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Impact of Combined Grazing by Prairie Dogs with Goats or Cattle on Vegetation and Hydrology of a Chihuahuan Desert Grassland

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Abstract: Impact of combined grazing by prairie dogs with goats or cattle on vegetation and hydrology of a Chihuahuan desert grassland of northern Mexico was assessed. Twice replicated grazing treatments were: (1) yearlong continuous goat grazing at a high intensity in a prairie dog colony, and (2) sequential rotation grazing by cattle along with prairie dogs at a moderate intensity. The pasture grazed by prairie dogs with cattle supported fewer plant species (n = 50) than the pasture grazed by goats with prairie dogs (n = 63). The synergistic grazing by goats and prairie dogs caused a 68% reduction in the aboveground biomass, with a directional change favoring herbaceous vegetation at the expense of grasses. The average biomass production of forbs increased 65% and the average grass standing crop decreased by 400% under the combined grazing regime of prairie dogs and goats, in comparison to the pasture grazed by prairie dogs and cattle. Most forbs with higher contribution to the total standing crop on the site grazed by prairie dogs and goats were non-edible. The standing crop of shrubs was higher ($P<0.05$) on the site grazed by prairie dogs and goats than the site grazed by prairie dog and cattle. Plant diversity was higher on the pasture grazed by prairie dogs and goats than the pasture grazed by prairie dogs and cattle. The infiltration rate was higher ($P<0.05$) in the pasture grazed by prairie dogs and cattle than the pasture grazed by prairie dogs and goats. Uncontrolled continuous grazing by goats at a heavy stocking rate in a prairie dog colony had a drastic impact on plant community structure and hydrology in the vicinity of the goat pens in comparison to the site grazed by prairie dogs and cattle. Thus, confinement of large herds of goats to the same pasture year-round in prairie dog colonies must be avoided.

Key words: Herbivory, grazing management, grasses, forbs, infiltration rate.

Information on impacts of prairie dogs on the mixed-grass prairies in the United States indicates that this herbivore has profound effects on grassland vegetation. Forage on sites inhabited by prairie dogs are subject to frequent and intense defoliation (Koford, 1958), and sometimes plant utilization goes beyond the ground surface, as prairie dogs dig into the soil to expose plant tissues, when the aboveground part is consumed (Koford, 1958; Smith, 1967). This disturbance results into decrease in the canopy height (Archer *et al.*, 1987; Day and Detling, 1994), and increment (Bonham and Lerwick, 1976; Winter *et al.*, 2002) or reduction (Weltzin *et al.*, 1997b; Fahnestock *et al.*, 2003) in the species number, aerial cover or biomass of shortgrass species. Also, the burrowing activity of prairie dogs alter hydrology and nutrient cycling (Coppock *et al.*, 1983), which alters plant diversity in a positive

(Bonham and Lerwick, 1976; Archer, *et al.*, 1987; Detling *et al.*, 1998) or a negative (Weltzin *et al.*, 1997a) direction. The disturbance caused to soils and vegetation by prairie dogs can reach a higher level by synergistic grazing by livestock along with prairie dogs. The mixed grazing effect of prairie dogs and large ungulates (cattle and bison) on vegetation of the mixed-grass prairie has been studied (Knowles, 1986; O'Meilia *et al.*, 1982; Fahnestock *et al.*, 2003), but we are unaware of such studies on combined grazing by prairie dogs with goats. This lack of information is especially critical because in arid areas of northern Mexico inadequate grassland management and goat overstocking are common (Manzano *et al.*, 2000), and generally result into barren areas around the goat pens (Mellado *et al.*, 2005). This study was, therefore, designed to evaluate vegetation standing crop and infiltration rates in pastures grazed by prairie dogs with goats or cattle.

