Forum

Future climate variability will challenge rangeland beef cattle production in the Great Plains

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On the Ground

- Climate projections indicate the Great Plains will experience higher mean temperatures and greater interannual precipitation variability in the future.
- Greater precipitation variability will challenge the economic viability of rangeland beef cattle production by further disrupting forage supply and animal demand.
- Beef producers are uncertain of future climate impacts, indicating assistance with adaptive strategies is needed.
- Private-state-national partnerships may help sustain rangelands and economically viable beef cattle production with increasing climate variability.

Keywords: Climate change adaptation, Climate vulnerability, Drought preparedness, Rangeland management, 21st century rangelands, Sustainable rangelands

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Introduction

The vulnerability of rangeland beef cattle production to climate variability in the Great Plains has been demonstrated by previous climate extremes, and climatic variability is projected to increase throughout this century. However, the vulnerability of these enterprises to increasing climate variability has received minimal attention despite its enormous regional ecological and economic importance.[1,2] The existence of this critical knowledge gap is uncertain, but it may be a consequence of the greater complexity and longer duration of the production cycle for beef cattle than for crops.[2] Crop production is often completed within 3 months, whereas rangeland beef cattle production can approach 3 years. Alternatively, it may be a consequence of insufficient recognition of the potential impact of future climate variability on beef cattle production in the region.[3] This knowledge gap increases regional climate vulnerability and the potential for implementation of poorly designed “crisis management” actions when adverse climate conditions are encountered.[4]

A climate-induced decrease in regional beef cattle production may have numerous socioeconomic and ecological implications. The Great Plains supports 50% of the Nation’s brood cow herd (16.3 million in 2017), and beef cattle production represents a major component of the agricultural economy ($43 billion [in USD] in 2017) and is associated with the largest remaining tract of native grassland in North America—the northern mixed grass prairie.[2] Consequently, a major decrease in rangeland beef cattle revenue may contribute to changes in land use and cover, land values and ownership, delivery of diverse ecosystem services, and viability of rural economies, in addition to the Nation’s beef supply. Furthermore, financial hardship among production enterprises, coupled with increasing management challenges associated with greater climatic variability, may create conditions that contribute to rangeland degradation.[5] We argue the region and Nation are best served by maintaining viable working landscapes and rural communities that can balance agricultural production and environmental conservation goals.

Our goal is to summarize current scientific evidence addressing the vulnerability of rangeland beef cattle production to future climate variability in the Great Plains. Specific objectives are to: 1) compare future climate projections with the past and assess their influence on interannual variability of forage production; 2) evaluate consequences of increasing forage variability on economic viability of beef cattle production; and 3) assess current and future capacity of beef cattle producers to individually and collectively improve climate risk preparedness. Greater awareness of potential consequences of increasing climate variability on rangeland beef production is an important first step toward development of climate adaptation planning to sustain working rangelands throughout the Great Plains.

Future climate and forage production

Climate projections for the Great Plains indicate the mid- and late-century climate will differ substantially from the 20th century. Observed mean annual temperature (1981–2010) was highest in the Southern (16.9 °C [62.4°F]) and lowest in the Northern Plains (6.7 °C [44.1°F]). These values are projected to increase 2.9 °C (5.2°F) and 5.0 °C (9.0°F) by mid- and late-century (2041–2065 and 2075–2099), respectively, for the entire region.[6] Mean annual precipitation (1981–2010) was highest in the Southern Plains (683 mm/year [27.9 inches/year]) and lowest in the Northern Plains (511 mm/year [20.1 inches/year]), and it is projected to increase approximately 11.5% in the Northern Plains, but remain relatively constant in the Southern Plains (Fig. 1). Atmospheric CO_2 concentrations are projected to increase from current values of 415 to 936 parts per million throughout the century in a high emissions scenario.[7]

