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THE EFFECTS OF MANAGEMENT AND PRECIPITATION ON FORAGE COMPOSITION OF A SOUTHERN TALLGRASS PRAIRIE

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1. SUMMARY

This study described how paddock management and precipitation patterns affected forage composition of a southern tallgrass prairie in 1984-1995, and examined regional 3-month total precipitation forecasts from 1995-2001 for their potential as a management tool. Forage composition varied during the study. Large changes occurred in 1988-89, due to a short dry period, and persisted through 1995. The dominant forage groups were correlated with precipitation during different quarters, which interacted with management to cause paddock differences. Experimental 3-month forecasts did not accurately predict precipitation of La Niña events during 1995-2001. If these forecasts could be improved, they would be useful tools for drought management.

2. INTRODUCTION

Tallgrass prairie is an important resource for livestock producers in central Oklahoma. It is part of the forage system used for grazing yearling cattle before their shipment to feedlots. Composition of the plant community is important to the long-term productivity of these prairies. With proper management of these plant communities, grasses like big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*) and little bluestem (*Schizachyrium scoparium*) can produce > 60% of total production (Northup and Daniel 2000).

Tallgrass prairies are subject to numerous stressors that affect both productivity and species composition. If excessive, livestock grazing can adversely impact land condition. Grazing of leaves causes grass plants to limit root growth until the leaves become reestablished, causing short-term reductions in the exploration of the soil for water and nutrients (Coyne et al. 1995). Cattle will also selectively graze among the different species that comprise available forage, placing some species under greater stress than others. As such, grazing systems keyed to high levels of utilization can cause changes in the plant community.

Soil moisture is a limiting resource for plant growth in the southern Great Plains. Short-term (< 2 yr) droughts are common, and prolonged wet and dry periods have occurred (Garbrecht et al. 2000). Variation in seasonal and annual precipitation can be extreme, and the timing of events unpredictable (Schneider et al. 2000). As with grazing, precipitation patterns could cause changes in species composition and level of production of grasslands.

Producers must consider responses of key plant species to management and precipitation to ensure the sustainable use of tallgrass prairie. Accurate forecasts of seasonal total precipitation could serve as useful management tools, particularly if such measures of precipitation could be related to forage production. This study examined the effects of paddock management and timing of precipitation on forage composition in a tallgrass prairie, and the accuracy of regional 3-month precipitation forecasts.

3. METHODS

3.1. Study Area. This study was conducted in experimental paddocks (Daniel 2001) on the USDA-ARS Grazinglands Research Laboratory in central Oklahoma during 1984-1995. The plant community was described as tallgrass prairie, dominated by native warm-season grasses (NRCS 1999). The paddocks were located between the ridge and bottom of an area (3-5% slope) with a westerly exposure. Monthly averages of daily minimum and maximum temperatures differed by 12^{o}C, and high daily maximum temperatures occurred in summer (Fig.1). Yearly precipitation patterns were bimodal, with maximums in May-June and September.

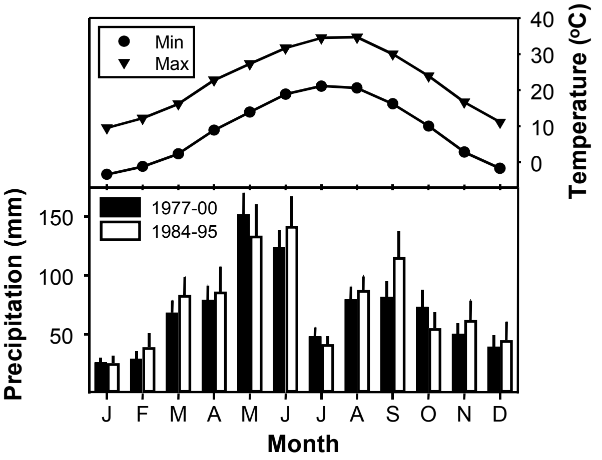

Fig.1. Monthly precipitation and mean minimum and maximum temperatures for a southern tallgrass prairie site in Oklahoma; vertical bars are +1 s.e.