Materials and Methods

Study site

The study was conducted on two adjacent natural stands of the mixed prairie in northern Mexico (101° 6 W, 26° 26 N): one grazed by prairie dogs along with goats, and the other along with cattle. The study sites had similar soil characteristics, and large (100 active boroughs per ha) active prairie dog colonies. The study site grazed by prairie dogs with goats comprised a 500 ha paddock in a level terrain, whereas the pasture shared by prairie dog and cattle was a 222 ha paddock. In both pastures we chose prairie dogs towns that were not adjacent to or surrounding water points.

The average elevation is 2100 m. The growing season (frost-free days) extends from March to November. Average annual precipitation is 307 mm, occurring mostly from June to October (75% of total precipitation). Mean annual temperature is 13.4°C. Soils of the study site are mainly light loamy with depths varying from 2 to 2.5 m. The study site has large active prairie dog colonies, which are at least 50 years old. The dominant grasses are: *Bouteloua curtipendula* (Michx) Torr, *Bouteloua gracilis*, *Buchloe dactyloides* (Nutt.) and *Stipa clandestina*. Other abundant plant species included *Croton dioicos* Cav., *Sphaeralcea angustifolia* (Cav.) D. Don. and *Solanum elaeagnifolium* (Cav.).

Animals and their management

A commercial flock of approximately 200 goats (38 to 45 kg adult live weight) of undefined genotype, whose pen was established in the middle of a prairie dog colony, was used. Goats were herded daily by a shepherd and were returned to pen every evening and were kept overnight without water and feed. Water was available only once a day at a watering point away from the pen and mineral supplements were not given during the study. Adjacent to this site there was a commercial beef cattle ranch where prairie dogs and cattle grazed together on a similar grass community. Population size was approximately 150 multiparous Charolais cows (with young) which calved in the spring (March-April of 2003) and calves were weaned in the fall (October). The general grazing practice was the removal of about 50% of the perennial grass production (15 ha animal^{-1}

unit) in a rotational grazing scheme spread over 20 pastures of the ranch.

Sampling procedure

Standing crop was estimated by hand clipping to the ground level of individual plant species in 26, 1 m^2 plots scattered over two replications of both pastures. Browse biomass was estimated considering only the foliage of these plants. Clipped samples were oven dried at 60°C for 48 h and weighed to estimate air-dry standing crop. There were four periods of vegetation sampling: mid-January (winter), mid-April (spring), mid-July (summer) and mid-November (fall). Rainfall was simulated in the pastures in the fall of 2003. A portable rainfall stimulator was used to apply rainfall to square plots (n = 6 per site, randomly selected) about 0.14 m^2 in size. Metal strips surrounding plots were inserted 5 cm deep into the ground and these were bolted to a runoff tray. The stationary nozzle was placed at 1.65 m above the soil and it simulated a rainfall of 163 mm h^{-1} for 30 minutes. Simulated rainfall had a normal raindrop size (0 to 6 mm). All plots were pre-wet by applying 50 L of water with a sprinkler. After the water was applied, the plots were covered with a plastic sheet for 24 hours. The total runoff (0.14 m^2) was collected and measured every 5 minutes when the rainfall was simulated. At the end of the simulated rainfall, water infiltration was determined by the difference between applied rainfall and the quantity of runoff.

Statistical analysis

Differences in standing crop between grazing treatments were tested through the GLM procedures of SAS (1989). Data were analyzed as a split-plot in time, with two replications. Two replications pose limitations in detecting differences between pastures, but combination of prairie dog and ungulates and land resources limitations did not allow a larger design. Plots were considered experimental units, with grazing treatments assigned to main plots and seasons to split plots. Whenever there was grazing treatment by season interaction, the least significant difference test was performed to determine the effect of pasture within season. Each main plant species was analyzed separately.

For the entire data in both pasture species richness (number of species, N) and Shannon diversity ($H' = -\Sigma p_i \log p_i$, where $p_i = -n_i/N$) were determined. Infiltrability data were analyzed by analysis of variance in a completely random block design to determine differences between pastures grazed by prairie dogs either with goats or cattle.