Forage availability

Forage production is projected to remain relatively constant throughout the Great Plains during this century.[8] This is, in part, a consequence of positive effects of increasing atmospheric CO_2 balancing negative effects of increasing atmospheric temperature on forage production. However, projections of consistent long-term forage production obscure increasing interannual climate variability and its adverse impact on rangeland beef cattle production. Years of forage surpluses (>25% above the long-term mean) are projected to occur more often in the Northern Plains and to lesser extent in the Central Plains (Fig. 2).[6] Years with forage deficits (>25% below the long-term mean) will occur more often in the Southern and Central Plains. Forage production in deficit years will decrease throughout the region, and forage production in surplus years will increase in the Southern Plains, to further amplify interannual forage variability. Climate risk planning should consider the different climatic conditions and challenges between the Northern and Southern Plains.

Negative impacts of forage deficit years will be magnified by a drying trend throughout the Great Plains. Greater drying is a consequence of a warmer atmosphere capable of holding more water, which increases evapotranspiration to further reduce available soil water.[9] Temperature-induced increases in evapotranspiration are a major cause of the current drying trend and it is projected to further increase as the century progresses. It will be greatest in the Southern Plains, which has the highest mean annual temperature, and lowest in the Northern Plains where temperatures are lower and precipitation is anticipated to increase. Decreasing soil water availability may minimize

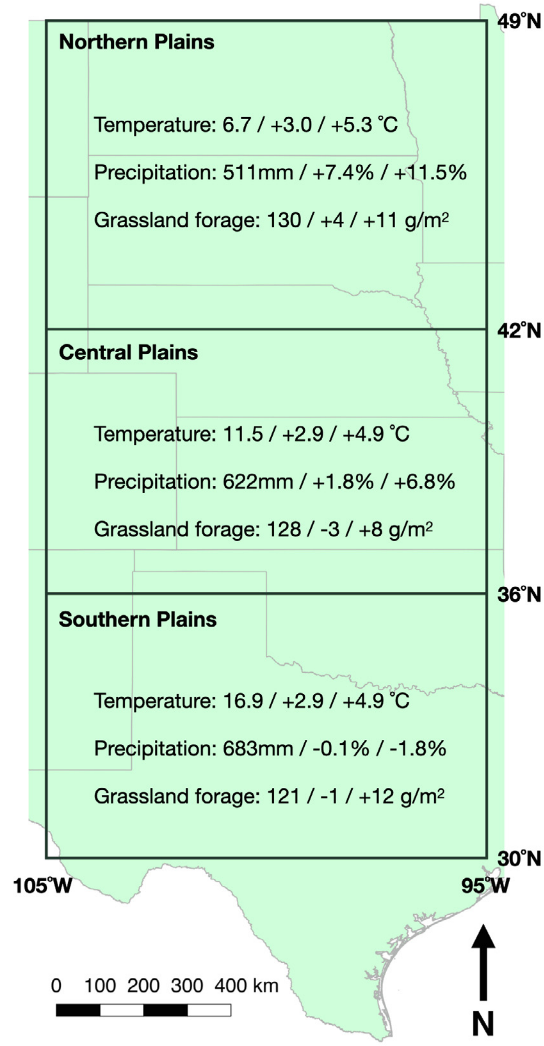

Figure 1. Observed mean annual temperatures and total annual precipitation, and simulated grassland forage production for the historical reference period (left values), and their projected changes for the mid-21st century (middle values) and late-21st century (right values), for the Northern, Central, and Southern Great Plains.

beneficial effects of elevated atmospheric CO_2 on forage production.[8]

Forage quality and species composition

Forage quality is anticipated to decrease in future climates and will further challenge sustainable cattle production. Analysis of cattle fecal samples showed that increasing temperature and decreasing precipitation reduced both crude protein and digestible organic matter of forage.[10] This suggests that reductions in forage quality may be most pronounced in drought years, at a time when forage quantity is already limited. Even though climate-induced changes in forage quality are relatively small, it has been estimated they could reduce steer growth by 13.6 kg (30 lb) per animal (12.5%) over a 113-day grazing period in northeastern Colorado.[11] The consequences of decreasing forage quality

