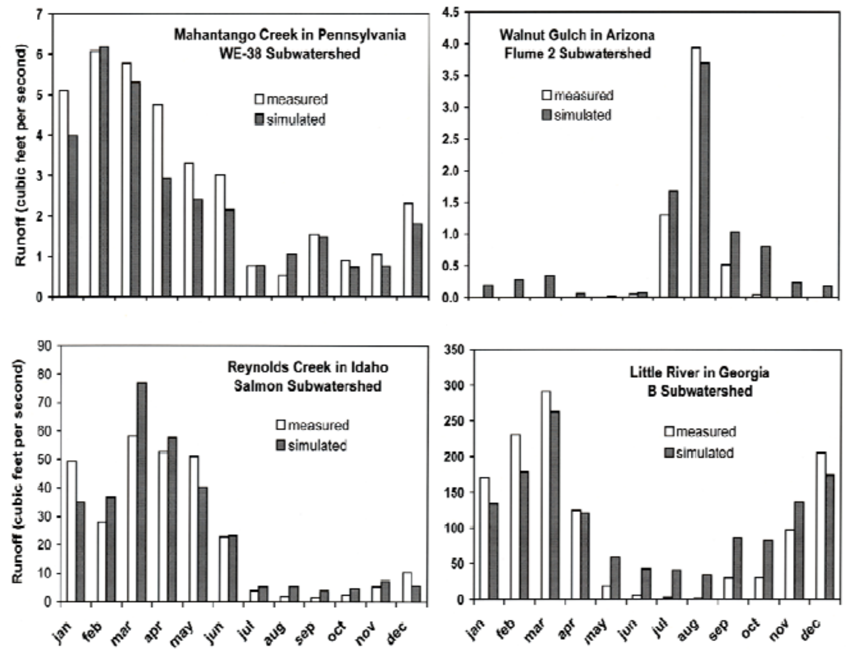


Fig. 2. Average monthly measured and simulated runoff on selected ARS subwatersheds.

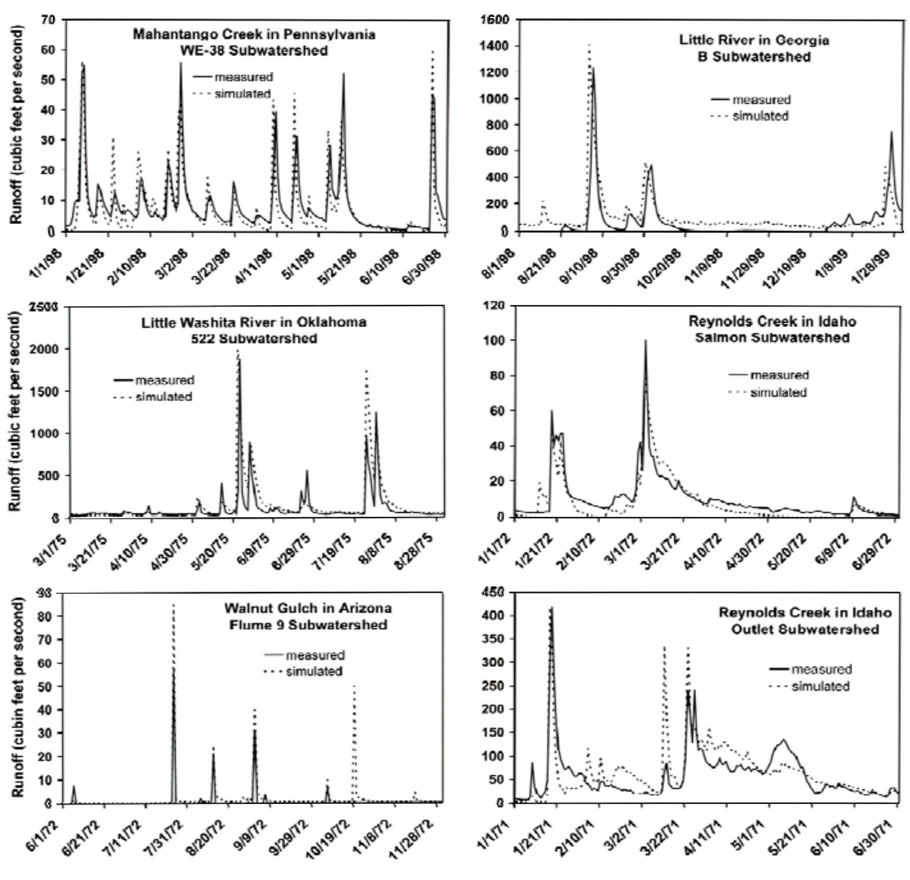


Fig. 3. Daily measured and simulated runoff for selected ARS subwatersheds.

IMPACT OF GRAZED WINTER WHEAT ON LATE SUMMER RUNOFF

John A. Daniel, William A. Phillips, and Brian K. Northup

RATIONALE

Management of wheat pastures during the summer can affect surface runoff and thereby, soil erosion. The conventional practice is to leave winter wheat fields fallow to capture water from summer rains and replenish the soil water for the next wheat crop. A summer forage crop is sometimes planted following wheat to extend the grazing season for cattle production. However, little is known about the impact of extended grazing seasons on surface runoff and erosion.

OBJECTIVE

The objective of this project was to determine how extended grazing of wheat pastures, using conventional and double cropping management practices, affected surface runoff and erosion.

METHODS

We conducted this study from 1998 to 2002 on four 4-acre pastures that were instrumented experimental watersheds. The pastures are representative of those used for wheat production in the Red Prairies region of Kansas, Oklahoma and Texas.

In 1998, all pastures were initially cultivated by moldboard plow and repeated disking to prepare the ground. Subsequently all operations used conservation tillage practices, and pastures were annually planted to winter wheat and grazed by stocker cattle during the winter and spring of each year (December - April). Two of the pastures were managed using conventional summer fallow (WWF) practices while two other pastures were managed under planting a summer legume (WWSL) during the summer fallow period. Two, 16 x 16 foot exclosures were established on each pasture to restrict livestock grazing to represent ungrazed wheat pasture (**Fig. 1**).

Pastures in summer fallow had all residue following grazeout mown and remaining live vegetation killed by spraying glyphosate herbicide. Fallow conditions were maintained until wheat was planted in late September or early October. The summer legume Korean Lespedeza was broadcast into the WWSL pastures in early March and the seed was worked into the soil by hoof action as the stockers were allowed to graze until May. The summer legumes were then allowed to grow until mid-July when stocker cattle were returned to the pastures from mid-July to mid-September. After the stockers were removed, the fields were prepared for planting for the next cycle of winter wheat.

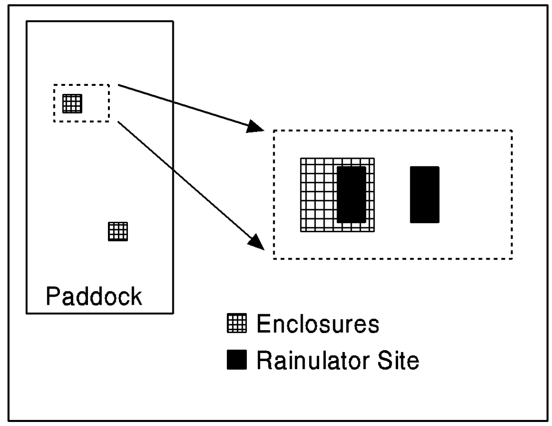


Fig. 1. Layout of pair subplots and rainulator sites.

Stocker calves weighing 500 lbs were typically placed on the pastures during the winter as forage supplies became adequate. Additional stockers were added to the pastures in early March to increase grazing pressure on the forage through the end of grazeout. The calves weighed about 650 lbs at the end of the wheat grazing period. When forage supplies were short during the winter, grazing was terminated until the first part of March.

A rainfall simulator was used to determine how these two management practices affected surface water runoff and erosion by simulating intense, late summer storms (4 in/hr, 15 min. events). Simulations were conducted in September of 2001 and 2002, at the end of grazing of the WWSL-managed pastures, and after the WWF-managed pastures had been fallow since May.

RESULTS

We found that grazed plots produced runoff sooner than the ungrazed plots (**Fig. 2**), and no difference in the time to runoff between the grazed WWF and WWSL treated areas (**Table 1**). In the ungrazed plots, WWSL plots produced runoff in 23 minutes compared to 15 minutes from the WWF plots. The amount of water collected as runoff from our simulated, high intensity, short duration rainfalls provided estimates of runoff generated by different forms of pasture management and agricultural practices. Results showed a difference in runoff, with grazed plots losing 47%, compared to 8% by the ungrazed plots (**Table 2**). In addition, the plots managed under summer fallow produced more runoff than the grazed WWSL practice (**Table 2**). Roughly 71 % of the water applied by the simulator to the grazed summer fallow practice was lost as runoff, compared to 23 % by the grazed summer legume pastures. In contrast, ungrazed WWF and WWSL plots lost only 11 % and 5 % of the applied water. Summer fallow after winter wheat is considered a water conservative technique in the southern Great Plains region. A crop is not grown and soil water is allowed to accumulate. In contrast, planting a summer crop, such as legumes, is considered a more aggressive practice in terms of water use. Soil water is utilized rather than allowed to accumulate for the next fall crop. The study showed three times more precipitation was lost as runoff when wheat graze-out was combined with a summer fallow period, compared to planting a legume during the fallow period to extend the grazing season. This result is nearly the reverse of what was expected. It may be that the long dry summers produced a temporary crust on the soil surface which restricted water infiltration and allowed surface runoff to occur. The root structure of the legumes, a tap root with large lateral branch roots, may have reduced the effects of surface crusting and improved water infiltration on the WWSL plots.

Results of this study indicate that livestock grazing can impact the amount of precipitation lost to runoff after a hot dry summer. Storm events at the end of a dry summer are generally not gentle soaking rains, but typically fast-moving, intense storms. In such a situation, the combination of grazing wheat pasture until May followed by summer fallow lost most of the precipitation as runoff. To reduce this loss of water, pasture management should ensure that sufficient plant residues are left on the soil surface to encourage infiltration.

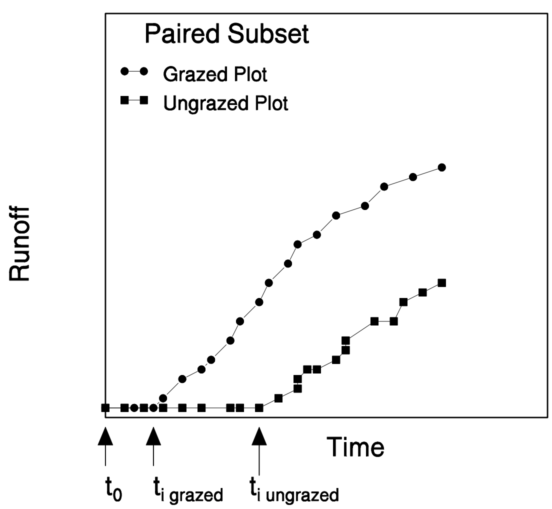


Fig.2. An example of a rainfall simulation hydrograph.

Table 1. Time to runoff during rainfall simulations.

Treatment	Management	Mean
		(min.)
Ungrazed	WWF	14.5
	WWSL	23.0
Grazed	WWF	6.0
	WWSL	7.5
Ungrazed	All Practices	19.1
Grazed	All Practices	6.5

Table 2. Means precipitation lost to runoff in percent.

Treatment	Management	Mean
		%
Ungrazed	WWF	12
	WWSL	5
Grazed	WWF	71
	WWSL	23
Ungrazed	All Practices	8
Grazed	All Practices	47

MITIGATING DAIRY RUNOFF WITH SURFACE IMPOUNDMENTS

John A. Daniel and David L. Elmendorf

RATIONALE

Public concern over agriculture's impact on water quality has prompted the formulation of regulations to restrict and reduce nutrient movement in surface water and prevent environmental damage. Runoff from animal feeding operations (AFO's) can be a major concern for water quality because nutrients and pathogens from such operations can be carried into streams and lakes. Surface runoff pollution problems can include reduced oxygen levels and fish kills. Such water pollution problems are difficult to treat and costly to rectify. In addition, the livestock industry is concerned that complicated and costly environmental regulations that currently apply to AFO's and other animal feeding operations may be expanded to include grazed pastures and other agricultural lands that are not regulated under current environmental rules.

OBJECTIVE

The objective of this study was to determine if small surface impoundments (ponds) could reduce nutrient and pathogen levels in runoff moving through an agricultural watershed.

METHODS

This study was conducted on a small 2500-acre agricultural watershed located primarily at the USDA-ARS Grazinglands Research Laboratory (GRL) from 2001 through 2003. The watershed was representative of tall grass prairie found in the southern Great Plains. A 350 head dairy operation was situated at the upper end of the watershed outside the boundary of the GRL. Runoff crossed onto the GRL and flowed through two successive ponds within the drainage of the watershed (**Fig. 1**). Grassed channels connected the dairy and the two ponds. Vegetation in these channels was primarily bulrushes, sedges, and foxtail barley. Cattails are found in areas with standing water.

Beginning in January 2001, we collected monthly water samples from the ponds and the point below the dairy (Source; **Fig. 1**). Samples were analyzed for nutrients, including nitrate-N, water-soluble phosphorus (WSP), and bioavailable phosphorus (BAP). Bacterial indicators, fecal (FC) and total colliforms (TC) and heterotrophic bacteria (HC), were also analyzed and counted.

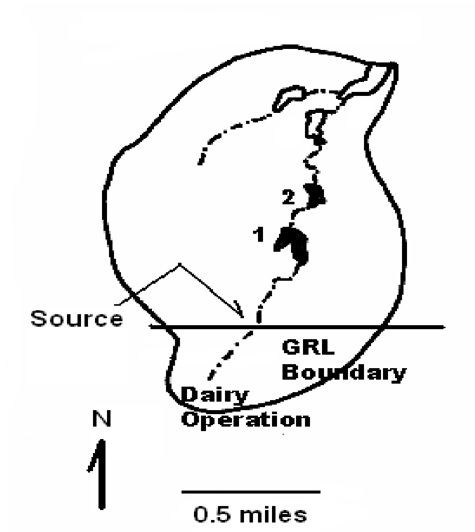


Fig. 1. Study watershed and location of impoundments and dairy.

RESULTS

Average nitrate-N concentrations in both ponds were low (< 1 ppm); however, a consistent decrease in nitrate-N content from the source (0.30 ppm) to the second pond (0.10 ppm) was found (**Table 1**). A reduction of total nitrate-N was also recorded at the inlet into the first pond. This suggests that the grassed drainage between the source and the first pond also reduced the nitrate-N levels.

Bioavailable phosphorus (BAP) concentrations decreased downstream from an averaged level of 219 ppb at the source to 20 ppb in the lower impoundment. These results suggest that surface impoundments can be partially successful in reducing the downstream movement of BAP. This is important because BAP is the primary phosphorus form which promotes algae growth and leads to fish kills.

Concentrations of water-soluble phosphorus (WSP) were also lower in the downstream

Table 1: Three-year average of nutrient concentrations and reduced percentage of nutrients in the sampling sites.

Sample Site	Nitrate – N		BAP		WSP	
	ppm	%	ppb	%	ppb	%
Source	0.30	100	219	100	1601	100
Pond 1	0.21	71	186	85	1251	78
Pond 2	0.10	33	20	9	331	21

Phosphorus is reported in ppb - parts per billions because the levels are so low.

ponds, than just below the dairy operation. The grassed channel reduced the WSP content to 78% of the initial source and the impoundments were successful in further reducing the WSP level from 1600 to 330 ppb.

Similar to nutrients, the highest pathogen levels occurred just below the dairy (**Table 2**). After passing through the first pond, fecal coliform and total coliform counts in the water were reduced by 98% and 84% of their original levels. Also, 60% of the heterotrophic bacteria in the water were removed. Because these ponds were also used by wildlife and grazing livestock, monthly pathogen levels of pond water would occasionally increase slightly. Still, the results indicate the grassed drainage between the dairy and the first pond was effective at reducing pathogen levels.

While the ponds in this study have originally been designed and built to control sediment movement and supply livestock with water, they can also be effective at removing nutrients and pathogens from runoff. The use of a series of impoundments and grassed drainages between impoundments can be effective at enhancing water quality downstream from small dairy operations.

Table 2: Three-year average concentrations and reduced percentage of pathogens in the sampling sites

	Fecal Coliform		Heterotrophic Bacteria		Total Coliform	
Sample Site	Counts	%	Counts	%	Counts	%
Source	104512	100	47147238	100	201781	100
Pond 1	2406	2	18491476	39	28185	14
Pond 2	415	0	18383333	39	6037	3

TRACING SOIL EROSION WITH RARE-EARTH ELEMENTS

X.-C. John Zhang

RATIONALE

Soil losses from small watersheds or erosion plots have been well documented. These data are extremely useful in understanding soil erosion, assessing in-field and off-field impacts on crop and forage production, and developing best management practices to reduce soil erosion. But these soil loss data do not include information that identifies sites of sediment origin within a watershed or a field. Knowing the sediment source areas in a watershed or field could aid conservationists to develop and evaluate new erosion control measures, as well as help farmers and ranchers fine-tune their farming and grazing plans to safeguard sensitive parts of the watershed or landscape.

To identify sediment sources, various types of tracers, including radioactive materials and exotic particles such as glass beads, have been used. Although these tracers have proven useful, each has limitations. Ideal tracers for studying soil erosion and sediment sources should possess the following properties: be strongly bound with soil particles or easily incorporated into soil aggregates, be easy and inexpensive to measure, have low background concentration in soils, not interfere with sediment transport, have low plant uptake, be environmentally safe, and include multiple tracers that are similar in chemical properties but are distinct in signature (finger printing). Rare earth elements have been found to possess the aforementioned properties except for their binding abilities to soil particles, which is the most important attribute a sediment tracer must have.

OBJECTIVES

This study evaluated the binding abilities of five rare-earth element [lanthanum (La), praseodymium (Pr), neodymium (Nd), samarium (Sm), and gadolinium (Gd)] with soil particles and soil aggregates (small clods), and to further test the feasibility of tracing soil erosion in the laboratory under artificial rainfall.

METHODS

A silt loam soil, having approximately 13% sand, 18% clay, and 69% silt, was tagged with five rare-earth element oxide powders by thoroughly mixing them. Six inches of the blank (untagged) soil was packed into a box, and 1-inch of the rare-earth element-tagged soil was then packed on the top. The soil in the box was washed with 5 gallons of distilled water (about 5 inches of water depth). Following washing, the tagged soil layer was removed, air-dried, and then sieved in water to determine rare-earth element concentration in each particle size group. The soil below the tagged layer was sampled in 1-inch depth increments, and air-dried, and analyzed for rare-earth element concentration.

In addition, a laboratory plot (13 ft by 13 ft) was used to evaluate the feasibility of tracing soil erosion under rainfall. The 13-foot long slope was evenly divided into 5 segments (31.5 inches each), and each segment was tagged with a different rare-earth element tracer. The plot was set to 10% slope and six consecutive artificial rains were applied to the soil bed. All rains lasted 1 hour. Rainfall intensity was 2.4 inches per hour for the first four rains and 3.5 inches per hour for the last two. Runoff and soil loss were measured at the outlet every 3 min during each rain.

RESULTS

The rare-earth element concentrations in each particle size group were similar to those in the composite soil sample (**Fig. 1**), indicating that rare-earth element tracers were fairly evenly distributed in all soil particle groups. However, the rare-earth element concentrations in the silt-sized group (between Sieve No. 400 and No. 270) were somewhat lower than those in the whole soil, while the rare-earth element concentrations in the clay-sized group(Sieve No. >500) were somewhat higher than those in the whole soil, showing slightly preferential binding to clay size over silt size. Overall results indicate that the rare-earth element tracers when directly mixed with soil were fairly uniformly incorporated into various-size soil aggregates or clods.

The rare-earth element concentrations in each sampling depth, along with the rare-earth element background concentrations in the soil, are shown in **Table 1**. The first 1-inch layer contained the tagged soil, and the soil layer below contained untagged (blank) soil. Washing with 5 gallons of water caused no movement of the rare-earth element tracers from the tagged layer at the top of the soil to the underlying untagged soil, because the rare-earth element concentrations in the underlying untagged soil were more or less the same as the rare-earth element background concentrations of the soil. This result indicates that the rare-earth element tracers were bound well with soil particles and aggregates.

Cumulative soil losses from each segment from the six rains as measured by the rare-earth element tracers are shown in **Fig. 2**. **Fig. 2** shows how many pounds of soil eroded from each segment were transported to the outlet of the plot during each rain. The figure shows that most soil losses for the six rains were from the upper-middle slope of the samarium and praseodymium segments, and the least losses were from the neodymium segment near the outlet. Results indicate that not all soil eroded from

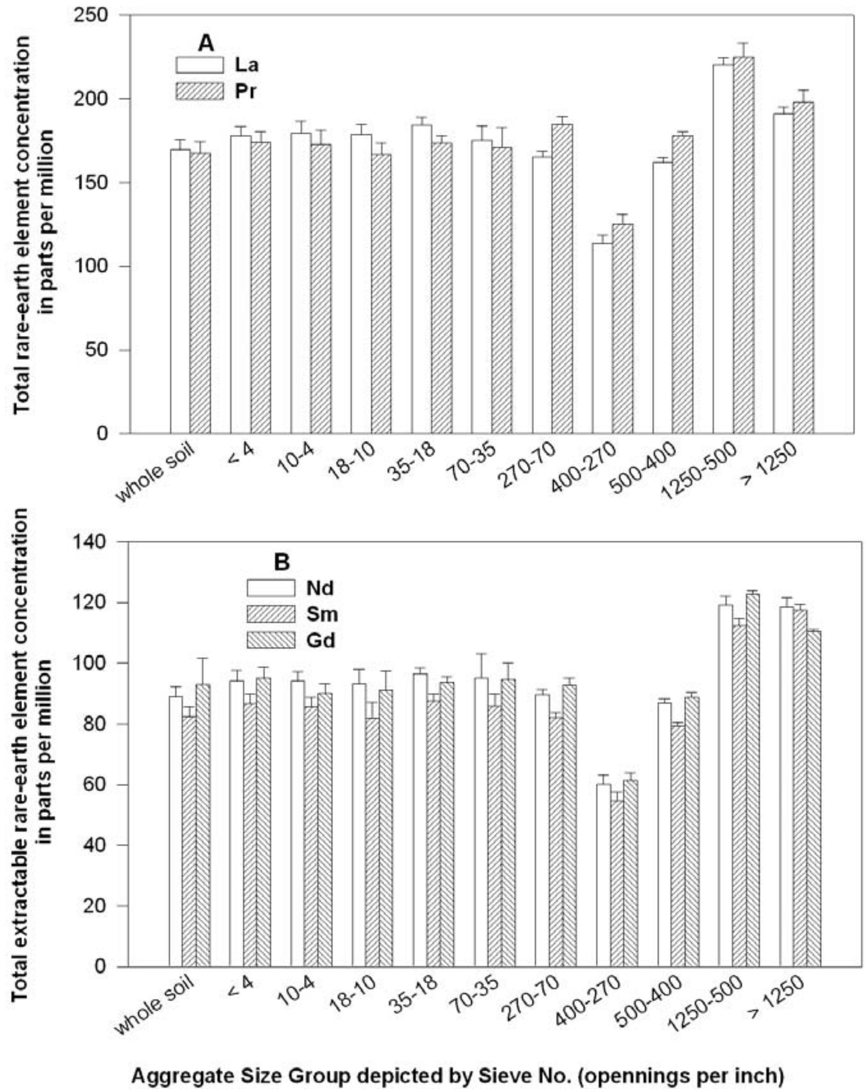


Fig. 1. Total rare-earth element concentrations in each size group after running 5-inch depth of water through the rare-earth element tagged soil and wet-sieving in water. Lanthanum (La), praseodymium (Pr), neodymium (Nd), samarium (Sm), and gadolinium (Gd).

each segment was transported to the outlet; some of the eroded soil was deposited somewhere down slope. However, results of this work suggest that the rare-earth element tracing method is able to pinpoint where the eroded soil is from and where it is ending up. **Fig. 3** shows total sediment deposition on a one-foot strip along the slope from each segment and for the six rains. By the end of the sixth rain, most of sediment deposition was from the uppermost slope of the Gd and Sm segments.

Overall results of this work show that the rare-earth element tracers were uniformly incorporated into all size groups of soil aggregates and bound well with soil particles and aggregates. Results further show that the rare-earth element tracers can do a good job in tracing sediment sources and soil redistribution due to erosion. This method has applicability to research in the national Conservation Effects Assessment Program which evaluates the effects of USDA conservation programs on protecting water quality and reducing soil translocation by identifying and modeling sediment source and sink areas (See Starks et al., this publication).

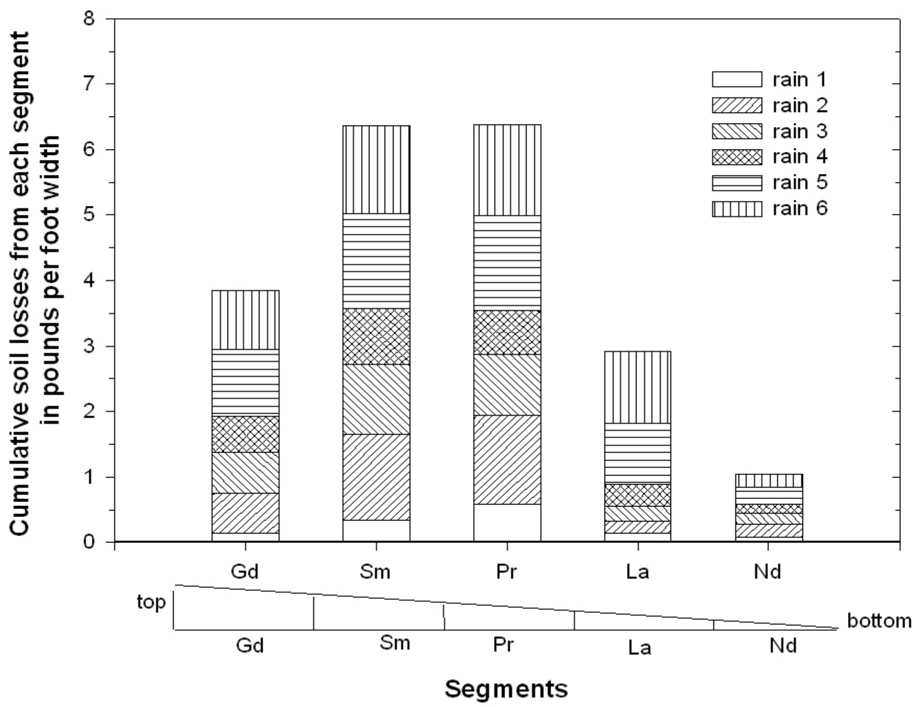


Fig. 2. Cumulative soil losses from each tagged segment measured at the outlet for the 6 rains. Lanthanum (La), praseodymium (Pr), neodymium (Nd), samarium (Sm), and gadolinium (Gd).

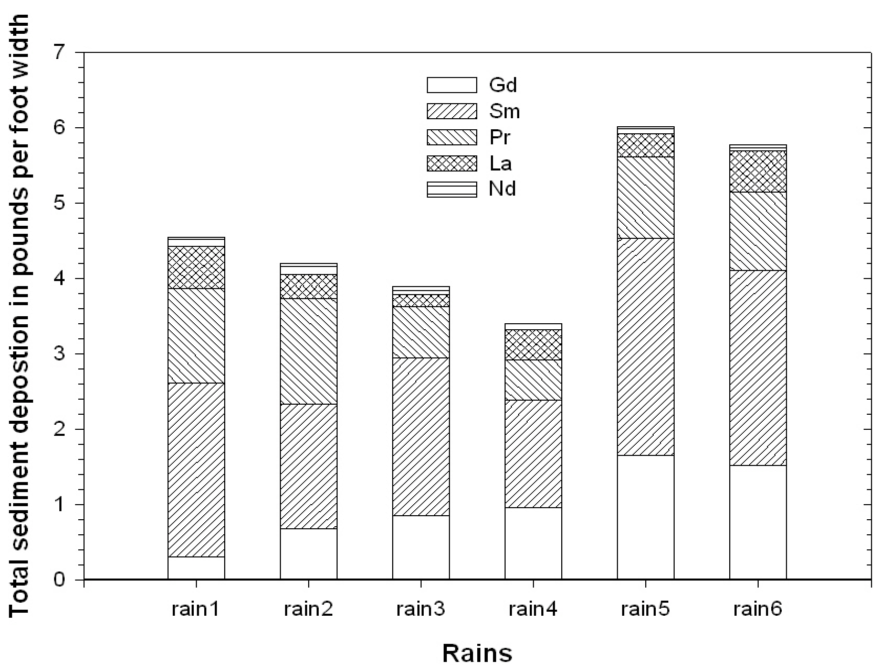


Fig. 3. Total sediment deposition on a one-foot strip along the slope from each segment and for the 6 rains. Lanthanum (La), praseodymium (Pr), neodymium (Nd), samarium (Sm), and gadolinium (Gd)

Table 1. Change of rare-earth element concentrations with depth after running 5-inch depth of water through the soil. The background Rare-earth element concentrations of the blank soil are also given in the last row.

Depth	lanthanum	prasedymium	neodymium	samaium	gadolinium
inches	ppm				
0 - 1	169.6	167.4	89.1	82.4	93.0
1 - 2	13.3	3.3	11.0	2.3	2.1
2 - 3	12.5	3.2	11.0	2.1	2.0
3 - 4	12.4	3.1	11.0	2.1	2.0
4 - 5	12.3	3.1	11.0	2.1	2.0
5 - 6	12.6	3.1	11.1	2.1	2.0
Backgrounds	12.8	3.2	11.0	2.2	2.1

DIRECT COMPARISON OF TWO SYSTEMS FOR THE MEASUREMENT OF CARBON DIOXIDE, WATER, AND ENERGY FLUXES IN TALLGRASS PRAIRIE

Geoffrey Doyle, William Dugas, and Herman Mayeux

RATIONALE

Despite the current debate surrounding the issue of human activity and its possible effects on climate and ecosystems, one fact is unchallenged: the concentration of carbon dioxide (CO_2) in the atmosphere is increasing at a rate of approximately 1% per year and has risen by over 30% since the beginning of the Industrial Revolution. Carbon dioxide is the most important of several greenhouse gases that have been linked to global warming. However, scientists have been unable to account for the fate of all the CO_2 released into the atmosphere by the energy, transportation, and manufacturing industries, and some hypothesize that much of it is absorbed by the vegetation and soils of natural and some agricultural ecosystems. This possibility led to recent efforts to measure the gains and losses of CO_2 by the soils and vegetation of different ecosystems. Plants take up CO_2 during photosynthesis, and plants and soils loose CO_2 during respiration.