Different management regimes (Table 1), based on levels of grazing pressure, were applied to a set of grazed paddocks in 1984-94, and sets (n=2) of permanent ungrazed enclosures were established in each paddock. An unmanaged paddock (no burning, grazing or haying during 1977-95) was also included in the study. Variable numbers of yearling cattle (350 kg average) were assigned to the grazed paddocks each year to achieve targeted grazing pressures, within the limits set by annual production.

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Table 1. Management applied to experimental paddocks on a southern tallgrass prairie site during 1984-95.

Management	Stocking Rate [1]	Utilization [2]
	(AUD ha^{-1})	(%)
Heavily grazed	213	65
Lightly grazed	114	35
Unmanaged	0	0

[1] AUD represents forage required to support one, 454 kg cow plus 136 kg calf, or equivalent amounts of other grazers, per day.

[2] Planned utilization level of herbage. Based on forage allowance of 11.5 kg AUD^{-1} and average annual production of 3920 kg ha^{-1}.

3.2. Forage Responses. During each year, plant responses within units were described by estimation (ranking) techniques. The proportion that plant species within four forage groups contributed to annual production was described. Included were: (1) key warm-season grasses (big bluestem, little bluestem, indiangrass and switchgrass [*Panicum virgatum*] noted as 'Big 4'); (2) weedy warm season grasses (8 species, noted as WSG); (3) annual bromes (*Bromus tectorum* and *Bromus japonicus*); and (4) broad-leaved plants (23 species, noted as forbs).

During 2000 and 2001 ('wet' and 'dry' years, respectively), curves of annual production were defined on a site with similar soil, topography and exposure as the paddocks. Biomass was clipped from 0.5 m^{-2} quadrats on plots (n=8) in upland and lowland areas at 2-week intervals from March-August. Precipitation received was organized in the same 2-week intervals, for comparison with the timing of forage production.

3.3. Precipitation. Monthly and 3-month precipitation levels for 1984-95 were developed from daily rainfall records for the study site. Monthly precipitation received in the central Oklahoma region during 1995-2001, and results of experimental forecasts, were collected from existing databases.

3.4. Analyses. Forage responses were transformed (arcsin $\sqrt{Y}$), standardized by unit variance, and used to define differences between initial values (1984), and years during the remainder of the study. The 1984 values were used as standards in comparisons because they closely matched those recorded for good condition range sites (NRCS 1999). Spearman's rank correlations between contribution of forage groups to annual production and quarterly, calendar year, and seasonal (previous 4th quarter and first 3 quarters of target year) precipitation in 1984-95 were calculated by management unit to determine the combined effects of precipitation and management.

Data from databases for 1995-2001 and climate forecasts were normalized by the 30-year (1977-2001) median to test the ability of forecasts to predict 3-month totals of precipitation (Schneider and Garbrecht 2002). The experimental forecasts utilized the current best understanding of links between large-scale (regional to global) conditions and local 3-month total precipitation.

4. RESULTS AND DISCUSSION

4.1. Forage Responses. Forage composition changed under all forms of management (Fig.2). Cycles were present in all forage groups, with different amplitudes related to management. Significant changes (> ±1 s.d.) began in 1988-89, and the largest eventually occurred on the unmanaged, ungrazed, and heavily grazed paddocks. Production by the forage groups under light grazing was closer to the pre-study levels (within ±1 s.d), except 1988-89. The 'Big 4' grasses largely declined under all forms of management (Table 2) and were replaced by combinations of the other forages. Bromes increased in ungrazed enclosures, and at times in the grazed units. Production by weedy warm-season grasses increased for short periods under heavy grazing, most notably annuals (4 species), and the perennial species silver beardgrass (*Andropogon saccharoides*, a low quality introduced grass) and native dropseeds (*Sporobolus spp.*). Composition of forage produced by the grazed paddocks was approaching pre-study levels in 1995, following deferment from grazing for one year.