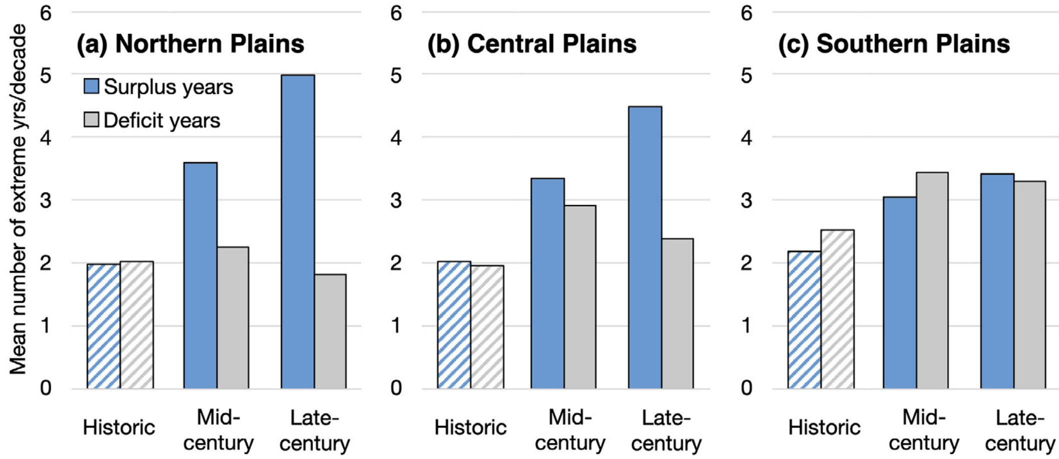

Figure 2. Mean number of years per decade with extreme surplus (blue bars) and deficit (gray bars) of forage production for the Northern, Central, and Southern Plains. Striped bars show the historic reference (1981–2010), and solid bars represent future simulations for the mid- and late-21st century (2041–2065 and 2075–2099) for the high-emission scenario.

are anticipated to be greatest for reproductive and lactating animals.

Plant community composition may be modified by climate variability and change. Warm-season (C4) grasses are projected to gradually replace cool-season (C3) grasses in the Northern Plains as the century progresses, and cool-season grasses decrease to trace amounts by mid-century in the Central Plains.[8] Woody plant encroachment has reduced rangeland forage and cattle production in the Southern Plains beginning early last century.[12] Woody plant encroachment is now occurring in the Central Plains,[13] and woody plants are projected to encroach into the Northern Plains west of the 100th latitude later in the 21st century.[8] Collectively, changes in plant community composition may reduce the proportion of total plant production providing quality forage to support beef cattle production.

Economic impacts on beef production systems

Greater climate variability will make it more difficult to balance forage supply and demand, including animal maintenance during deficit years and the ability to convert forage into animal production in surplus years. Economic viability is anticipated to decline more rapidly than cattle production as a result of increasing supplemental feed costs, reduced calf weaning weights, and destocking-restocking cycles. For example, Wyoming ranchers were surveyed in the mid-2000s to assess the impact of an earlier drought (2000–2004) on their operations. Ranchers indicated the two most severe impacts were reductions in grazing capacity and in hay production for use as winter feed.[14] The most common response to this reduction in forage availability was partial herd reduction (i.e., destocking) to better match forage demand to forage supply. Producers often purchased additional winter feed and leased additional grazing access to maintain animals. The amount purchased increased in proportion to duration and intensity of the drought.

Destocking-restocking cycles

Destocking during drought has adverse financial consequences on a production enterprise for three major reasons. First, selling cows before the end of their reproductive life is inefficient, because costs of developing breeding females often require calf sales for several years to offset the initial investment. Second, animals are sold at a discounted value, as more animals are marketed locally in response to limited forage production and high supplemental feed costs. Third, the time required to replace breeding cows by retention of heifers reduces opportunities to utilize forage produced during subsequent wet years, and it creates an additional economic loss when heifer calves are retained rather than sold. Replacement heifers are bred as yearlings, which represents a minimum lag of 2 years before a calf is marketed the following year.[15] In addition, conception rates of heifers are much lower than mature cows, and approximately 20% of them will be marketed as yearlings without a calf, further slowing replacement of breeding cows.[16]

