Economic Viability of Beef Cattle Grazing Systems under Prolonged Drought

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Abstract:

Prolonged drought in the Southern Great Plains of the USA in recent years has raised concerns about vulnerability of beef cattle grazing systems under adverse climate change. To help address the economic viability of beef grazing operations in the Southern Great Plains, this paper provides an economic assessment of beef grazing systems under baseline and prolonged drought situations comparable to the 2011 drought in this region. A coupled economic and environmental modeling system was used to determine the impacts of the prolonged drought scenario on the net incomes of beef grazing systems. The results of the model simulations support the conclusion that prolonged drought of the extent witnessed in recent years would be financially detrimental to beef grazing operations, unless viable mitigation measures are implemented. Beef grazing operations are projected to lose at least a third and in some cases close to half of net incomes when faced with prolonged drought weather patterns.

Keywords: drought, beef, grazing, FEM, economic viability, APEX, Southern Great Plains

Introduction:

Prolonged drought in the Southern Great Plains of the USA in recent years has raised concerns about vulnerability of beef cattle grazing systems under adverse climate change. In Texas alone, over 5 billion dollars of agricultural sales were lost in 2011 (AgriLife Today), with more than half attributed to a loss in cattle and hay sales. The year to year drought events also caused significant damage to plant biodiversity in the region, and substantial periods of time would be required for restoration of forage productivity. Consequently, the biogeophysical impacts of the recent droughts may last years beyond the actual period of drought incidence, with concomitant impacts on the financial viability of local beef grazing operations. Coupled with the adverse climate events, land use pressures stemming from conversion of millions of acres of grassland to cultivated cropland in this bioclimatic region impose greater limits on the availability of farmlands to support established grazing cycles.

In response to these events, a five-year multidisciplinary and multi-institutional project funded by the United States Department of Agriculture is under way to evaluate alternative mitigation strategies that will enable beef cattle grazing systems to be more resilient under climate change, land use, and global market pressures. The multidisciplinary team includes economists, agronomists, animal scientists, forage specialists, agricultural engineers, hydrologists, sociologists, extension service personnel, climate scientists, and GIS technicians in four universities and three research institutions. In this paper, we present results of initial farm economic viability assessments of alternative drought intensity scenarios using interfaced economic and biogeophysical models to highlight the degree of economic vulnerability of beef grazing operations under prolonged drought (Steiner et al., 2014).

Background:

The Southern Great Plains (SGP) including the states of Texas, Oklahoma and Kansas, is a significant contributor to beef cattle production in the United States, and beef production is a significant source of income for farmers in these states. Beef produced on pasture and rangelands and dual purpose winter wheat in this region is also a vital portion of cattle production systems in other regions of the nation. Recent weather patterns highlight the fact that the SGP is also subject to significant climate variability, with consequent impacts on farm incomes and meat and grain production for the nation. Agricultural losses in Texas alone exceeded $5.2 billion due to extreme drought in 2011 (AgriLife Today, 2011), while losses in Oklahoma were about $1.7 billion in the same year.

Besides the effects on total agricultural sales, the recent drought has also been blamed for observed declines in cattle numbers on pastures across the region. Agricultural Census data support anecdotal evidence that there was a significant reduction in beef cattle operations and cattle numbers between 2007 and 2012, a reversal of a general upward trend in cattle numbers in the region since 1997 (Table 1). Census data also indicate that net incomes of beef operations declined sharply over the same period (Table 2).

Table 1. Beef cow inventories for recent census years: farm numbers and total inventories

	Kansas		Oklahoma		Texas		Three-state Totals	
Year	Farms	Cows	Farms	Cows	Farms	Cows	Farms	Cows
1997	30,218	1,424,975	53,502	1,947,902	141,385	5,333,740	225,105	8,706,617
2002	27,616	1,539,636	50,465	2,050,866	131,506	5,545,824	209,587	9,136,326
2007	25,776	1,516,374	47,059	2,063,613	131,769	5,259,843	204,604	8,839,830
2012	23,272	1,270,538	44,106	1,677,903	133,924	4,329,341	201,302	7,277,782

Table 2. Average income and net cash farm income of beef cattle operations for recent census years ($/farm)