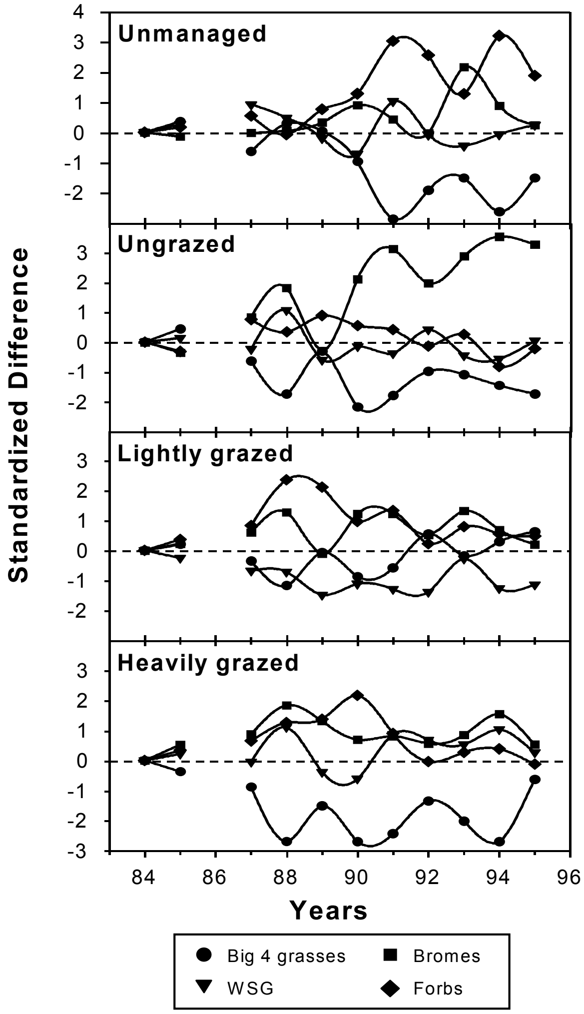

Fig.2. Standardized differences in response of key forage groups to management; 1986 data were missing.

Table 2. Mean (±1 s.e.) percent contribution (across treatments) of forage groups to total production of a tallgrass prairie during different years.

Forages	1984	1988-89	1995
'Big 4'	63 (3)	28 (6)	45 (5)
WSG	10 (5)	25 (7)	14 (5)
Annual Brome	4 (2)	14 (2)	7 (4)
Forbs	8 (2)	20 (6)	15 (8)

Composition of forage produced by the unmanaged area was radically different from the other paddocks by 1995 (Fig. 2). 'Big 4' grasses (68% [1984] vs 35% [1995] of total forage) were replaced by weedy forbs (8% [1984] vs. 35% [1995] of total forage) beginning in 1989-90. Included were thistles (*Cirsium* spp.), annual sunflower (*Helianthus annuus*), and horseweed (*Conyza Canadensis*). This response showed that lack of management on tallgrass prairie could reduce productivity of tallgrass prairies like continual heavy grazing (e.g. loss of productive species). Without management, plant litter accumulated (5700 kg ha^{-1} average) on the soil surface, which is less prevalent on grazed paddocks, and apparently inhibited spring growth by 'Big 4' grasses, but had less of an effect on the forbs.

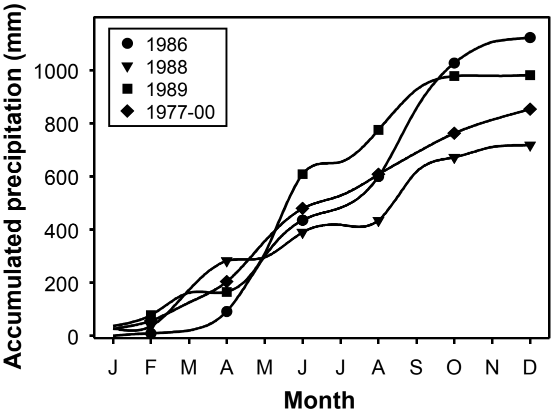

Fig.3. Precipitation patterns for three years of a grazing study, and long-term average, for a tallgrass prairie site.

Shifts in forage composition that began in 1988-89 corresponded to short dry periods in both years (Fig. 3). These periods (October 1988-February 1989; May-August 1988; March-April 1989) corresponded to key times for either soil moisture recharge, or plant growth. Dry conditions during these periods apparently had over-riding, short-term effects on the plant community, as noted in the changes under all management systems. They apparently created gaps in the plant community filled by either quick-growing or drought-adapted species, which changed forage composition. Shortfalls in precipitation were also noted in other years (January-March 1986, and 1994), which may have contributed to other shifts in forage composition. The apparent link between precipitation shortages and changes in forage composition indicated that such relationships might be useful for describing responses of plant communities.

