# VEGETATION AND SOIL CHANGES IN SHORTGRASS PRAIRIE NEAR A BEEF CATTLE FEEDYARD

Richard W. Todd, Wenxuan Guo, Bobby A. Stewart, Clay A. Robinson*

ABSTRACT: Shortgrass prairie downwind from a 25,000-head beef cattle feedyard near Bushland, Texas changed after the feedyard was stocked in 1970. Objectives were to determine pre-1970 vegetation, quantify current vegetation, and describe changes in vegetation, soil P and dust deposition with distance from the feedyard. Pre-1970 vegetation was documented with published measurements. In 2000, plant cover was quantified using 600 quadrats. Soil P, conserved in the local soil, was measured in soil samples from 119 locations. Dust was collected at 12 locations. Pre-1970 vegetation was predominantly blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths] and buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.]. From 1966-1972, cover was 18.8% blue grama and 7.4% buffalograss. In 2000, perennial grass (75-99% blue grama) cover averaged 3.7% at <150 m from the feedyard, and increased to 28% at >525 m from the feedyard. Conversely, annual grass (67% *Hordeum pusillum* Nutt.) and annual forb [72% *Kochia scoparia* (L.) Schrad.] covers were 49% and 35% nearest the feedyard and decreased to 9% and 1%, respectively, at >525 m. Over a similar distance, soil P decreased from 75 mg $kg^{-1}$ to 17 mg $kg^{-1}$. Dust deposition rate decreased with distance from the feedyard. Manure dust contribution to total dust ranged from negligible to 89%. It was estimated that 20-30 kg N $ha^{-1}$ $yr^{-1}$ were deposited over 30 years to areas nearest the feedyard. Changes in vegetation and soil P were greatest at <500 m from the feedyard. Vegetation and soil P were near values expected for shortgrass prairie at >500 m downwind from the feedyard.
KEY TERMS: shortgrass steppe; vegetation change; plant nutrients; nutrient transport; feedyard dust; soil phosphorus.

## INTRODUCTION

The High Plains of the Texas Panhandle and surrounding states are a mosaic of irrigated and dry cropland and grassland. More than half the agricultural land area is grassland, and most of that is native rangeland. Shortgrass prairie dominates most rangeland, especially on upland clay and silty clay soils. Blue grama and buffalograss are the major native species of the southern High Plains shortgrass prairie.

More than 7 million fed beef cattle, about a third of those marketed in the United States, are found within a 200,000 $km^2$ area of this region centered on Amarillo, TX. Most are fed in more than 100 feedyards with capacities greater than 5000 head (Eck and Stewart, 1995). These concentrated feeding operations can potentially affect the local environment in many ways, including accumulation of manure, runoff from pens, and emissions of ammonia, dust, odors, and pathogens.

In 1970, a 25,000-head feedyard was constructed and stocked adjacent to an 18.5-ha shortgrass prairie on the USDA-ARS Conservation and Production Research Laboratory (CPRL), Bushland, TX. After several years, CPRL scientists observed changes in the pasture's vegetation nearest the feedyard. We hypothesized that manure dust was blown from the feedyard by prevailing southwesterly winds and this input of plant nutrients changed competitive relations between plant species, resulting in changes in vegetation composition. Our objectives were to 1) describe the historical vegetation of the pasture before the feedyard was operated; 2) quantify the composition of the current vegetation; and 3) describe changes in vegetation, soil P and dust deposition with distance downwind from the feedyard.

## MATERIALS AND METHODS

Research was conducted at the USDA-ARS-CPRL, Bushland, Texas (35°N, 102°W, elevation 1170 m) in 2000-2001. The soil is a Pullman silty clay loam (fine, mixed, thermic Torrertic Paleustoll) with slope < 1%. Prevailing winds at CPRL are southerly to southwesterly, with 46% of mean hourly wind directions between 157 and 248°. Average annual precipitation is 476 mm, 75% of which falls from April through October.

Historical vegetation was determined from descriptive accounts given in Whitfield et al. (1949) and measurements reported in Eck et al. (1975). Contemporary vegetation was quantified in 600 randomly located 0.1-$m^2$ quadrats

* Respectively, Soil Scientist, USDA-ARS, PO Drawer 10, Bushland, TX, 79012, Phone 806.356.5728, Fax 806.356.5750, Email rtodd@cprl.ars.usda.gov; Research Assistant, Texas Tech University, Lubbock, TX; Director, Dryland Research Institute, West Texas A&M University, Canyon, TX; and Associate Professor, West Texas A&M University, Canyon, TX.

