The Relation of Grazing to Plant Succession in the Tall Grass Prairie

WILLIAM T. PENFOUND[1]

Professor of Botany, University of Oklahoma, Norman, Oklahoma.

Highlight

Grassland plots were subject to moderate grazing until 1949, but half of the plots were protected after that time. In general, complete protection from grazing resulted in rapid plant succession, an improvement in vegetation composition, a decrease in forage, and an increase in fresh and humic mulch.

The harmful effects of heavy grazing have been enumerated by many investigators, especially J. E. Weaver and his associates. These detrimental effects include changes in composition, an increase in weeds and a decrease in forage, mulch and the rate of succession. Heavy grazing may also result in poorer physical structure of the soil, decreased fertility and an increase in bare soil, runoff and erosion.

Some harmful effects of light grazing and no grazing have been reported. According to Weaver and Fitzpatrick (1934), the accumulation of excessive mulch retarded growth in the spring and probably eliminated many seedlings. As early as 1948, Tomanek observed that "The highest seasonal yield of short grass . . . was produced in the moderately grazed pasture, fol-

[1] *The writer is indebted to Messrs. Davis, Jackson, Hutcheson and Waliullah for assistance in the field work and to Dr. E. L. Rice for advice and for the 1954 data in Table 1. Financial assistance was provided by the National Science Foundation, through grant G-9620.*

lowed . . . by the undergrazed, overgrazed and heavily grazed locations." In a study of the prairie vegetation of an abandoned, revegetating roadway near Lincoln, Nebraska, Weaver and Rowland (1952) observed that growth and flowering were delayed and yields were lower in the abandoned roadway than in the grazed prairie. In the area of our study, Kelting (1954) observed that a protected prairie possessed fewer species, and less living cover and forage than the grazed prairie. In the soil of the protected prairie the volume-weight values and the amount of organic carbon were lower than in the grazed prairie.

Smith (1940b) referred to the tall grass prairie in the area of study as a mixed prairie with little bluestem[2] and sideoats grama as the dominants. No mention was made of the other tall grass species that are now dominant. Since his studies were made in the late thirties, near the end of the extended drought, it seems possible that recovery of the prairie had proceeded only to the midgrass stage.

Several investigators have delineated the stages of succession in revegetating cropland in the tall grass prairie area (Booth, 1941; Kelting, 1954; Smith, 1940a and Weaver, 1954). Among workers who have reported on plant succession in forested areas are Drew (1942) and Quarterman (1957). The reports of these investigators suggest that both drought and grazing decrease the rate of plant succession.

Description of Plots

The study plots are located in the Grassland Investigations Project, about ten miles southwest of Norman, in McClain County, Oklahoma. The four plots (units) utilized were designated as protected prairie (2 acres), grazed prairie (ca. 20 acres), protected cropland (5 acres) and grazed cropland (ca. 3 acres). These plots were situated on a sandy loam soil with a gentle, north-facing slope. The cropland units were planted to Korean clover in 1941, and allowed to revert to natural conditions. At the time of fencing, in 1949, all prairie and cropland plots had been subjected to moderate, longtime grazing. The protected units were ungrazed and all units were unburned since 1949. At the Oklahoma City Airport, about 12 miles north of the plots the average annual precipitation is 30.82 inches (Weather Bureau, 1963). During the period of study, however, the precipitation varied from 17.84 inches in 1954 to 46.46 inches in 1959.

In the autumn of 1950, after the first growing season of protection, little bluestem was the major dominant in the tall grass prairie. At this time there were few differences in composition between the protected and the grazed prairies. At the end of the first growing season (1950) the dominants in the protected cropland were prairie threeawn and Korean clover (Penfound and Rice, 1957). As was true for the prairie plots there were only minor differences between the composition of the protected cropland and that of the grazed cropland just beyond the fence.

Methods

The protected prairie and protected cropland plots were sampled more often than their contrasting grazed units, although all plots were sampled in 1959 and 1962. In all four plots, the autumnal composition was determined by means of 25 quadrats of 0.1 square meter each. From the field data, frequency and cover were calculated, but only relative foliage cover data are presented herein. In 1959, standard errors were calculated for actual foliage cover, and were found to average about 25 percent of the means. In comparing relative foliage cover in Tables 1 and 2, it is probable that, except for the dominants, the means are not significantly different unless they vary by 100 percent or more.