	Kansas		Oklahoma		Texas	
Year	Income	Net income	Income	Net income	Income	Net income
1997	70,680	12,818	33,090	3,038	22,907	507
2002	76,790	9,163	37,091	4,529	24,725	-628
2007	121,164	17,745	51,260	4,977	32,176	-2,222
2012	156,297	13,674	57,937	2,888	33,692	-5,144

To address the issues surrounding vulnerability of beef cattle grazing systems and related climate change issues, the USDA National Institute for Food and Agriculture funded a grazing coordinated agricultural project (Grazing CAP) consisting of a multi-institutional and multi-disciplinary team of experts from Kansas State University (KSU), Oklahoma State University (OSU), University of Oklahoma (OU), two Agricultural Research Service laboratories [El Reno, OK (ARS-ER) and Bushland, TX (ARS-BL)], The Samuel Roberts Noble Foundation (SRNF), and Tarleton State University (TIAER) . The project integrates research, extension, and education efforts in Kansas, Oklahoma, and Texas, but this paper focuses on one research aspect relating to economic viability of beef grazing operations under prolonged and intense drought.

The Study Area:

The area of interest for this study consists of two USDA major land resource areas (MLRAs): MLRA 78C (Central Rolling Red Plains; eastern part) and MLRA 80A (Central Rolling Red Prairies of Central Oklahoma) (Figure 1). These MLRAs cover a territory close to 20,000 square miles in area that stretches from north central Texas (including the city of Abilene) to southern Kansas. Grazed pastures and rangeland are a key feature in this region (Table 3). Particularly in

Oklahoma, dual purpose winter wheat is grazed by cattle and then harvested for grain, a more profitable use of the land than either grazing or grain harvest alone (Decker et al., 2009).

While rangeland dominates land uses in this region, there is significant diversity in soils, climate, and land use. Consequently, economic evaluations were performed for all major soil types and weather distributions in the region, and the results were aggregated for each county and states.

Table 3. Land use in the three states comprising the proposed study area (data from NRI, x1000 acres)*.

	Rural	Cropland		CRP	Pasture	Rangeland	Forest	Other
		Cultivated	Non-cultivated					
KS	49,507	20,508	1,523	3,165	2,498	15,788	1,686	736
OK	40,443	7,592	574	1,060	8,421	14,193	7,487	499
TX	155,500	16,073	502	4,021	16,330	98,070	10,651	2,425

*From Engle et al. 2012, proposal to USDA-NIFA.

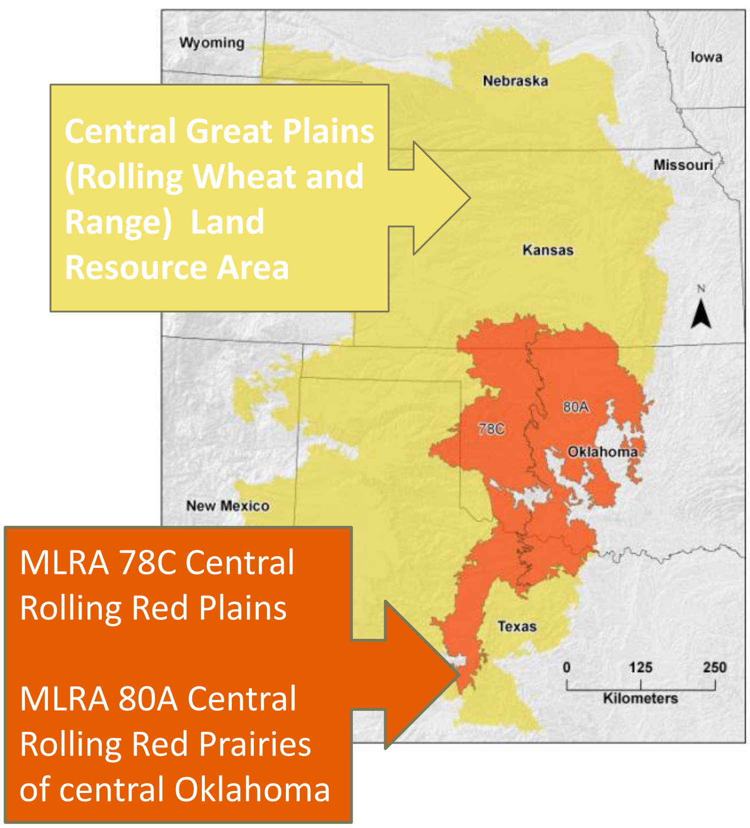

Figure 1. Major land resource areas in the Southern Great Plains

Methodology:

Prolonged drought is typically defined by using regional climate scenarios developed through reanalysis of global climate models. However, a review of available climate projections indicates that forecasts of precipitation for the Southern Great Plains suffer from significant inaccuracies due to their inability to accurately predict convective processes that are a major factor in precipitation events in this region. Consequently, in this assessment, a prolonged and intense drought scenario is defined based on historical climate events. The specific drought scenario used in this study is defined below.

To evaluate the economic viability of beef grazing systems under drought scenarios, the interdisciplinary and integrated modeling system defined below was calibrated using extensive climate, land use, farm attribute, and management data from the Southern Great Plains. Statistical disaggregation of the 2012 Agricultural Census and resultant clustering of farm attribute data were used to define the types and sizes of beef grazing operations that are relevant for each ecological subregion in the Southern Great Plains. Data from hundreds of beef cattle collaborators maintained by the Noble Foundation were used to refine the definition of farm types for the economic, agronomic, and environmental assessments.

Modeling System:

The integrated computer modeling system includes a module for automatically generating representative farms, an environmental module consisting of Agricultural Policy Environmental eXtender (APEX; Williams et al., 2000), a field scale module, and Manure Denitrification/Decomposition (DNDC) model, and an economic module consisting of the Farm-level Economic Model (FEM; Osei et al., 2000), an annual farm economic simulation model. The environmental models were further augmented with use of an animal growth model and International Panel on Climate Change (IPCC) engineering coefficients.

To assess the impacts of drought on farm profits, crop yields, and water quality indicators in contrast to the baseline weather pattern, a drought scenario was defined in terms of monthly precipitation deviations from the long-term normal. The baseline and drought scenarios were simulated using two computer simulation models, APEX and Farm-level Economic Model (FEM; Osei et al., 2000; Osei et al., 2012).

The two computer simulation models were calibrated and used for the present study. FEM was used to determine the impacts of baseline and drought scenarios on farm incomes, costs, and net income. The APEX model was used to estimate crop yields and selected edge-of-field water quality metrics, namely sediment, total nitrogen and total phosphorus in surface and subsurface flow. APEX and FEM have been linked in a previous effort to enable seamless transfer of data between the two models (Osei et al., 2008). In this study the two models were applied in fully linked mode (Figure 1) to enable transfer of biophysical parameters to the economic simulation model. The two models were calibrated separately prior to their use in the simulations.