(Daubenmire, 1959). Species were assigned to a vegetation class; annual grasses were cool-season winter annuals, annual forbs were weedy introduced warm-season species, and perennial grasses were desirable native warm-season species. Vegetation was sampled on 5-7 June and 21-23 Aug., 2000. Adjacent feedyard pens covered about 22 ha and were located west and southwest of the native pasture. The distance of each quadrat downwind from the feedyard was calculated along a southwest to northeast line, corresponding to the direction of prevailing southwesterly winds. Quadrats were grouped into seven distance classes by 75-m increments, with 67 to 97 quadrats per distance class.

Phosphorus is relatively immobile and conservative in manure and Pullman soil (Smith et al., 1983; Sharpley et al., 1984; Jones et al., 1985), and was used as an indicator of manure dust additions. Soil cores were collected on June 3-5, 2000 at 119 locations to a depth of 0.3 m on a 22.5-m x 30-m grid. Samples were air-dried, ground and passed through a 2-mm sieve, and then analyzed for Mehlich 3 (M3) extractable P (Mehlich, 1984). Dust was passively collected in thirty-six pans (0.28 x 0.23 m) located at 12 stations. Pans were installed on 28 Feb. 2000 and removed on 6 Mar. 2001, and the five collection periods varied from 43 to 104 days. Samples were air-dried, composited by position and collection period, and analyzed for M3 P.

## RESULTS

### Historical Vegetation

Whitfield et al. (1949) described the shortgrass pasture as "dominated by blue grama and buffalograss". A photograph of the pasture taken in 1945 reveals the typical aspect of blue grama-buffalograss steppe. Biomass from 1943 through 1948 ranged from 270 to 1550 kg ha$^{-1}$ air-dry forage and averaged 730 kg ha$^{-1}$. A 1.4-ha area in the northeast corner of the pasture was studied by Eck et al. (1975) from 1966 through 1972. Vegetation cover there averaged 27.6%. Blue grama made up 57 to 74% of the vegetation cover and averaged 68.1%. Blue grama averaged 18.8% ground cover, buffalograss 7.4% cover, and together they comprised 95% of the vegetation cover. Annual biomass ranged from 420 to 1530 kg ha$^{-1}$ and averaged 1240 kg ha$^{-1}$.

Vegetation in the rest of the pasture was not measured. However, the range of annual production was similar for the pasture during the 1940s and during 1966-1972. Visual observations by CPRL scientists support the historical uniformity of the pasture's vegetation. Uniformity of shortgrass prairie dominated by blue grama and buffalograss is typical where topography and soil vary little, as in this case. Vegetation of the pasture also showed temporal uniformity for 29 years between 1943 and 1972. Studies that followed in the 1970s and 1980s (Smith et al. 1983; Jones et al. 1985), and 1990s (Willis, 1995) also characterized the vegetation as predominantly blue grama and buffalograss. We assumed that the plant composition reported by Eck et al. (1975) represented the entire pasture, and reflected the historical vegetation prior to construction and operation of the feedyard.

### Contemporary Vegetation

Annual grass cover [67% little barley (Hordeum pusillum Nutt.), with Japanese and downy bromes (*Bromus japonicus* Thunb. ex Murr. and *B. tectorum* L.)] sampled in June averaged 49% nearest the feedyard and decreased with distance downwind from the feedyard to 9% at more than 525 m (Fig. 1a). Annual forb cover [72% kochia, with redroot and smooth pigweeds (*Amaranthus retroflexus* L. and *A. hybridus* L.)] also decreased with distance from the feedyard in June and August from 8 and 35%, respectively, nearest the feedyard, to <1% at more than 525 m (Fig. 1b).

Perennial grass cover (blue grama, buffalograss, western wheatgrass [*Pascopyrum smithii* Rydb.], sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray]) increased with distance downwind from the feedyard (Fig. 2a). In June, perennial grass cover averaged 1.5% less than 150 m from the feedyard and increased to 22.4% at distance greater than 525 m. Perennial grass cover in August ranged from 4.2% closest to the feedyard to 29.2% at distance downwind from the feedyard greater than 525 m. Perennial forb cover (<4%, mostly silverleaf nightshade [*Solanum elaeagnifolium* Cav.]) was variable in distribution and showed no directional pattern, except for a near-absence of perennial forbs in quadrats less than 150 m from the feedyard (Fig. 2b).