Table 3. Correlations between contributions of forage groups to annual production, and precipitation, on a tallgrass prairie site; * = 0.01<P<0.10, ** = P<0.01.

Treatments	Forage Groups			
& Times [1]	'Big 4'	WSG	Bromes	Forbs
Heavy grazing				
Seasonal	0.19	-0.55*	0.45	0.23
Annual	0.32	-0.58*	0.55*	0.07
4th quarter	-0.01	0.01	0.19	-0.06
1st quarter	0.11	-0.69**	-0.07	0.34
2nd quarter	0.16	-0.26	0.52*	-0.08
3rd quarter	0.21	-0.39	0.45	0.49*
Light grazing				
Seasonal	0.49*	-0.24	-0.25	0.28
Annual	0.06	-0.53*	-0.29	0.20
4th quarter	0.40	0.22	-0.07	0.02
1st quarter	0.49*	0.36	-0.08	0.03
2nd quarter	0.26	-0.51*	-0.25	0.13
3rd quarter	-0.12	-0.55*	-0.22	0.53*
Ungrazed				
Seasonal	0.51*	-0.46	-0.44	0.28
Annual	0.31	-0.55*	-0.14	0.35
4th quarter	0.37	-0.09	-0.29	-0.16
1st quarter	0.54*	-0.02	-0.59*	0.36
2nd quarter	-0.02	-0.64*	0.22	0.07
3rd quarter	0.28	-0.09	-0.45	0.63*
Unmanaged				
Seasonal	0.25	-0.41	0.24	-0.05
Annual	-0.14	-0.18	0.23	0.41
4th quarter	0.32	-0.40	0.24	-0.46
1st quarter	0.74**	-0.11	-0.25	-0.65**
2nd quarter	-0.30	-0.20	0.49*	0.34
3rd quarter	-0.04	-0.26	0.02	0.49*

1. Seasonal = accumulated precipitation from previous 4th quarter and January-September of current year; Annual = calendar year; 4th quarter = accumulated precipitation from October-December prior to the growing season when forage composition was measured.

4.2. Precipitation & Management Effects. Several weak (r=0.49-0.74), though significant (P<0.10), correlations were noted between forage composition and precipitation received during different time periods (Table 3). In some instances, these correlations were significant across management systems (positive correlations between forb production and 3rd quarter rainfall), but in other cases varied with management. Production by 'Big 4' grasses was not correlated with 1st quarter precipitation under heavy grazing (compared to the other forms of management), or with 2nd or 3rd quarter precipitation. Correlations between production by annual bromes and precipitation also varied with management, with positive correlations noted for 2nd quarter precipitation under heavy grazing or no management. Production by the weedy warm-season grasses was negatively correlated to precipitation on seasonal, calendar year and quarterly (1st or 2nd) bases, depending on management.

Plausible, biologically relevant explanations, based on growth patterns and habits of species within the forage groups, can be assigned to the significant correlations (Table 3). Many of the dominant forbs were warm-season annuals that began growth in April and flowered by September, which matches soil moisture derived from 3rd quarter rainfalls. Alternatively, annual bromes are shallow-rooted species that produce most of their growth in March-May, thereby taking advantage of 2nd quarter precipitation, particularly when early growth by the dominant warm-season grasses was reduced by management (Fig. 2). The weedy warm-season grasses were either shallow-rooted annuals (Northup and Daniel 2000) that required gaps within the plant community to become established, or were rarely grazed perennials. Lower precipitation during the year enhanced production by these grasses, particularly when combined with the deleterious effects of heavy grazing on the plant community. As the weedy warm-season grasses grow concurrently with the dominant grasses (and warm-season forbs), combinations of both factors were required to enhance production by these secondary species.