Negative effects of dry years on enterprise profitability is greater than positive impacts of wet years.[16] Modest forage benefits realized during years of above average precipitation compared with substantial forage deficits during years of below average precipitation make dry years far more costly in terms of forage supply and calf performance. Even when long-term mean growing season precipitation remains constant, greater interannual precipitation variation increases the number of years with negative annual returns. For example, a 50% increase in annual precipitation among years, although long-term total precipitation remained constant, increased the number of years with negative annual returns from 1 in 6 to 1 in 3 (Fig. 3). Mean cow numbers decreased by 40% in response to this increase in interannual precipitation variability compared with historic climatic patterns over a 35-year period.[16] This decrease in cow numbers reduced enterprise income sufficiently to require a 19% increase in off-ranch income to

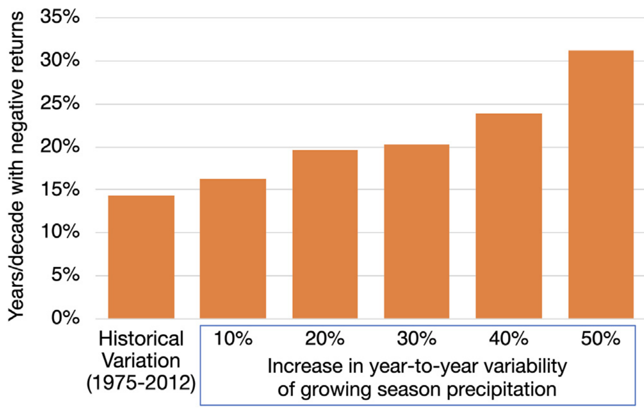

Figure 3. Relative change in number of years per decade with negative enterprise returns in response to increasing year-to-year precipitation variability during the growing season. Increasing variability was simulated by increasing the standard deviation of the historical (1975–2012) precipitation distribution, while maintaining a constant total decadal precipitation.

maintain economic viability (Fig. 4). Future variability in interannual precipitation is projected to increase by 26% in the Central Plains and 52% in the Southern Plains by late century, compared with the historic mean (1981–2010).[6] This unprecedented increase in interannual variation in precipitation and forage production may represent a major challenge to the viability of traditional beef cattle enterprises.

Enterprise viability and restructuring

The extent to which cow-calf enterprises in the Great Plains can absorb increasing losses associated with climatic variability and remain economically viable is unknown. For example, the average enterprise in Kansas lost over $148 (USD) annually per cow from 2014 to 2018 when accounting for all costs.[17] The most profitable one-third of enterprises averaged only $60.53 (USD) per cow annually over the same period. This narrow profit margin minimizes options to absorb additional costs of increased climate variability either through cash costs of purchasing or leasing additional feed, or through noncash costs of increased depreciation associated with destocking of brood cows.

The most commonly implemented drought response strategies are unable to offset negative impacts of drought, and depending on current livestock prices, they may even exacerbate the situation.[18] For example, if a drought occurs during a peak-to-peak period of a cattle cycle (i.e., highest prices due to lowest supply), supplemental feeding results in much lower profitability than simply destocking. In addition, enterprise profitability may be more sensitive to variation in cattle prices than weather, but management decisions should optimally capture opportunities associated with favorable market conditions.[19] These adverse economic outcomes demonstrate urgency in developing both local and regional climate risk planning to contend with increasing climate variability.[2,20]

Increasing climate variability is likely to restructure rangeland beef production throughout the Great Plains. For example, mid-size enterprises (100–200 cows) may be more vulnerable than either smaller or larger enterprises, because large enterprises have more resources and greater management flexibility to commit to adaptation strategies.[21] Smaller enterprises may be less vulnerable because cattle production may not represent the primary revenue source[22]; however, smaller enterprises may eventually leave the market if continuation becomes too costly. Further, as more severe regional droughts occur in the Southern Plains, the national cow herd is likely to shift toward the Central and Northern Plains.[2] For example, Texas lost 570,000 cows, and the Dakotas and Nebraska gained 403,000 cows from 2010 to 2020.[23] Although higher market values could offset additional cost of beef production in future climates, trends in national and