Rangelands (including grasslands) cover approximately 50% of the earth's land surface, and the role of rangelands and agriculture in the global C cycle is not clearly understood. Many researchers believe that rangelands may absorb more atmospheric C than they release on an annual basis. Long-term measurements of CO_2 movement between the vegetated land surface and the atmosphere will help determine whether rangelands are a source or sink of atmospheric CO_2.

Currently, two methods are available for measuring CO_2 movement or flux between ecosystems and the atmosphere. The Bowen ratio/energy balance (BREB) system operates much like a weather station for determining rates of movement of CO_2 and water vapor between the surface and the atmosphere. Combining the measurements of the CO_2 and water vapor gradients above the plant canopy with those of energy, sensible heat, soil heat flux, and net radiation from sunlight allows one to calculate the amounts of CO_2 and water vapor that enter or leave an ecosystem.

The eddy covariance or eddy correlation (EC) system is also used to measure CO_2 and water vapor fluxes over a broad area. This system is generally more expensive, and theoreti cally more complex than the BREB, but it is comparatively simple to operate. While sensible heat and latent heat fluxes are measured using appropriate sensors, the EC method measures the CO_2 flux directly using the correlation (statistical relationship) of high-frequency measurements of wind components (including vertical eddies) and CO_2 concentration. Both systems make continuous measurements and integrate the fluxes over a large area, more than 10 acres.

Both BREB and EC systems are used to measure CO_2 and water vapor fluxes. The EC system is becoming the "standard" measurement system, but for more than a decade the ARS Rangeland CO_2 Flux Network has successfully used the BREB system over rangeland ecosystems. This network of 10 sites is part of the new ARS AgriFlux network, a larger network organized to discover whether rangelands, pastures, and croplands are functioning as CO_2 sources or sinks.

Numerous studies compared the measurement of sensible heat and latent heat by both systems, but few compared even short-term (a week or less) CO_2 flux measurements. Measurement of latent heat flux is also important because it is equal to the rate of evaporation of water.

OBJECTIVE

The objective of this study was to compare the two methods for making measurements of fluxes of sensible heat, latent heat, water vapor, and CO_2 on the same site and for an extended period of time, in order to determine whether the two provide similar results.

METHODS

Measurements were made within a 74-acre pasture located at the Grazinglands Research Laboratory (N 35°32'56.8" W 098°02'22.9", elevation = 1340 feet). Dominant prairie species included big bluestem (*Andropogon gerardi* Vitman), little bluestem [*Schizachyrium halapense* (Michx.) Nash.], annual bromes (*Bromus japonicus* Thunb; *Bromus tectorum* L.), and others common to tallgrass prairie. The soil at this site is classified as Norge loamy prairie (Fine, mixed, thermic Udertic Paleustalf) with a depth greater than 3 feet, high water holding capacity and slope averaging about 1%. This pasture has not been burned since 1990, but was occasionally sprayed with a broad-leaf herbicide, and grazed seasonally at moderate stocking rates. The EC and BREB instrumentation were placed side-by-side in the approximate center of the study site.

Eddy correlation instrumentation consisted of a CSAT–3 three-dimensional sonic anemometer (Campbell Scientific, Inc., Logan, UT) mounted at 8 feet, oriented 180° from magnetic north and connected to a CR23X data logger (Campbell Scientific, Inc., Logan, UT). Air CO_2 and water vapor concentrations were measured at 10 Hz with an open path infrared gas analyzer (LI-COR 7500, LI-COR, Inc., Lincoln, NE) located approximately 6 inches from the center of the sonic anemometer and oriented approximately 15° away from the anemometer, and also connected to the CR23X data logger. Air temperature and relative humidity were measured with a model HMP45C probe (Campbell Scientific, Inc., Logan, UT). Twenty-minute averages of 10-Hz measurements of sensible heat flux, latent heat flux, and CO_2 flux were recorded from August 2001 to the present. Fluxes away from the vegetation and into the atmosphere are considered positive.

BREB measurements were made simultaneously with the EC measurements, using a Campbell Scientific, Inc. Model 023/CO_2 Bowen ratio system. Bowen ratios were calculated from 20-minute average temperature and humidity gradients measured every 2 seconds at 3.1 and 8 feet above the soil. Twenty-minute averages of sensible heat were calculated from the Bowen ratio and average net radiation and soil heat flux/storage. Net radiation and soil heat flux were measured using a Q*7.1 net radiometer (REBS, Seattle, WA) and heat flux plates and soil temperature sensors, respectively. Fluxes of CO_2, corrected for vapor density differences at the two heights, were calculated as a product of this turbulent diffusivity and the average CO_2 gradient that was measured using an infrared gas analyzer (LI-COR 6262, LI-COR, Lincoln, NE), in conjunction with the humidity gradient. All sensors were connected to a CR21X data logger (Campbell Scientific, Inc., Logan, UT).

An EC system timing error was discovered in 2003 by the LI-COR Company. This error resulted in improper communication between the infrared gas analyzer and the data logger, which tended to suppress EC CO_2 and water vapor fluxes. This error was repaired in October 2003. Measurements made before October 2003 are referred to as "pre", and those made after are referred to as "post".

RESULTS

Sensible heat flux. EC measurements of sensible heat flux were approximately 70% of BREB sensible heat flux measurements, and, as expected, no significant differences were noted between pre and post periods. EC sensible heat flux measurements were not affected by the timing error between the gas analyzer and the data logger (**Fig. 1**).

Latent heat flux. There was a large difference between latent heat flux from the two methods in both the pre and post periods. During the post period, the relationship between latent flux measured by BREB and EC methods had a slope equal to 0.86; during the pre period, the slope was 0.58, indicating that the timing correction increased the agreement between the two measuring systems (**Fig. 2**). Average latent heat flux was approximately 150.5 watts yard^{-2} day^{-1} during the summer. This flux is equal to 0.25 inches day^{-1} of evapotranspiration.

Energy balance closure. Prior to the correction of the timing error there was a consistent lack of daily EC energy balance closure, i.e. sensible heat plus latent energy was less than net radiation minus soil heat flux, by 25–35%. Closure closer to 1.0 was observed during the post period, perhaps due to higher latent heat flux measurements obtained after the timing error was corrected. However, energy balance closure was sometimes greater than 1.0 after the correction. Values less than 1.0 suggest an incomplete energy balance, indicating that the method does not account for all energy entering the system from sunlight, and therefore may not be accurately estimating the magnitude of energy fluxes.

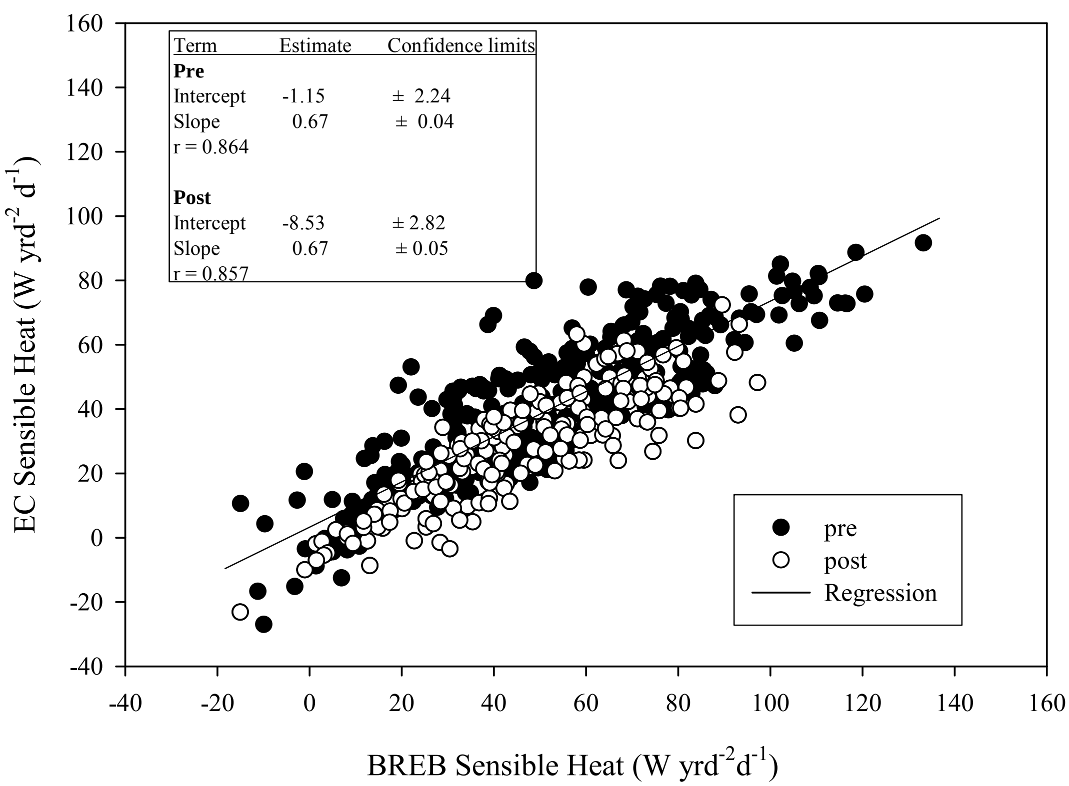


Fig. 1. Daily sensible heat flux densities (H) as measured by the Bowen ratio system and the eddy covariance system (watts yard^{-2} day^{-1}).

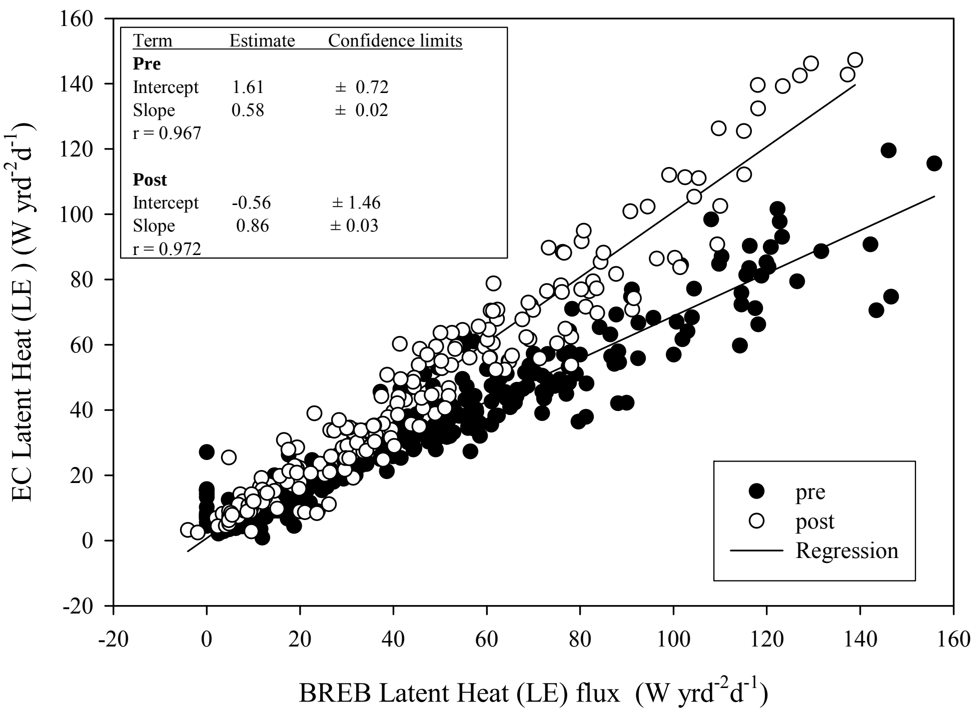


Fig. 2. Daily latent heat flux densities (LE) as measured by the Bowen ratio system and the eddy covariance system (watts yard^{-2} day^{-1}).

Carbon dioxide flux. The tallgrass prairie was a source of CO_2 for about 8 months each year, in fall, winter and spring, due to loss of CO_2 by respiration from soils and vegetation (**Fig. 3**). The prairie was a sink in summer, from May through August, with maximum CO_2 uptake occurring during the active growing season of the warm-season perennial grasses that dominate the prairie. Both systems demonstrated that this tallgrass prairie site is a C sink when annual fluxes are calculated, with an annual CO_2 flux for the entire period of almost 200 lb CO_2 acre^{-1} year^{-1} (224 kg CO_2 ha^{-1} year^{-1}) into the vegetation, when averaged over the 3 years of this study. This value is close to the average annual CO_2 fluxes of most other grasslands in the western and central U.S. monitored by ARS AgriFlux network. This result and those of other AgriFlux network participants indicate that most rangelands in the central and western U.S. are removing small amounts of CO_2 per acre from the atmosphere each year. However, when extrapolated over the 800 million acres of rangeland in the U.S., these low rates represent huge amounts of CO_2 that are removed from the atmosphere and no longer contribute to the greenhouse effect.

For those days when CO_2 flux was less than zero, indicating net uptake of CO_2 by the vegetation, daily BREB CO_2 fluxes were more negative than EC fluxes, indicating that EC measured a lower rate of CO_2 uptake than BREB. However, for days with daily flux greater than zero (net ecosystem loss of CO_2), daily BREB fluxes were slightly more positive; EC measured lower rates of CO_2 loss compared to the BREB (**Fig. 4**). The slope of average daily flux of the two systems was almost equal before and after the timing error correction (**Fig. 4**), indicating a slight change after this correction.

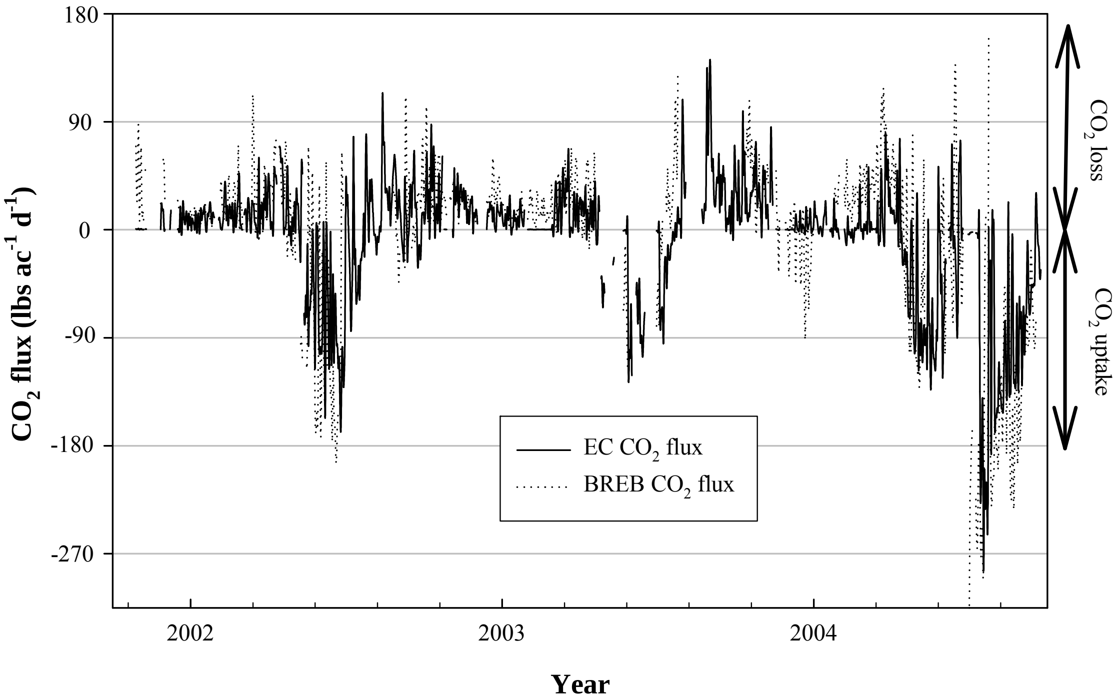


Fig. 3. Carbon dioxide fluxes versus time as measured by the Bowen ratio system and the eddy covariance system (lbs $acre^{-1}$ day^{-1}), about 9 lbs per acre equals 1 gram per square meter; negative values indicate CO_2 uptake by the vegetation, while positive values indicate CO_2 loss to the atmosphere.

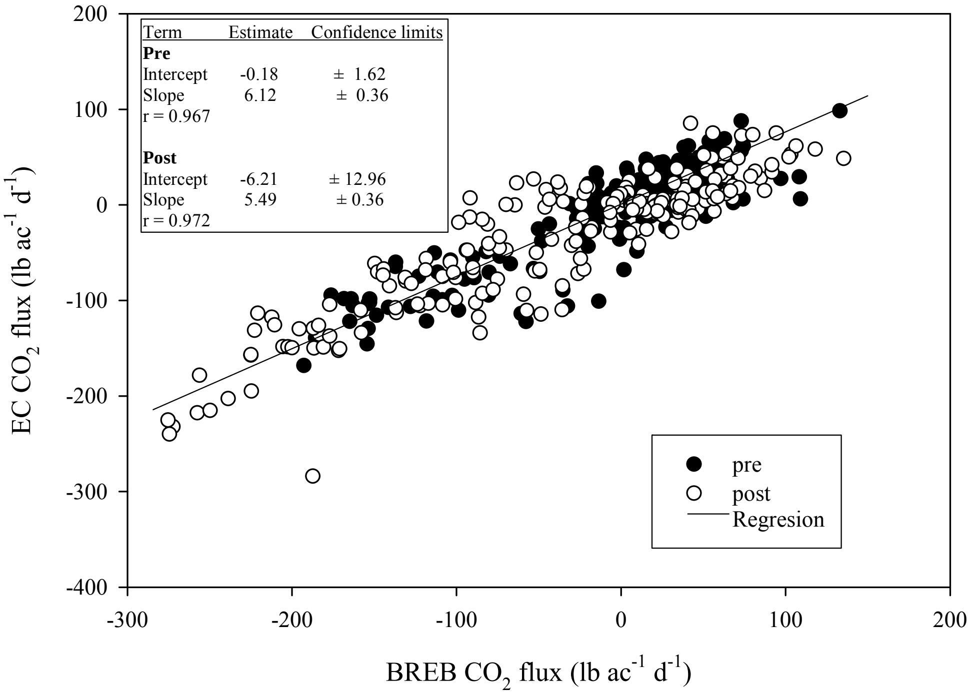


Fig. 4. Daily carbon dioxide (CO_2) as measured by the Bowen ratio system and the eddy covariance system (lbs $acre^{-1}$ day^{-1}), about 9 lbs per acre equals 1 gram per square meter.

INCORPORATING PERENNIAL COOL-SEASON GRASSES INTO A WINTER WHEAT STOCKER PRODUCTION SYSTEM

Brian K. Northup, William A. Phillips, and Herman S. Mayeux

RATIONALE

Putting low-cost gain on beef calves with forages before entering the feedlot is a major agricultural activity in the southern Great Plains. The primary cool-season forage grazed by these stocker calves is winter wheat. Wheat is an annual crop that must be established each year, and planting date and precipitation are among the important factors influencing fall forage production. Perennial cool-season grasses do not have to be established each year and begin growth in early September. They also cease growth in early winter, so high quality forage will be in short supply during January and February. Alternatively, perennial cool-season grasses grow for a longer period than wheat during the spring, allowing stocker cattle to be retained on high quality forage until the summer grazing period. A combination of perennial cool-season grass and winter wheat may lower risks associated with the traditional all-wheat system of producing pasture for stocker calves, and allow calves to sustain high average daily gains throughout the fall through spring grazing seasons.

OBJECTIVE

This study compared the performance of stocker calves grazing perennial cool-season grasses in the winter and spring with calves grazing winter wheat. The goal was to determine the cost/lb of gain by stocker calves using either the traditional all-wheat pasture system, or a combination of wheat and perennial cool-season pastures.

METHODS

We conducted studies during the 2001 to 2002 and 2003 to 2004 grazing seasons. Eighteen 5 acre pastures were planted to one of two introduced varieties of wheatgrass, 'Manska' intermediate wheatgrass and 'Jose' tall wheatgrass, and allowed 1 year of establishment before grazing was initiated. Other pastures were planted to winter wheat each September using clean tillage practices. Pastures were fertilized with an average of 80 lb N/acre each year.

The fall grazing period began in mid-November with calves (averaging 460 lb) assigned to wheat pastures at 0.5 head/acre and to perennial pastures at 1.5 head/acre. The stocking rate for the perennial pastures was set to use the available high-quality fall forage in about 60 days, and still allow sufficient regrowth. Once the utilization targets for the wheatgrasses were reached, the calves were moved to previously ungrazed wheat pastures in early January and grazed at a stocking rate of 1.2 head/acre to complete the 129-day winter grazing season. The spring grazing period began in mid-March, with calves grazing wheat pastures at 3.0 head/acre and the wheatgrass pastures at 1.8 head/acre. The calves grazed wheat until completion of graze-out on about May 1, and the perennial pastures were grazed until about June 1.

Stocker calf performance was divided into winter and spring periods and the cost/lb of gain was calculated for each period. We assumed that the winter grazing period was 30% of the annual production costs of pastures, and the spring grazing period was the remaining 70%. This division was based on the timing of production of the total amount of forage generated by the pastures during the October through May time period.

RESULTS

The wheatgrass pastures produced enough forage in the fall to support 1.3 head/acre for 58 days in mid-November to mid-January. Average daily gains during this period were 2.50 lb for calves grazing wheatgrass, compared to 3.27 lb for calves grazing winter wheat. The lower daily gains observed for calves grazing wheatgrasses may be due to lower forage intake, digestibility, or protein content of the wheatgrasses in comparison to winter wheat. At the end of the winter grazing season, calves that grazed only winter wheat used 1.9 acres of pasture per calf and produced 323 lb/acre of gains at a cost of $0.17/lb of gain (**Table 1**). Calves that grazed wheatgrass pasture the first half of the fall grazing period and wheat pasture the second half used a total of 1.6 acres/calf, with 48% of this area being in wheatgrass. The overall average daily gain for the wheat + wheatgrass system was 85% of daily gains for calves grazing wheat only. Although the wheat + wheatgrass system produced only 274 lb/acre of gains, costs of gain were less than wheat at $0.14/lb.

Calves were able to graze the wheatgrass pastures about 30 days longer than wheat pasture during the spring. While the spring growing season of the wheatgrasses was longer than wheat, the stocking rate was less because daily forage production was lower than wheat. The wheatgrasses produced similar amounts of forage per acre to wheat, but their slower growth cycle and longer growing season means peak forage production generally does not occur until late June. As a result, the number of grazing days/acre was similar (**Table 2**). Once again, average daily gains and gains/acre were less for calves grazing wheatgrasses as compared to calves grazing wheat. However, costs/lb of gain for stocker calves grazing wheatgrass were also lower than costs recorded for wheat, at $0.17/lb compared to $0.20/lb.

Establishment costs of wheatgrass pasture averaged $222/acre, which was 2.3 times the $95/acre annual cost of planting clean-tilled wheat. A large portion of establishment costs for the perennial pastures was related to seed costs, which was $2.65/lb for Manska and $1.35/lb for Jose. The pastures were planted with 15 lb seed/acre, so seed costs alone for Jose and Manska were $21/acre and $40/acre. A second major cost of developing wheatgrass pastures was the deferment of grazing in the establishment year. Based on the historical value of stockers grazed at the Grazinglands Research Laboratory, we estimated deferment costs to be $109/acre. However, because the wheatgrasses are perennials, establishment costs must be

Table 1. Performance of stocker calves during a 129-day winter grazing season using winter wheat or perennial wheatgrass plus wheat as the forage resource.

	Forage resources †	
Trait	Wheat only	Wheatgrass + wheat
Land resources, acres/calf		
Wheat pasture	1.90	0.84
Wheatgrass pasture	—	0.77
Total	1.90	1.61
Average daily gain, lb	2.59	2.19
Stocker gain, lb/acre		
Wheat pasture	323	129
Wheatgrass pasture	—	145
Total	323	274
Pasture cost, $/lb gain ‡	0.17	0.14

† Calves in the wheat only system grazed winter wheat pasture for 129 days. Calves in the wheatgrass + wheat system grazed wheatgrass pasture for 58 days and winter wheat for 71 days.

‡ Thirty percent of the annual pasture cost was charged against winter stocker gains. Cost/lb of gain for wheat only system = ($95/acre x 30% x 1.9 acres)/323 lb of gain. Cost/lb of gain for wheatgrass + wheat system = (($95/acre X 30% X 0.84 acres) + ($68/acre x 30% x 0.77 aces))/274 lbs of gain.

Table 2. Performance of stocker calves during the spring using winter wheat or perennial wheatgrass as the forage resource.

	Forage resources †	
Item	Wheat	Wheatgrass
Land resources, acres/calf	0.33	0.55
Stocker grazing, days/acre	110	114
Average daily gain, lb	2.95	2.42
Stocker gain, lb/acre	325	276
Pasture cost, $/lb gain ‡	0.20	0.17

† Calves in the wheat system grazed winter wheat pasture for 36 days. Calves in the wheatgrass system grazed wheatgrass pasture for 63 days.

‡ Seventy percent of the annual pasture cost was charged against spring stocker gains. Cost/lb of gain for wheat system = ($95/acre x 70%)/325 lb of gain. Cost/lb of gain for wheatgrass system = ($68/acre x 70%)/276 lbs of gain.

spread over the projected life of the stand as part of annual costs. In this study, we assumed a stand life of 7 years, as it was representative of the average life span of pasture improvements planned by the USDA-NRCS. When amortized over the stand life, annual costs of the wheatgrasses including deferments averaged $68/acre, which was well below the $95/acre annual costs for planting wheat pasture. If the break-even point for establishment and maintenance costs is considered, wheatgrass pasture takes about 3.8 of the 7 years of planned stand life to equal the cost of planting wheat annually.

Establishment costs are an economic hurdle to the use of perennial cool-season grasses, particularly the costs of deferring grazing in the first year. All perennial cool-season grasses require a first-year deferment of grazing to ensure a healthy and vigorous stand. In this study, deferment costs represented 49% of the total establishment costs if wheat ground were converted to perennial pasture. However, there is an opportunity to partially recover some of this lost revenue. If growing conditions during the establishment year are reasonable, a hay crop could be harvested from the perennial pasture, to remove standing forage and prepare the pastures for fall grazing. Our first-year hay crop from the wheatgrass pastures averaged 3 tons/acre. Based on a local hay value of $55/ton, we were able to capture about $90/acre of returns above harvest costs during the first growing season. This return would reduce the total cost of deferment to $19/acre, or $2.70/acre/year over the projected stand life. This would lower the annual cost of wheatgrass pasture to $55/acre, further reducing the costs per pound of gain and the break-even point to about 2.8 years compared to wheat pasture. We did not include this potential return in the results reported in **Table 1** as it depends on growing conditions, and may not occur in all establishment years. If returns from a first-year hay crop are realized, they can greatly improve the economic value of perennial wheatgrass pastures.

Although establishment costs of the wheatgrass pastures in this experiment were high, amortizing establishment costs over 7 years generated lower annual costs than were recorded for wheat pasture. Further, costs of gain were below those of traditional wheat pasture despite lower gains by calves in wheat + wheatgrass or wheatgrass-only systems. Perennial wheatgrasses could be an effective component of a two-forage system for stocker calf production in the southern Great Plains. For example, producers who graze stocker calves in the winter could reduce the risks of production by dividing their land resources equally between wheatgrass and wheat pasture without increasing the cost of production. Wheatgrass pasture could be grazed in November and December, allowing wheat to accumulate forage for use in January and February. Also, the longer spring grazing season of the wheatgrasses would allow calves to be marketed a month later, avoiding the seasonal glut of stocker calves entering the market from wheat pasture in late April and early May.

FILLING FORAGE GAPS WITH NON-TOXIC ENDOPHYTE-INFECTED FESCUE

Brian K. Northup, William A. Phillips, and Herman S. Mayeux

RATIONALE

Putting low-cost gains on yearling cattle with forages is a major agricultural activity in the southern Great Plains. The primary forage production system within the region has two components: winter wheat for fall through spring grazing, and warm-season perennial grasses for grazing in the summer. This system has two important gaps when high-quality forage is not readily available, September-November and April-May. Introduced perennial cool-season grasses have longer growing seasons than wheat, and could help fill these gaps.

OBJECTIVE

This experiment tested how well an introduced cool-season perennial grass could fill the forage deficit gaps in a stocker production system that uses winter wheat as the base forage.

METHODS

Studies were conducted during 2002 through 2004 on three, 4.5-acre pastures planted to 'Jessup Max-Q', a non-toxic endophyte-infected tall fescue. Pastures were grazed from late October to early December in the fall and from late April to late May in the spring. The objective of our grazing strategy was to provide high quality forage for 30- to 45-day periods before wheat pasture was ready in the fall, and to bridge the gap between the graze-out of winter wheat and start of the grazing season for warm-season grasses. The amount of fescue available for grazing was measured at the start of each grazing period, and livestock gains were determined by weighing the calves at the beginning and end of the grazing period. Pasture establishment and maintenance (fertilizer, weed control) costs were recorded and used to compare values of weight gains of calves on winter wheat and tall fescue pastures.

RESULTS

Tall fescue pastures produced 1810 lb/acre of forage by mid-October, which was 36% of the annual total. These pastures supported an average of 89 stocker grazing days/acre in the fall. Fall grazing was initiated on October 21 each year and pastures were grazed for 35 days at a stocking rate of 2.5 head/acre (**Table 1**). At an average daily gain of 1.59 lb, 139 lb of gain/acre was produced at a cost of $0.17/lb during the fall period. In other experiments, we determined that the pasture cost of grazing stocker calves on wheat from November through February was roughly $0.17/lb of gain, so cost of gain for the two types of pasture were similar. Stocker producers who graze winter wheat can use fescue pastures to fill the fall forage deficit period and begin the fall grazing season 30 days earlier.

Spring grazing of the tall fescue pastures was initiated around April 21 after wheat graze-out had finished, and had produced 3240 lb/acre of forage by mid-April (64% of total). These pastures supported an average of 102 stocker grazing days/acre during late April through May, at a stocking rate of 3.4 head/acre (**Table 1**). At an average daily gain of 2.95 lb, a total of 300 lb of gain/acre was produced. Average daily gains and gain/acre by stocker calves on the fescue pastures were greater in the spring than in the fall due to improved growing conditions for the fescue and the corresponding greater abundance of forage. Costs of gain for the fescue pastures were $0.18/lb of gain, compared to $0.20/lb of gain for winter wheat during March through April.