Blue grama comprised from 75 to 99% of perennial grass cover, and its cover increased more than 13-fold with distance from the feedyard in June, and almost 10-fold in August. Blue grama cover more than 450 m from the

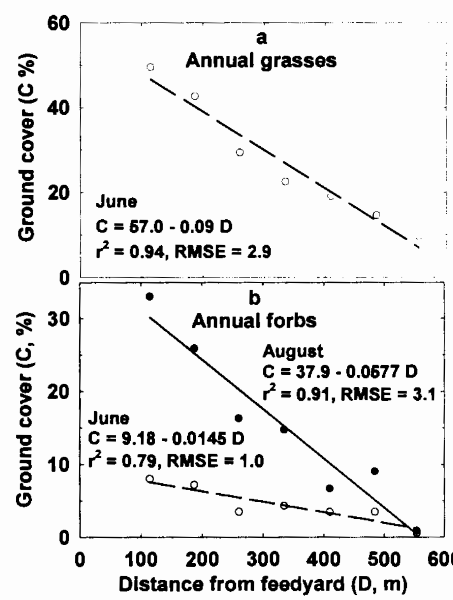


Figure 1. Ground cover of annual grasses (a) and annual forbs (b) with distance downwind from feedyard.

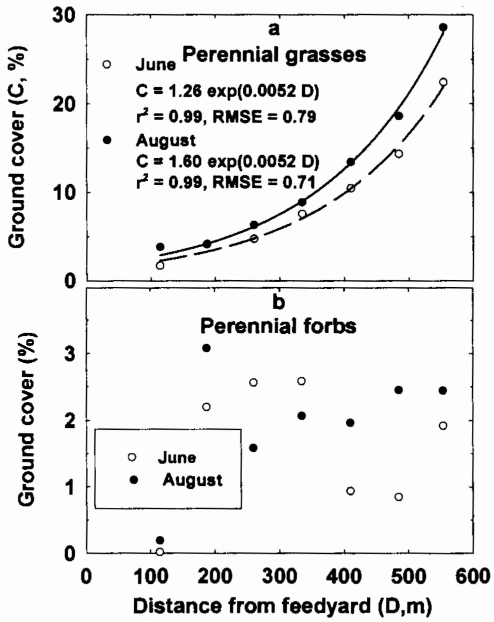


Figure 2. Ground cover of perennial grasses (a) and perennial forbs (b) with distance downwind from feedyard.

feedyard (16.7% in June and 21.5% in August) was similar to the18.8% cover measured by Eck et al. (1975). Buffalograss was absent or uncommon and comprised from zero to less than 2% of the total vegetation cover, compared with 27% of the total vegetation cover reported by Eck et al. (1975).

Total vegetation cover closest to the feedyard was 58% in June, due largely to little barley, and 39% in August. In quadrats farthest from the feedyard, total vegetation cover averaged 34% and 32% (June and August, respectively), about 20% greater than the 27.6% reported by Eck et al. (1975).

Soil P, Dust Deposition and P Concentration, and Nutrient Loading

Mehlich 3 extractable P concentration of Pullman soil is typically around 15 to 20 mg $kg^{-1}$ in surface horizons of undisturbed shortgrass prairie. We measured five times that concentration in the top 0.3 m of soil at less than 150 m downwind from the feedyard, with M3 P concentration ranging as high as 186 mg $kg^{-1}$. Soil M3 P decreased with distance downwind from the feedyard to levels within the typical range at more than 525 m from the feedyard (Fig. 3).

Dust deposition rate during the five collection periods decreased with distance downwind from the feedyard (Table 1). Deposition rate at 117 m was greatest during early summer, averaging as high as 3.3 g $m^{-2}$ $d^{-1}$, and lowest during winter, when it averaged 0.38 g $m^{-2}$ $d^{-1}$. Deposition rates ranged from 0.12 g $m^{-2}$ $d^{-1}$ (winter) to 0.55 g $m^{-2}$ $d^{-1}$ (early summer) at 541 m from the feedyard. For the 323 days of dust collection, the weighted mean deposition rate over the entire pasture was 0.65 g $m^{-2}$ $d^{-1}$, an annualized dust deposition rate of 2.4 Mg $ha^{-1}$ $yr^{-1}$. Mehlich 3 P concentrations were greatest during early summer, when dust was estimated to range from 67 to 89% manure. Lowest measurable P concentrations were during the fall, when the fraction of manure in dust ranged from 1 to 20% across the pasture. Winter dust contained no measurable P. Weighted average M3 P concentration of dust samples across the pasture was 1370 mg $kg^{-1}$, giving a mean manure dust fraction of about 29%.