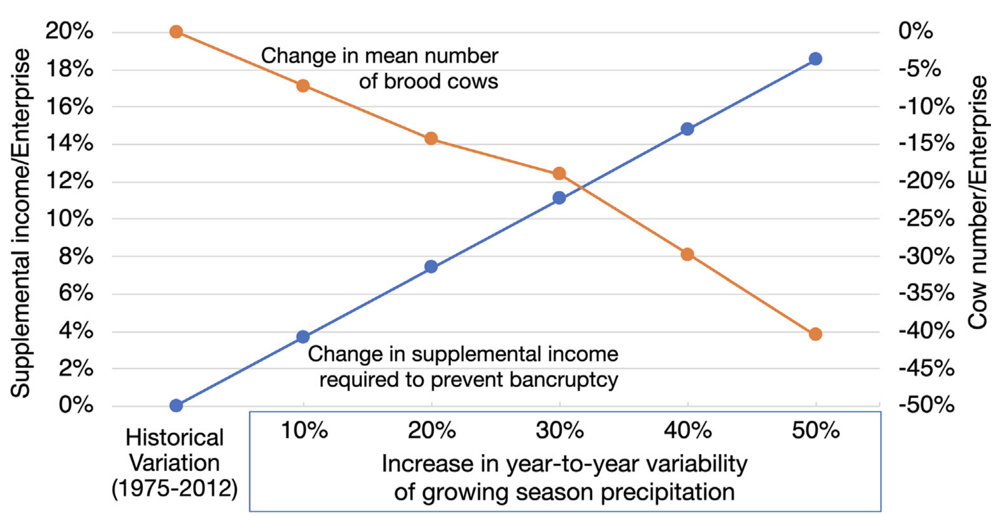

Figure 4. Relative changes in supplemental annual income required to avoid bankruptcy and change in mean number of brood cows per enterprise in response to increasing year-to-year precipitation variability during the growing season. Increasing variability was simulated by increasing the standard deviation of the historical precipitation distribution.

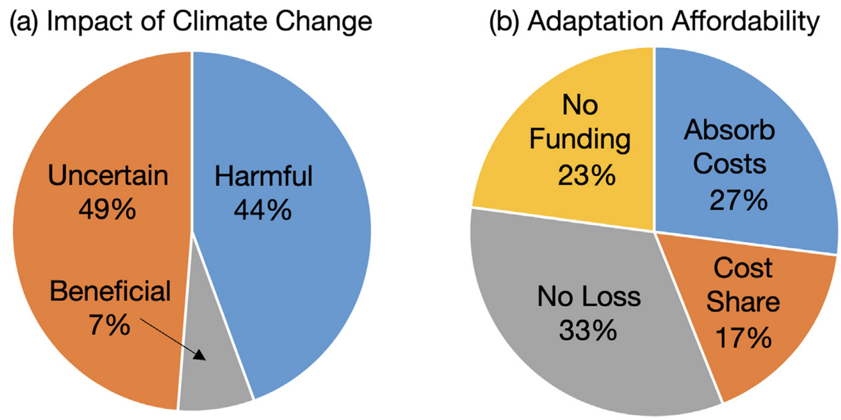

Figure 5. Beef cattle producer perceptions of the impact of climate change on their enterprises (a), and their ability to afford costs of new climate related adaptations (b). Results are based on 1,210 responses to mail surveys conducted in 2016 in Kansas, Oklahoma, and Texas.

international consumer demand and development of international trade agreements are difficult to project.