Fescue establishment costs were $258/acre, which was 2.7 times the cost of planting wheat at $95/acre. A large portion of the establishment cost for fescue pastures was related to the cost of Max-Q seed ($4.40/lb x 15 lb/acre seeding rate = $66/acre), which was 26% of establishment costs. A second major cost of developing fescue pastures was the deferment of grazing in the establishment year. Based on previous research at the Grazinglands Research Laboratory, our costs of deferment averaged $109/acre. However, because fescue is a perennial, establishment costs must be spread over the projected life of a stand as part of annual costs. In this study we assumed a stand life of 7 years, as it was representative of the planned life spans of grazing projects developed by the USDA-NRCS. When amortized over the stand life, annual costs including deferment were only 82% of the costs of planting wheat ($78/acre for fescue versus $95/acre for wheat).

Establishment costs have always been a hurdle to the use of perennial cool-season grasses, particularly the cost of deferring grazing in the first year. To ensure a healthy stand, perennial cool-season grasses require a first-year deferment (October through June) of grazing. In this study, deferment costs represented 42% of the total establishment costs when wheat pasture is converted to perennial pasture. However, there is an opportunity to partially capture some of this lost 'first-year' revenue. If growing conditions for the perennial grass are reasonable, a hay crop could be harvested in mid-summer of the establishment year, to remove standing forage and prepare the pastures for fall grazing. Our first-year hay crop averaged 2.7 tons/acre. Based on a local hay value of $55/ton, we were able to capture about $81/acre of returns above harvest costs during the first growing season. By harvesting a first-year hay crop, the total cost of deferment was reduced from $109/acre to $28/acre, or $4/acre/year over the projected stand life. This would reduce the annual cost of fescue pasture from $78/acre to $66/acre, making the overall cost per pound of gain for fescue pastures lower than those of wheat pasture. We did not include this potential return in the results reported in **Table 1**, as it will depend on growing conditions and may not occur in all establishment years. If returns from a first year hay crop are possible, they can greatly improve the economic value of fescue pastures.

Despite high establishment costs, pastures of non-toxic endophyte-infected tall fescue were effective at generating gains by stocker calves, and did so at times when the traditional forages were not available. Fescue pasture could be used to start the fall grazing season roughly 30 days early and prepare stocker cattle for grazing wheat. Fescue pasture can also be used to bridge the gap between graze-out of winter wheat and the start of the grazing season for warm-season grasses, or to delay marketing of calves for an additional 30 days. As used on the fescue pastures, intensive short-duration grazing is similar to harvesting a hay crop, and allows for long recovery times between grazing periods. This approach may extend the life of the stand and help further lower the costs of establishing perennial pasture.

Table 1. The performance of stocker calves grazing fescue pastures using intensive short duration grazing practices in the fall and spring.

	Grazing season	
Trait	Fall	Spring
Initial body weight, lb	574	668
Length of grazing season, days	35	30
Stocking rate, calves/acre	2.5	3.4
Average daily gain, lb	1.59	2.95
Stocker gain, lb/acre	139	300
Pasture cost, $/lb gain †	0.17	0.18

† The annual pasture cost of $78/acre was charged as follows; 30% in the fall and 70% in the spring.

NO-TILL SEEDING OF COOL-SEASON GRASSES INTO UNIMPROVED WARM-SEASON PASTURE

Paul W. Bartholomew and Robert D. Williams

RATIONALE

Provision of forage during the October-March cool season is a problem for livestock farmers throughout the southern Great Plains, but is especially difficult for resource-limited producers who may be obliged to purchase feed for up to 5 months of the year. While hay-making may be the answer to this problem for some farmers, for many, and particularly smaller producers, the costs of hay-making equipment may not be economically justified. Winter grazing of wheat, rye or oat pastures can be an effective way of over-wintering livestock, but time and equipment constraints on livestock farms may limit the possibilities for ground preparation and planting of these annual crops. For low-input and resource limited systems, the inclusion of cool-season perennial pasture grasses in a sequence with unimproved warm-season grasses appears to offer a means of increasing carrying capacity and improving year-long forage output that avoids the need for frequent ground preparation and sowing. By using minimal-tillage seeding techniques to introduce cool-season species into existing pasture, labor and equipment costs for seeding can be reduced and soil erosion risk may be minimized. However, the viability of cool-season grass introduction into unimproved warm-season pasture as a means of increasing cool-season forage output in low-input systems has received little research attention.

OBJECTIVES

The objectives of this work were to evaluate the productivity of a range of cool-season grasses sown to complement or replace unimproved warm-season pasture and to measure the impact of different establishment methods and prior cropping on forage output.

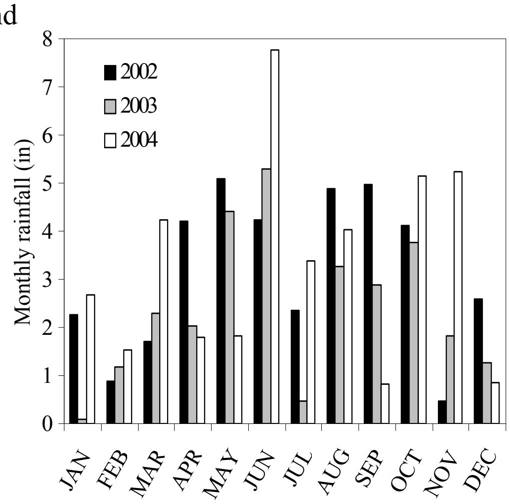
METHODS

A replicated small-plot experiment was carried out over three years (2002-04) near Langston, OK, on a Coyle series soil that had been in hay pasture for over 10 years. The existing pasture was composed of a mixture of natural pasture species, including; sideoats grama, split-beard bluestem, little bluestem, big bluestem, switchgrass, old field threeawn, Florida paspalum, Scribner's panicum, and California joint-tail. Six cool-season grass species were evaluated: 'Ky31' tall fescue, 'Marshall' Italian (annual) ryegrass, 'Jose' tall wheatgrass , 'Lincoln' smooth brome, 'Luna' intermediate wheatgrass,) and 'Newhy' creeping wheatgrass x bluebunch wheatgrass hybrid. Grass seed was oversown with a no-till seeder into the mowed stubble of Korean lespedeza or natural pasture, or drilled directly into cultivated soil on clean-till treatments, in fall of 2001. Control treatments, in which no overseeding of cool-season grass was made, were included as "unsown" plots on cultivated, lespedeza and natural pasture areas. The seeding rates used followed standard recommendations (fescue and ryegrass sown at 28 and 30 lb/acre, brome and wheatgrasses at 14 and 18 lb/acre). A reinforcement seeding of lespedeza (20 lb/acre) was surface-broadcast in early April of 2002, to ensure legume growth during the summer, but plots were subsequently managed to encourage self-seeding and no overseeding of lespedeza was made after early April 2002. Italian ryegrass plots were resown, using a no-till seeder, in fall of 2002 and 2003.

Urea (50 lb N/acre) and triple superphosphate (22 lb P/acre) were applied in February each year. Forage productivity was estimated by clipping to a forage height of 2 inches during the last two weeks in May of each year, and of re-growth as plots reached 6-8 inches. Three clippings were taken using a sickle-bar mower in 2002 and 2004 and two clippings in 2003. The contribution of sown cool-season grass, warm season legume (lespedeza) and warm-season grass to forage dry matter yield was estimated at each harvest by hand separation of an 8 oz sample from each plot.

RESULTS

Rainfall and temperature conditions over the 3 years of the experiment are summarized in **Fig. 1**. Rainfall was low in April and May of 2004, compared with the same period in 2002 and 2003, and growth of all cool-season grass species was limited. July and August of 2003 were hot and dry, whereas June and July of 2004 were wetter than average and July and August 2004 were cooler than average. These differences contributed to differences in warm-season grass production in these 2 years. In each of the 3 years of the experiment, Marshall Italian ryegrass was consistently the highest- and Newhy the lowest-yielding sown grasses. Jose tall wheatgrass yield was ranked in second place, and



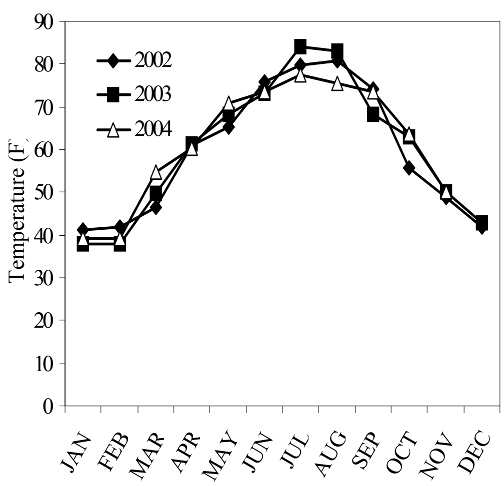


Fig. 1. Monthly rainfall totals and average daily temperatures for 2002-04 at the Langston, OK field site.

and was greater than that of Ky31 tall fescue in the first production year, but declined in subsequent years. Lincoln smooth brome, in contrast, increased its yield ranking from 5th in the first year to 3rd in the third year. Comparisons of cumulative total and component forage yields of the cool-season grass, warm-season grass, and lespedeza over 3 years are presented in **Fig. 2**. In total over 3 years, plots sown with Marshall ryegrass produced the greatest cool-season grass yield (5680 lb/ac) and the greatest overall forage yield (9150 lb/ac). Yields of cool-season grass were greater when these were seeded into cultivated ground, or overseeded into lespedeza stubble, compared with no-till seeding into dormant warm-season pasture. On average, cool-season grass seeded into lespedeza stubble produced 17% greater yields than when seeded into cultivated ground. Mean yield of cool-season grass no-till seeded into dormant warm-season pasture was 56% of that obtained from cool-season grass sown in cultivated ground. Although tillage increased yield of cool-season grasses compared with no-till seeding in pasture, cultivation significantly reduced the warm-season grass component of yield, which reduced total forage output over the 3 years to 71% of the average yield obtained with cool-season grasses no-till seeded into pasture. When lespedeza was included in the pasture sequence, warm-season grass yield was further depressed compared with tillage treatments. The decline in yield of the warm-season grass, however, was partly compensated by the contribution of lespedeza to the total forage output, and by an increase in mean cool-season grass yield, so that total output was on average 87% of that of no-till overseeding of cool-season grass into pasture. Only four treatments generated total forage yields greater than those obtained with undisturbed pasture (**Fig. 3**). Among treatments sown on cultivated ground, only plots sown to Italian ryegrass produced a greater total yield than that obtained from undisturbed pasture.

Although systems based on use of the existing warm-season grass pasture generally show a year-long forage yield advantage compared with cool-season grass sown into cultivated ground, this advantage may be diminished when the quality of the forage produced in the different systems is taken into consideration. Work is continuing to measure differences in forage quality among the different pasture improvement strategies tested.

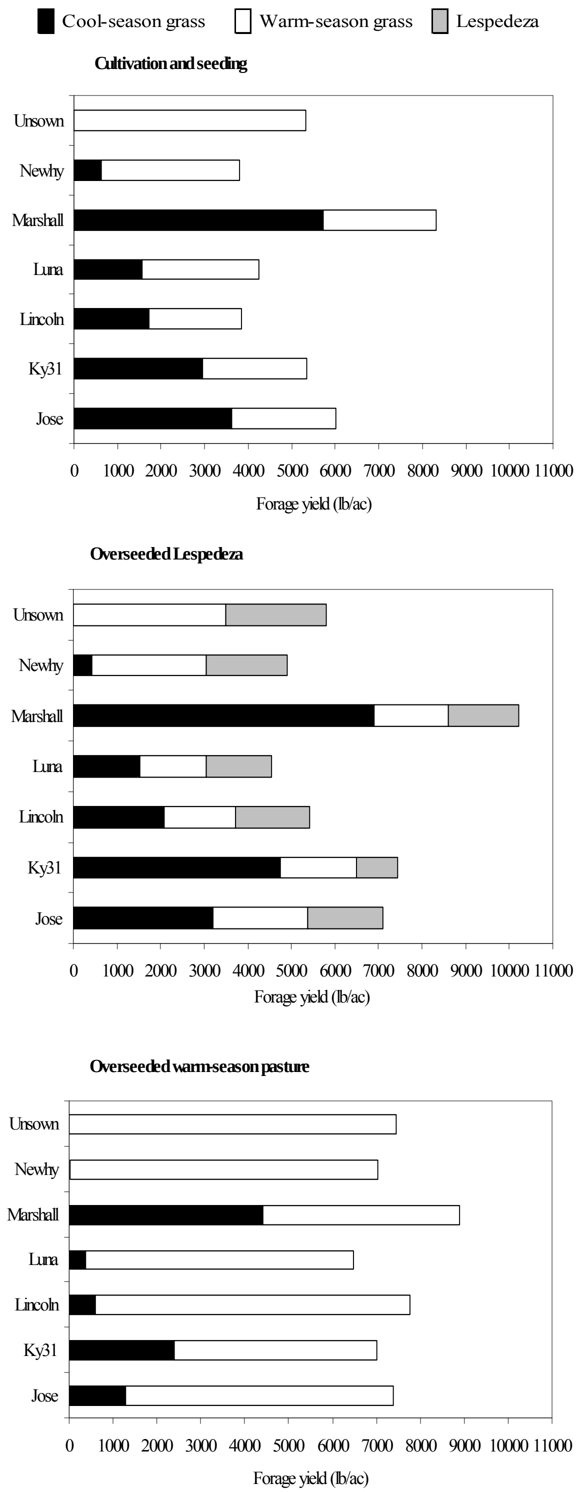


Fig. 2. Cumulative total and component forage yields, over 3 years, of pasture seeded with cool-season grasses, following cultivation, or by no-till seeding into stubble of Korean lespedeza, or into dormant unimproved warm-season pasture.

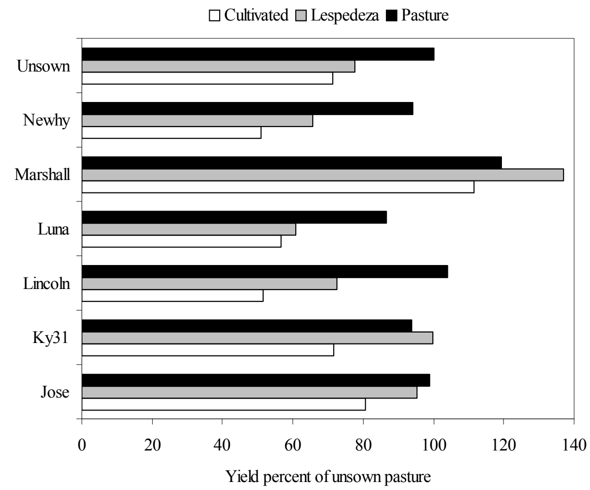


Fig. 3. Total forage yield, over 3 years, of pasture, lespedeza stubble, and cultivated ground seeded with cool-season grasses. Yields are expressed as a percentage of the yield of natural pasture not overseeded with cool-season grass (Unsown).

The results of this work indicate that:

- Cool-season grass can be established in dormant warm-season natural pasture without herbicide suppression, but cool-season grass yield is on average only 56% of that obtained following cultivation and sowing.
- Compared with no-till seeding into dormant warm-season pasture, sowing cool-season grass into cultivated ground may increase spring forage yield, but the destruction of existing natural pasture reduces summer yield and may result in reduced year-long forage production.
- A self-seeding summer legume such as Korean lespedeza can be grown in sequence with cool-season grass and can contribute to overall forage output and to an increase in cool-season grass production.

WIND AND MECHANICAL MOVEMENT OF ITALIAN RYEGRASS SEED

Robert D. Williams and Paul W. Bartholomew

RATIONALE

Italian ryegrass (*Lolium multiflorum L.*) can be a productive and high-quality cool-season forage in the southern Great Plains, however, its annual habit may limit its adoption by farmers who wish to avoid regular reseeding. Although it is an annual, Italian ryegrass can persist through self-seeding. If it can be managed to produce a seed output sufficient for effective re-establishment without compromising yield as a hay crop, Italian ryegrass may represent a viable alternative to perennial cool-season grasses. One management practice under consideration is the use of a partial harvest that leaves plants for seed production and re-establishment. An understanding of seed production, seed-shed, seed dispersal, and plant reestablishment is necessary to determine how large a ryegrass population needs to be to insure sufficient seed for reestablishment. Although wind dispersal of Italian ryegrass seed seems unlikely, mean wind speeds of 4 to 6 mph, with gusts of 26 to 38 mph, at our location are not uncommon and could help spread the seed across the field.

OBJECTIVE

The objective of this work was to examine the effects of wind and harvesting of hay on seed dispersal and distribution of Italian ryegrass.

METHODS

Italian ryegrass was no-till overseeded into dormant unimproved warm-season pasture in the fall of 2002. The established ryegrass was mowed before heading leaving four 9 square foot uniform grass blocks. Seed traps (6 inch diameter) were placed at intervals of 0, 1, 2, 3, 4, and 6 ft from the edge of the grass blocks in eight compass directions (N, NE, E, SE, S, SW, W, and NW). Trapped seed were counted every 7 to 10 days until the ryegrass was harvested on July 28. The seed traps were removed immediately before harvest and a 0.25-square foot area was vacuumed in the same compass directions and spacing. These samples were used as an additional method to estimate the number of Italian ryegrass seed deposited. Additional vacuum samples were collected at each edge of the grass blocks after harvest, as well as in the direction the forage was raked and piled for removal.

During the study, wind speed was continuously recorded at 11 inches above ground level, and the mean wind and maximum wind speed was logged every 15 minutes. Mean wind speeds ranged from calm to 13 mph, while wind gusts up to 58 mph were recorded. The measured wind speed and a simple ballistic equation were used to estimate the distance the wind would carry a ryegrass seed.

RESULTS

Regardless of compass direction and excluding seed deposited at the edge of the grass block, 80% of the seed was trapped within 3 ft of the edge (**Fig. 1**). Some seed were trapped at 6 ft from the edge of the grass block, but this only account for 8% of the total seed recovered. When seed trapped at the edge of the grass block was included in the calculations, 58% of the seed recovered was located at the edge. Overall, seed deposition was greatest within 1 ft of the edge of a grass block and decreased with dis-

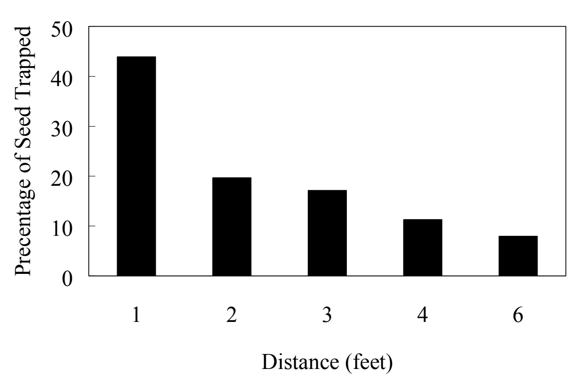


Fig. 1. Seed recovered in traps, express as percent of total recovery, at 1, 2, 3, 4 and 6 ft from the grass block edge.

tance from the edge. Based on the ballistic equation of seed dispersal by the wind, a conservative estimate of the distance of seed travel was 9 ft or less and is consistent with 80% of the trapped seeds traveling a distance of 3 ft or less. Based on these results, a sufficient number of seeds for reseeding would be within 3 ft of the edge of a grass block.

Because the prevailing wind is from the south, the majority of the seed were found north of the plots (**Fig. 2**). Seed found at distances greater than 2 ft were generally to the NE, E, and SE, probably as a result of intense wind following the general line of thunderstorms through the area. Although the vacuumed samples (data not presented) recovered more seed than were recovered in the seed traps, the patterns of seed deposition were similar.

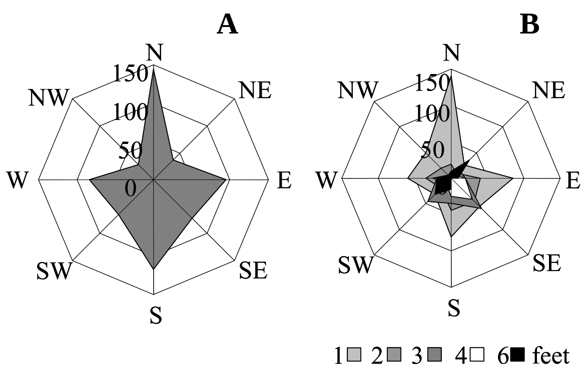


Fig. 2. Seed recovered at the grass block edge (A) and at 1 to 6 ft from the edge in eight compass directions (B).

Harvesting the grass blocks resulted in further deposition of seed near the edges of the blocks **(Fig. 3)**, as well as in the direction the forage was raked for removal **(Fig. 4)**, based on vacuum samples of seeds collected before and after the harvest. Although further seed deposition was expected during harvest, less seed was recovered than anticipated. Examination of the baled forage revealed that many seed were still attached to the seed heads.

Our research demonstrated that some Italian ryegrass seed was wind dispersed, and most seed were found well within the estimated 9 ft travel distance. Numerous seed were deposited at the edge of the grass blocks, and the majority of the seed were within 3 ft of the block edges. Mowing and baling would increase number of seed deposited, particularly in the direction the forage was raked for harvest. Unfortunately, passive seed distribution provides only limited dispersal of Italian ryegrass seed and is unlikely to allow uniform re-establishment by self-seeding.

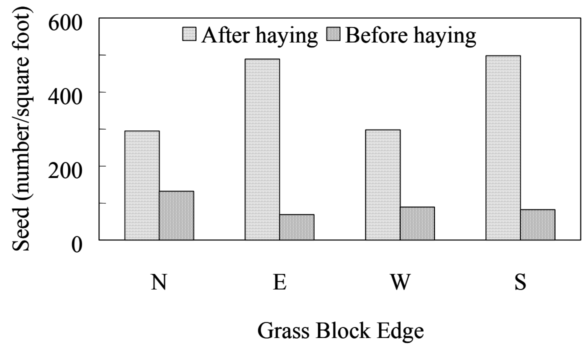


Fig. 3. Seed recovered by vacuum samples at the grass block edge before and after hay harvest.

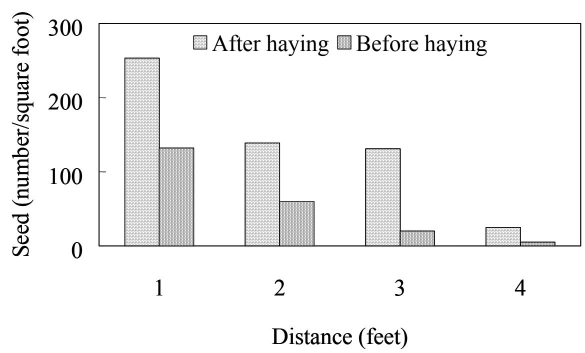


Fig. 4. Seed recovered by vacuum samples in direction of forage harvest at 1 to 4 ft from the grass block edge before and after hay harvest.

USING REMOTELY SENSED ESTIMATES OF CRUDE PROTEIN TO MAKE SUPPLEMENTAL FEED DECISIONS

Patrick J. Starks, William A. Phillips, Samuel W. Coleman and Duli Zhao

RATIONALE

It is common in Oklahoma for stocker producers to initiate feeding of supplements to calves grazing warm-season grasses on a fixed date, generally marking the last half of the grazing season. However, it could be inefficient or costly to blindly follow a fixed-date supplementation program. With the fixed-date approach, it is commonly assumed that crude protein (CP) concentration will be relatively high (> 8%) when stockers are turned out onto warm-season grass pastures about June 1. It is further assumed that the CP concentration will be above this threshold until at least July 1. In fact, the date when forage CP concentration declines to this threshold level (8%) depends upon variety, pasture management, and the weather. For instance, in 2001 we measured the CP concentration of 'Midland' bermudagrass that was fertilized with 110 lbs N/acre before our first forage sample was collected in April. By June 1 the CP concentration was already at the minimum threshold and continued to decrease until a concentration of about 4% was reached (**Fig. 1**). A real-time assessment of CP concentration at the beginning of the grazing season could have been used to warn the stocker producer of potential problems so that adjustments could have been made at that time.

In earlier studies, we developed and validated a remote sensing calibration equation which converts pasture canopy reflectance, measured with a hyperspectral radiometer, into estimates of forage CP. The CP values obtained via remote sensing were statistically similar to values obtained from laboratory measurements. We hypothesized that real-time remote sensing of forage quality can be used to determine when the feeding of supplements should begin.

OBJECTIVES

The objective of the research is to compare stocker calf performance and amounts of supplement inputs under four different supplementation management strategies, where one strategy incorporates remote sensing used as a tool to trigger the starting date of supplementation.

METHODS

A multi-year study was initiated in 2003 to address the objective. At the beginning of the2003 summer grazing season stocker calves were randomly assigned to 4-acre bermudagrass pastures. All pastures were fertilized with 60 lbs N/acre before grazing was initiated. The pastures were also randomly assigned to one of four supplementation treatments, which included a no supplement control (NS), traditional supplementation initiated on a fixed-date (FD), supplement

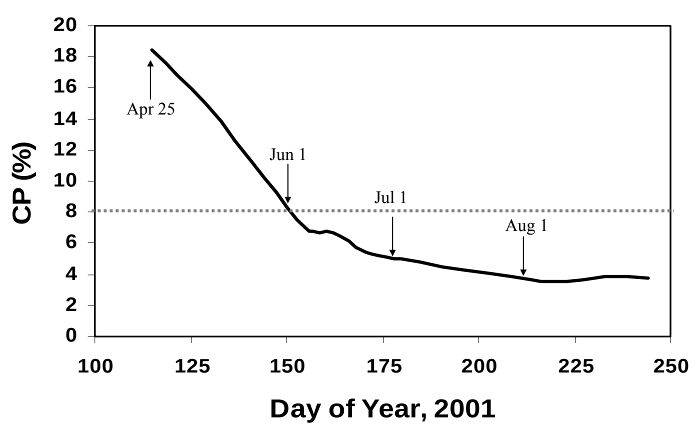


Fig. 1. Changes in crude protein (CP) concentration of 'Midland" bermudagrass during the 2001 summer growing season. The dashed line is the 8% crude protein threshold level.

based on laboratory analysis of feces (F/NB), and supplement initiation based on remote sensing of CP concentration (RS). In the NS treatment stockers received no supplementation during the summer grazing season. Stockers assigned to the FD treatment received 2.5 lbs of 20% CP supplement fed in three meals per week during the last half of the grazing season. The F/NB group of stockers was fed supplements based upon analysis of fecal material and recommendations from the Grazinglands Animal Nutrition (GAN) Lab, located at Texas A&M University, to achieve target weight gains of 2 lb/day. In the remote sensing (RS) treatment, supplements (same as in FD treatment) were supplied to the stockers when remotely sensed estimates of CP reach a "trigger" value of 6.8%. Fecal samples were collected from RS and F/NB stockers every two weeks and sent to the GAN Lab for analysis. Remotely sensed pasture reflectance data were collected weekly at 10 random locations in each of the RS and F/NB pastures and converted into estimates of %CP the same day. Cattle were weighed at the beginning, middle, and end of the grazing season. This experiment was repeated in 2004 and will be repeated in 2005 in order to capture a wider range of environmental conditions that affect plant growth and nutrient quality.

RESULTS

Visual comparison of CP determined from RS, F/NB and standard laboratory analysis (see **Fig. 2** for an example) indicated that all methods produced similar estimates in four of the six pastures where these comparisons could be made. The other two pastures were characterized by large amounts of standing dead vegetation and bare soil showing through the canopy. At present, our remote sensing approach does not take into account these factors and, therefore, does not produce reasonable estimates of CP under these conditions. Thus, these two pastures were eliminated from further analysis in the study. Statistical analysis of the RS and laboratory data indicated that there was no difference between the two methods of estimating CP.

Results from the first year of study indicated that stockers assigned to the RS treatment received supplements about 2 weeks earlier than those assigned to the FD treatment. It was further observed that the stockers in the RS treatment received supplements either 5 days earlier or 4 days later than those assigned to the F/NB treatment, depending upon the pasture being grazed by the stockers.

Stockers in the FD and RS treatments gained, on average, 11.3 and 12.3 lbs more than those assigned to the NS (i.e., "control") group, while stockers in the F/NB group gained almost 30 lbs more (**Table 1**). In spite of the large gains observed in the F/NB group, the efficiency at which supplemental feed was used was about the same for all treatments (**Table 1**).

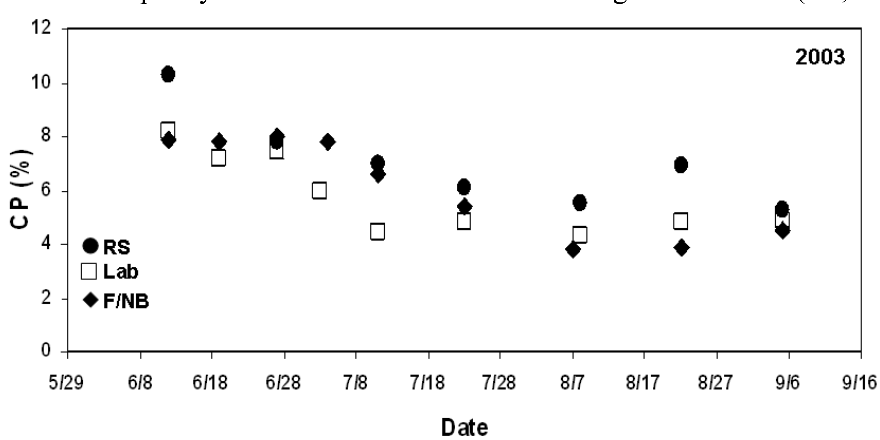


Fig. 2. Comparison of seasonal variation in crude protein (CP) concentration as determined from remotsensing (RS), laboratory analysis (Lab), and fecal analysis (F/NB).

We believe the preliminary results provide evidence that a remote sensing approach provides accurate, timely forage quality information that stocker producers can use in the field to make informed decisions regarding the management of cattle, pasture, forage, and supplement resources.

Table 1. Increase in stocker weight gains as compared to the unsupplemented stockers treatment, supplement intake, and supplement conversion efficiency for fixed day (FD), fecal nutrient balance analysis (F/NB) and remote sensing (RS) supplementation management strategies

	Supplement management strategy		
Trait	FD	F/NB	RS
Gain increase, 1bs	11.3	29.8	12.3
Supplement intake, lbs	105	261	128
Efficiency, lbs gain/lbs intake	0.108	0.114	0.096

SPATIAL VARIABILITY OF A PERENNIAL COOL-SEASON PASTURE AT THE ONSET OF FALL GRAZING

Charles T. MacKown, Amy R. Radford, Brian Northup, and Reonna Slagell-Gossen

RATIONALE

Winter wheat is the primary source of cool-season forage that supports the stocker cattle industry in the southern Great Plains. While winter wheat offers management flexibility and economic advantages to those producers who grow wheat as a dual purpose crop for both grazing and grain, proper management, as in any forage-livestock production system, is required. Use of winter wheat as a forage is not free of risks. Annual tillage operations used for wheat are costly and can contribute to soil loss, particularly on marginal or easily erodible land. Opportunities for favorable purchasing and marketing of stockers can be limited by insufficient wheat forage in the fall and shortage of spring forage when producers elect to harvest a grain crop. Wet wheat pastures are easily trampled leading to excessive loss of forage. Inadequate wheat forage for any reason adds to the costs of feeding livestock and can limit livestock weight gains.