Results

The average number of plant species in the pasture grazed by prairie dogs and goats was 63, whereas the site grazed by prairie dogs and cattle had 50 species. Averaged over seasons, the aboveground biomass in the pasture grazed by prairie dogs and cattle was double ($P<0.05$) of that on the prairie dogs with goats site (Table 1). Total herbaceous standing crop had a sharp increase ($P<0.05$) in the pasture grazed by prairie dogs and goats compared to the pasture shared by prairie dogs and cattle. On the other hand, grass standing crop in the pasture used by prairie dogs and goats was five-times higher than that on the prairie dogs and cattle site. The only grass that was not affected

Table 1. Variation in mean standing crop of primary plant species found on pastures grazed either by prairie dogs and goats (PD-G) or prairie dogs and cattle (PD-C) in a grassland of northern Mexico

Species	Spring		Summer		Fall		Winter	
	PD-G	PD-C	PD-G	PD-C	PD-G	PD-C	PD-G	PD-C
Aristida arizonica	168	162	171	157	69	30	30	86
Bouteloua uniflora	6	12*	61	178*	63	133*	10	32*
Buchloe dactyloides	25	68*	21	30	4	30*	5	9
Dasyochloa pulchella	18	5*	26	12*	25	9*	10	3
Erioneuron avenaceum	14	8	14	9	29	10*	86	10*
Lycurus phleoides	1	17*	4	29*	1	88*	1	38*
Muhlenbergia arenicola	3	185*	4	238*	1	300*	1	68*
Scleropogon brevifolius	1	27*	4	45*	1	22*	1	18*
Stipa clandestina	23	8*	33	7*	17	3*	15	3*
Lesquerella fendleri	0	87	4	71*	1	15*	1	30*
Tiquilia canescens	170	66*	310	93*	284	140*	167	83*
Tymophylla setifolia	32	10*	100	36*	315	30*	99	55
Zinnia acerosa	118	9*	360	88*	189	70*	176	66*
Total shrubs (kg ha^{-1})	110	18*	180	55*	230	18	180	38
Total forbs (kg ha^{-1})	330	189*	637	354*	803	532*	687	416*
Total grasses (kg ha^{-1})	285	892*	347	2198*	255	1336*	203	1096*
Total vegetatat (kg ha^{-1})	725	1092*	1164	2607*	1288	1886*	1070	1550*
Species diversity (H')	1.42	0.58	1.25	0.50	1.64	0.44	1.11	0.63

Within seasons *($P<0.05$).

by grazing of either goats or cattle in conjunction with prairie dogs was *Aristida arizonica*. The aboveground biomass of *Muhlembergia arenicola* was as least 60-times higher in the pasture used by prairie dogs and goats than that on the site grazed by prairie dog and cattle and this difference was most pronounced in the fall. Averaged over seasons, *Buchloe dactyloides* and *Lycurus phleoides* were 10- and 20-times higher ($P<0.05$) in the pasture grazed by prairie dogs and cattle than that on the site grazed by prairie dogs and goats. The only grasses with higher standing crop on the site grazed by prairie dogs and goats were *Erioneuron avenaceum* and *Stipa clandestina*.

Three forbs, *Lesquerella fendleri*, *Tiquilia canescens* and *Zinnia acerosa* constituted about one-half of the total standing crop in the pasture having combined grazing of prairie dogs and goats, but contributed only 10% to the total forage produced on the site grazed by prairie dogs and cattle. *Lesquerella fendleri* was the only forbs found in higher ($P<0.05$) numbers on the site grazed by prairie dogs and cattle than the pasture grazed by prairie dogs and goats. Other functional plant groups (e.g. cacti, shrubs) were practically non-existent in the pasture grazed by prairie dogs and cattle, but the standing crop of shrubs increased ($P<0.05$) in the paddocks having combined grazing of prairie dogs

and goats. The Shannon diversity index for plant species in the pasture grazed by prairie dogs and goats averaged 1.4, and it was 0.5 for the site grazed by prairie dogs and cattle.

A significant difference in mean infiltration rate occurred at each 5-min increment of the simulated rainfall event between pastures (Fig. 1). The pasture grazed by prairie dogs and goats had a lower infiltration rate than the site grazed by prairie dogs and cattle.