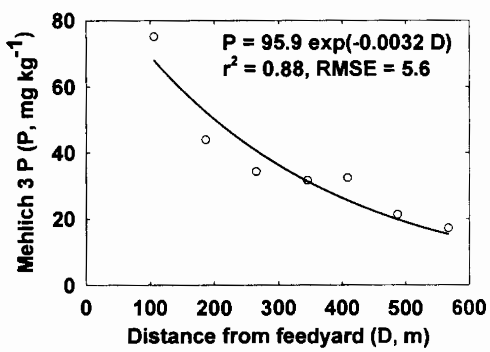


Figure 3. Mehlich 3 phosphorus (P, mg $kg^{-1}$) in top 0.3 m of soil, with distance (D,m) from feedyard.

Table 1. Regression coefficients and statistics for the change of dust deposition rate (R, g $m^{-2}$ $d^{-1}$) with distance (D, m) downwind from feedyard, fitted to R = a exp(-b D).

| Collection Period | Begin Date | # Days | a | b | $r^2$ | RMSE |
|---|---|---|---|---|---|---|
| Spring (sp) | April 12 | 43 | 1.17 | 0.0036 | 0.78 | 0.24 |
| Early summer (es) | May 31 | 48 | 4.78 | 0.0044 | 0.87 | 0.49 |
| Late summer (ls) | July 17 | 62 | 3.61 | 0.0048 | 0.93 | 0.27 |
| Fall (f) | Sept. 17 | 66 | 1.78 | 0.0045 | 0.82 | 0.25 |
| Winter (w) | Nov. 23 | 104 | 0.40 | 0.0026 | 0.57 | 0.08 |

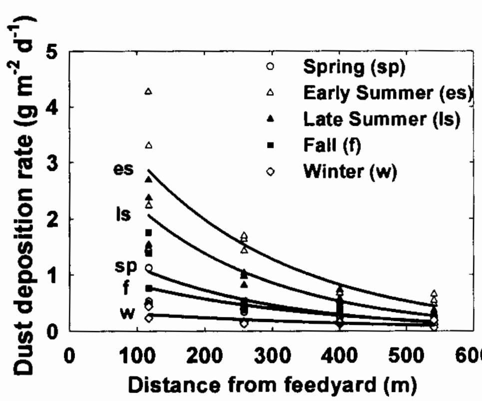


Figure 4. Seasonal dust deposition rate with distance downwind from feedyard.

Nutrient loading to the pasture was estimated using the total dust deposition rate and dust P concentration; or by calculating how much manure dust deposition is needed to increase soil M3 P in the top 0.3 m from an undisturbed concentration (15 mg $kg^{-1}$) to the mean observed concentration (35 mg $kg^{-1}$). Mean annual manure dust deposition to the entire pasture was estimated to be 710 kg $ha^{-1}$ $yr^{-1}$ based on dust measurements, and 330 kg $ha^{-1}$ $yr^{-1}$ based on increase in soil P. Nitrogen loading to the pasture decreased with distance from the feedyard, ranging from 31 to 3 kg $ha^{-1}$ $yr^{-1}$ with estimates based on dust, and from 19 to <1 kg ha$^{-1}$ yr$^{-1}$ when based on soil P increases (Fig. 5).

## CONCLUSIONS

Increase in annual grasses and forbs and decrease in perennial grasses observed in shortgrass prairie closest to the feedyard were consistent with changes measured when High Plains rangeland was fertilized with inorganic nitrogen (Rauzi, 1978; Rauzi and Fairbourn, 1983; Samuel and Hart, 1998; Paschke et al., 2000). Nitrogen additions of 20-30 kg ha$^{-1}$ yr$^{-1}$ over 30 years that we estimated could easily have induced vegetation changes, given the sensitivity of shortgrass prairie to increased soil fertility. As vegetation changed, a complex of interrelated factors most likely contributed to the degradation of the pasture, including differences in soil water availability caused by changes in vegetation composition and seasonality, and preferential use and grazing of the west side of the pasture by cattle. Changes in vegetation and soil phosphorus, and nutrient loading by dust were greatest at less than 500 m from the feedyard. Vegetation and soil phosphorus were near values expected for shortgrass prairie at more than 500 m downwind from the feedyard.

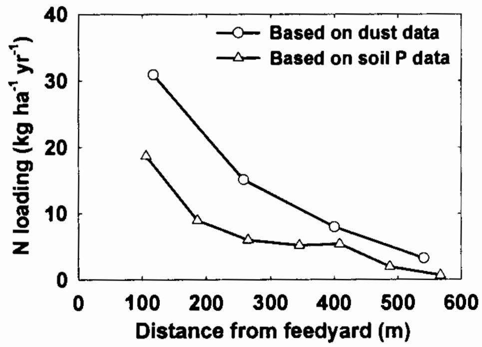


Figure 5. Estimated annual nitrogen loading to shortgrass prairie with distance downwind from feedyard.

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