Replacing some wheat pastures with perennial cool-season grass could reduce risks and feed costs. With proper management they could play important roles in the production of stocker cattle in the southern Great Plains. Pastures of cool-season perennial grasses could give producers greater flexibility in marketing stockers by providing forage earlier in the fall than winter wheat, and generate forage for a longer period in the spring than wheat. However, adoption of cool season perennial grasses is challenged by high establishment cost, risk of failure, and deferment of grazing during the establishment year. Constraints presented by the environment of the region and a shortage of information on sustainable forage management and animal responses are drawbacks to the use of perennial cool-season grasses. The capacity of perennial cool-season grasses to function in stocker production systems in the region must be evaluated with multi-disciplinary studies, to examine plant, livestock, and soil responses to management.

OBJECTIVE

This study examined the spatial distributions of forage production (dry weight), plant N composition, and soil traits in a perennial cool-season grass pasture and relationships among these plant and soil properties to identify possible management practices that could be used to increase the amount of fall forage and enhance its N composition.

METHODS

Seed of ‘Manska’ pubescent intermediate wheatgrass was planted in September 2001 in a Dale silt loam (fine-silty, mixed, superactive, thermic Pachic Haplustolls) soil of a 5-acre field formerly farmed to continuous winter wheat for over 30 years. At the end of May 2002, a hay crop was harvested and residual growth was shredded the last week of Aug 2002. Fertilizer was broadcast late October 2002 at 40 lbs N/acre. In November, forage and soil samples were collected from 208 locations arranged in a modified grid pattern (**Fig. 1**). At each location, plants were clipped at a height of 2 inches from a 2.15 square foot rectangular area, dried at 150°F and finely ground with a cyclone mill. A 12-inch x 2-inch soil core taken from the clipped area was separated into depths of 0 to 4 inches and 4 to 12 inches, then air dried, and ground with a hammer mill. The elevation of each sample location was measured last.

Forage samples were analyzed for dry weight, total nitrogen (N), and nitrate-N (NO_3^--N). Soils were analyzed for plant available mineral N, Mehlich III available soil phosphorus (P), potassium chloride extractable aluminum (Al), soil pH, and total N and carbon (C).

Computer software was used to analyze the data. Descriptive statistics were generated and geostatistical routines were used to create contour maps depicting the spatial distribution of forage, soil and elevation traits across the pasture.

RESULTS

Among the forage traits, the coefficient of variation (CV, a measure of relative variability) for total N concentration in forage was less than the CV values for forage dry weight and nitrate-N concentration (**Table 1**). Abundant forage was available just before fall grazing; on a dry weight basis, nearly 50% of the 208 samples had more than 2200 lbs/acre, and the overall average for the pasture was 2400 lbs/acre. The small CV for total N concentration in the forage indicates that the protein quality throughout the pasture was relatively uniform regardless of local differences in the abundance of forage. Risks of nitrate toxicity were low. While the maximum forage nitrate-N measured (3200 ppm) would carry some risk for all classes of cattle, the pasture average was only 550 ppm nitrate-N (**Table 1**), and 84% of the samples had nitrate-N levels less than 1000 ppm, a level considered safe for all cattle. Based on spatial distribution patterns (**Fig. 2**), areas of the pasture with higher levels of nitrate appear to be associated with areas having the greatest abundance of forage, the greatest tissue concentration of total N, and the most available N (sum of N uptake and soil mineral N, where N uptake is the product of forage produced and total N concentration). None of the spatial distribution patterns of the forage traits appeared to be related to the elevation trends in the pasture (**Fig. 2**).

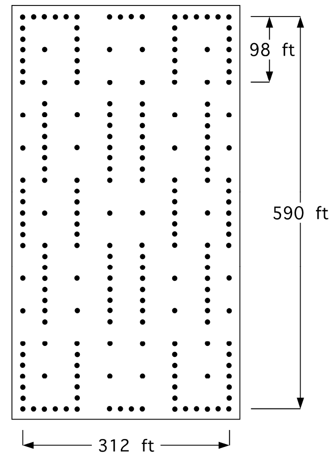


Fig. 1. Locations of forage and soil samples collected from a 5-acre pasture of Manska pubescent intermediate wheatgrass.

Among the soil traits, soil pH, total C, and total N had CV values much less than the traits of exchangeable Al and plant available mineral N and P (**Table 1**). Normally, soil organic C and N are closely linked, and for this pasture the spatial distributions for soil total C and N were quite similar. Neither of these soil traits had spatial distributions that appeared to correspond to the slight change in elevation across the pasture (**Fig. 2**). Spatial distributions of available P and pH were similar at one end of the pasture but not the other. Distribution patterns for both of these traits, however, did not correspond to the distribution patterns of other soil traits or changes in elevation (**Fig. 2**). Liming to correct low pH in much of the pasture could improve availability of nutrients and perhaps reduce the variability of forage production within the pasture. The absence of clear links between the spatial distribution patterns of soil traits and forage traits in this pasture indicate measurements of soil traits (mineral N, available P, pH, extractable Al, and total C and N) before the onset of fall grazing are unlikely to provide useful information for predicting fall forage production and quality or identifying management strategies to improve these traits.

Table 1. Descriptive statistics of forage and soil traits of a 5-acre pasture of Manska pubescent intermediate wheatgrass.

Trait	Mean	CV†	Minimum	Median	Maximum
		Forage traits			
Dry wt., lbs/acre	2400	42	420	2200	6100
Total N, %	3.4	13	2.3	3.4	4.5
NO_3^--N, ppm‡	550	91	8.1	420	3200
		Soil traits			
Available N, lbs/acre	92	39	29	88	265
Mineral N, lbs/acre	12	32	6.2	9.8	23
P (Mehlich III), ppm	65	33	27	60	140
pH (1:1, 0-4 inches)	5.5	7.7	4.9	5.4	7.2
Al (KCl extracted), ppm	5.3	140	0.24	2.5	49
Total C (0-4 inches), %	0.91	15	0.67	0.91	0.14
Total N (0-4 inches), %	0.079	14	0.045	0.078	0.120
Elevation, ft	1.9	40	0.0	2.1	3.0

† CV, coefficient of variation, %.
‡ ppm, parts per million.

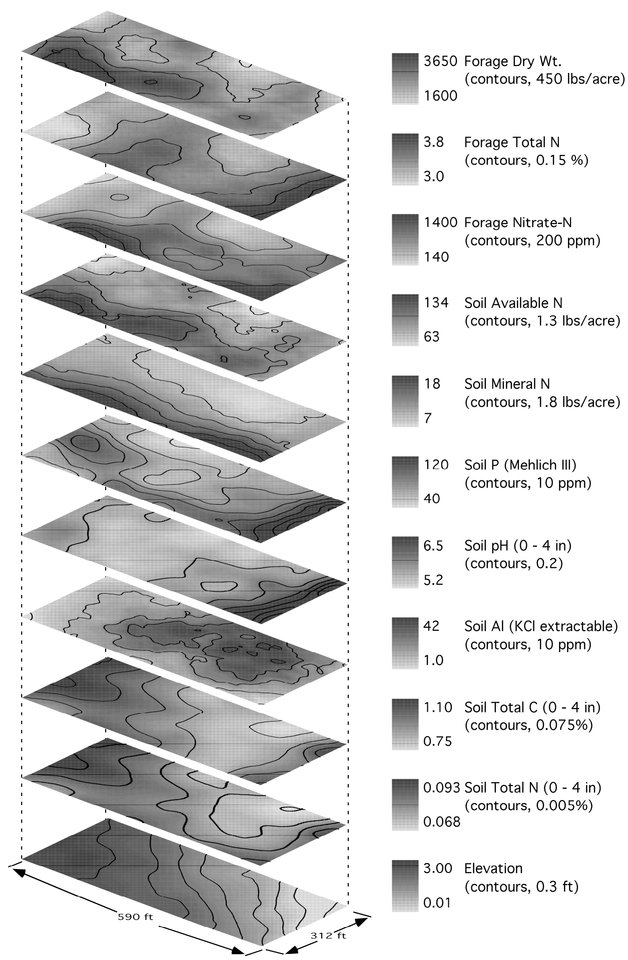


Fig. 2. Geostatistical interpolated spatial distribution maps for forage, soil and elevation traits of a 5-acre pasture of Manska pubescent intermediate wheatgrass at the onset of fall grazing in 2002.

SPATIAL USE OF BERMUDAGRASS PASTURE BY YEARLING HEIFERS AND DAILY ANIMAL BEHAVIOR

Brian K. Northup and Michael A. Brown

RATIONALE

Cattle grazing pastures are confronted by a variety of forage choices as they obtain energy and nutrients required for maintenance, growth, and reproduction. Choices made among the different forages are part of the normal behavior patterns of a grazing animal. Cattle behavior can be affected by such factors as pasture dimensions, presence of structures, water and mineral placement, and the availability of different forages. Distribution of available forage and nutrients of warm-season pasture is also highly variable in both space and time. This variation can affect how cattle make use of pastures, and could make it difficult to achieve uniform distribution of grazing pressure.

Little is known about the spatial use of bermudagrass pastures by cattle, or how pasture condition may affect patterns of use. Generally, it is assumed that cattle on 'poor' condition pasture will spend more time grazing and use a larger portion of the total pasture than livestock on 'good' condition pasture.

OBJECTIVE

The objectives of this study were to determine how Brangus yearling heifers utilized pastures of bermudagrass that were in different condition, to describe livestock behavior patterns during part of the grazing season, and to describe some possible reasons for the observed patterns of pasture use and animal behavior.

METHODS

We conducted this study over a 42-day period during June and July 2003 on four, 5.0-acre pastures in one of two condition classes; poor condition with low production and large amounts of low quality forages, and good condition with greater production that was largely composed of bermudagrass. These 232 x 928 foot pastures were oriented with the long axis running north to south and down slope. The pastures were divided into 16, 116 x 116 foot grid cells using highly visible posts, and water tanks were placed in the corners of both the north and south ends of the pastures. The location of the cattle herds within the grid cells of the pastures was recorded 3 days per week at 10-minute intervals between 7:00 AM and 10:00 AM, for a total of 324 observations per pasture. This time corresponded to one of the key periods when cattle were actively grazing. Also, activities of the cattle were recorded at each of these time intervals.

We also attached a collar containing a global positioning system (GPS) to one heifer in each pasture. These collars recorded the location of cattle every 5 minutes on a 24-hour basis during the grazing period. The location information for the last 40-days of the period was used to describe the number of visits the cattle made to 226 ft^2, 6-sided hexagonal cells (924 per pasture) within each pasture. The 11520 observations recorded per pasture were used to determine use of different areas of the pastures on a daily basis, and the percent of cells within pastures receiving visits of different lengths by the cattle. This approach allowed us to roughly estimate amounts of pasture that were grazed, ungrazed, or used for activities other than grazing. Preliminary field observations showed that the cattle rarely grazed a cell for over 7 minutes per day, and cells where activities other than grazing occurred were occupied for over 10 minutes per day. As such, visits to cells longer than 6 minutes were considered to be activities other than grazing.

RESULTS

We found that cattle on the good pastures spent more of the morning grazing periods ruminating and socializing and less time grazing than cattle on poor pastures (**Fig. 1**). Regardless of pasture condition, the cattle spent more of the morning periods in the southern parts of the pastures, though cattle on good pastures made slightly better use of the entire pasture (**Fig. 2**).

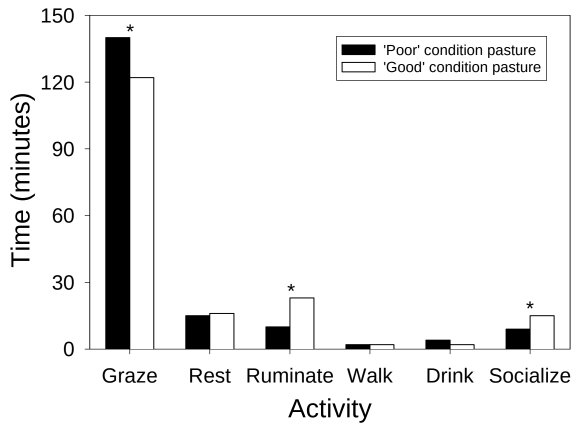


Fig. 1. Time devoted by cattle in different condition pastures to 6 behaviors during 3-hour grazing periods each morning, averaged over a 42-day period. A pair of bars marked with an * indicates a significant difference (probability level less than 5% between pastures).

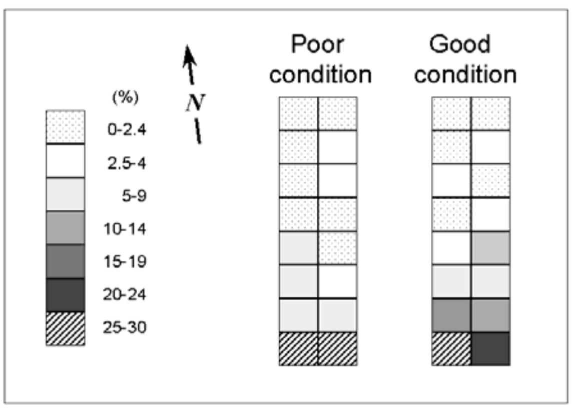


Fig. 2. Percent of 3-hour morning grazing periods spent by cattle in different 116 x 116 ft cells within 5-acre pastures in either poor or good condition, averaged over a 42-day period.

The cattle spent little of the mornings grazing the northern parts of either pasture type throughout the 42-day period, despite plentiful forage and available water. The greater spatial use of the good pastures was unexpected. We expected to see cattle on the poor pastures graze the pastures more uniformly as they sought acceptable forages. However, the cattle on the poor pastures did graze individual cells with acceptable forage for longer periods than the cattle in good pastures.

On a 24-hour basis, cattle with the GPS collars spent the majority of each day in the southern one-third of both types of pastures (**Table 1**), though cattle on the good pastures spent more time in the remaining two-thirds of the units than cattle on poor pastures (50% versus 40%). There was also little difference in percent of GPS cells receiving different lengths of visits on the two types of pastures (**Table 2**). Cattle in both types of pasture visited 60 to 62% of available GPS cells (roughly 560 of the 924 total), or about 2.9 acres of pasture area, for less than 2 minutes/day. Also, roughly 16% of the total available cells, or about 0.74 acres, of both types of pastures did not have a visit recorded by GPS during the study. This was a surprising result given the number of observations (11520 per pasture), small pasture size (5 acres), and shortage of available forage in the more favored parts

Table 1. Percent ±1 standard error of GPS observations of cattle locations on a 24-hour basis, in different sections of poor and good condition pastures during a 40-day period; 11520 observations were recorded per pasture.

Pasture section	Poor condition	Good condition
	%	
North	25 ± 2	23 ± 3
Central	15 ± 5	27 ± 3
South	60 ± 5	50 ± 2

Table 2. Percent ±1 standard error of hexagonal GPS cells within 5-acre pastures used by cattle during a 40-day period, by length of visit; each pasture had 924 cells.

Visit length	Poor condition	Good condition
minutes/day	%	
0	16 ± 2	15 ± 3
< 2	60 ± 1	62 ± 3
2-4	15 ± 2	12 ± 1
4-6	2 ± 1	5 ± 1
6-8	2 ± 1	2 ± 1
8-12	4 ± 1	2 ± 1
> 12	1 ± 1	2 ± 1

of the pastures by the end of the trial. Less than 500 lb/ace of forage was available in the most-used cells by the end of the study, compared to 2500 to 3500 lb of forage in the least-used areas.

Reasons for the heavy use of the southern sections of pastures were not immediately evident. Amounts and composition of available forage in southern sections at the start of grazing did not appear different from those of the northern or central sections of the pastures. To search for reasons related to available forage, we used the morning observation periods to determine the three most-heavily grazed areas in each pasture. Forage samples were then collected from each area to describe standing crop, and to determine protein content, digestibility and fiber content of available forage. We then attempted to correlate these forage values to the time spent grazing these areas. None of the measured forage characteristics were related to use of an area by the cattle.

This study showed that the cattle did not make uniform use of these 5-acre pastures, and reasons for this response were not readily apparent. The cattle seemed to respond to combinations of factors other than available forage or pasture condition. Some factors influencing pasture use were possibly related to social interaction among individuals and the herding instinct of cattle. There were neighboring herds of cattle in pastures within 0.5 mile to the south of our pastures. The cattle in our pastures possibly sensed these cattle, and desired to join them. Physical characteristics of the pastures also likely had some effect. The southern end of the pastures was towards the bottom of a slope, and cattle may prefer to graze in areas with less slope. Also, the prevailing wind during this study was from the south, and cattle may have a distinct preference for grazing into the wind. This research indicates that achieving uniform grazing distribution and forage utilization requires the consideration of factors beyond forage availability, pasture condition, or dietary requirements of cattle.

DETERMINING THE DISTRIBUTION OF SOIL CHARACTERISTICS IN PASTURES WITH NEAR INFRARED REFLECTANCE SPECTROSCOPY

Brian K. Northup, John A. Daniel, and Herman S. Mayeux

RATIONALE

Native prairie and cultivated wheat pasture are important land resources used to produce forage for stocker cattle in Oklahoma. If applied incorrectly, both grazing and cultivation can have negative effects on land and soil condition. Application of high stocking rates to native prairie over a number of years can adversely affect the plant community, and potentially reduce carbon (C) and nitrogen (N) in soil. Cultivation can decrease organic C content of the soil by increasing microbial activity and the rate of organic matter (OM) decomposition. The combination of planting continuous wheat and grazing of wheat pasture could reduce soil quality. Understanding responses of soils to pasture management is crucial to sustainable grazing. There is a need for rapid, low-cost tech-niques that provide accurate estimates of soil quality to help improve pasture management. The laboratory techniques currently used require large amounts of time, labor, and equipment. One procedure that could provide quick and accurate estimates of characteristics associated with soil quality is near-infrared reflectance spectroscopy (NIRS). The NIRS instrument exposes a sample to a broad range of near-infrared light and measures which wavelengths are reflected. Reflected wavelengths are related to chemical compounds contained within the sample, and compared to a reference database that defines relationships between laboratory-determined values and NIRS-predicted values. Considerable research has been published on the use of NIRS for measuring soil traits in some regions of the United States. At present, there is little information available on the capacity of NIRS to predict soil characteristics of grazing lands in Oklahoma.

OBJECTIVES

This study evaluated the capacity of NIRS to predict soil C, N, and OM concentrations of soils from both native grass and cultivated wheat pastures, and to describe how those soil resources were distributed within pastures under different forms of management.

METHODS

In November 2003, soil samples were collected at 5-foot intervals along 500-foot transects located in three, 4-acre pastures that received different forms of management from 1977 to 2003. One pasture was continuously farmed in winter wheat and grazed by stocker cattle. The two remaining pastures were native tallgrass with one pasture grazed in summer at roughly 65% use of available forage and the second left unmanaged (no grazing, burning, or haying), which is hereafter called 'relict'. Transects ran from a ridge common to all pastures, down slope to the base of the hill. Soils were of the Renfrow-Kirkland series and are common to upland sites of the Red Prairie Region of Oklahoma. Two-inch diameter soil cores were collected and divided into depth increments; the 0-2, 2-4, and 4-10 inch depths are reported here. After scanning all samples with NIRS, 114 of the 900 total samples were analyzed by traditional laboratory techniques. Soil C and N were determined in an auto-analyzer by combustion, and OM was estimated by weight loss after heating samples in a 750°F oven. Laboratory-determined values were then related to key reflected wavelengths for 54 samples using multiple regression techniques to develop prediction equations. Sixty additional samples were used to validate how accurately the developed equations predicted soil characteristics. The prediction equations were used to describe NIRS-determined values for all samples. Running averages of predicted C, N, and OM concentrations for neighboring groups of five sample locations (25 feet) were calculated along the transects to examine the effects pasture management.

RESULTS

Development of NIRS Relationships. Application of NIRS to the samples was rapid. Each sample required about 2 minutes to load and scan, and to store the resulting spectrum. All three traits were then described with information from the same scan with the developed predictive equations. Equations developed to predict soil C, N, and OM with NIRS produced concentrations that were similar to levels in samples determined by the traditional techniques (**Fig. 1**). Slopes of the prediction equations for soil C, N, and OM were 1.002, 0.987, and 0.974, respectively; a slope of 1.0 would indicate a perfect match between laboratory and NIR-determined values. No differences were noted between the slopes of the three equations and a line with a slope of 1.0. Relationships between

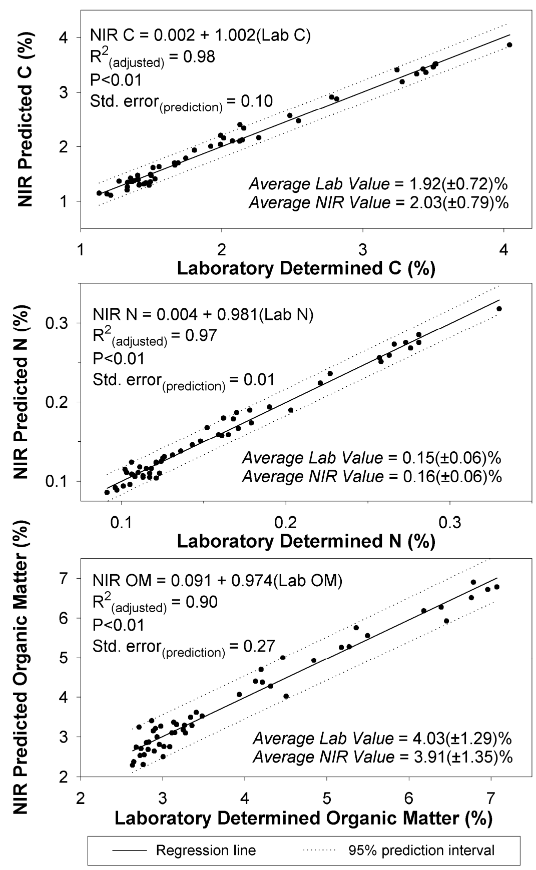


Fig. 1. Relationships between laboratory and NIRS-determined C, N, and OM concentrations in soil samples from three pastures; numbers in parentheses with average values are standard deviations.

laboratory-determined and NIRS-predicted values of C and N were strong ($R^2 > 0.98$) and prediction errors were low (about 5% of predicted values). The relationship between laboratory-determined and NIRS-predicted soil OM was the weakest of the three developed equations ($R^2 = 0.90$, prediction error = 7%), perhaps due to the greater chemical complexity of OM composition. A comparison of average laboratory and NIRS values from the validation set indicated NIRS tended to slightly over-predict soil total C, and under-predict soil OM concentrations.

Distribution of Soil Resources. Distribution of soil total C and N along all three transects was highly variable. Soil C concentrations shifted from high to low values across small areas, sometimes less than 50 feet (**Fig. 2**). The upper 2 inches of soil had the greatest concentrations of C in all three pastures and the two deeper layers had 33% to 50% of the concentrations measured in the top layer. In the native pastures, C concentration declined with depth, while concentrations in the two lower layers of the wheat pasture were similar. Carbon concentrations in the two upper soil layers of the wheat pasture were 33% and 25% less than values recorded for the native pastures. In fact, soil C in the upper layer of the wheat pasture was similar to the deeper layers of the native pastures. Distribution patterns of soil total N were similar to those of soil C. Areas with high or low C concentrations had corresponding concentrations of N (**Fig. 3**). Soil total N also responded similarly to pasture management and soil depth. Part of this similarity was related to the carbon-to-nitro-gen ratio of the soils, which tends to be relatively stable for a soil type. Overall, the analyzed samples had a ratio of 12.6 C atoms per N atom.

Soil OM, which is important to both soil structure and quality, had a distribution pattern similar to C (see **Fig. 2**). Since 50% of OM is comprised of C, its similarity in distribution to soil total C of these soils is expected. The upper 2 inches of soil had the greatest concentration of OM in all three pastures. The deeper layers of the native pastures had successively lower levels of OM, and the two bottom layers of wheat pasture were similar and had the lowest concentrations.

The similarity in overall concentrations in the upper soil profile of the relict and grazed native pastures was an interesting result, particu-

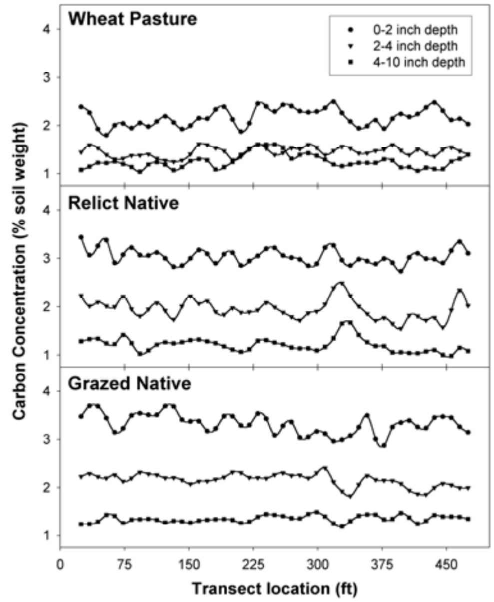


Fig. 2. Running averages of soil total C concentrations along 500-foot transects in pastures receiving three forms of management; running averages were calculated for 25 foot intervals along transects.

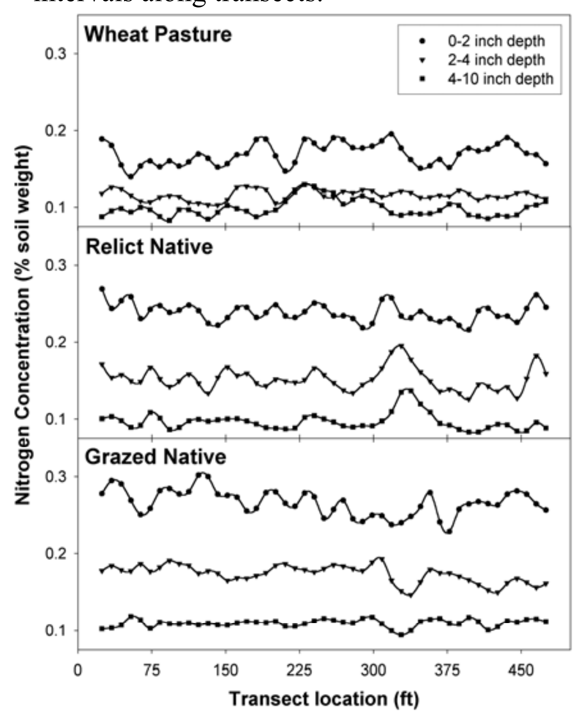


Fig. 3. Running averages of soil total N concentration along 500-foot transects in pastures receiving three forms of management; running averages were calculated for 25 foot intervals along transects.

larly as the grazed pasture had received high levels of use for 26 years. We might expect the grazed pasture to have lower concentrations than the relict pasture. However, studies in other parts of the Great Plains have shown little or no change in C contents of soils under native prairie in response to long-term (over 20 years) grazing, while other studies have documented slight decreases due to grazing. Management of the grazed pasture generally included at least one rest period per year during the summer, which may have contributed to its similarity with the relict pasture. This probably allowed the vegetation to recover some vigor before the dormant season and replace C, N, and OM. Cultivation and production of annual crops or forages have repeatedly been shown to reduce soil C, N, and OM, compared to perennial vegetation. The reductions in concentrations in the wheat pasture were not unexpected, but still represented an important negative effect on condition of the upper section of the soil profile.

AN EARLY ANNUAL RYEGRASS FOR FORAGE AND HAY

Bryan Kindiger and Vincent Russo

RATIONALE

Easy establishment, rapid autumn growth, and exceptional forage quality make annual ryegrass a popular choice with livestock producers. Annual ryegrass is grown on nearly 3 million acres in the United States. The majority of this acreage is found in the southeastern United States, where it is utilized for winter pasture. However, annual ryegrass is becoming a major forage species for grazing stocker cattle in portions of Texas, and it could be utilized in a similar fashion in Oklahoma. Acreage of annual ryegrass has expanded significantly in Texas, Oklahoma, Arkansas, and Tennessee. Most annual ryegrass is seeded into perennial warm-season grasses in order to extend the grazing season.

OBJECTIVE

Identify and evaluate novel cool-season annual grasses that have high adaptation, productivity, forage quality and other traits that make them useful for livestock production and other applications in the southern Great Plains.

METHODS

Replicated screening and performance evaluations of annual ryegrass cultivars from a range of sources were conducted over a 4-year period at Waukomis, El Reno and Lane, OK. These were generally fertilized with a single application of nitrogen as ammonium nitrate at a rate of 50 lbs/acre in October. Plots were initially harvested when the forage reached an average height of 12 inches, and one to three additional clippings were made each season at a cutting height of 4 inches to simulate rotational grazing.

RESULTS

One of the novel cool-season grasses in our evaluations was an extremely early annual ryegrass provided to us by the Japanese Grassland Farming and Forage Seed Association. ‘Shiwasuaoba,’ the Japanese name given to the cultivar, roughly translates to Early or December Flower. When sown in September, heading usually occurred in late March to early April. Multi-year production trials indicated that Shiwasuaoba could not match the total annual forage production of later maturing annual ryegrass cultivars like ‘Marshall’. However, ‘Shiwasuaoba’ produced early yields that were competitive with later maturing ryegrass cultivars such as ‘Ribeye’ and ‘Zorro’ (**Table 1**). Its early forage production was equivalent to that of early annual ryegrass cultivars such as ‘Gulf’ annual ryegrass (**Table 2**), and Shiwasuaoba flowered approximately 7 days earlier than Gulf. Disease susceptibility studies conducted in Japan demonstrated that Shiwasuaoba has medium resistance to crown rust and good resistance to most other diseases of ryegrass.