Biologically relevant explanations also exist for responses of the 'Big 4' grasses, and can be related to biomass accumulation (Fig. 4). These species (70% of total biomass) produce most of their growth during May-July. With such a growth pattern, 2nd and 3rd quarter rains would presumably be more important to productivity. However, peak production was apparently related more to precipitation in January-April, since biomass accumulation during 2000-2001 diverged in May. In central Oklahoma, the 'Big 4' grasses begin growth in February and grow slowly until April. During this time, warm-season grasses establish enough leaf area to capture photosynthate for production of additional leaf tissue, and for transport to the root reserves needed for later plant growth and development (Coyne et al. 1995). Hence, 1st quarter (and occasionally previous 4th quarter) rather than summer precipitation was more related to production by the dominant grasses (Table 3). Once growing conditions became optimal (May-July), these grasses rapidly produced biomass, within the limits set by available moisture. When dry conditions existed during January-April (e.g. 2001), the 'Big 4" grasses apparently had fewer reserves available to support both aboveground growth and the expansion of root systems in the summer. This response highlights how heavy grazing pressure, in combination with dry conditions, could impact the dominant grasses. Such combinations would result in reduced development of root systems and plant development. Reduced production by 'Big 4' grasses on the unmanaged unit was likely related to the effects of below-optimum (from shading) growing conditions in the growing season.

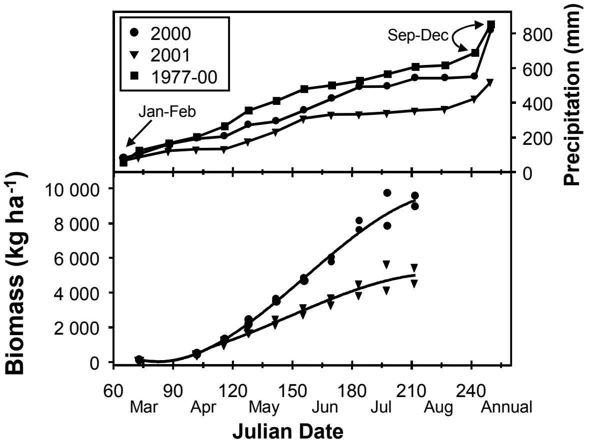

Fig. 4. Accumulated biomass and precipitation during 'wet' (2000) and 'dry' (2001) years on a tallgrass prairie site; 'Big 4' grasses comprised over 70% of the biomass.

The lack of strength (r=0.4-0.74) of the significant correlations (Table 3) is an important caveat for this study. It was likely caused by factors related to the complexity of the system (plant-soil-grazer-precipitation) involved. Timing (and intensity) of both precipitation received and management applied may have caused variations in annual responses. There also tends to be time lags between the occurrence of causative agents (dry or wet periods, applied grazing) and their full effects on the plant community, which adds to the variability. Interactions among forage groups in response to management also likely weakened the correlations. Finally, the number of degrees of freedom was limited, which would enhance the effects of outliers. Some caution is required in using these results.

4.3. Forecast Accuracy. Forecasts of 3-month precipitation totals were marginally accurate during the 4th and 1st quarters of the 1997-98 El Niño event (Fig. 5, arrow). These forecasts were based on large-scale processes, and were proven to be most accurate for the stronger events, though reliability varied with region (Schneider and Garbrecht 2002). In this instance, the timing and shift towards greater precipitation was correctly forecast, though the amount was under-forecast. None of the forecasts for drought conditions (e.g. the 1999-2000 La Niña event) were accurate.

While forecast procedures are evolving and improving, and new techniques are incorporated as they become available (Schneider et al. 2000), the current lack of accuracy represents a significant shortcoming for the end-users of predictions. Though El Niño conditions could be more easily (and more accurately) predicted (Schneider and Garbrecht 2002), the crucial need is improved forecasts for La Niña conditions, since droughts can negatively affect the composition and productivity of plant communities. Such forecasts would allow producers to quickly adjust grazing systems to either limit the potential of damaging the plant community with high stocking rates, or take advantage of short-term increases in production by the weedy grasses by altering the timing (or intensity) of grazing.