Adaptive capacity for climate risk planning

The capacity of beef cattle producers to cope with current climate variability and to independently and collectively adapt to increasing climate variability is largely unknown. However, limited evidence suggests an "adaptation deficit" may exist among rangeland beef producers, which is characterized by insufficient climate risk preparedness to current climate variability.[22,24] This raises the concern that the adaptive capacity of many beef producers, which will vary widely among individuals and enterprises, may be overwhelmed by increasing variability of future climates. Prior investigations of adaptive capacity—ability to recognize, respond, and manage system change—of rangeland cattle producers have emphasized perceptions of risk, interest in climate adaptation, and financial and emotional flexibility to make necessary changes.[24,25]

Perception of risk

Responses of 1,210 beef cattle producers in Kansas, Oklahoma, and Texas to a 2016 survey to examine their beliefs, concerns, and attitudes regarding climate change indicated that a majority (87%) were concerned about the consequences of "climate change".[26] However, in comparison with the local and tangible concerns of drought and heat (84% moderate or high concern), "climate change" ranked as a lower concern (57% moderate or high concern, data not shown). Approximately one-half of producers were uncertain of the impact of climate change on their enterprises, but 44% indicated climate change would have a harmful effect (Fig. 5A). A small minority of producers (7%) believed they would benefit from climate change. A majority of producers (57%) indicated that management changes would be required to adapt to climate change, and 11% indicated that increasing climate variability would prevent them from continuing their operations. Collectively, these perspectives indicate, in spite of considerable uncertainty, a large degree of awareness exists among producers in the Southern Plains regarding the impact of future climate.

Interest in climate adaptation

A majority (75%) of producers acknowledged they should take steps to adapt for climate variability. Extension programs (80%), consultants (71%), industry representatives (67%), and state and federal agencies (62%) were recognized as potential sources of support for development of climate adaptations.[26] Yet, when asked about their comfort with risk, a similar proportion of producers expressed preference for continuation of existing management practices (39%), as those that expressed interest in development of new practices (41%). Some producers (20%) expressed interest in new practices, but preferred to see results of experimentation by others before adopting them (unpublished data). Collectively, these perspectives demonstrate considerable climate change awareness among beef cattle producers. A large majority acknowledge the need for climate adaptations, but they require assistance to overcome challenges associated with adoption and implementation.[1,26]

Financial and emotional flexibility

Approximately three-quarters of beef producers indicated that financial resources were available to invest in climate adaptation (Fig. 5B). Although, 33% indicated investment would be contingent upon prospects of earning an equivalent return, and 17% indicated they could only invest if a form of cost share was available.[26] However, 23% of producers indicated they could not afford to implement adaptation practices (unpublished data). Producers interested in utilizing cost share dollars to implement climate risk adaptation indicated they were uncertain if they qualified or how to best implement adaptations if cost share was provided.[27] Insufficient time, labor, and equipment were described as additional constraints to adoption of new practices. Nearly one-half (43%) of producers indicated they lacked time, 53% lacked