Investigations at ARS’ South Central Agricultural Research Center near Lane, OK, indicated that Shiwasuaoba has potential for use as a hay crop in rotation with irrigated vegetable crops. Vegetables were established either by sowing directly into the grass stubble or sowing after the soil had been worked into beds. Results obtained in annual ryegrass-vegetable rotation trials indicated that sweet corn and pumpkin can be successfully sown immediately following harvest of Shiwasuaoba using no-till techniques, and that sweet corn could be followed by bell peppers or cucumbers. In total, it was possible to harvest three crops in a single year (annual ryegrass hay, sweet corn, and bell pepper or cucumber) before it was time to sow annual ryegrass again in the fall (**Table 2**). When Shiwasuaoba annual ryegrass was included in the rotation, vegetable yields were sometimes superior to rotations that included other grasses or did not include a winter cover crop of annual ryegrass or wheat.

Since its registration in 2004, Shiwasuaoba annual ryegrass has been evaluated by Pennington Seeds throughout the South and Southern Plains. Pennington Seeds is the exclusive distributor for this new cultivar in the USA. Marketing of this cultivar will begin in the fall of 2005.

Table 1. Early forage yields (dry weight basis) of 'Shiwasuaoba' when compared to longer-maturity ryegrass cultivarsgrown at El Reno, OK. Sowing date was 19 September 2000.

	Harvest dates			
Cultivar	20 April 2001	10 May 2001	6 June 2001	Total
	tons/acre			
Zorro	0.86	5.04	1.51	7.41
Marshall	1.01	4.07	1.21	6.29
Dalita	1.16	3.50	1.18	5.84
Rust Master	1.35	3.01	1.06	5.42
Ribeye	0.77	3.45	0.88	5.10
Shiwasuaoba	0.78	1.44	0.55	2.77

Table 2. Production results for a grass-sweet corn-(cucumber or bell pepper) rotation grown at Lane, OK in 2003-2004. Sowing date of ryegrass (Shiwasuaoba and Gulf) and winter wheat was 3 October 2003. Harvest dates in 2004 were as follows: ryegrass and winter wheat (29 March); sweet corn (1 July); cucumber (30 August), bell pepper (16 and 23 September).

	First crop	Second crop	Third crop	
Treatment	Hay yield	Sweet corn	Cucumber	Bell pepper
	tons/acre†			
Fallow	—	2.2	4.0	3.1
Wheat	2.1	1.3	3.9	3.7
Shiwasuaoba ryegrass	1.6	2.3	4.2	4.2
Gulf ryegrass	1.6	2.3	2.5	3.5

†Dry weight basis for hay yield and market weight for vegetable yields.

Fall Forage Traits of Winter Wheat Populations Selected from Grain-only and Dual-purpose Production Environments

Charles T. MacKown and Brett F. Carver

RATIONALE

Southern Great Plains wheat pastures in Oklahoma, the Texas Panhandle, southern Kansas, eastern New Mexico, and southeastern Colorado have a pivotal role in the US beef industry. Each year millions of fall stocker calves pass from more than 500,000 farms across the southern USA onto these wheat pastures to gain weight before they are finished in feedlots of the Great Plains. Typically in Oklahoma, about 40% of the wheat acreage is grown as a dual-purpose crop (grazing plus grain). Wheat producers choosing a dual-purpose management system have greater flexibility and additional economic advantages compared to those choosing to grow wheat as a forage-only or grain-only crop, but they need to follow a recommended set of management practices (earlier planting, higher seeding, additional nitrogen (N)) to optimize returns. These dual-purpose management practices may add certain risks, including increased disease and pest stresses and increased nitrate (NO_3^-) levels in wheat forage that pose health risks affecting performance of young grazing ruminants.

Wheat cultivars used for dual-purpose are typically developed by wheat breeders that make selections based on performance in grain-only production systems rather than dual-purpose systems. Because of genotype by environment interactions and genotype by production system interactions, cultivar development based solely on selection in a grain-only production system may compromise gains in genetic improvement of desirable traits for wheat used in dual-purpose production. Because evaluation and selection of wheat genotypes in a dual-purpose system requires the added complexity and expense of using livestock, knowledge of the benefits of using a dual-purpose production system to select genotypes intended for dual-purpose is essential.

OBJECTIVE

We compared fall forage traits of bulk populations of wheat crosses selected from grain-only and dual-purpose systems to evaluate the benefits of tailoring a wheat breeding program for dual-purpose wheat. Traits included shoot biomass, total N, and NO_3^- concentration at the onset of fall grazing.

METHODS

Twenty-four sets of three sub-populations comprised the experimental materials used in this study. Released and experimental genotypes of winter wheat were hybridized in single-cross and three-way cross combinations to form 23 populations; one additional set came from a foundation-seed source of hard red winter wheat treated in the same way as the hybridized populations. The generation sequence of the 24 sets of sub-populations is illustrated in **Fig. 1**. Generations were grown at the Oklahoma State University Wheat Pasture Center near Marshall, OK

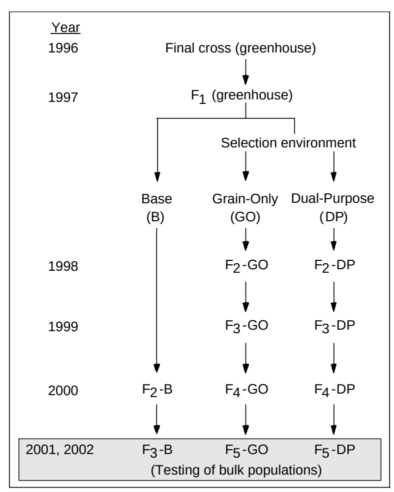


Fig. 1. Generation sequence of base (B) and selected (grain-only, GO; dual-purpose, DP) bulk sub-populations of winter wheat used for testing in a dual-purpose system.

in plots assigned to grain-only and dual-purpose systems following recommended practices for each system. Each generation advance was achieved by harvesting each sub-population in bulk. No artificial selection was imposed beyond that originating from environmental conditions inherent to each system. In addition to the system-derived pairs of sub-populations, a base sub-population was produced by growing the original F_2 generation in a seed-increase nursery at Oklahoma State University, Stillwater, OK, 35 miles east of the Wheat Pasture Center. System-derived sub-populations were evaluated as F_5 bulks, whereas the base sub-populations were evaluated as F_3 bulks.

The 24 triplicate sets of sub-populations were arbitrarily divided into two nurseries of 12 sets each (Nursery 1, Nursery 2) to accommodate replicated field testing using a split-plot design with three complete blocks. Three commonly grown hard red winter wheat cultivars with different juvenile growth habits were included as checks. These included Custer (semi-prostrate), Jagger (semi-erect to erect), and 2174 (erect). Experiments were established in the 2001-2002 and 2002-2003 cropping seasons at the Wheat Pasture Center and recommended dual-purpose management practices followed. At the onset of grazing, between late October and late November, samples were collected to measure forage biomass and forage total N and NO_3^- by clipping plants to a stubble height of 1.6 inches.

RESULTS

The dry weight and forage NO_3^- response of each of the 24 sets of genotypes from the three selection environments (grain-only, dual-purpose, and base) were not significantly management system in 2001 and 2002. Nearly always , this genetic background x selection environment interaction effect was also not significant for forage total N. When averaged across the 24 sets of genotypes, the fall forage dry weight of the bulk populations selected from the dual-purpose environment tended to be about 5% less than the dry weight of grain-only populations in 2001, while in 2002 there were no differences among the three selection environment sub-populations (**Fig. 2**). Overall the fall forage dry weight in 2002 averaged nearly 46% less than that of 2001. While the environmental conditions and the 56 days between planting and than that of 2001. While the environmental conditions and the 56 days between planting and collecting the forage samples were normal in 2001, the interval between planting and forage sampling in 2002 was 7 days less and was accompanied by cooler, cloudy days. This probably accounts for the marked difference in fall production of wheat forage. Compared with the 2001 ranking trend in fall forage productivity among the selection environments, the poor climatic conditions and shorter duration for forage development may have masked a similar trend in 2002. Each year the amounts of fall forage averaged for each of the three selection environments fell within the range of forage dry weight of the check cultivars (see **Fig. 2** and **Table 1**).

Wheat forage from bulk populations selected from a dual-purpose management system consistently had overall total N concentrations that were slightly greater (2.6%) than those of base and grain-only sub-populations (**Fig. 3**). Because the dual-purpose selections seem to have a more prostrate growth habit than the

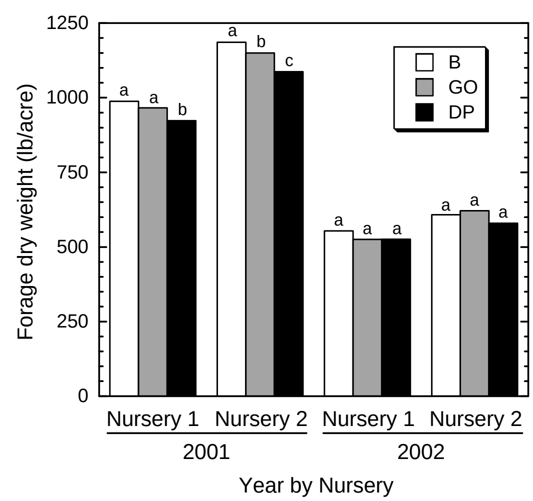


Fig. 2. Forage dry weight of base (B) and selected (grain-only, GO; dual-purpose, DP) bulk sub-populations of two nurseries (Nursery 1 and Nursery 2) managed as dual-purpose wheat crops in 2001 and 2002. Within a year-by-nursery combination, mean bars having a different letter are significantly different at a probability level less than or equal to 10%.

Table 1. Fall forage dry weight, total N, and NO_3^--N for three check cultivars included in both nurseries in 2001 and 2002. Values are means of two nurseries, three replications, and three adjacent sub-plots within each cultivar.

	2001			2002		
Cultivar	Dry weight	Total N	NO_3^--N	Dry weight	Total N	NO_3^--N
	lb/acre	%	ppm	lb/acre	%	ppm
Custer	867 c†	3.98 b	1500 b	557 b	3.92 c	792 a
Jagger	1040 b	4.22 a	1470 b	620 ab	4.26 a	471 b
2174	1470 a	4.16 a	1790 a	666 a	4.13 b	371 b

† Values in a column followed by a different letter are different at a probability level of 5%.

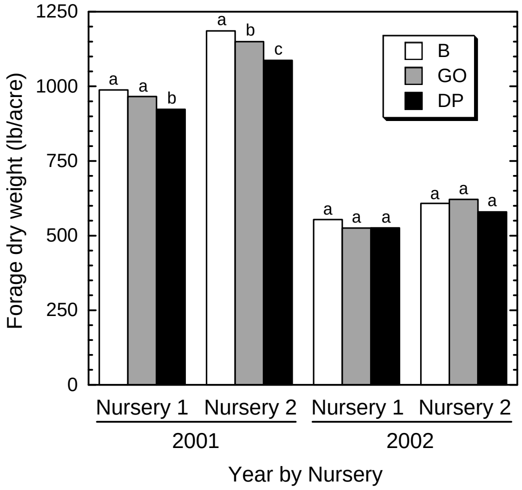


Fig. 2. Forage dry weight of base (B) and selected (grain-only, GO; dual-purpose, DP) bulk sub-populations of two nurseries (Nursery 1 and Nursery 2) managed as dual-purpose wheat crops in 2001 and 2002. Within a year-by-nursery combination, mean bars having a different letter are significantly different at a probability level less than or equal to 10%.

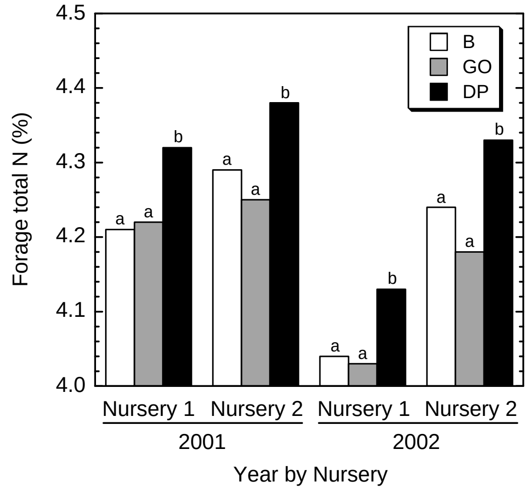


Fig. 3. Forage total N concentrations of base (B) and selected (grain-only, GO; dual-purpose, DP) bulk sub-populations of two nurseries (Nursery 1 and Nursery 2) managed as dual-purpose wheat crops in 2001 and 2002. Within a year-by-nursery combination, mean bars having a different letter are significantly different at a probability level less than or equal to 5%.

other selections (data not shown), the proportion of the total biomass as leaf blades with high N concentration was probably greater than that of the other sub-populations. Among the bulk populations, total N concentrations ranged from 4.09 to 4.43% in 2001 and from 3.95 to 4.54% in 2002. These total N concentrations were comparable to those of the check cultivars (**Table 1**). In all cases the levels of total N (crude protein equivalent greater than 20.0%) were more than adequate to support high rates of weight gain for stocker calves, so the slight difference in total N created by selection system should not affect stocker performance.

Selection environment of the bulk populations did not affect forage NO_3^--N concentrations, but differences among genetic backgrounds were significant (2001 range 1270 to 3070 ppm; 2002 range 402 to 1280 ppm). Overall, mean NO_3^--N levels of fall forage from 2001

(2020 ppm) exceeded the levels in 2002 (661 ppm) by about 3-fold. Similarly, the average forage NO_3^-levels of the check cultivars in 2001 exceeded the levels in 2002 by about 3-fold (**Table 1**). In both 2001 and 2002, a few of the same genetic backgrounds within a nursery had NO_3^- concentrations that ranked among the highest, while at the lower range of NO_3^- levels, other genetic backgrounds had concentrations that ranked consistently lowest (data not shown). In 2001, at least 50% of the 24 genetic background sets had NO_3^--N levels exceeding 1790 ppm, the highest level among the check cultivars, while only one was less than Jagger (1470 ppm), the lowest check cultivar (**Table 1**). In 2002, nearly all sets had NO_3^--N levels that fell within the range of NO_3^--N levels of the check cultivars, except for one genotype with a level of 1280 ppm, which exceeded the highest check NO_3^--N level by 62%. Because nearly 50% of the entries in 2001 had NO_3^--N concentrations greater than 2000 ppm, considered a threshold for risk to all cattle, changes in N fertilizer management and development of wheat cultivars intended for dual-purpose use with decreased NO_3^- concentrations would seem prudent.

In summary, in terms of fall forage productivity and the concentrations of total N and NO_3^-, we found no clear advantage to choosing either the natural selection environment of the dual-purpose or the traditional grain-only production systems for generating bulk populations from which to derive new wheat cultivars. Even though there was a trend towards decreased fall forage biomass and a more pronounced prostrate growth habit when bulk populations of a range of wheat genetic backgrounds were exposed to natural selection effects of a dual-purpose production system, this strategy should not be ignored entirely. Initial fall forage biomass represents only one component of a dual-purpose wheat breeding program; other critical components include vegetative regrowth and grazing tolerance, grazing period duration and timing of first-hollow-stem stage, and grain yield after grazing. All of these traits may benefit from exploiting a dual-purpose selection environment for development of cultivars intended for this purpose. More focus on the concentration of NO_3^- in fall forage seems warranted considering the apparent diversity among wheat genetic backgrounds that could be used to decrease NO_3^- risks to young ruminants that likely are unadapted to abundant levels of forage NO_3^-.

QUICK TESTS FOR FORAGE NITRATE

Charles T. MacKown

RATIONALE

Risks due to nitrate-nitrogen (NO_3^--N) consumption by ruminants is affected by various animal factors (e.g., rumen microbes, animal age and condition, environmental stresses), water quality, and diet. Levels of forage NO_3^--N depend on nutrient management, species, growth stage, and environmental stresses. Forages containing less than 1000 ppm (0.10 %) NO_3^--N (dry weight basis) usually pose no risk for cattle. Low levels of ingested NO_3^- are reduced by rumen bacteria to nitrite and then ammonia, and any excess ammonia absorbed by the blood stream is excreted in the urine as urea. However, when high levels of NO_3^- are ingested, the capacity of the normal NO_3^- conversion process becomes overloaded and a portion of the NO_3^- is absorbed by the blood stream as nitrate and nitrite. Some of the NO_3^- that is absorbed recycles back to the rumen through saliva thereby adding again to the NO_3^- pool in the rumen. In contrast, absorbed nitrite inhibits the oxygen transporting capacity of red blood cells by oxidizing the ferrous iron of hemoglobin to ferric iron (methemoglobin), leading to chronic livestock performance problems including suppressed appetite, rate of weight gain, and milk production, and in severe cases, acute toxicity and possibly death. With timely and accurate assessment of NO_3^- concentration in forages and water, potential risks of livestock exposure to excessive NO_3^- intake may be properly managed or avoided.

In the southern Great Plains, the primary cool-season forage used for stocker cattle is winter wheat. The NO_3^- of annual cereals and cool-season grasses used as forages increases with increasing amounts of N fertilizer applied. In the past 4 years, at the onset of fall grazing of a 5 acre wheat pasture fertilized with 40 lbs N/acre, we collected forage samples from the same 48 locations in two transects. Average ± standard error NO_3^--N levels of 5250 ± 176, 585 ± 38, 1250 ± 77, and 6580 ± 137 ppm in 2001, 2002, 2003, and 2004, respectively, carry risks ranging from none in 2002, to generally safe for non-pregnant cattle in 2002, to potentially toxic for all cattle in 2001 and 2004 (see **Table 1** for forage NO_3^--N guide).

Normally, forage NO_3^- is measured in the laboratory using a finely-ground oven-dried sample extracted with hot water. This method is less timely than NO_3^- quick-test assays of plant sap, but the plant sap method requires prior calibration to NO_3^- in dried forage. Because forage NO_3^- is water soluble, it may be possible to effectively extract fresh tissue directly to estimate NO_3^--N on a dry-weight basis and assign a level of risk.

OBJECTIVE

This research sought a quick, easy, and accurate field assay for forage nitrate so consultants and producers could make informed decisions about potential risks to livestock. First, a field NO_3^- extraction method for fresh wheat pasture samples was compared to a laboratory extraction method with dried samples to evaluate NO_3^- extraction efficiency. Second, we compared NO_3^- assay methods that included a standard laboratory method, a non-traditional biochemical-linked laboratory and field-test method, and two quick-test methods that use small hand-held instruments. Finally, we used a NO_3^- standard addition technique for an accuracy test and to detect the presence of substances in extracts that interfere with the different NO_3^- assays.

Table 1. Risk guide for NO_3^--N levels (dry matter basis) in forage when stock water is low in NO_3^-. Nitrate-N ranges based on University of Wisconsin Extension guide. For these risks, Oklahoma State University NO_3^--N ranges are more conservative and each value can be multiplied by 0.6 to approximately adjust the ranges.

ppm NO_3^--N	% NO_3^--N	Risk
less than 1000	less than 0.10	Generally safe for all cattle
1000 -2000	0.1 – 0.2	Generally safe for non-pregnant cattle; limit to 50% of total intake of pregnant animals
2000 - 4000	0.2 – 0.4	Some risk for all animals; limit to less than 50% intake
above 4000	above 0.4	Potentially toxic for all cattle ; do not feed

METHODS

Forage samples with a wide range of NO_3^- levels were obtained from field-grown '2174' winter wheat fertilized with 50 to 210 lbs N/acre. Samples were collected in early April (early graze-out stage) and before mid May (harvest for hay stage) and were cut into about 0.5 inch segments, and subdivided for oven drying (140°F) or freezing (-112°F) for "fresh" tissue tests. Oven dried samples were finely ground with a laboratory cyclone mill.

Nitrate was extracted from dried and ground samples by mixing with hot water (208°F) for 1 hour. Frozen fresh tissue samples were thawed and extracted in a dilute alcohol solution (5% propanol) with a hand-held blender operated at high-speed (11,600 rpm) for about 2 minutes to thoroughly macerate the tissue. For the different methods, known quantities of NO_3^- were added to a low NO_3^- extract from oven-dried tissue to determine presence of interfering substances. The laboratory and quick-test NO_3^- assay methods evaluated are summarized in Table 2.

RESULTS

The extraction protocol for fresh forage was intended to allow rapid and complete extraction of NO_3^- with an inexpensive hand-held blender, but it failed to extract nearly 18% of the NO_3^- in oven-dried samples (**Fig. 1**, deficit from a slope of 1.0). Fresh tissue maceration and inclusion of propanol to increase permeability of intact plant cells was less effective for NO_3^- extraction than was achieved with finely-ground oven-dried wheat forage extracted with hot water. The extraction efficiency of fresh tissue NO_3^-, however, was constant over a nearly four-fold range in tissue NO_3^-. To express fresh tissue NO_3^- on a dry-weight basis, the moisture content of the forage must be measured or estimated. Relatively rapid gravimetric moisture measurements could be obtained by either conventional or microwave drying. Alternatively, dry matter estimates could be achieved using a developmental growth stage calibration curve that would probably be acceptable for screening forage for potentially toxic levels of NO_3^-. To accurately measure NO_3^- levels of fresh forage, either the efficiency of NO_3^- extraction must be improved, or the extraction efficiency for each source of forage determined and used to adjust the NO_3^- level. If a microwave oven were available, simply heating the blend of macerated fresh tissue should increase the efficiency of NO_3^- extraction.

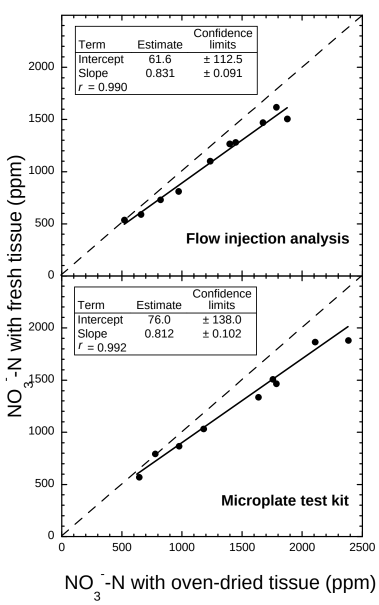


Fig. 1. Relationships between NO_3^- extracted from fresh and oven-dried wheat forage and analyzed by flow injection analysis and microplate test kit laboratory methods. The diagonal dashed lines represent a 1:1 relationship for NO_3^- measured by the two methods.

Nitrate concentrations measured with the standard laboratory method (flow injection analysis) for extracts from oven-dried and fresh winter wheat forage were consistently less than those of the non-traditional enzyme-linked laboratory method (microplate test kit) and all of the NO_3^- quick-test methods used in this study. Results using the NO_3^- test kits containing enzyme were strongly correlated with those obtained by the test-strip reflectance quick-test method; for oven-dried forage $r \geq 0.98$ and for fresh forage $r \geq 0.99$. For extracts of fresh forage, assays of NO_3^- using flow injection analysis (1:100 dilution of extract) were usually lower than the assays of NO_3^- with the other methods (**Fig. 2**).

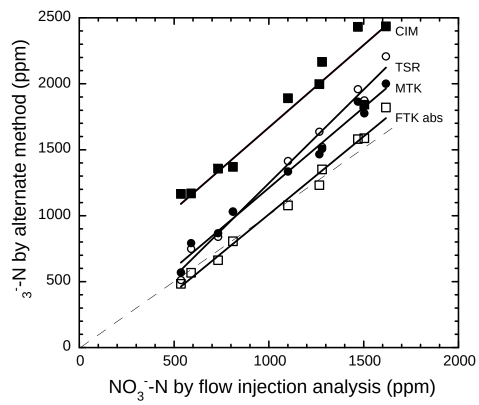


Fig. 2. Laboratory microplate test kit (MTK, ●), compact ion meter (CIM, ■), test-strip reflectance (TSR, ○), and enzyme based field test kit (spectrophotometer detection; FTK abs, □) assays of NO_3^- compared to measurements obtained by flow injection analysis using fresh forage extracts. Forage NO_3^- concentrations are expressed on a dry weight basis. Diagonal dashed line corresponds to NO_3^- measurements by alternate methods that would be equivalent (1:1) with the flow injection analysis method.

Because the substances in plant extracts adversely affect the measurement of NO_3^- with the laboratory flow injection analysis method, we have routinely used a dilution ratio of no less than 1:10 when NO_3^- is measured in extracts of oven-dried plant samples. Apparently, the extraction protocols and dilution of extracts used with these samples of wheat forage caused interference. This was confirmed using an extract of oven-dried wheat forage from this study to compare the concentrations of NO_3^- added to the extract with concentrations of NO_3^- added to water (**Fig. 3**). Interference by substances in the extract were minimal for the non-traditional laboratory microplate test kit. The differences in NO_3^- measured with the flow injection analysis method and the test-strip reflectance and microplate test kit mirrored the differences in response to apparent substance interferences in the oven-dried sample extract treated with NO_3^- (**Fig. 3**). With the compact ion meter quick-test method, measurements of NO_3^- treated extract from the oven-dried sample were slightly greater than those with NO_3^- in water (**Fig. 3**), and would account partially for the measured NO_3^- differences between the compact ion meter and all the other methods. Underestimation (flow injection analysis, TSR) and overestimation (compact ion meter) of tissue NO_3^- values would be important when examining physiological processes of NO_3^- metabolism of forages. However, in terms of screening for potentially harmful NO_3^- levels in forage, livestock management decisions would likely be similar despite differences in NO_3^- values among the quick-test methods.

In summary, selection of a particular NO_3^- assay method for laboratory or field quick-tests depends on needs for accuracy and ease of use. The laboratory and field NaR kits lack potential interferences and possible human health concerns associated with flow injection analysis use of a copper-cadmium NO_3^- reduction column. They also and were the most accurate. Among the quick-test NO_3^- assays, the hand-held test-strip reflectancemeter was easiest to use and only slightly less accurate than the NaR kits. Compared to the hand-held ISE meter, both of these methods were much less variable and did not overestimate forage NO_3^- values. The NO_3^- field-extraction method underestimated tissue NO_3^- concentration and requires either improvement in extraction efficiency or proper calibration with dry forage samples before it will be useful.

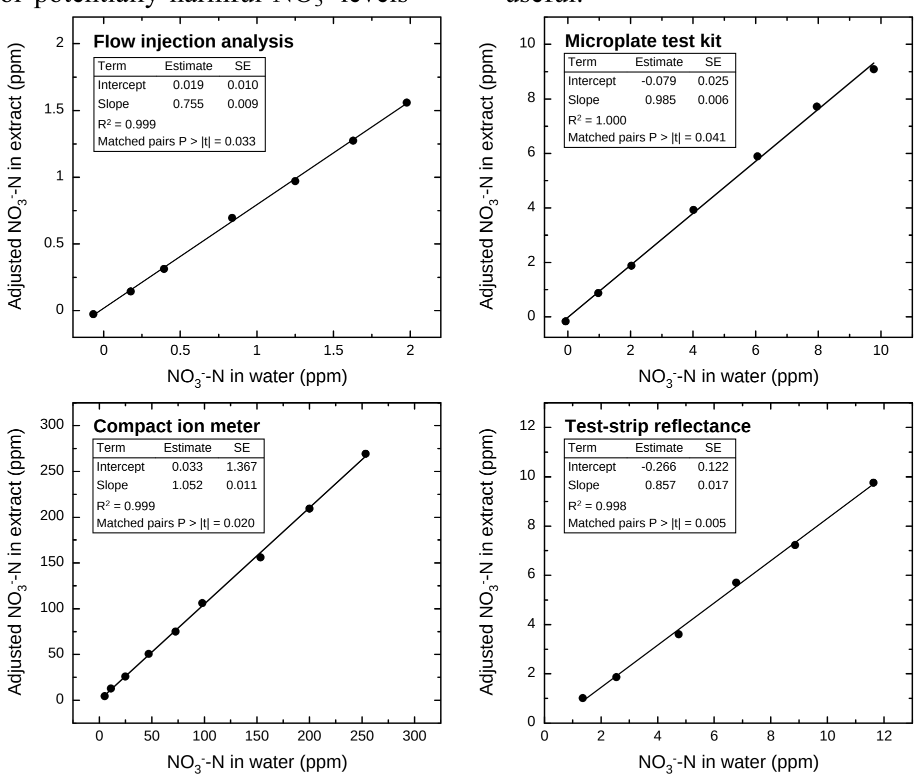


Fig. 3. Linear regression and matched pairs statistical analyses of NO_3^- additions to an extract of oven-dried forage. For each method (FIA, flow injection analysis; MTK, laboratory microplate test kit; TSR; test-strip reflectance; CIM, compact ion meter), the NO_3^- concentration of untreated extract was subtracted from the treated extracts and the adjusted NO_3^- concentrations of the extract compared to results obtained for NO_3^- in water.

PERFORMANCE OF DIVERSE SORGHUM AND SORGHUM X SUDANGRASS HYBRIDS FOR BIOMASS/BIOENERGY PRODUCTION WITH TWO HARVEST MANAGEMENT SYSTEMS

Brad C. Venuto

RATIONALE

To effectively implement production of energy from biomass, an evaluation of alternative biomass sources and production systems is necessary. Biomass may be derived from low-input systems, such as Conservation Reserve Program acreage, or the residue by-products of intensive crop production, such as corn and wheat stover or sugar cane processing residue. Alternatively, dedicated cropping systems may be developed using crops selected and grown specifically for high biomass production. Some warm-season annuals have shown high forage yields per unit of land and cultivars are available that have been selected specifically for biomass production. The response of these annuals to different harvest management practices, designed specifically for biomass production, has not been intensively studied.

OBJECTIVES

The objective of this study was to evaluate the biomass productivity of diverse annual forage sorghums, sorghum x sudangrass hybrids, and a sudan grass using two harvest systems and grown with a minimal amount of agronomic inputs.

METHODS

Field plots consisting of 25 sorghums and sorghum x sudangrass hybrids and 'Piper' sudangrass were seeded in early May 2004 at El Reno, Oklahoma. All entries were seeded at 20 lbs per acre. Soil type was a Brewer silty clay loam. Due to dry conditions and uneven germination, the trial was irrigated with 2 inches of water 1 week after planting. A mid June broadcast fertilizer application of 75 lbs of N per acre was made to all plots. No additional fertilizer was applied. The experimental design was a randomized complete block with three replications of each entry. Plot size was approximately 5 ft by 25 ft and consisted of six rows spaced 8 inches apart. Plots were divided into 5 ft by 10 ft sub-plots and two harvest treatments applied consisting of (1) a single late season harvest or (2) a late summer harvest followed by a ratoon harvest after first frost (**Fig. 1**). Statistical analysis was performed using analysis of variance procedures and standard means separation. Partial correlations were calculated after removing fixed effects.