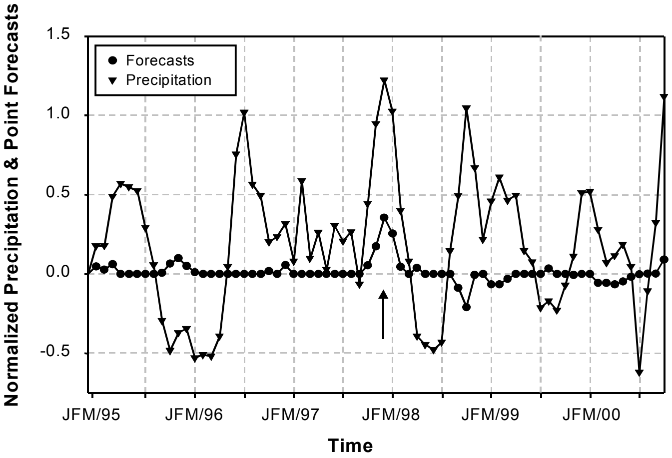

Fig. 5. Time series of 3-month totals, overlapping month by month, for precipitation and point forecasts in central Oklahoma. Positive and negative values represent, respectively, wetter and drier conditions than normal; JFM represents the 1st quarter of each year.

5. CONCLUSIONS

Both climate and management can affect the productivity of tallgrass prairie by influencing competitive interactions among plant species, and hence the composition of the plant community. Management created the opportunity for changes in the plant community (over time) by placing selective stress on many of the plant species. Precipitation then acted as the catalyst for change by applying additional stress to all the species and creating gaps (as the most-stressed species declined) that were filled by increases in the less-affected species.

There is a well-defined need to recognize the effects of seasonal drought on managed tallgrass prairie, and the potential impact of accurate seasonal forecasts on paddock management. A lack of accurate forecasting tools for seasonal (3-month) time periods means that drought management, an important part of grazing systems in the Great Plains (Reece et al. 1991), can be incorrectly applied and cause producers to bear unneeded (present and future) production costs. The development of such tools is particularly relevant for the southern Great Plains. While the 1984-1995 time frame occurred within a ‘wet’ period (1977-2000) for the region (Garbrecht et al. 2000), seasonal dry periods did arise and interact with management to cause changes in forage composition on this site.

If the climate of the Great Plains shifts toward drier conditions, as happened in the last century (Garbrecht et al. 2000), accurate 3-month predictions of precipitation will become more important to producers. The ability to accurately forecast (both length and intensity) droughts would allow producers to make early, proactive changes to pasture management. Such flexibility is particularly important for producers who intensively graze grasslands in an attempt to maximize economic returns. Given the recent (1981-2000) frequency of stronger La Niña events, accurate forecasts of 3-month precipitation could be a useful support tool for the management of grazing lands in Oklahoma.

6. REFERENCES

Coyne, P.I., M.J. Trlica and C.E. Owensby, 1995: Carbon and nitrogen dynamics in range plants, 59-167. *In:* D. Bedunah and R. Sosebee (eds), *Wildland plants: Physiological ecology and developmental morphology.* Society for Range Management, Denver, CO

Daniel, J., 2001: The water resources and erosion watersheds, Fort Reno, OK, *USDA-ARS Grazinglands Research Laboratory Report GRL 1-01.*

Garbrecht, J., W. Phillips, and J. Schneider, 2000: Implications of decade-long precipitation cycles on grazing strategies, *Proceedings, 1st National Conference on Grazing Lands,* 73-82.

NRCS, 1999: *Soil survey of Canadian County, Oklahoma, Supplement One.* USDA-NRCS.

Northup, B.K., and J.A. Daniel, 2000: The impacts of climate and management on species composition of a southern tallgrass prairie in Oklahoma, *Proceedings, 1st National Conference on Grazing Lands,* 693-699.

Reece, P.E., J.D. Alexander, and J.R. Johnson, 1991: Drought management on range and pastureland: a handbook for Nebraska and South Dakota. *Nebraska Cooperative Extension Handbook EC 91-123.*

Schneider, J., and J. Garbrecht, 2002: NOAA’s climate forecasts: Introduction and assessments from an agricultural viewpoint. *Proceedings, Grazing Lands Dollar$ and Cent$*, Oklahoma City, OK.

Schneider, J., J. Garbrecht and F. Rossel, 2000: Reliability of 3-month forecasts for use in grazing lands management. *Proceedings, 1st National Conference on Grazing Lands*, 83-89.