Discussion

Plant species diversity may either increase or decrease in response to herbivory, depending on initial conditions, intensity of grazing, and selective grazing (Harper, 1969). In the present study prairie dog and goat grazing reduced total standing crop, total grass biomass and increased herbaceous vegetation compared with the pasture used by prairie dogs and cattle. This was expected because of the high impact of both prairie dogs and goats on vegetation structure. In the case of prairie dogs these colonial animals clear large quantities of vegetation, as a predator avoidance mechanism and to facilitate visual communication among individuals (Hoogland, 1995; Detling, 1998). This activity and the fact that these herbivores are predominantly grass feeders (Fagerstone *et al.*, 1981; Wydeven and Dahlgren, 1982; Uresk, 1984), are largely responsible for forbs dominance on pastures with older prairie dogs colonies (Copock *et al.*, 1983; Whicker and Detling, 1988; Cid *et al.*, 1991; Fahnestock and Detling, 2002) and increment in the bare ground (Fahnestock *et al.*, 2003). In the arid zones of Mexico, large goat flocks are permanently confined to the same pasture, and this results in an irreversible vegetation destruction via defoliation, trampling and changes in microclimatic and soil conditions, particularly in the areas surrounding rural settlements having abundant goat flocks (Mellado *et al.*, 2005). Additionally, herbs in the diets of prairie dogs (Fagerstone *et al.*, 1977) and goats (Mellado *et al.*, 1991, Fajemisin *et al.*, 1996) in arid and semi-arid environments are abundant, which further contribute to the predominance of less palatable herbaceous vegetation.

Much of the herbaceous vegetation invasion, which has occurred around the goat pens, could be attributed to lessening of the competitive ability of grasses and palatable forbs to withstand unpalatable forbs competition in an overgrazing regime. Thus, forbs with higher contribution to the total standing crop on the site grazed by prairie dogs and goats (*Tiquilia canescens*, *Tymophylla setifolia* and *Zinnia acerosa*) are rarely consumed either by goats (Mellado *et al.*, 1991, 2003) or prairie dogs (Mellado *et al.*, 2005). This suggests that reduction of grasses and palatable forbs due to overgrazing by prairie dogs and goats decreased the competitive effect on the less desirable forage plants. Moreover, faecal and urinary inputs to soils on such intense and frequently grazed sites could also increase nitrogen and minerals availability to the unpalatable forbs.

The most abundant grass represented in the vegetation of the pasture used by prairie dog and goats was *Aristida arizonica*. Its relative abundance was due to the avoidance of this grass by goats (Mellado *et al.*, 2005), probably because of its low

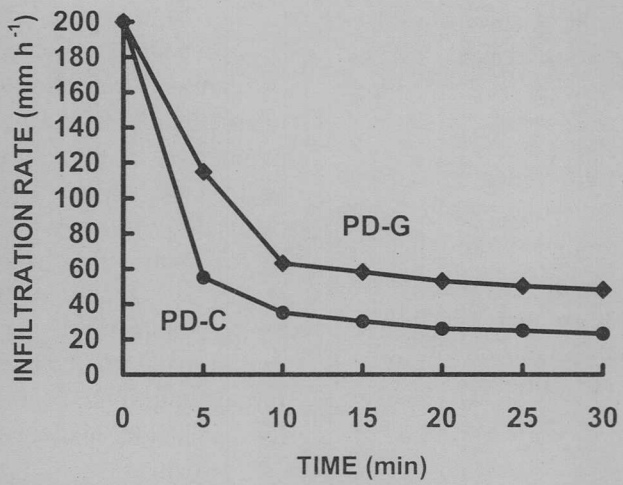

Fig. 1. Infiltration rate means across the 30 minute simulated rainfall for pastures grazed by prairie dogs and goats (PD-G) or prairie dogs and cattle (PD-C) in a grassland in northern Mexico. There are significant differences ($P<0.05$) between pastures for each 5-min interval.

nutritive value (the lowest among the grasses in this site; Ramirez *et al.*, 2004). The only grasses whose standing crop was higher on the pasture grazed by prairie dogs and goats, compared to the pasture used by prairie dogs and cattle, were: *Dasyochloa pullchella*, *Erioneuron avenaceum* and *Stipa clandestina*. These grasses are heavily consumed by both prairie dogs and goats (Mellado *et al.*, 2005).