Plots assigned to the first harvest treatment were harvested in late September. For the second harvest treatment, plots were first harvested in early August and again in early November. Plant height and plant stem diameter (10 stems per plot) were measured at harvest. The number of stems per square foot, designated as 'stem density', was measured after harvest. Plant maturity was rated at the August and September harvests using a scale of 1 to 10; 1 = vegetative; 2 = less than 5% flower, 3 = anthesis, 4 = early milk, 5 = mid milk, 6 = late milk, 7 = early dough, 8 = mid dough, 9 = late dough and 10 = mature. Lodging was rated for the September harvest.

RESULTS

Maximum dry matter was obtained utilizing the single harvest system (**Table 1**). There was an entry by harvest treatment interaction, which indicates that not all entries responded similarly to the two harvest treatments. Some entries produced significantly more biomass at the September harvest than for the combined August plus November harvests, while others produced equivalent or less biomass. Entries that produced greater biomass in September tended to be those entries that were late maturing or non-flowering. Lodging was a problem for

Fig. 1. View of entries on 17 Sep. 2004 depicting growth before harvest of plants in the one-cut system and regrowth following the first harvest in early August of plants in the two-cut system.

some entries in the single harvest treatment (harvested in September), but it was not a noticeable problem for the two harvest treatment (harvests in August and November).

Correlations measure the strength of the relationship between two traits but are not always indicative of a cause and effect relationship. Correlations range from -1 to 1 where large absolute values indicate a strong relationship and values closer to zero indicate weaker relationships. Biomass production was highly correlated with height and stem diameter for the August (**Table 2**) and September (**Table 3**) harvests. Stem density at either harvest was not related to yield. Although stem diameter and stem density were negatively correlated, height was not well correlated with either stem diameter or stem density. This means that taller plants do not necessarily have larger diameter stalks. Stalk diameter did not change between the August and September harvest (0.61 vs. 0.59 inches, respectively). However, plant height did increase significantly overall (107 vs. 112 inches, respectively). For some entries the increase in height from the August to the September harvest was substantial, while for others there was no increase in height (data not shown).

A comparison of early maturing entries with late maturing or non-flowering entries was made. Maturity was negatively correlated with height for both harvest dates, indicating an increase in height for plants that matured late or remained in a vegetative state. Maturity was not significantly correlated with yield for the August harvest, but was the most highly correlated (negatively) variable with the September harvest yield. This result could be anticipated based upon the normal cessation of vegetative growth as a plant becomes reproductive. Those later maturing or non-flowering plants remained in a vegetative state and continued to increase growth and biomass accumulation between the August and September harvest dates.

While the results for this report are only the first year data of a 3 year study, these preliminary findings demonstrate that significant variation for biomass production exists among readily available cultivars of sorghum and sorghum x sudangrass hybrids. It also indicates considerable biomass yield potential for these annual grasses. Matching harvest management with cultivar should maximize this yield potential and provide harvest scheduling options for biomass producers.

Table 1. Dry matter (DM) production from 25 sorghum and sorghum x sudangrass hybrids and 'Piper' sudangrass grown at El Reno, Oklahoma, in 2004 and harvested using two-cut and one-cut systems.

	Two-cut system			One-cut system
Entry	August	November	Total	September
	tons DM per acre			
Sudangrass				
Piper	5.7	1.8	7.5	7.3
Sorghum x sudangrass				
Japanese Tall	8.3	4.4	12.7	20.0
Ultrasorgo	7.4	3.9	11.3	17.8
Pacesetter Plus	7.8	3.1	10.8	16.5
Sucrosse 9-R-PS	7.4	3.8	11.2	16.3
Sweeter 'N Honey Too	7.2	4.5	11.7	16.1
RSI 36027	6.9	4.4	11.3	16.1
Pacesetter	7.1	2.7	9.8	14.2
Sweeter 'N Honey	7.8	2.8	10.6	11.7
Green A	7.4	3.3	10.7	11.6
Sucrosse 5-R BMR	7.1	2.8	9.9	11.4
Honey Graze IV	7.2	2.9	10.1	9.7
Sweeter 'N Honey BMR	6.7	3.2	9.9	8.8
Honey Graze BMR	6.3	2.7	9.0	8.3
Hybrid forage sorghum				
2-way 199PS	8.2	3.9	12.0	17.2
WXF-113	8.5	3.6	12.1	16.1
Silo 600D	7.3	3.3	10.7	15.2
2-way SRS	8.7	3.2	11.9	14.2
Silo Master	7.8	3.5	11.2	13.5
2-way F-145	10.0	3.5	13.5	13.5
Silo 700 D	7.9	3.6	11.5	12.9
2-way	9.4	3.4	12.8	12.6
RSI 32736	7.6	2.3	9.9	12.2
Mor-Cane II	7.6	2.6	10.2	10.9
Dairy Master BMR	6.5	3.5	10.0	10.3
2-way BMR	5.7	2.1	7.9	8.2
Mean	7.5	3.3	10.8	13.2
CV, % †	11.5	22.5	11.8	14.9
LSD (0.05) ‡	1.4	1.2	2.1	3.2

† CV%, coefficient of variation expressed as a percentage.
‡ LSD (0.05), least significant difference at the 0.05 probability level.

Table 2. Partial correlations among measured variables for August 2004 harvest of sorghum and sorghum-sudangrass hybrids and 'Piper' sudangrass for biomass production at Fort Reno, OK.

	Height	Stem diameter	Stem density	Maturity	Dry matter
Yield	0.20 (0.0825) †	0.27 (0.0188)	0.06 (0.5904)	-0.18 (0.1277)	-0.06 (0.6199)
Height		-0.13 (0.2585)	0.22 (0.0550)	-0.30 (0.0093)	-0.02 (0.8856)
Stem diameter			-0.52 (<.0001)	-0.19 (0.0923)	-0.56 (<.0001)
Stem density				0.14 (0.2172)	0.45 (<.0001)
Maturity					0.68 (<.0001)

† Numbers in parentheses are observed significance levels testing the hypothesis that the associated correlation is zero. Generally, values less than 0.10 would indicate that the correlation differs from zero.

Table 3. Partial correlations among measured variables for September 2004 harvest of sorghum and sorghum-sudangrass hybrids and 'Piper' sudangrass for biomass production at Fort Reno, OK.

	Height	Stem diameter	Stem density	Lodging	Maturity	Dry matter
Yield	0.47 (<.0001) †	0.24 (0.0374)	-0.13 (0.2651)	-0.33 (0.0036)	-0.63 (<.0001)	-0.06 (0.6091)
Height		0.02 (0.8492)	0.09 (0.4406)	-0.18 (0.1120)	-0.71 (<.0001)	-0.39 (0.0004)
Stem diameter			-0.83 (<.0001)	0.29 (0.0125)	-0.15 (0.1929)	-0.32 (0.0044)
Stem density				-.38 (0.0007)	0.03 (0.8088)	0.30 (0.0086)
Lodging					0.30 (0.0076)	-0.22 (0.0544)
Maturity						0.55 (<.0001)

† Numbers in parentheses are observed significance levels testing the hypothesis that the associated correlation is zero. Generally, values less than 0.10 would indicate that the correlation differs from zero.

THE IMPACT OF BIOMASS/BIOENERGY HARVEST ON CONSERVATION RESERVE PROGRAM ACREAGE IN NORTHWESTERN OKLAHOMA

Brad C. Venuto and John A. Daniel

RATIONALE

Standing dead material and buildup of organic litter on CRP (Conservation Reserve Program) acreage can negatively impact plant growth over time. Previous research has shown that annual haying or grazing treatments can remove this material without affecting the following year's plant growth. In addition to removal by haying or grazing, this plant material could be harvested for biomass/bioenergy production. Before biomass harvest of CRP land is advocated, it will be necessary to determine the productivity of this acreage and to ascertain what environmental impacts the harvest of biomass will have on this resource.

OBJECTIVES

The objectives of the research were (1) determine the biomass/bioenergy yield and economic value of typical CRP land in northwestern Oklahoma, and (2) determine the environmental impact of an annual biomass harvest, including any change in plant species composition, plant growth, and soil characteristics.

METHODS

Three CRP locations were identified in cooperation with the NRCS District Conservationist stationed at Buffalo, Oklahoma. Within each location, a site dominated by introduced Old World bluestem and a site of predominantly native grasses were identified as harvest areas. Within each harvest area, there were four treatment plots consisting of no harvest, one harvest in mid-summer, one harvest in early fall, and one harvest in late fall. Plot size was 20 ft by 20 ft with two replications of each harvest treatment resulting in eight plots (four treatments x two replications) at each site. For mixed native species sites, species composition was determined so that the relative contribution of each species to the total plot biomass could be estimated. All plots were harvested to approximately 6 inch stubble height, biomass wet weight was recorded, and a sample was collected for dry matter determination and subsequent chemical analysis for fiber levels, carbon, hydrogen, nitrogen, and ash content. Soil samples were also collected at time of harvest. These analyses provide information on the quality of the material for bioenergy production. This report contains results for measurements made in 2004, the first year of the 3 year study.

RESULTS

Mean dry biomass yields were higher for the Old World bluestem compared to the mixed native species CRP (**Table 1**; 5040 vs. 2470 lbs/acre, respectively). Some variation in yield was observed among harvest dates within a location, particularly at the Owens location for the second harvest. However, there was no observed harvest by location interaction for either the Old World bluestem or native mixed species harvest areas. The locations also ranked consistently for biomass production with the Owens location producing more than the other two locations for Old World bluestem and mixed native species. The Adams location was not different from the McElhiney location for Old World bluestem production, but was below the McElhiney location for biomass production of mixed native species.

Dry matter at harvest is an important consideration for biomass harvest. Transportation costs are a significant component of biomass production for bioenergy and lower moisture content can result in considerable cost savings. Also, direct combustion of biomass for bioenergy is enhanced by higher dry matter content. Significant differences in dry matter were observed among harvest dates (**Table 2**). Mean dry matter did not change between the October and December harvest dates for Old World bluestem, but dry matter continued to increase across harvest dates for native mixed species.

Table 1. Dry matter biomass yield of Old World bluestem and mixed native species harvested in 2004 on three dates and at three locations from Oklahoma Conservation Reserve Program acreage.

	Old World bluestem				Mixed native species			
Location	Aug. 3	Oct. 5	Dec. 6	Mean	Aug. 3	Oct. 5	Dec. 6	Mean
	lbs/acre							
Owens	5330	7530	6420	6430	2970	4490	2830	3430
McElhiney	4500	4440	4660	4530	2090	2600	2410	2370
Adams	4410	3920	4140	4160	1760	1700	1350	1600
Mean	4750	5300	5070	5040	2270	2930	2200	2470
CV, % †	22.7	16.0	37.0	26.6	20.3	20.8	17.9	20.2
LSD (0.05) ‡	NS§	2710	NS	1830	NS	1950	NS	680

† CV%, coefficient of variation expressed as a percentage.
‡ LSD (0.05), least significant difference at the 5% probability level.
§ NS, not significantly different at the 5% probability level.

Table 2. Dry matter percent (DM) of Old World Bluestem and mixed native species harvested in 2004 on three dates and at three locations from Oklahoma Conservation Reserve Program acreage.

	Old World bluestem				Mixed native species			
Location	Aug. 3	Oct. 5	Dec. 6	Mean	Aug. 3	Oct. 5	Dec. 6	Mean
	DM %							
Owens	47.5	65.7	60.6	57.9	57.1	69.6	83.7	70.1
McElhiney	55.1	72.0	66.9	64.7	57.3	75.9	72.5	68.6
Adams	52.4	71.6	71.9	65.3	56.5	56.9	83.7	65.7
Mean	51.7	69.7	66.5	62.6	57.0	67.5	78.0	68.1
CV, % †	6.2	3.5	6.7	5.5	16.7	18.3	3.7	13.4
LSD (0.05) ‡	NS	NS	NS	4.7	NS	NS	9.4	NS

† CV%, coefficient of variation expressed as a percentage.
‡ LSD (0.05), least significant difference at the 5% probability level.
§ NS, not significantly different at the 5% probability level.

Because there was considerable litter accumulation and dead material from previous year's growth, dry matter values may have been inflated. Subsequent harvest years may more accurately reflect expected values for repeated annual harvests. However, although the McElhiney native species harvest area had been grazed in the recent past and the litter and dead growth was reduced relative to the other sites, this was not reflected in noticeably different dry matter relative to the other native species sites.

The number and frequency of native species at each location varied (**Table 3**). Significant differences were observed among the locations for each species counted. However, no treatment within location difference was observed for any of the respective species.

Soil moisture varied among locations and among harvest dates. Overall mean moisture differences were observed among the locations with the Owens location wetter than the McElhiney location and the McElhiney location wetter than the Adams location (10.5, 9.9 and 8.0% soil moisture, respectively). No difference in soil moisture averaged across sites and locations was observed for the first two harvest dates, but soils were significantly wetter at the December harvest date. Soil moisture at harvest was not correlated with biomass yield, but was correlated moderately with plant dry matter ($r = 0.41$; Probability level = 0.0125).

These preliminary results indicate that CRP acreage planted to Old World bluestem, based entirely upon biomass production, might be a more suitable CRP biomass resource in western Oklahoma than mixed native species. Because the costs per acre to harvest and process biomass are not proportionately different for a 5040 versus a 2470 lb per acre yield, the Old World bluestem would seem to provide a greater economic advantage. However, this conclusion must be verified by subsequent data collection including the long-term impact of continued annual biomass harvests from these CRP areas.

Table 3. Species and mean number of plants per plot for mixed native species in 2004 on Conservation Reserve Program acreage at three Oklahoma locations.

	Location		
Species	Owens	McElhiney	Adams
	No. of plants per plot		
Little bluestem	20.4	45.3	0.5
Side oats grama	6.0	0.0	48.8
Big bluestem	1.5	3.6	0.1
Indian grass	9.4	31.4	8.5
Switch grass	2.5	0.6	17.1
Bundleflower	0.9	0.0	21.8

GRASSPEA: A POTENTIAL FORAGE AND GRAIN LEGUME FOR THE SOUTHERN GREAT PLAINS

Srinivas C. Rao, Brian K. Northup, and Herman S. Mayeux

RATIONALE

Putting low-cost gain on yearling cattle with forages is an important activity for producers in the southern Great Plains. The primary forages used in this area are winter wheat (grazed from fall through spring), and warm-season perennial grasses for summer grazing. This system has two important gaps in time (**Fig. 1**) when high-quality forage is not readily available, in September through November, and May to June. Finding forage species that can fill these gaps is needed for the development of sustainable, year long, cost-effective grazing systems for stocker calf production.

One species with the potential to fill the May to June gap, with the added advantage of using fixed nitrogen, is the annual legume grasspea also known as chickling vetch, (**Fig. 2**). Grasspea is widely grown in India, southern Europe and North Africa to produce forage and grain for both human and animal consumption. Grasspea is well adapted to cool-season production periods in those areas, particularly as a green cover or second crop in place of a fallow period. It is tolerant of drought conditions, but is also capable of growing on land subject to regular flooding.

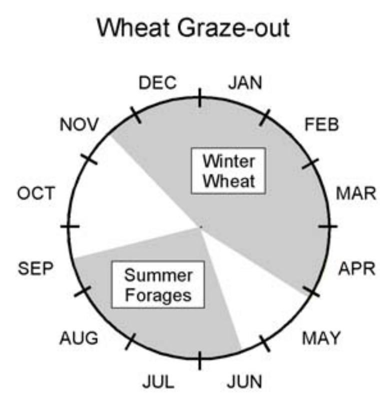


Fig. 1. A traditional forage system used for grazing yearling stocker cattle in the southern Great Plains.

Fig. 2. Grasspea at flowering – 70 days after seeding.

OBJECTIVE

Over the past decade, new grasspea cultivars have been developed for the northern Great Plains. At present, much of the work on the usefulness of this species has focused on its use as a green cover crop in areas of southern Canada and South Dakota. It is not known whether grasspea will work as a forage or grain crop in the southern Great Plains. This study was conducted to determine whether a new cultivar of grasspea ('AC-Greenfix') could produce forage to fill the May to June forage gap in Oklahoma. Also, nutritional values of the forage and capacity of this cultivar to produce a grain crop was evaluated.

METHODS

Three replicate fallow plots were fertilized with 60 lbs/acre of phosphorus and disked each March of 2001 to 2003. No nitrogen fertilizer was used during the study. Seeds were treated with commercial liquid inoculum and planted in rows with a 24-inch spacing in mid March at the rate of 75 lbs/acre. Whole plant samples were clipped 1 – 1.5 inches aboveground on five dates from May 7 to July 15, with collections made on approximately the same day of each year. Samples collected on the last two dates (June 26 and July 15) were also separated into grain (both mature and immature) and non-grain plant parts. The samples were then oven-dried and used to measure forage and grain production, and analyzed for crude protein and digestible dry matter.

RESULTS

Grasspea initially accumulated dry matter slowly between planting and the last week of May (**Fig 3**). The average rate of daily growth during this period was 29 lbs per acre but increased nearly four-fold to 121 lb/acre/day between the last week of May and the end of June. Total amount of forage varied across sampling dates each year with higher amounts recorded during 2001 than the other years, due to greater amounts of rainfall in that year (data not shown). When averaged across the 3 years, the greatest amount of aboveground dry matter measured on the last two sampling dates (June 26 and July 15) was not different and averaged 5500 lb/acre.

Crude protein of the forage was highest (32%) on May 7 and declined as the season progressed, and grasspea matured (**Fig. 3**). The greatest decline in crude protein concentration was from 27% to 21% between May 23 and June 6. This decline in crude protein concentration coincided with a 2-fold increase in forage dry matter accumulation. By late June and early July the forage crude protein concentration was 15.5%.

Similar to crude protein concentration, the digestible dry matter of the aboveground crop was highest (87%) on May 7 and progressively declined during the next 59 days (**Fig. 3**). The greatest decline in digestible dry matter occurred between May 23 and June 6, when digestibility declined from 83 to 76%. Digestible dry matter on the last sampling date was 69%.

On June 26 and July 15, grasspea plants contained around 70% non-grain material (leaf, stem and chaff) (**Table 1**). Crude protein concentration ranged between 9% and 11% for the non-grain material, and 27% to 29% for the grain. Digestible dry matter of the non-grain material was between 57 and 63%, while digestibility of the grain was about 95%.

Grasspea could potentially be a component of both grazing and crop production systems in the southern Great Plains. At peak forage production, grasspea produced an average of 5730 lb/acre of dry forage with 16.4% crude protein, a value approaching that of purchased protein supplements. Further, grasspea contained large amounts of nitrogen within aboveground tissues, which could be used as a green manure to help improve soil condition. If grazed, we calculate that grasspea could have supplied 940 lb/acre of crude protein for cattle. Grasspea has the potential to provide large amounts of forage and nutrients for livestock, if grown during the spring forage deficit period. It also may be grown for grain in the southern Great Plains.

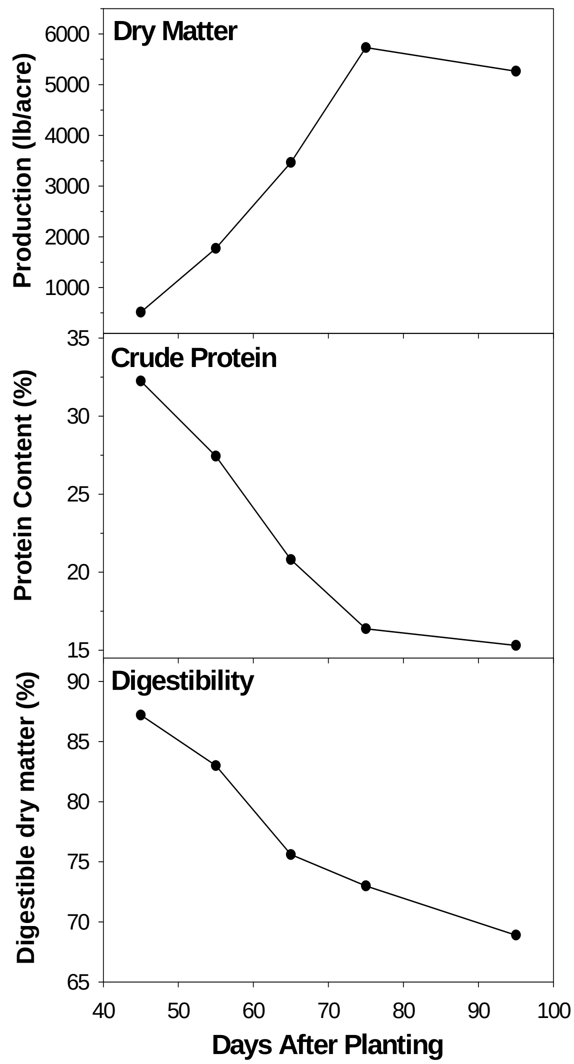


Fig. 3. Grasspea dry matter accumulation, crude protein concentration, and digestibility during the growing season.

Table 1. Grasspea dry matter, crude protein concentration, and digestible dry matter of leaf-stem-chaff (LSC) and grain at the end of the growing season.

	Dry matter		Crude protein		Digestible dry matter	
Date	LSC	Grain	LSC	Grain	LSC	Grain
	lb/acre		%		%	
June 26	4000	1730	10.9	27.4	62.8	95.5
July 15	3730	1540	9.2	29.3	56.7	95.8

PERFORMANCE OF FORAGE SOYBEANS IN THE SOUTHERN GREAT PLAINS

Srinivas C. Rao, Brian Northup and Herman Mayeux

RATIONALE

A primary goal of grazing programs is to provide high-quality forage year-round to reduce costs of stored forages or concentrate feeds. However, pasture available for grazing livestock in the southern Great Plains is often in short supply during late summer and early fall. Current grazing systems in this region rely on winter wheat as the primary forage during fall and winter, and on summer perennial grasses such as Old World bluestem and bermudagrass during late spring and early summer. However, high-quality forage is unavailable from late July through November, as warm-season grasses become mature and quality of available forage declines. Therefore, additional plant species that can supply forage during this deficit period are needed to develop sustainable forage-livestock production systems for the southern Great Plains.

OBJECTIVE

The objective of this study was to evaluate the usefulness of soybeans bred in the mid-Atlantic and southern states for forage production in the southern Great Plains. Our approach was to compare the forage production patterns and the nutritive value of novel forage-type soybeans to a common grain-type soybean during the summer fallow period of continuous winter wheat production.

METHODS

This experiment was conducted on three replicate blocks of 33 by 99 ft plots during 2001 through 2003. Forage-type cultivars used in the study were 'Donegal', 'Derry', and 'Tyrone' and were compared to the commonly grown grain-type cultivar 'Hutcheson', an earlier maturing cultivar. Maturity groups for Donegal, Derry, and Tyrone, and Hutcheson were MG V, MG VI, MG VII and MG V, respectively. Following grain harvest of no-till winter wheat in June, plots were sprayed with glyphoate at 1.3 lb of actual ingredients. During the growing season, plots were hand weeded as necessary. All plots were broadcasted with 60 lbs of P2O5 per acre and soybean seeds were inoculated and planted no-till at 60 lbs per acre in rows with a 24-inch spacing. No nitrogen fertilizer was added to the plots. Studies were conducted under rainfed conditions, except 2003. May and June of 2003 was extremely dry. Plots were irrigated twice during June with 2 inches (total of 4 inches) to ensure germination and establishment. Whole plant samples were clipped 1 inch above ground and collected at six different dates (August 1 to October 9) each year to determine oven-dry yields of forage. These were separated into leaf (including petioles and chaff), stem and mature seed. Each plant part was then analyzed for protein concentration and digestible dry matter.

RESULTS

Aboveground yields: Total aboveground yield of Hutcheson and the late-maturing forage cultivar Tyrone was less than the yield of the forage-types Derry and Donegal until 25 September. However, the difference between Donegal, Derry and Tyrone disappeared in October (**Table 1**). By October, the forage cultivars Tyrone, Donegal, and Derry produced 48, 47, and 16% more biomass, respectively, than Hutcheson.

Accumulation of leaf and stem dry matter varied by sampling date among cultivars (**Table 2**). The forage-type cultivars Derry and Donegal produced more leaves and stems than the grain type, Hutcheson. For forage samples collected through August 27, Derry and Donegal had 12 to 21% greater leaf and 8 to 18 % greater stem dry matter than Hutcheson or Tyrone, the other forage-type soybean. Forage yield of Tyrone at the first harvest (August 1) was less than the other cultivars, which could be partially attributed to its later maturity. However, by late August, differences in leaf and stem dry matter among the forage cultivars diminished, and they produced more dry matter than Hutcheson in late September.

Table 1. Aboveground dry matter of four cultivars at different sampling dates during 2001 to 2003.

Sample date	Cultivars			
	Derry	Donegal	Tyrone	Hutcheson
	lb/acre			
Aug. 01	220	210	140	190
Aug. 14	360	410	280	300
Aug. 27	630	660	570	550
Sep. 10	1300	1250	1120	840
Sep. 25	2280	2740	1930	1860
Oct. 09	2630	3120	3010	2230

Table 2. Leaf and stem dry matter for cultivars at different sampling dates during 2001 to 2003.

Sample date	Leaf				Stem			
	Derry	Donegal	Tyrone	Hutcheson	Derry	Donegal	Tyrone	Hutcheson
	lb/acre							
Aug. 01	140	130	90	120	80	80	50	70
Aug. 14	210	250	170	180	150	160	110	120
Aug. 27	370	400	330	330	260	260	240	220
Sep. 10	710	770	610	520	590	480	510	320
Sep. 25	780	940	760	500	680	620	670	360
Oct. 09	1010	1280	1290	870	560	660	840	390

By early October, accumulation of leaf dry matter by Derry, Donegal and Tyrone was 56, 88, and 52% greater, respectively, than Hutcheson and stem production was 88, 72, and 86% greater.

Grain yield (**Table 3**) averaged across growing seasons was highest for Donegal (1180 lbs/acre) and least for Tyrone (880 lbs/acre) at final harvest. Lower grain yield by Tyrone was due to the prolonged vegetative growth period by this cultivar, and a shorter time available for pod fill. It is interesting that one of the forage-type soybean Donegal produced more grain than the grain-type cultivar, though both cultivars are in the same maturity group.

Table 3. Grain yield averaged across years at two sampling dates during 2001 to 2003.

Cultivars	Sep. 25	Oct. 09
Derry	820	1060
Donegal	1180	1180
Tyrone	500	880
Hutcheson	1000	970

Crude protein concentration of leaves for the different cultivars was very similar within sampling dates. Leaf crude protein averaged across cultivars ranged from 20.6% in August to 15% in October. Stem crude protein concentration among cultivars and sampling dates varied. Stems of Tyrone had the highest crude protein concentration (1.5 to 2.0 % greater than other forage cultivars) at later harvest dates. Stem crude protein ranged from 12.5% in August to 6.25% in late September and early October. Digestible dry matter of leaves for all cultivars ranged from 84% in the early part of the growing season to 79% in October. Stem digestibility of the cultivars was similar, and averaged 62%. The seed protein concentration averaged 26%, and was 1 to 2% higher in Derry and Hutcheson. Digestible dry matter of the grain averaged 87%, and no difference was noted among cultivars.

Results indicate that the soybean cultivars Derry and Donegal bred for forage production would be better choices for grazing until 25 September, whereas Tyrone for October grazing than Hutcheson, a common grain-type cultivar, in the southern Great Plains. The forage-type cultivars Donegal and Tyrone produced the most total and leaf dry matter during the first week of October. Tyrone also had lower grain yields at final harvest than the other forage cultivars. We conclude that either Tyrone or Donegal could provide sufficient amounts of high-quality forage for grazing cattle during the late summer and early fall, when other forages in the southern Great Plains are less productive and of poor quality.

FINISHING BEEF CATTLE ON WARM-SEASON GRASS PASTURES

William A. Phillips, Michael A. Brown, J. William Holloway, Bobby Warrington, Elaine E. Grings, and Herman S. Mayeux

RATIONALE

In the southern Great Plains, stocker calves are often grazed on warm-season grasses. Stocker producers that purchase calves in May specifically for grazing warm-season grasses for 90 to 110 days can experience great fluctuation in profitability because the market value of stocker calves usually declines over the summer months. In order to increase profitability and decrease risk, stocker producers need alterative ways to market warm-season forages such as bermudagrass and Old World bluestem.

OBJECTIVE

The objective of this experiment was to determine performance of stocker calves in a summer beef cattle finishing system that utilizes warm-season grass pastures under intensive-grazing management in conjunction with a self-feeder filled with a high-energy diet.

METHODS

The following five experiments were conducted over an 8-year period (1994 through 2002) and observations were made on a total of 1139 calves. Each experiment is described in Table 1. All calves were born in late winter or during the spring, weaned in the fall, shipped to El Reno, OK, and raised as stocker calves until the initiation of the finishing phase the following spring. Heifer and steers calves from Arkansas were sired by Hereford bulls from Angus, Brahman and reciprocal cross cows. Steer calves from Texas were sired by Brahman, Senepol, or Tuli bulls from Angus cows, but the heifers were sired by Limousin bulls from crossbred cows. Steer calves from Florida were purebred Angus or Romosinuano. A composite breed of 50% Red Angus, 25% Charolais and 25% Tarentaise was used in the last experiment with calves from Montana.

Within each experiment, calves were assigned to either a pasture or conventional finishing system. The pasture finishing system consisted of two components. First, warm-season grasses were grazed beginning in early June at a high stocking rate (three to four times normal) to harvest the forage at its best stage of quality. When approximately 80% of the standing forage had been harvested (3 to 4 weeks after initiation of grazing), the second component of the system, a self-feeder filled with high energy feed, was added to each pasture. This system is referred to as “grain-on-grass”.

Calves finished with the conventional system were housed in pens in a covered building with concrete flooring. The same diet (13% crude protein, 0.9 Mcal net energy for maintenance/lb, and 0.6 Mcal net energy for gain/lb) was fed to both the conventional and grain-on-grass groups. Calves were considered finished when the fat thickness over the twelfth rib was 0.4 inch or greater. Carcass quality grade was expressed as a numerical value (low choice = 12.0 and select = 11.0). Feed intake was expressed as pounds of feed consumed per calf for the finishing period.

RESULTS

The overall average body weight of the calves at the beginning of the finishing period ranged from 720 to 880 lbs (**Table 1**) and averaged 810 lbs. Final body weight was greater for calves from AR and TX that were finished with the grain-on-grass system as compared to calves finished with conventional confinement feeding (**Table 2**). Generally the calves finished on the grain-on-grass system had less internal fat and lower carcass yield grades than calves finished in the feedlot, but carcass quality grades (low choice = 12) were similar between finishing systems.