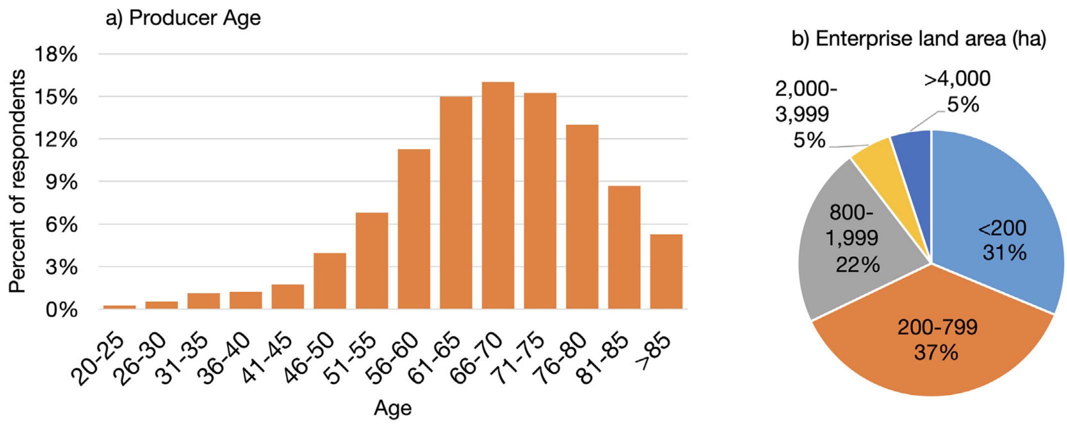

Figure 6. Distribution of age of beef cattle producers (a), and land area (ha) of individual enterprises (b), in the Southern Great Plains. Results are based on 1,210 responses to mail surveys conducted in 2016 in Kansas, Oklahoma, and Texas.

labor, and 43% lacked the equipment necessary to adopt new practices.

The varied interest and ability of producers regarding climate adaptation may be influenced by differences in producer age and enterprise land area.[26] For example, average producer age was 67, and those retiring within 5 years (34%) are unlikely to invest in increased climate preparedness (Fig. 6A). In addition, availability of financial capital to invest in climate risk adaptation is affected by size of individual enterprises.[22] The majority (59%) of producers operated enterprises of 200–1,999 hectares (494–4,940 acres), with 10% having larger and 31% having smaller land areas (Fig. 6B). Larger enterprises often have greater adaptive capacity and resources to invest in climate adaptation than smaller ones.[21,22]

Producers valued flexibility in grazing management strategies, and they credited their own success and longevity to adaptability and flexibility. They were reliant on experience, which was often multi-generational, and observation to guide their decision making.[27] In addition, peers were considered an important source of information regarding effectiveness and adoption of alternative management practices. However, this may become problematic if producers are faced with climate variability that exceeds their prior experience and that of their peers. Continuation of these beef cattle enterprises, 60% of which were third or fourth generation, is difficult to determine[26]; but economic viability of beef cattle production under conditions of greater climate variability will represent an important consideration.

Preparation for future climate variability

Beef cattle production in the Great Plains may benefit from the lessons learned after a series of carefully examined droughts experienced by the Australian cattle industry during the 20th century.[28] In the Australian experience, neither individual cattle enterprises nor supporting organizations were able to adapt to recurring drought at 20-year intervals. Consequently, both financial hardship and rangeland degradation occurred. This outcome was a result of greater emphasis on short-term variables of immediate concern (e.g., forage and cattle production) rather than on long-term variables (e.g., plant community composition and soil erosion). The authors concluded that successful climate adaptation requires involvement of multiple societal sectors to maintain economically and ecologically viable cattle production.[28] Therefore, it may be wise to explore development of integrated private-state-national partnerships to contend with the increasing magnitude of climate challenges anticipated this century. The economic and political influence of the beef cattle industry may provide the required motivation to initiate development of effective partnerships to address climate adaptation strategies.

Primary requirements to maintain viable rangeland beef cattle production with increasing climate variability are to: 1) minimize the adverse economic impact of destocking-restocking cycles on individual enterprises, and 2) prevent degradation of rangeland resources associated with wide fluctuations in forage availability and animal demand. These requirements are linked by the magnitude of variation in interannual forage availability and incentives to retain animals during drought and increase animal numbers in wet years. Strategies to promote and enhance rangeland conservation should be directly integrated into climate risk planning from the outset. Economic incentives to reduce or relocate cattle as drought intensifies may represent a viable strategy, but it would require collaboration within the private sector or partnerships with state and national organizations.

Recognition that 21st century climate will substantially differ from the 20th century is an essential requirement for development of effective climate risk planning. Producers may be most receptive to programs that present climate risk as being both local and specific to their enterprises and concerns.[26] Therefore, climate risk planning should account for socioeconomic and cultural considerations associated with the varied capabilities and land areas of beef production enterprises that influence decision-making process.[29,30] This will require a shift in perspective from one of "climate disaster," which implies climate variability is unexpected, to one of "climate preparedness" where climate variability is anticipated.[4,31] This perspective may establish a foundation for proactive investments in climate risk planning that may be more beneficial than compensation for losses in response to unanticipated climate variability.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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