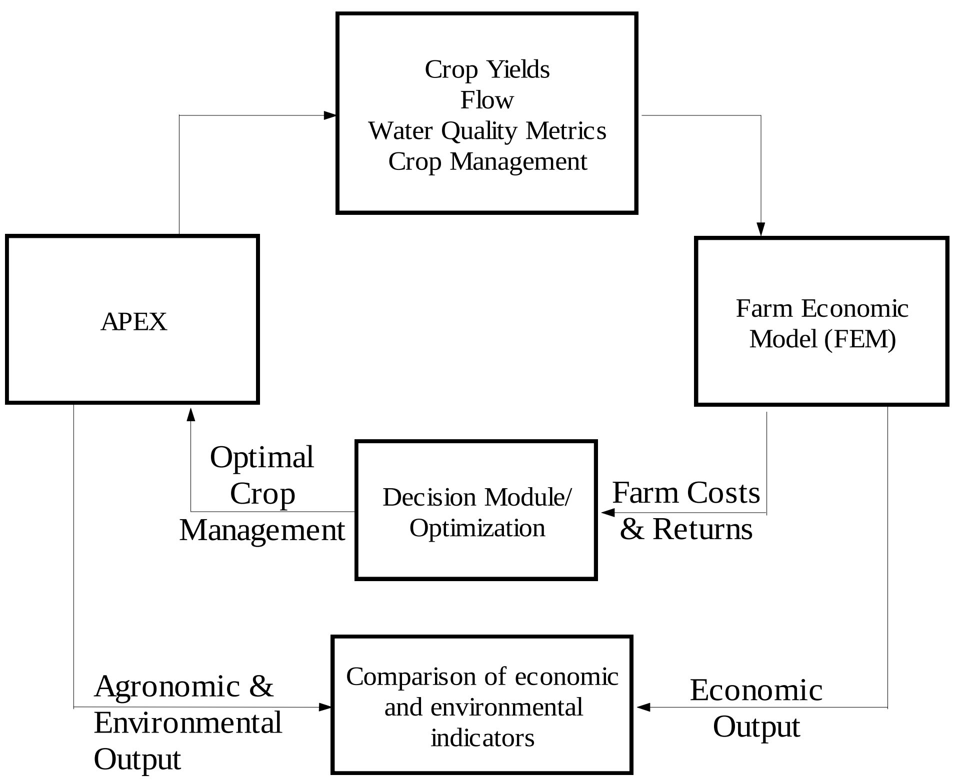

Figure 2. Schematic of FEM and APEX linkage for scenario simulation and analysis

FEM is a whole-farm simulation model that is used to simulate farm-level economic impacts in response to alternative agricultural policy and practice scenarios. FEM operates on annual time step and can be executed for extended periods of 30 years or more. Key categories of input data required to simulate a farm in FEM include type of livestock system, manure management methods, cropping systems and cultural practices, facilities and equipment, field attributes, input and output prices, and other external factors. Economic outputs generated by FEM include total revenue, total cost, net farm returns, livestock rations, crop and livestock sales, costs of individual production components (crop and livestock enterprise costs, fertilizer expenses, labor costs, etc.), debt payment, and owner's equity (Osei et al., 2000).

Prior to the simulations performed in this paper, FEM was calibrated against current (2013 and 2014) farm custom rates tabulated for many states in the continental U.S. Estimated costs of planting, tillage, nutrient, and chemical application operations and harvesting costs from the FEM model were all found to be consistent with corresponding custom rates data reported for recent years. A comparison of FEM output to selected custom rates data is shown in Table 4.

Table 4. Comparison of custom rates and FEM model output ($/acre).

		FEM Model Output	
Field operation	*Custom rate*	*Fixed Cost*	*Total*
Moldboard plow	18.68	13.37	19.79
Tandem Disk	13.46	7.36	15.13
Chisel Plow	14.32	7.35	16.33
Field Cultivator	11.36	2.88	11.76
Offset Disk	14.4	5.96	16.23
Rotary Hoe	7.56	4.89	8.06
Row Crop Cultivator	10.42	4.99	11.68
Bulk Fertilizer Spreader	6.61	1.14	5.69

APEX is a modified version of the Erosion Productivity Impact Calculator (EPIC) model that has been used widely to simulate alternative management scenarios such as variations in manure and fertilizer application rates, tillage options, and adoption of other cultural and structural management practices. APEX operates on a daily time step and can be applied for a wide range of soil, landscape, climate, crop rotation, and management practice combinations. It can be executed for a single field or used for a wide range of multi-filed configurations including whole farms or small watersheds. APEX is detailed enough to simulate precise management practices such as filter strip impacts on nutrients losses from waste application fields. The main APEX components are weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, management practices, crop management and growth, and pesticide and nutrient fate and transport. Choice of simulated cropping system, manure and/or fertilizer nutrient characteristics, tillage practices, soil layer properties, and other characteristics are input for each simulated subarea. Key outputs include crop yields, edge-of-field nutrient and sediment losses, and other water and nutrient balance indicators.

APEX was calibrated against annual county-level crop yield data assembled by the USDA National Agricultural Statistics Service (USDA-NASS) and available on the USDA-NASS web site. The model is included in USDA's web-based Nutrient Tracking Tool (Saleh et al., 2011) and has been calibrated extensively by many other authors for use to assess edge-of-field water quality impacts across a wide variety of agricultural lands in the U.S. and other nations (Gassman et al., 2010).