Overall average daily gain was less from calves finished on pasture as compared to calves finished in the feedlot. During the first 30 days of the finishing period, calves in the grain-on-grass group had less average daily gain than calves in the conventional feedlot group (data not shown). This was primarily due to the lower energy density in grass as compared to a feedlot diet. Calves finished in the grain-on-grass system were also subjected to more solar radiation than calves fed in confinement under a roof. As a result, they may have expended more energy trying to overcome the additional heat stress, plus they also invested more energy in physical

Table 1. Description of the source of the calves, number of calves, sex of calf, initial body weight, and stocking rate for calves finished on forage (OWBS = Old World bluestem and BERM = bermudagrass) for each experiment.

	Experiment				
Item	1	2	3	4	5
Source of calves	AR	AR	TX	FL	MT
No. of calves	145	155	122	160	557
Sex of calves	steers/heifers	steers	steers/heifers	steers	steers
Initial body weight, lb	823	882	715	783	847
Stocking rate, ac/calf	0.25	0.25	0.25	0.29	0.33
Forage source	OWBS	OWBS	OWBS	BERM	OWBS/BERM

Table 2. Final body weight, number of days on feed, average daily gain, total feed intake, carcass quality grade, and carcass yield grade for cattle finished under conventional confinement feeding (CONV) or grain-on-grass (GOG).

		Experiment					
Trait	System	1	2	3	4	5	Mean
Source of calves		AR	AR	TX	FL	MT	
Final body weight, lb	CONV	1150	1170	1120	1100	1190	1150
	GOG	1180	1200	1170	1090	1190	1170
Days on feed	CONV	120	122	167	117	121	129
	GOG	122	122	165	126	140	135
Average daily gain, lb	CONV	2.73	2.71	2.51	2.84	2.76	2.71
	GOG	2.89	2.58	2.75	2.47	2.55	2.65
Total feed intake, lb/calf	CONV	2880	2610	3090	2170	2430	2640
	GOG	2670	2100	3110	2010	2620	2500
Carcass quality grade	CONV	11.0	10.9	11.1	12.1	11.7	11.4
	GOG	11.0	10.6	10.7	11.6	11.6	11.1
Carcass yield grade	CONV	2.95	2.88	2.75	2.90	2.74	2.54
	GOG	2.76	2.62	2.68	2.61	2.70	2.67

activity than calves confined to a pen. Breed of calf and point of origin were confounded, but it appeared that within the grain-on-grass system, calves from Arkansas were better equipped to handle higher solar radiation than calves from Montana (**Table 2**).

The amount of feed needed to finish a calf was less with the grain-on-grass system in three of five experiments. Within those three successful experiments, we used the amount of the feed saved by finishing calves with the grain-on-grass system to calculate the value of the pasture. The cost of our feedlot diet was around $100/ton ($0.05/lb) and we saved on average of 300 lbs of feed/calf by using the grain-on-grass system. At an average stocking rate of 0.26 calves/acre, the value of an acre of pastures was calculated to be $58.

Another advantage of feeding calves on pasture is lower waste disposal cost. Calves fed on pasture distributed waste across the pasture each day. Feeding in a lot required a lagoon for storage of waste for disposal at a latter date. On average, a calf fed on pasture consumed 2,500 lbs of feed which contained 50 lbs of nitrogen. We estimated that 12 lbs out of the 50 lbs of nitrogen consumed was retained as gain. As a result, 38 lbs of nitrogen per calf was distributed across the pasture in feces and urine. With an average stocking rate of 0.26 calves/acre, over 140 lbs of nitrogen was deposited per acre, which should reduced the need for nitrogen fertilizer.

Finishing cattle on pasture is an option that can be used to market warm-season grasses for greater net returns per acre. However from our experience with grain-on-grass finishing, calf breed, point of origin, initial body weight and finished body weight are important considerations. We concluded that calves that were reared in a southern environment and are genetically predisposed to moderate mature body weight are better suited for finishing on pasture than calves from a northern region or calves with large mature body size. Another important factor is initial body weight in relationship to final body weight. If light calves are fed for an extended period of time, pastures do not have the opportunity to recover and stand persistence is decreased.

PERFORMANCE OF TROPICALLY ADAPTED BEEF BREEDS AS STOCKER CALVES

William A. Phillips, Samuel W. Coleman, J. William Holloway, David G. Riley, and Chad C. Chase

RATIONALE

Cow-calf producers in the southern U.S. use the Brahman breed to incorporate genetic adaptation to heat stress into their cow herds. Although born and reared in subtropical environments, calves produced in the South are usually transported after weaning to more temperate environments for growth and finishing. In previous research, we have reported that calves with as much as 50% Brahman breeding performed well as stocker calves. However, when sold as feeders, they were discounted due to potentially poor feedlot performance and lower carcass quality as compared to steers with little or no Brahman breeding.

In order to overcome these problems, new tropically adapted beef breeds are being evaluated in cow herds in the southern U.S. However, the stocker performance of calves generated by these new breeds has not been documented.

OBJECTIVE

The objective of these experiments was to compare the performance of stocker calves representing different tropically adapted beef breeds.

METHODS

Three experiments were conducted in cooperation with the USDA-ARS Subtropical Agricultural Research Station in Brooksville, FL (Experiments

1 and 2) and with the Texas A&M Research and Extension Center, Uvalde, TX (Experiment 3).

In Experiment 1, purebred Angus and Romosinuano calves were born in late winter, weaned in the fall, vaccinated, and preconditioned for 14 days before being transported 1200 miles to El Reno, OK. Calves grazed winter wheat pastures for 125 days (winter phase) and 84 days (spring phase). A total of 160 steers were evaluated over two production cycles.

The calves used in Experiment 2 were also from Brooksville and were purebred Angus, Brahman, or Romosinuano and the two breed reciprocal crosses. Calves were managed as described above and grazed winter wheat pastures for 122 days during the winter and 49 days during the spring phases. A total of 296 steer calves were evaluated over two production cycles.

In Experiment 3, calves were sired by Angus, Brahman, Senepol or Tuli bulls from Angus cows managed on southwest Texas rangeland. Calves were born in the spring and shipped to El Reno in the fall after weaning. Calves were assigned to different winter management groups for a winter grazing period that averaged 113 days. In the spring, all calves grazed winter wheat pastures as a single herd. A total of 188 calves were used over three production cycles.

RESULTS

Romosinuano are native to Colombia, South America and have good heat tolerance. They are a red in color with no hump and small ears. The Angus calves used in Experiments 1 and 2 were from a herd selected and bred at Brooksville for several generations. In Experiments 1 and 2, Romosinuano gained less weight during the winter than the Angus steers (**Table 1 and 2**). As in most tropical adapted breeds, they have a thin hair coat and less subcutaneous fat as compared to Angus steers. As a result, they must expend more energy during cold weather to keep warm than temperate breeds. In Experiment 2, purebred Romosinuano and Brahman calves and reciprocal crosses of these two breeds gained less weight during the winter than purebred Angus calves. Purebred Romosinuano steers calves performed slightly better as stockers than purebred Brahman steer calves, but both tropical breeds gained less weight as stockers than purebred Angus steers calves. Using the Romosinuano breed instead of Brahman in a crossing breed program with the temperate Angus breed does not appear to decrease stocker calf performance.

The performance of calves sired by tropical-adapted bulls and reared in southwest Texas is shown in **Table 3**. Tuli are an early-maturing, medium-sized Sanga breed, while the Senepol are a *Bos taurus* breed from the U.S. Virgin Islands. Angus and Senepol sired calves gained more weight during the winter than Brahman or Tuli sired calves. During the spring, the Brahman sired calves compensated for poor winter performance by gaining more weight than the other three breed types. As a result, the Brahman sired calves gained more total weight than the Senepol or Tuli sired calves or the Angus sired calves. These data illustrate the advantage of retaining ownership of stockers that have low average daily gains during the winter to capture compensatory gains in the spring. Although the feedlot data is not shown, the Senepol and Tuli sired calves produced leaner carcasses with higher marbling scores than Brahman sired calves, which make them more valuable as feeder calves at the end of stocker period.

Table 1. Stocker performance of Angus and Romosinuano steer calves used in Experiment 1.

Trait	Angus	Romosinuano
	lb/calf	
Initial body weight	494	475
Gain during winter	225	167
Gain during spring	92	93
Total gain	317	260

Table 2. Stocker performance of Angus, Brahman, Romosinuano or reciprocal crossed steer calves used in Experiment 2.

Trait	Angus	Brahman	Romosinuano	Angus crosses†	Tropical crosses‡
			lb/calf		
Initial weight	522	570	506	589	563
Winter gain	204	155	175	204	174
Spring gain	131	106	124	138	132
Total gain	335	261	299	342	306

† Angus crosses includes Angus x Brahman, Angus x Romosinuano, Brahman x Angus, and Romosinuano x Angus.
‡ Tropical crosses includes Brahman x Romosinuano and Romosinuano x Brahman.

Table 3. Stocker performance of steer calves sired by Angus, Brahman, Senepol, or Tuli bulls from Angus dams reared in southwest Texas and used in Experiment 3.

	Sire breed			
Trait	Angus	Brahman	Senepol	Tuli
		lb/calf		
Initial body weight	401	505	463	444
Winter gain	129	101	122	114
Spring gain	117	160	114	108
Total gain	246	261	236	222

PERFORMANCE OF BORAN, TULI, GELBVIEH, AND BRAHMAN F1 CROSSES IN OKLAHOMA

William A. Phillips, Robert P. Wettemann, Samuel W. Coleman, and J. William Holloway

RATIONALE

Alternative sources of genetic adaptation to tropical environments in beef cattle raised in the Southern Plains have not been fully characterized. Boran and Tuli are two tropically adapted breeds that are currently under evaluation at several locations in the U.S as a replacement for the Brahman breed. Boran is a pure Zebu breed (*Bos indicus*) that evolved in southern Ethiopia, while Tuli are Sanga type cattle developed in Zimbabwe.

OBJECTIVE

The objectives of the present study were as follows: (1) determine the effect of tropically adapted sire breeds on pre-weaning and post-weaning performance of F_1 calves, and (2) determine the subsequent performance of the F_1 females.

METHODS

Angus and Angus x Hereford cows were bred by artificial insemination each spring (1991 through 1994) using semen from Boran, Brahman, Gelbvieh, and Tuli bulls. Calves were born the following spring and male calves were castrated at birth. Calves were weaned at approximately 7 months of age. To reduce the effect of age, all weaning weights were adjusted to a constant 205 days of age. Cows were weighed each fall at weaning and hip height was recorded to monitor growth rate.

A new herd was formed from the females generated from the matings described above. All heifers were bred to have their first calf as a 2-year old and were exposed to Red Poll bulls. Subsequent calves were sired by Simmental, Charolias, or Brangus bulls, but only one terminal sire breed was used within a year. Management of the F_1 cows was typical of the cow/calf industry in Oklahoma. A total of 276 calving records over six calving cycles were recorded for the F_1 cows.

RESULTS

There was no interaction between sex of calf and sire breed, so results can be presented as means by sire breed and sex of calf. Overall, male calves were heavier than female calves at birth (89.5 lbs vs 80.5 lbs) and at weaning (473 lbs vs 449 lbs). Male calves also had slightly greater average daily gain (ADG) from birth to weaning than female calves (1.87 lbs vs 1.80 lbs). Calves sired by Tuli bulls had lower birth weights and weaning weights than calves sired by Brahman bulls (**Table 1**). Calves sired by Boran and Gelbvieh bulls were intermediate to Brahman and Tuli for birth weight and weaning weight. In general, very few cows required assistance in calving. However, there was a tendency for Brahman-sired calves to require more assistance than calves sired by bulls from the other breeds. This may be due to higher birth weights in Brahman-sired calves.

Pre-weaning calf performance of calves from the F_1 females are presented in **Table 2**. Calves from Gelbvieh-sired cows were heavier at birth than calves from the other three genotypes. Boran- and Brahman-sired cows produced heavier calves at weaning as compared to calves from Gelbvieh- and Tuli-sired cows. Calf ADG followed the same pattern as weaning weight. Brahman-sired cows weighed more in the fall than the other three genotypes (**Table 2**). Although Brahman-sired cows were the tallest and heaviest of the breed types studied, they weaned a similar amount (41.8 lbs) of calf per 100 lbs of cow body weight as the Gelbvieh- and Tuli-sired cows (41.1 and 42.7 lbs). Boran-sired cows were the most efficient of the four genotypes studied. Boran-sired cows weaned 44.7 lbs of calf per 100 lbs of cow body weight. These data are based on average cow body weight and do not take calving percentage into consideration.

Average hip height of F_1 cows followed the same pattern as fall body weight (**Table 2**). Linear regression of body weight on age showed that Brahman- and Gelbvieh-sired cows grew at similar rates (64 lbs/year) and grew faster than Boran- and Tuli-sired cows (48 lbs/year).

We concluded that Boran-sired cows are smaller in size than Brahman-sired cows, but the amount of calf weaned per cow will be similar. Therefore, cow efficiency will be greater for Boran-sired cows than for Brahman-sired cows. Tuli-sired cows were also smaller, but weaned as much calf per 100 lbs of cow body weight as Brahman-sired cows. With lower body weight, we would anticipate that Tuli-sired cows would have lower maintenance cost than Brahman-sired cows, but the Boran-sired cow will still be the most efficient.

Table 1. Least squares means for preweaning performance of calves sired by Boran, Brahman, Gelbvieh, and Tuli bulls from Angus and Angus x Hereford cows.

	Sire breed				
Traits	Boran	Brahman	Gelbvieh	Tuli	SE†
Number of calves	44	41	37	51	
Birth weight, lbs	87.8	91.1	87.1	77.9	4.8
205-day weaning wt, lbs	445	491	461	432	25
ADG‡, lbs	1.75	1.95	1.81	1.73	0.11

† SE, standard error.
‡ADG, average daily gain.

Table 2. Least squares means for birth weight and weaning traits of calves from F_1 dams and fall body weight and fall hip height of F_1 cows averaged across all age groups.

	Sire breed				
Item	Boran	Brahman	Gelbvieh	Tuli	SE†
Number of calves	72	79	50	75	
Birth weight, lbs	82.3	79.6	90.0	80.5	1.8
205-day weaning weight, lbs	500	518	460	465	9.2
ADG‡, lbs	2.03	2.14	1.81	1.88	0.04
Cow body weight, lbs	1120	1240	1120	1090	21
Cow hip height, inches	52.4	54.7	53.1	52.4	0.3

† SE, standard error.

‡ADG, average daily gain.

RELATIONSHIP OF SIRE EXPECTED PROGENY DIFFERENCES TO MILK YIELD IN BRANGUS COWS

Michael A. Brown, Samuel W. Coleman, and David L. Lalman

RATIONALE

The development of alliances among different segments of the beef cattle industry requires a better understanding of each segment's influence on subsequent productivity. Stocker cattle have spent a significant portion of their life dependent on their dam during the cow-calf segment and preweaning influences impact their performance as stockers. Preweaning factors such as climate, forage type, management, and maternal environment all affect productivity as stockers. The preweaning maternal environment includes the milk production by the dam, which is difficult to measure. Consequently, a necessary first step in evaluating relationships of preweaning environment to postweaning performance is to determine if milk yield can be predicted from data which are more easily estimated than actual milk yield. One example of such data is maternal weaning weight expected progeny differences, which are commonly referred to as milk EPD's. Most beef cattle breed associations publish EPD's for various traits for individual animals registered with the association, including milk EPD's, to allow comparisons among individual animals for predicted genetic merit. Estimates of milk EPD's for sires allow estimates of differences in weaning weights of progeny of their daughters attributable to maternal effects in their daughters.

While there is general consensus that larger milk EPD's are associated with greater milk production and calf weaning weights, the relationships reported among milk EPD's, milk yield, and weaning weight vary with production environment and breed. Superior milking cows would be expected to require greater levels of feed energy to support milk production. This implies that there may be a practical maximum for milk EPD's for given nutritional environments.

OBJECTIVE

The objectives of this research were to evaluate relationships of Brangus sire milk EPD's to milk yield of their purebred daughters and weights of their daughters' calves.

METHODS

Registered Brangus females (n=246) representing a wide sampling of the breed were acquired between 1998 and 2000. Cows were managed on native rangeland, Old World blue stem, and common bermudagrass during the summer. They were wintered on dormant warm-season forage with supplementation of hay (prairie hay, bermudagrass, or Old World bluestem) and protein cubes (40% crude protein, 76% total digestible nutrients) as needed. In the spring, cows calved on wheat pasture until the spring of 2002 when cows calved on wheat pasture or native rangeland infested with cool-season annuals such as downy brome. Estimates of forage crude protein and dry-matter digestibility for the pastures used in the milk production study, averaged over the 3 years are given in **Table 1**.

Milk yield of 50 to 60 cows representing 65 Brangus sires was measured monthly in each year in 2000, 2001, and 2002. A portable machine was used to milk cows at 28-day intervals starting at 49 days postpartum in late April and ending in late September. The number of daughters per sire averaged 2.1 (range = 1 to 9). Distribution of ages of cows in the study included 41 2-year-old, 56 3-year-old, 27 4-year-old, and 36 mature (5+ years) cows. Repetition of cows across years was minimal.

Table 1. Forage crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) estimates during the 6 months when milk production was measured.

	Month					
Trait	April	May	June	July	August	September
CP, %	11.1	10.4	5.9	5.9	5.2	4.9
IVDMD, %	63.3	64.9	50.3	49.0	50.6	50.5

The distribution of sire EPD's for the experiment is given in **Fig. 1**. There were 19 cows with sire EPD's greater than or equal to 14.8 lb and 30 cows with sire EPD's greater than or equal to 14.2 lb (data not shown). The average active sire EPD for milk for the Brangus breed was 8.7 lb in the fall of 2003 and the average accuracy of milk EPD's for all registered Brangus was 0.15, where accuracy is a relative value from 0 to 1.0 with higher values indicating higher accuracy.

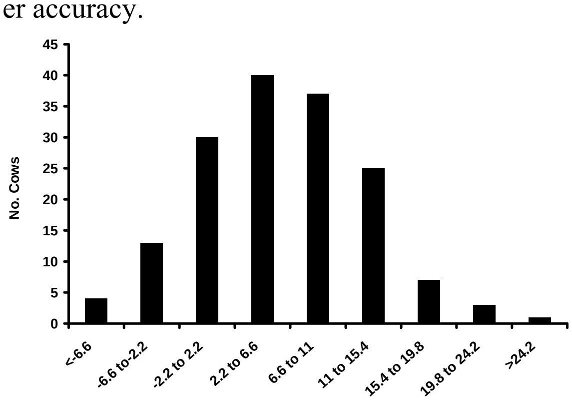


Fig. 1. Distribution of sire milk EPD for daughters in the experiment.

RESULTS

24-hour Milk Yield on Sire EPD. Predicted values for the regression equations of 24-hour milk yield averaged over the 6 months (average 24-h milk yield) on sire milk EPD's are plotted in **Fig. 2**. The regression of average milk weight on sire milk EPD's was curvilinear. This curvilinearity indicates that there is a point at which increases in sire milk EPD's are not associated with increases in daughter milk yield. Sire EPD's in excess of 12.7 lb did not result in increased average milk yield. This implies that one or more factors may be limiting the expression of maternal genetic potential for milk production in these cows.

Fig. 2. Plot of the predicted values of the regression of daughter average 24-hour milk yield on sire milk EPD.

Because increases in cow body weight (BW) are associated with increased nutrient requirements for maintenance of BW and therefore limitations in nutrients available for milk production, the effect of cow BW on the relationship of sire milk EPD to daughter milk yields was investigated. The relationships between cow BW and sire milk EPD's are given in Fig. 3 and Fig. 4. The response surface (**Fig. 3**) illustrates that the relationship of average 24-h milk

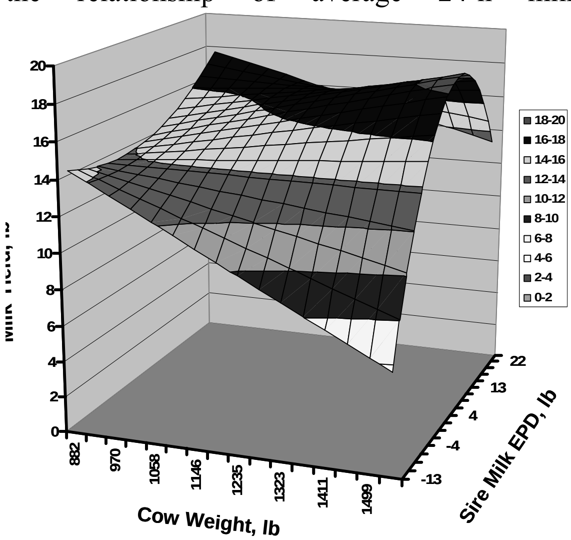


Fig. 3. Plot of the predicted values of the regression of daughter average 24-hour milk yield on sire milk expected progeny difference (EPD) at various levels of daughter body weight.

yield to sire milk EPD's is reasonably linear at lower cow BW (< 1150 lb) while at 1150 lb or greater, the relationship becomes curvilinear. Moreover, it appears that the sire milk EPD's at which maximum average 24-hour milk yield is predicted becomes smaller as cow BW increases (**Fig. 4**).

These data indicate that the relationship of milk yield to sire milk EPD's depends on cow BW. For heavier cows, increases in milk yield of daughters diminish as sire milk EPD's increase from low to high values. Moreover, there is a practical maximum effective sire EPD that is determined by the weight of the cow and the nutritional environment. In most grazing management environments, heavier cows would have lower practical maximum effective sire EPD's. This implies that there is little economic utility in increasing sire EPD's beyond the point at which the nutritional environment and cow maintenance requirements preclude the expression of genetic potential for milk yield. To illustrate this, published nutrient requirements of cows with an average milk yield of 11 lb/day range from 9.1-10.6% crude protein (CP) and from 55.3-59.4% total digestible nutrients (TDN). In lactating cows of superior milk yield (22 lb/day) these requirements are 11.3-16.4% CP and 63.0-82.9% TDN. If it is assumed that selectivity of higher quality forage during grazing could result in a diet with a 3% increase in both CP and TDN, then protein and energy provided by forage (**Table 1**) would fail to meet the nutrient requirements of cows with either average or superior milk yield during June, July, August, and September.

To further illustrate the impact of changes in nutrient availability on milk yield (April, when forage quality was good vs. July, when forage quality was marginal; **Table 1**), a subset of the data (n=52) was evaluated for cows that were "average" in milk yield (average 15 lb/day) and

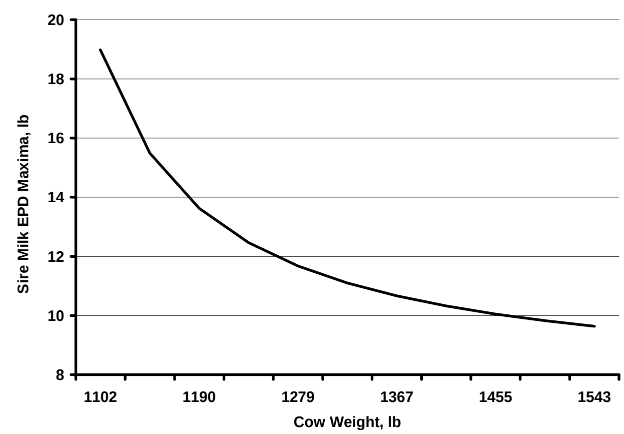


Fig. 4. Plot of maximum sire milk expected progeny difference (EPD) vs. daughter body weight from the quadratic regression of daughter average 24-hour milk yield on sire milk EPD and daughter body weight.

high in milk yield (average 31 lb/day) in April milk yield. Data were adjusted for year, age of dam, and days of lactation; cow weight was not an important factor in change in milk yield in this sample of cows. Decreases in milk yield from April to July, were evident in cows with high milk yield (-9.5 lb) whereas average cows did not change in milk yield from April to July

(0.2 lb). These results suggest that a decline in nutritive value of forage had larger effects on higher milking cows than the cows with "average" milk yield.

We found that the combination of cow BW and sire milk EPD should be matched to the nutrition available to the cow herd, but that the benefits of exploiting high milk EPD sires should not be ignored. Higher EPD sires will be useful in non limiting nutritional environments and in correcting deficiencies in milk EPD in low milk EPD herds.

PREDICTION OF ANIMAL GAINS FROM FORAGE CANOPY LIGHT ABSORBANCE USING HYPERSPECTRAL RADIOMETRY

Michael A. Brown and Patrick J. Starks

RATIONALE

Supplementation of grazing animals with grain or hay, without regard to nutrients received from the grazed forage, can be costly when the supplement is not needed. There are times within the grazing season when supplementation can be economically efficient, but determining those times in advance is difficult. Previous work has shown that forage quality can be predicted from near-infrared spectroscopy in the laboratory and recent work has shown that it may be possible to estimate forage quality in the field using hyperspectral radiometry. Since intake is a partial function of forage quality and animal gains depend on both intake and quality, direct prediction of animal gains may be possible to assist livestock producers in determining when and how much supplementation is needed to meet production goals.

OBJECTIVE

Evaluate the potential to predict animal weight gains from forage canopy spectral absorbance measurements taken in pastures using a hyperspectral radiometer.

METHODS

Spring-born lambs (n=135) grazing four 3-acre bermudagrass pastures in June and July of 2002 and 2003 were used to evaluate relationships between forage canopy light absorbance and summer gains of lambs. Forage canopy light reflectance was measured on-site within the four bermudagrass pastures every two weeks for eight weeks in eight subsamples per pasture. Subsample locations were chosen at random in each sampling period and therefore the sampling location within pasture varied among sampling periods. Forage canopy light reflectance was measured in 252 wavelengths from 375.4 nm to 1115.0 nm. Canopy density precluded reflectance from bare soil. Forage canopy light reflectance data was converted to canopy light absorbance data prior to analyses. Lamb average daily gain (ADG) was estimated every two weeks for June and July each year. Lamb gains were then predicted at two-week grazing periods using forage canopy light absorbance data collected at the beginning of each grazing period. Data analyses were done using stepwise regression techniques to identify the best prediction equations that used the fewest wavelengths possible. The stepwise equation using the maximum R^2 criterion for selection of best wavelengths was:

$$ADG = \beta 0 + \beta i^*Absorbance_i$$
where, i=1 to 252 wavelengths

RESULTS

The "best" 1-, 5-, 10-, and 17-variable regression equations are given in **Table 1**. The "best" one-wavelength model accounted for only 3% of the total variation, the "best" five-wavelength model accounted for 29% of the total variability, the "best" 10-wavelength model accounted for 59% of the total variability, and the "best" 17-wavelength model accounted for 92% of the total variability. The percentage of the total variability accounted for by a particular model is a measure of the quality or accuracy of that model in predicting lamb ADG. To demon strate this, observed and predicted ADG were plotted for each grazing period for the "best" 1-, 5-, 10-, and 17-wavelength models (**Fig. 1 to Fig. 4**). The gain for period 1 is predicted from canopy absorbance measurements taken at the beginning of the grazing period. Thus, if projected gains were not in accordance with gains needed, it would be feasible to provide supplementation at the first of the grazing period to increase the gains to more acceptable levels.

The best one-wavelength model (**Fig. 1**) was inadequate in the prediction of lamb ADG from forage canopy light absorbance. Differences between the predicted and observed values for lamb ADG were very apparent. The plots of observed and predicted ADG for the best 5-wavelength and 10-wavelength models (**Fig. 2 and 3**) were an improvement with better concurrence of predicted vs. observed ADG. Increasing to 17 wavelengths in the model gave further improvement and demonstrated the accuracy of prediction possible (**Fig. 4**).

It appears from these results that prediction of animal ADG from forage canopy light absorbance measurements taken prior to the gain period is possible. In these data, accurate prediction was done using only 7% of the measured forage canopy spectral absorbance wavelengths. By measuring forage canopy light absorbance it may be possible to improve precision of supplementation of animals on pasture to better achieve targeted gains.

Table 1. Regression equations for lamb ADG on forage canopy wavelength absorbance for the "best" 1-, 5-, 10-, and 17-variable models.

Regression	No. of wavelengths in model			
parameter	1	5	10	17
Intercept	-0.12687	-1.68610	-1.81635	-0.72869
Wavelength, nm				
357.3			-0.75457	-2.00282
363.4				1.34699
375.5		2.72101	6.74279	7.01984
378.5	0.21171	-0.15855	-0.70853	
381.5			-3.79271	-6.13015
396.7			3.62611	23.42235
399.7				-20.29290
530.1			-15.96220	-10.7354
578.6		-4.64190	7.93861	
633.1				6.91498
715.0				-23.98520
721.0		2.99445	4.78824	27.42197
1066.6			-0.65955	-2.42472
1075.6				-4.25168
1087.8		0.28390	0.34725	
1096.9				1.76621
1099.9				-1.03842
1102.9				1.97937
1109.0				-0.76522
1112.0				2.01410
R^2	0.03	0.29	0.59	0.92
Mean Sq. Error	0.0126	0.0092	0.0054	0.0011

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Fig. 1. Average observed and predicted values for lamb average daily gain (ADG) for the four two-week gain periods for a 1-variable regression model.

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Fig. 2. Average observed and predicted values for ADG for the four two-week gain periods for a 5-variable regression model.

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Fig. 3. Average observed and predicted values for ADG for the four two-week gain periods for a 10-variable regression model.

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Fig. 4. Average observed and predicted values for ADG for the four two-week gain periods for a 17-variable regression model.

ARS Integrated Watershed Data System: Development and Application

Jin-Song Chen and Jean L. Steiner

RATIONALE

The USDA and Agricultural Research Service have supported watershed research since the 1930's. Many of the research watersheds are still operational and research data continue to be collected. Research data include Geographical Information System maps, satellite images, and climatic, runoff, sediment, streamflow, land use and management, and water quality records. However, data have been managed and disseminated independently at each research location, greatly reducing the accessibility and utility of these data for multi-site analyses**.**

The Conservation Effects Assessment Project was recently established to assess the environmental benefits of conservation programs. Within the Conservation Effects Assessment Project, watershed assessment studies are conducted on specific watersheds at various scales that include field measurement and hydrologic simulations. These studies require a variety of data that describe hydrology, soils, climate, topography, management practices, and land use.

In recent years, watershed-scale assessments have been stimulated by the rapid growth of legal requirements to develop total maximum daily load limits, the development of Geographical Information System technology, and the need to conduct climate change studies. Accordingly, an increasing use of watershed data is expected. Therefore, a centralized ARS watershed data system would not only be a valuable resource to the agency itself, but also to others who are involved in hydrologic studies across the nation.

OBJECTIVE

Our objective is to develop and implement an ARS watershed data system to organize, document, manipulate, and compile climate, water, soil, management, and socio-economic data for assessment of conservation practices and other hydrologic analyses.