Both in summer and winter, the standing crop of *Buchloe dactyloides* showed no difference between pastures. This response could be attributed to the high tolerance of this grass to heavy grazing (Thurow *et al.*, 1988; Heitschmidth *et al.*, 1989; Fuhlendorf and Smeins, 1997; Hart, 2001). Moreover, this grass has been reported to be a minor component of the prairie dog diet (Kelso, 1939; Lerwick, 1974; Mellado *et al.*, 2005), and goats (Mellado *et al.*, 2003), even though it has been found abundant on the habitat of these herbivores (Guenther and Detling, 2003). The selective grazing by prairie dogs against *Bouteloua gracilis* and in favor of *Buchloe dacyloides* has been documented by Bonham and Lerwick (1976). Three grasses practically disappeared from the pasture grazed by prairie dog and goats: *Lycurus phleoides*, *Muhlembergia arenicola* and *Scleropogon brevifolius*. We speculate that heavy grazing was more damaging to these perennial grasses, because in the pasture grazed by prairie dog and cattle, with a conservative stocking, these grasses, particularly *Muhlembergia arenicola*, substantially contributed to the total biomass production.

Despite the fact that prairie dogs share many preferred species with cattle (*Bos taurus*) (Hansen and Gold, 1977; O'Meilia *et al.*, 1982), leading to competition between

these herbivores for forages, our study shows that long term conservative rotational cattle grazing has been an effective mean to maintain an adequate perennial grass production, which was five-times higher than the area grazed by prairie dogs and goats.

There were practically no shrubs or cacti on the prairie dog towns grazed by cattle. The same results have been found by Fahnestock and Detling (2002). This can be explained by the role of prairie dogs in constraining woody plant establishment in semiarid grasslands (Weltzin *et al.*, 1997a, 1997b).

In the present study decades of overgrazing by prairie dogs and goats produced large changes in plant species diversity. These results are consistent with data of Coppock *et al.* (1983), Archer *et al.* (1987) and Fahnestock *et al.* (2003), who observed higher plant species richness in prairie dogs colonies in mixed-grass prairie than the uncolonized sites.

The pasture grazed by prairie dogs and goats had a lower infiltration rate than the pasture grazed by prairie dogs and cattle. Differences between pastures were attributed to differences in controlling factors, particularly percentage bare ground and total forage standing crop. The higher plant biomass in the pasture grazed by prairie dogs and cattle was in better hydrologic conditions, which is in line with reports in semiarid environments where total vegetative cover is positively related to water infiltration rate (Thurow *et al.*, 1986; Warren *et al.*, 1986). With cattle, infiltration rate also generally decreases as grazing intensity increases (Pluhar *et al.*, 1987; Hatch and Tainton, 1990; Frost *et al.*, 1986).

Conclusions

These results indicate that high herbivore pressure by continuous grazing by prairie dogs and goats on pastures adjacent to or surrounding the goat pens cause a marked change in the vegetation and hydraulic characteristics of grassland, compared to the site grazed by prairie dogs and cattle. The drastic reduction of total standing crop, decrease in forage production of perennial grasses, marked expansion of unpalatable forbs for domestic and wild herbivores and lower infiltration rates on the site grazed by prairie dogs and goats indicated a downward trend in range condition. The synergistic grazing pressure of prairie dogs and goats in the vicinity of the goat pens was sufficiently heavy to severely stress grassland vegetation. This study, therefore, emphasizes the necessity of avoiding the confinement of large herds of goats on the same pasture year-round in the colonies of prairie dogs.

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