Data Sources:

A number of data sources were used for this study. Many of the following datasets are incorporated into the web-based NTT tool. Others were assembled specifically for this study. Various Geographic Information Systems (GIS) data layers were overlaid in order to determine the distribution of winter wheat growing areas in Texas, Oklahoma and Kansas. Once the data layers were constructed, it was assumed that all winter wheat areas would support winter grazing pastures for cattle.

<u>Cropland data layer (CDL):</u> A four-year GIS history of cropland cover for the entire United States was obtained from the USDA-NRCS data server. The cropland data used for this study covered the time period of 2010 through 2013. The CDL data is available at a 30-meter level of precision. However, to reduce the number of computations required, the CDL data layer was scaled up to a 900-meter level of precision for use in this study.

SSURGO soils data: The USDA-NRCS SSURGO soils data for each survey area have been assembled and uploaded onto the NTT server. For this study, the SSURGO data layer was overlaid on the CDL data in order to determine the soil types applicable to winter wheat production fields in Texas, Oklahoma and Kansas. A total of almost 2,200 unique soils were identified as winter wheat growing areas within the study area for 2013. For the economic evaluations reported here, a typical cow-calf representative farm typical of Oklahoma operations was simulated across all unique soils to determine the impacts of the drought scenario on farm incomes.

Weather data: Precipitation, minimum and maximum temperature, solar radiation, and other key weather variables were obtained from the USDA Parameter-elevation Regressions on Independent Slopes Model (PRISM) database. The weather data are available on the NTT server and were used for the present simulations. The PRISM data used for this study are available at a 4-kilometer resolution for the continental U.S. The simulations presented here were performed with a 47-year history of weather data from 1960 through 2006 to adequately reflect typical weather patterns in the Southern Great Plains.

Input and output prices: Additional data sources included wheat grain and forage prices, prices of various beef cattle, forage supplements, farm equipment, and crop chemical inputs. All crop chemical price data were obtained from USDA's Agricultural Prices Summary database. Equipment prices were based on current retail prices of the same types of equipment, tractors and other farm machinery. In addition, the economic model contains a nutrition optimization routine that uses data from the National Research Council's Nutrient Requirements of Beef Cattle.

Dual purpose winter wheat and beef grazing management: Typical winter wheat cultural practices for Oklahoma were also used for Texas and Kansas. Specifically, it was assumed that dual purpose winter wheat was the forage system used on all pastures. This simplification was made in order to minimize the number of simulations required for the scenarios. With the dual purpose forage system, winter wheat is seeded in September. Cattle are turned onto the pasture starting late September or early October until early March. Then the cattle are removed from the pasture and the wheat crop is allowed to mature for grain harvest in May or June. Specific planting and harvesting dates differ from north central Texas to Kansas. However, in this paper, the same dates were used for all field operations for simplification purposes.

Representative farm types:

For simplicity, only one representative farm was used for all simulations in this study. A beef grazing operation that is representative of pastures in Oklahoma was used. It was assumed that a typical beef grazing operation would be a 100-head cow-calf operation on 300 acres of pastureland. The pasture acreage used was based on a typical stocking rate for cow-calf operations in Oklahoma. Cows are assumed to graze winter wheat pastures until March. They are also assumed to graze the pasture in the summer months, but no mechanical forage harvesting is assumed. However, winter wheat grain is harvested in late May or June, a few months after the cows have been taken off the pasture.

Drought Intensity Scenario:

In this paper, we contrast the viability of beef grazing operations in the Southern Great Plains under current weather patterns (baseline scenario) against a drought scenario that reflects the reductions in precipitation experienced in the region in 2011. Specifically, the baseline scenario represents the historical weather pattern over the 47-year simulation horizon starting in 1960, whereas the drought scenario reflects a similar pattern of weather, but with significantly lower average monthly precipitation values.. Weather parameters included in the simulations included precipitation, minimum and maximum temperature, solar radiation, and relative humidity.