METHODS

The data system consists of two main parts -- a central web-based database for storage and management of data, and client application tools that allow users to access and interact with the data (**Fig. 1**). The data stored in the database will be viewed and validated using graphical and tabular interface tools. The data system will serve as a repository where diverse end-users can access, search, analyze, visualize, and report various types of integrated watershed data that are contributed from multiple locations.

A "metadata" standard will be developed as the guideline to document the existing and newly collected data to allow users to understand the nature and quality of the data. In essence, metadata answer who, what, when, where, why, and how about every facet of the data. A metadata search engine will be built so that users can search and determine if the dataset meets his/her needs based on the available metadata information.

A prototype data system is being developed at El Reno, Oklahoma, using data from the Little Washita River Experimental Watershed and other data. After a series of tests, a fully operational data management system will be developed that includes additional ARS experimental watershed data. The system will be called STEWARDS: Sustaining the Earth's Watersheds – Agricultural Research Data System.

EXPECTED BENEFITS

The ARS watershed data system would 1) provide one-stop data access and data exploration (**Fig. 2**) to the ARS scientists, as well as the general public; 2) support the Conservation Effects Assessment Project program in hydrological modeling and model testing; and 3) increase the lifetime and the utility of the existing ARS watershed data.

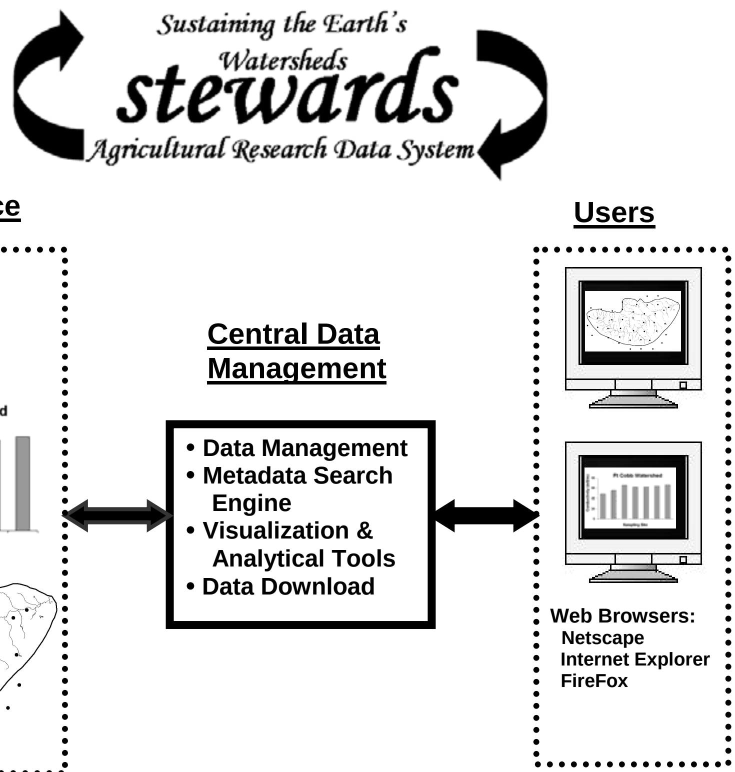

Fig. 1. Architecture of the ARS watershed data system.

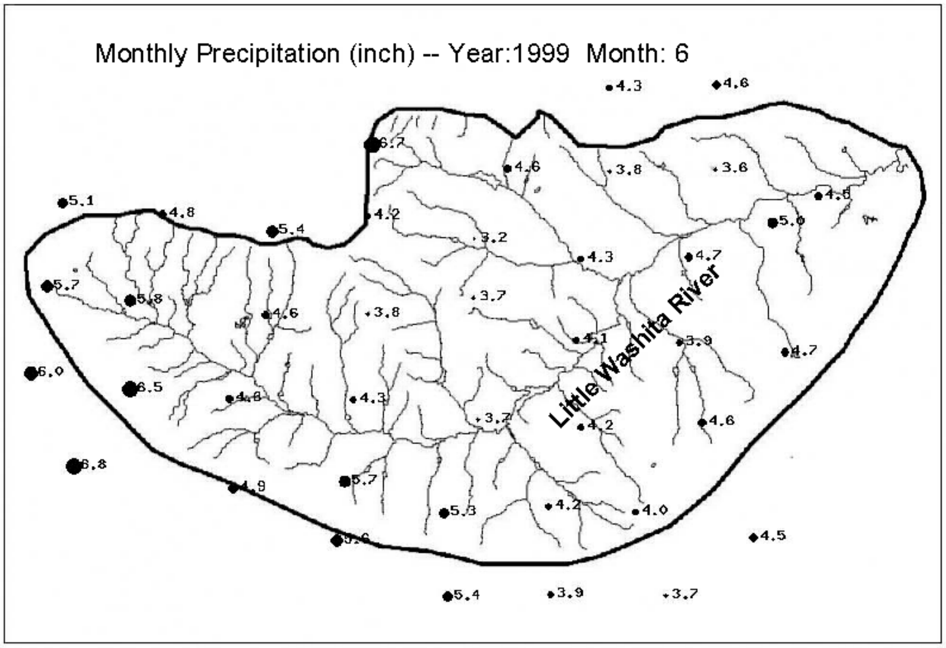

Fig. 2. A data visualization tool for exploring spatial variability of precipitation in the Little Washita River Watershed, Oklahoma, in the ARS watershed data system. The size of the solid symbols indicates the relative magnitude of annual precipitation (mm).

QUANTIFYING CONSERVATION EFFECTS IN UPPER WASHITA RIVER (OK) SUBWATERSHEDS: THE CEAP STUDY

Patrick J. Starks, Jean L. Steiner, Michael W. Van Liew, and John D. Daniel

RATIONALE

In response to the 2002 Farm Bill, the Conservation Effects Assessment Program was created to assess and quantify the effects and benefits of US Department of Agriculture conservation programs (see Steiner et al., this document). The principle focus of the Conservation Effects Assessment Program is a national assessment of environmental benefits of conservation programs to support policy decisions and effective program implementation. However, it is recognized that the benefits of conservation practices are best evaluated by studies on specific watersheds. Watersheds on Oklahoma's upper Washita River were chosen as one of twelve initial sites where portions of the Conservation Effects Assessment Program national Watershed Assessment Study will be implemented.

Throughout the Washita River basin, suspended sediments are a concern, and invasion of eastern redcedar reduces productivity and habitat of native range ecosystems with unknown hydrologic impact. The Fort Cobb Reservoir is listed on the Oklahoma 303(d) list (list of quality impaired waters) based on suspended sediments, elevated levels of phosphorus and nitrogen, low levels of dissolved oxygen, and the presence of nuisance algae. The Oklahoma Conservation Commission established the Fort Cobb Water Quality Project in 2001, under section 319 of the Clean Water Act. Major resource concerns include suspended sediment and nutrient loading from agriculture and channel bank instability in some of the tributaries. Infrastructures of several rural communities (bridges, a water treatment plant) are threatened and water bodies are impaired for municipal water supply, recreation, fish and wildlife. Degradation of wildlife habitat is of concern relative to fishing and hunting that are important in local economies and a quality of life issue for community inhabitants.

OBJECTIVES

The objective of the upper Washita River portion of the National Watershed Assessment Study is to assess the effects and benefits of selected conservation practices as they relate to reducing inputs of suspended sediments to surface water, and the reduction of phosphorus and nitrogen in surface and ground water in the Ft. Cobb Lake watershed (**Fig. 1**).

METHODS

A combination of field and modeling studies will be used to address this objective. Field studies will be conducted to establish reference values on conditions with and without conservation practices, and to quantify changes produced by the conservation practices. Weather and surface runoff data collected from 1961 to present in various sub-basins of the Upper Washita Watershed, particularly the Little Washita River Experimental Watershed (**Fig. 1**), will be used to prepare the simulation models for the watershed assessment study.

Substantial monitoring is supported in the Little Washita River Experimental Watershed and the Fort Cobb watershed by ARS, the Oklahoma Mesonet, and US Geological Survey (**Fig. 1**). Additional monitoring sites will be established and/or re-activated within the Fort Cobb watershed to support the research. Extensive stream monitoring was conducted from 2000 to 2002 by US Geological Survey in the Fort Cobb watershed. Bi-weekly measurements of stream water quality was initiated in late 2004 by ARS, and includes measurements of pH, dissolved oxygen, conductivity, salinity, total dissolved solids, temperature, turbidity, oxygen reduction potential, nitrate concentration, ammonia concentration, suspended sediment, and phosphorus. The Great Plains Resource Conservation and Development District will work collaboratively with ARS to contact farmers to obtain conservation and production management information relevant to the assessments.

Conservation priorities were identified by the Local Steering Committee of the Fort Cobb Water Quality Project. Cost sharing for conservation practices is funded by Oklahoma Conservation Commission and US Department of Agriculture Farm Bill programs (primarily the Environmental Quality Incentive Program and the Conservation Reserve Program). Practices being implemented include: pasture and hay planting, grassed waterway, fencing, use exclusion, grade stabilization structure, critical area planting, and others. The Erosion Productivity-Impact Calcuator, Agricultural Policy/Environmental eXtender, and the Soil and Water Analysis Tool models will be used to evaluate linkages across conservation practices, soil properties, edge of field responses, and watershed scale responses. Scenario analyses (e.g., timing and placement conservation practices) will be conducted with the Soil and Water Analysis Tool to determine watershed responses. The Conservational Channel Evolution and Pollutant Transport System model, which simulates stream bank and channel processes, may be used to assess stream bank stability within the watershed.

EXPECTED BENEFITS

As part of the Watershed Assessment Study, studies on the upper Washita River sub-watersheds will: 1) help provide guidelines for scaling study results from a watershed scale up to regional levels, 2) provide data to evaluate and improve the performance of national assessment models, and 3) provide credible research results on the effects of specific conservation practices or combinations of practices for different hydrology, soils, climates, topographies, and land uses. At a more local scale, Conservation Effects Assessment Program studies in the upper Washita River watershed are expected to lead to techniques and methodologies to mitigate water quality problems (nitrogen, phosphorus, sediment) currently impacting Ft. Cobb Lake.

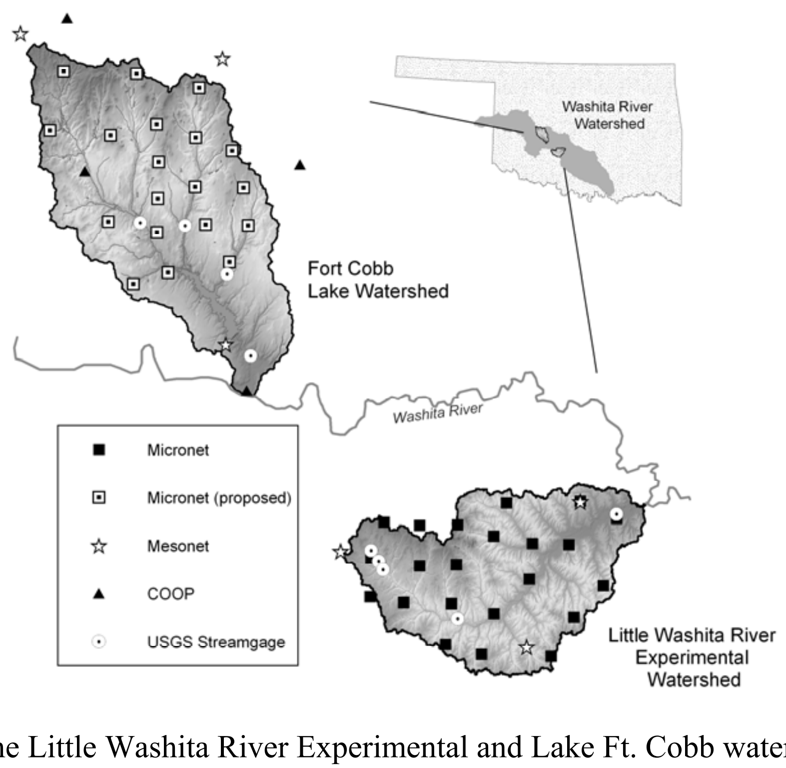

Fig. 1. Location of the Little Washita River Experimental and Lake Ft. Cobb watersheds. Measurement networks and locations are also shown.

PREDICTION OF SEASONAL RUNOFF FOR THE FT. COBB WATERSHED

Jurgen D. Garbrecht, Jeanne M. Schneider and Michael W. Van Liew

RATIONALE

Over the last century, the United States has experienced considerable water resources development. In Oklahoma, a large number of surface water reservoirs were constructed through the 1950's, 60's and 70's by the Army Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service (formerly the Soil Conservation Service), and other federal and state agencies. These reservoirs reduce flooding and provide water to meet domestic, agricultural, urban, industrial and environmental needs. Over the decades, demands on water quantity and quality have increased as a result of population growth, economic development, higher standards of living, and promotion of a sustainable environmental. Yet, for a variety of reasons, construction of new reservoirs has all but ceased. This has placed additional stress on the existing water resources system, and more effective water management approaches are needed to ensure continued adequate and reliable supply of water in the future. In recent decades, water demand increase has been met by water conservation measures. The issuance of climate forecasts up to a year in advance and the occurrence of climate variations (see related articles in the Research Report section) have also opened the door to managing water resources in terms of anticipated availability. However, it remains unclear to what degree these climate forecasts translate into useful surface water predictions for water resources management.

OBJECTIVE

The goal of this research is to demonstrate, by example of the Ft. Cobb watershed, that seasonal precipitation forecasts and decade-long precipitation variations can provide useful surface water estimates to support risk-based reservoir operations and water resources management. Such a demonstration will promote a better understanding and wider consideration of National Oceanic and Atmospheres Administration's seasonal climate forecasts and decade-long precipitation variations in water resources applications.

METHODS

In the first phase of this research, monthly watershed runoff for the Ft. Cobb watershed will be predicted for wet (1997) and dry (1998) seasonal precipitation forecasts issued by the National Oceanic and Atmospheres Administration's Climate Prediction Center. These seasonal forecasts project the odds in the coming months for dry, near-average or wet precipitation. The Ft. Cobb watershed supports a multipurpose reservoir that provides for flood control, water supply and recreation. Inflow predictions may assist in anticipating the likelihood of higher than or lower than desired water levels and monthly flood releases to the downstream channel. Monthly predictions of watershed runoff will be simulated using a computer tool called Artificial Neural Network. The speed and simplicity of Artificial Neural Network's are well suited to simulate the hundreds of rainfall-runoff outcomes that are necessary to reflect the full range of possible precipitation realizations of a forecast. Historical precipitation records from the National Weather Service and runoff records from the Bureau of Reclamation, the U.S Geological Survey and the Army Corps of Engineers will be used to calibrate and validate the Artificial Neural Network. A large number of possible monthly rainfall realizations that reflect the wet and the dry forecast will be generated and supplied to the Artificial Neural Network to simulate corresponding monthly watershed runoff. The predicted monthly watershed runoff values will be organized into flow duration curves as schematically illustrated in **Fig. 1**. A flow duration curve defines the amount of time or odds (horizontal scale) that a given runoff (vertical scale) is equaled or exceeded. The size of the difference between the wet and dry flow duration curves will determine the utility of the watershed runoff prediction. If the curves are close together, then there is little anticipated change in watershed runoff due to a forecast. However, if the difference is large, then the anticipated change can prove useful to water resources management. Finally, watershed runoff for the wet and the dry forecast will be processed by a reservoir water-accounting model to estimate reservoir water levels and potential flood release volumes in terms of reservoir inflow, water withdrawals, and evaporation losses. Here again, flood-release duration curves will be developed corresponding to the wet and dry forecasts, and the odds that a given flood release is equal or exceeded can be determined. In a second phase, decade-long climate variations will be analyzed in a similar way.

EXPECTED BENEFITS

While this demonstration is specific to the geographic scale and climatic and physiographic conditions of the Ft. Cobb watershed, the results of the research will reveal whether recent seasonal precipitation forecasts and decade-long climate variations have potential utility for watershed runoff prediction and decision making with respect to surface-water resources.

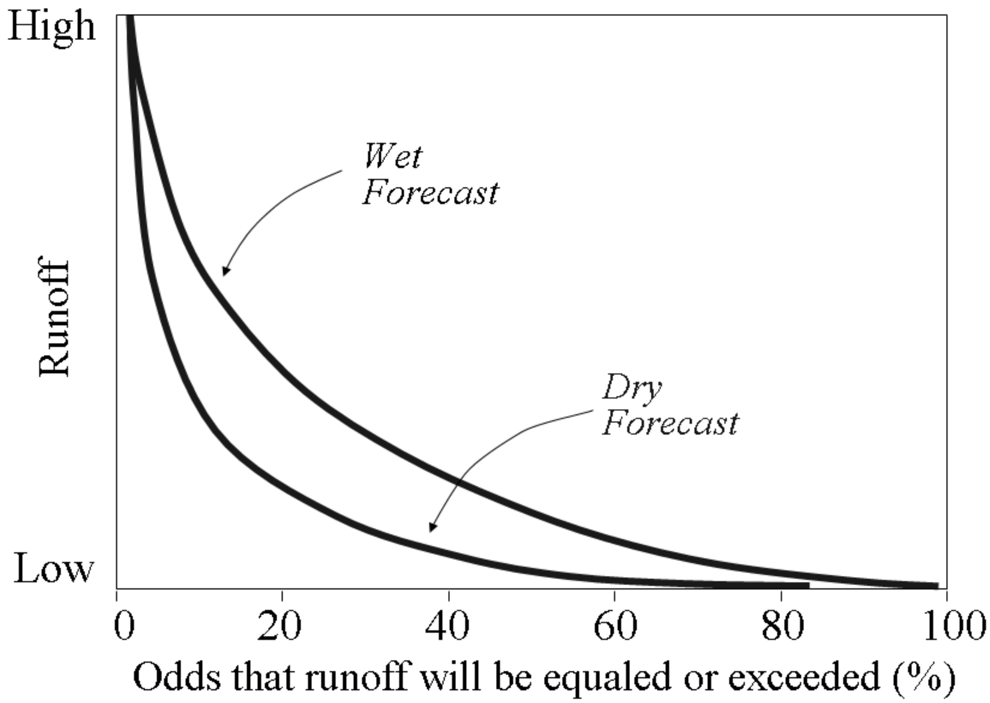

Fig.1. Flow duration curves for runoff under wet and dry precipitation forecasts.

Utility of Seasonal Temperature Forecasts in Central Oklahoma

Jeanne M. Schneider and Jurgen D. Garbrecht

RATIONALE

The National Oceanic and Atmospheric Administration (NOAA) has been issuing seasonal climate forecasts for precipitation and average temperature for more than 9 years now. The utility of the precipitation forecasts in central Oklahoma has been investigated previously, and findings are reported in the Research Report section of this volume. While precipitation is generally the limiting factor for agricultural production in Oklahoma, air temperature is also important. In particular, mild winters and earlier springs can affect timing and amount of winter wheat forage production. For example, given adequate soil moisture, growing degree days are a cumulative measure of winter wheat production potential. While an increase of only a couple of percent in average temperature may appear small, the cumulative effects over several months could lead to significant impacts on plant biomass production. The NOAA seasonal average temperature forecasts may eventually support applications such as forecasts of grazing potential for the upcoming fall or spring grazing season. However, the performance characteristics of the forecasts must first be evaluated to determine their suitability for applications in agriculture.

OBJECTIVES

To determine the potential utility of the NOAA seasonal climate forecasts of 3-month average temperature in the central Oklahoma forecast division to support agricultural planning and management.

METHODS

The forecast is for average daily temperature, averaged over 3 months. While daily highs and lows vary substantially, the average over 3 months doesn't change much from year to year.

The average temperature forecasts are probabilistic, representing a statement of odds for different values of average temperature during a certain period, rather than a prediction for a specific temperature value. This means that no single forecast is "right" or "wrong", and any assessment of dependability has to be made over a large number of forecasts. The assessment determines whether or not the forecasters got the odds right. Our initial assessment is over 70 forecasts, issued for January-February-March 1997 through October-November-December 2002, at the shortest lead time, 2 weeks ahead of each 3-month forecast period.

As was the case with previous evaluations of the precipitation forecasts, we discovered that the majority of the temperature forecasts for central Oklahoma have been equal or very close to historical odds for average temperature, essentially non-forecasts. We must determine whether forecasts for small but persistent departures from historical odds have potential decision support value when summed over a growing season.

Our methods are similar to those developed for the seasonal precipitation forecasts. We counted the number of forecasts that differed from the long-term record by some minimum percentage, and call this measure usefulness. Because the average temperature varies little from year to year, we used two different kinds of thresholds. The first kind is identical to that used for the analysis of the precipitation forecasts, except with a much lower threshold (± 2.5%). This approach considers how big a change the forecast is predicting compared to the historic average. In the second usefulness measure, the difference between the forecast and historical averages is compared to the standard deviation of the historical data rather than the average, and is set at ± 20%. This second approach considers how big a change the forecast is predicting compared to the historical variability.

We then sorted the forecasts into warmer or cooler conditions than average, applied the thresholds of usefulness, and counted how often the potentially useful forecasts "hit" or matched what actually occurred in terms of warmer or cooler than average. If the forecast odds are correct, the forecasts should "hit" about half the time. We call this measure the dependability of the warm or cool forecasts.

Future work will extend the analysis into more years to determine if the usefulness or dependability improves over time, develop growing degree forecasts from average temperature forecasts, and investigate the potential utility of the growing degree forecasts.

EXPECTED BENEFITS

If the forecasts prove to be useful and dependable, seasonal air temperature forecasts could be used to develop forecasts of forage or grain production, which could become part of enterprise-level decision support systems. Predictions of spring forage production would not only benefit from precipitation forecast, but also from seasonal air temperature forecasts.

CALIBRATING CROP MODELS TO SUPPORT RISK-BASED DECISION MAKING

X.-C. John Zhang and Jean. L. Steiner

RATIONALE

Agricultural simulation models (computer programs) can play a significant role in agricultural decision support tools that aim at maximizing efficiency of agricultural production and minimizing economic losses due to adverse climate conditions. Considerable progress in seasonal climate forecasts has been made in the past decades. New advances in seasonal climate forecasts provide a significant opportunity for optimizing agricultural production using agricultural simulation models. With the help of those computer models, cropping systems and management practices that accommodate anticipated seasonal climate forecasts can be analyzed, and alternative management practices can be found, which would take the advantage of favored conditions or reduce economic loss of adverse conditions. Research on using agricultural simulation models in conjunction with seasonal climate forecasts to improve agricultural production due to efficiency is being carried out worldwide. Many models such as the Decision Support System for Agrotechnology Transfer are being tested and used in many parts of the world. For meaningful applications in decision making, those models must be carefully evaluated against measured data, and their performance must be assessed in terms of how good and reliable the model predictions are. Preliminary evaluation based on grain yield showed that the Decision Support System for Agrotechnology Transfer model is promising. However, evaluation based on wheat forage biomass production and detailed evaluation of grain yield are still needed.

OBJECTIVES

The objectives of this work are to calibrate or fit the wheat model of the Decision Support System for Agrotechnology Transfer to local conditions and particular cultivars using measured wheat growth data at El Reno, Oklahoma, and to evaluate further the performance (predictability) of the calibrated model using the long-term wheat grain yield data measured at several experiment stations of the Oklahoma State University.

METHODS

This study is being conducted in field plots at the Grazinglands Research Laboratory at El Reno. Two cultivars (TAM W 101 and Jagger) are grown in a field under optimum fertilization. Phenological development (wheat growth stages) is recorded. Leaf area and biomass and stem biomass are measured each month. Data collection was started in 2004, and will be continued for three seasons.

Several long-term Oklahoma State University experiment stations, representative of the major wheat production regions including Altus, Stillwater, and Lahoma, will be selected. Measured daily weather data, soil properties, and wheat management and yield data on each site will be compiled. The calibrated Decision Support System for Agrotechnology Transfer wheat model will be used to predict wheat grain yield using these measured data for each selected site. Comparison of the measured and model-predicted wheat grain yields will be used to evaluate the goodness and reliability of model predictions.

EXPECTED BENEFITS

This study will produce genetic crop coefficients for TAM W 101 and Jagger cultivars, which are the direct results of the model calibration. The study will also produce information on the performance of the Decision Support System for Agrotechnology Transfer model that would lead to more appropriate and meaningful use of the model in decision making. Furthermore, this experiment will provide detailed data needed to fine-tune the model if necessary. The successful calibration of the model will pave the way for a comprehensive application of the Decision Support System for Agrotechnology Transfer model in risk-based decision making.

Developing Molecular Markers to Expedite Breeding Perennial Cool-season Grasses

Bryan Kindiger

RATIONALE

The use of molecular markers has been well established as an efficient approach to assist in the selection and development of improved crop cultivars such as wheat, maize and soybeans. It would be equally useful for expediting genetic improvement of forage grasses, if markers were available for them. We are developing molecular markers to assist us in development of new perennial cool-season forage grass cultivars that are productive, stress tolerant, and adapted to the southern Great Plains.

Since these markers are DNA based and the genes controlling both undesirable and advantageous traits are constructed of DNA, it is possible to associate DNA markers to genes of interest. By observing whether a particular DNA marker is associated with a plant trait during a backcross breeding program, we can infer whether the gene(s) controlling that trait are associated with a DNA marker (trait → marker ← gene).

We have focused on the development of DNA markers for the perennial grass genus *Poa*, commonly known as the bluegrasses. The native Texas bluegrass was chosen as our model species for this research because it has the drought tolerance and disease resistance that would be useful in new bluegrass cultivars with superior forage attributes. The bluegrass genus comprises at least 300 species, many of which can be hybridized with Texas bluegrass. Hybrids between Texas bluegrass and Kentucky bluegrass, big bluegrass, and Argentine bluegrass have already been generated and are being currently evaluated for their adaptation to the environmental extremes of the southern Great Plains.

OBJECTIVES

The primary objective of the grass forage breeding program is to develop rain-fed perennial cool-season grasses with superior production, forage quality and persistence when grazed. A second objective is to develop genetic markers that help us evaluate diverse breeding populations of bluegrasses and other polyploid species and expedite the development of new cultivars exhibiting superior forage attributes, persistence and physiological tolerance to the climatic extremes of the southern Great Plains.

METHODS

Hybrids between Texas bluegrass and other bluegrasses are being utilized to develop and evaluate a series of DNA markers suitable for a marker-assisted breeding program, plant genotyping and plant variety protection. As markers are developed by our evaluation of DNA sequence information, they are screened against the experimental bluegrass plant materials to determine whether the markers will identify genetic variation within the bluegrass genus. One of our cooperators, Barenbrug Seeds, is evaluating over 2,500 of these hybrids for particular agronomic and fertility traits at their Albany, Oregon facility. Cooperation with Oklahoma City University and the University of Perugia, Italy, also has facilitated the development, evaluation and utilization of DNA markers in these bluegrass hybrids.

EXPECTED BENEFITS

At the present time, we have developed approximately 200 DNA-based markers that are informative and useful across a wide range of bluegrass species. Two types of markers have been developed. The first type was developed utilizing regions of DNA that are known or suspected to be similar across many grass genomes (e.g. ryegrass, rice, wheat, etc.). The second type of marker is associated with genome regions that are unique to bluegrass and exhibit unique properties with respect to DNA sequence arrangements (e.g. palindromes, tandem repeats, low DNA complexity regions, etc.). Irrespective of type, these markers can be utilized to identify variability within or among a population of bluegrass individuals.

In an early utilization of this technology, we submitted a series of Texas bluegrass by Kentucky bluegrass hybrids to genetic marker analysis. These hybrids produce seed through either a sexual or an apomictic form of reproduction. Seed from a sexual reproducing hybrid will produce a wide array of varied offspring, segregating for many different traits and a wide range of qualities. A hybrid possessing an apomictic form of reproduction will produce offspring that are identical to the seed parent. In a traditional breeding program, the inability to distinguish between a sexual or apomictic plant prior to seed maturity lengthens the time necessary to identify and utilize desired plant materials for breeding. But by using a DNA marker associated with an apomictic form of reproduction, we can readily differentiate between sexual and apomictic plants at the seedling stage (**Fig. 1**). This marker can also be utilized to identify whether an experimental cultivar possesses advantageous forage qualities and will generate genetically uniform offspring in each generation.

As we move from marker development toward marker application, we anticipate that the bluegrass DNA markers will have wide utility in improving breeding and selection of superior cultivars, genotyping cultivars for plant variety protection, and the transfer of desirable traits among selected cultivars and improved populations. We anticipate applying these same techniques to the development of new smooth bromegrass and orchardgrass cultivars, in the future.

MW 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 MW

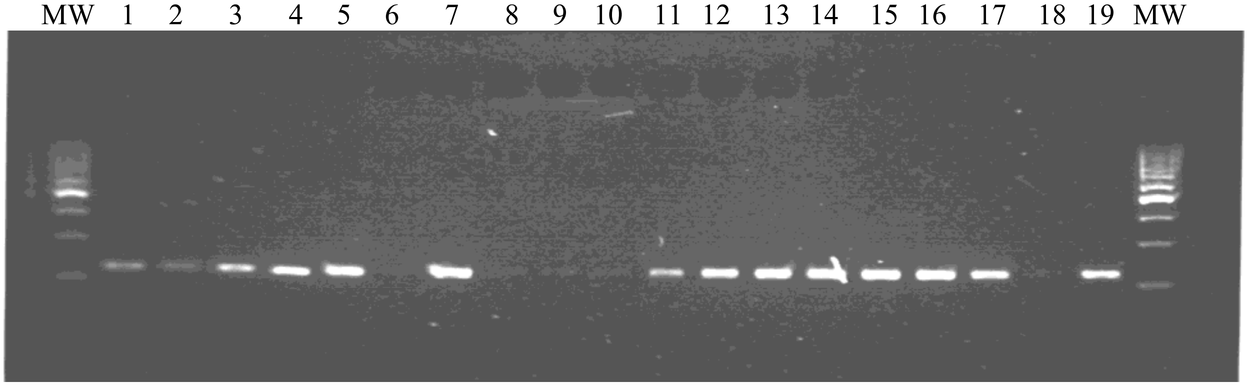

Fig. 1. The photograph illustrates the successful utilization of a DNA marker that detects genetic differences among Kentucky bluegrass and Texas bluegrass-Kentucky bluegrass hybrids. The absence of the band denoting the marker indicates that individuals 6, 8-10, and 18 produce seed by a sexual form of reproduction. The presence of the band indicates individuals 1-5, 7, 11-17, and 19 produce seed by an apomictic form of reproduction.

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