For the drought scenario, all the weather parameters were held fixed at baseline values, except for precipitation, which was reduced to reflect the levels recorded for selected weather stations in Kansas, Oklahoma, and Texas in 2011. Weather data for biophysical and economic model simulations were generated using a stochastic weather generation utility provided with the APEX model. For the drought scenario, long-term monthly average precipitation values were reduced by a proportion consistent with the reductions in average monthly precipitation during 2011 versus the long-term normal. In both baseline and drought scenarios, crop yields for each simulation were generated in the APEX model and transferred to FEM for economic simulation of beef grazing systems.

Each alternative strategy was simulated using the integrated modeling system defined above. A 47-year simulation horizon was used for each scenario, and the impacts on animal growth, farm economics, GHG emissions, and water and nitrogen and energy use, were analyzed. The results were compared to a status quo baseline that entailed no change from current management and current climate patterns. Only the economic impacts are presented in this paper, aggregated across all simulation within each of the three states.

Results and Implications:

Summary results from the integrated model simulations are presented in Table 5. As expected, prolonged drought represented by reduced precipitation levels typical of 2011 would have significant impact on grain and forage production and net farm income. Variance estimates (not reported here) indicate that all the pairs of numbers reported in the table (for baseline and drought scenarios) are significantly different. In general, beef grazing systems are projected to lose at least a third and in some cases close to half of net farm incomes under a prolonged drought scenario, as compared to status quo (baseline) weather conditions.

Table 5. Comparison of baseline and drought scenarios: annual averages across all major soils in the Southern Great Plains

		Kansas		Oklahoma		Texas	
Indicator	Unit	Baseline	Drought	Baseline	Drought	Baseline	Drought
Winter wheat yield	bu/acre	37.09	20.17	37.65	26.41	36.45	24.00
Gross Income	$/farm	208,779	186,362	209,535	194,630	207,926	191,438
Net Income	$/farm	46,601	24,184	47,357	32,452	45,748	29,260

Projected reductions in net income are greater than the reductions reflected in the agricultural census (Table 2) for 2012 when compared to 2007. There are several reasons for that. First, the agricultural census accounts for changes in farm numbers. Very poorly performing farms simply go out of business and the negative returns that would have been attributed to them never materialize and are consequently not reported in the Agricultural Census. In contrast, the present study did not consider the possibility of shutdown of the farm enterprise, implying that very poorly performing situations would be represented in the averages reported here.

Secondly, one key limitation of this study is that changes in price due to drought were not taken into account. For simplicity, it was assumed that the drought was restricted to the study region and that sufficient production of grain, forage, and beef cattle in neighboring regions would compensate for the drought-induced impacts in the SGP. The authors are aware that this is not a very realistic assumption, but accounting meaningfully for the impacts of prolonged drought on prices was beyond the scope of this paper.

Thirdly, while the simulations included here were based primarily on 2011 monthly average precipitation in contrast with long-term normals, the agricultural census data reflect a more dynamic transition across a decade or longer period of time. Finally, the Agricultural Census data are not restricted to beef grazing operations, while the present study focused solely on cow-calf grazing operations.

Conclusions:

Recent year to year drought events in the Southern Great Plains have underscored the need to reassess the economic viability of current beef grazing systems in the region. Agricultural Census data indicate that cow numbers declined over the same period of time when the year to year drought events were experienced in this region. The decline in cattle numbers was largely in response to poor pasture conditions and consequent increase in the cost of feed necessary to grow the cattle to market weight.

The present study is part of a multi-institutional and multi-disciplinary effort towards designing adaptation mitigation strategies that can help beef cattle operations to become more viable in the face of climate change and land use and global pressures. This study employed an integrated economic and biophysical modeling system to determine the viability of beef grazing operations under a prolonged drought that is similar to the precipitation levels of 2011.

Results of the simulations indicate as expected, that significant reductions in net farm income would result under a prolonged drought of severity similar to 2011. Winter wheat yields, gross and net farm income are all projected to decline significantly under the drought scenario as compared to a baseline that reflects long-term precipitation normals. A key limitation of this study is that prices were assumed to remain unchanged under the drought scenario as compared to the baseline scenario. Further study will account for price responses due to the drought. Economic and environmental implications of alternative adaptation and mitigation strategies will also be determined using the calibrated modeling system.

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