Results and Discussion

The total number of species sampled in the quadrats was somewhat lower in the protected prairie than in the grazed. (Table 1). This was due, undoubtedly to the heavy mulch cover in the protected prairie. There was, however, no diversity in the number of species in the protected and grazed cropland units during the same growing season, although there were differences in composition (Table 2).

In the protected prairie, the total percentage foliage cover did not differ significantly at the three sampling dates. The relative cover in the protected cropland, however, was very high in 1950, very low in 1954 and moderate in 1959 and 1962. In the protected cropland in 1950, it is probable that the high relative cover can be explained by the low spreading nature of prairie threeawn and especially of Korean clover which furnished most of the cover. The very low cover in both the protected prairie and protected cropland in 1954 was due, undoubtedly, to the poor growing conditions in that season (Table 3). Rainfall was deficient throughout the summer and very high temperatures prevailed during July (+5.3°F) and August (+3.9°F). Only slight differences in average foliage cover occurred between 1959 and 1962. Presumably, the growing season in 1959 was somewhat more favorable than in 1962 but the data do not indicate it.

Little bluestem was the major dominant in the tall grass prairie at the start of the study (Figure 1). In 1954, this species continued as the important domi-

[2] *Scientific names of all species are listed in Tables 1 and 2. Nomenclature according to Waterfall, 1952.*

nant (Table 1). By 1959, little bluestem had declined considerably and two of the other prairie dominants had shown a notable increase in relative cover (Table 1, Figure 2, left). The reason for the very high relative cover of big bluestem is not clear, although considerable annual fluctuation in this species had been noted in the past. By 1962, sideoats grama, coralberry, and three of the prairie dominants contributed most of the cover (Table 1, Figure 2, right). The high relative cover of sideoats was surprising, especially since the cover was high also in the grazed prairie during the same year. It seems probable that there are many such annual fluctuations in the prairie, which are probably related to unknown combinations of climatic factors.

Table 1. Relative foliage cover in prairie plots. Species arranged in order of appearance in succession from bottom upward.

Common name	Scientific name	Protected prairie			Grazed prairie	
		1954	1959	1962	1959	1962
Coralberry	*Symphoricarpos orbiculatus*		2.6	15.0	0.2	0.8
Switchgrass	*Panicum virgatum*	7.4	17.2	22.0	4.6	2.7
Big bluestem	*Andropogon gerardi*	0.4	28.4	11.0	1.2	4.6
Indiangrass	*Sorghastrum nutans*	7.0	9.6	8.7	4.5	6.9
Little bluestem	*Andropogon scoparius*	60.8	29.0	20.4	25.7	30.5
Heath aster	*Aster ericoides*	6.8	0.9	0.1	0.8	2.4
Sideoats grama	*Bouteloua curtipendula*	0.4	2.2	11.4	1.5	18.5
Fall witchgrass	*Leptoloma cognatum*	2.7	4.4	2.6	10.2	5.8
Scribner panicum	*Panicum scribnerianum*	2.0	1.0	1.0	7.5	3.6
Hairy Paspalum	*Paspalum pubescens*			0.1	9.7	1.4
Western ragweed	*Ambrosia psilostachya*	4.3			27.1	17.2
Other species		8.2	4.7	7.7	7.0	5.6
Number of species		26	21	19	31	29
Total % cover		30.7	35.5	42.2	52.1	47.3

Table 2. Relative foliage cover in protected cropland and grazed cropland. Species arranged in order of appearance in succession from bottom upward.

Common name	Scientific name	Protected				Grazed	
		1950	1954	1959	1962	1959	1962
Indiangrass	*Sorghastrum nutans*			0.3	16.5	0.4	0.3
Little bluestem	*Andropogon scoparius*	0.1	2.4	38.0	52.6	44.9	65.1
Fall witchgrass	*Leptoloma cognatum*	7.7	22.7	13.8	6.0	5.9	1.3
Scribner panicum	*Panicum scribnerianum*	13.4	27.9	32.9	14.0	10.4	3.5
Silver bluestem	*Andropogon saccharoides*		0.4	0.9	0.4	13.2	8.4
Heath aster	*Aster ericoides*	0.5	14.6	1.0	2.3	3.1	3.1
Western ragweed	*Ambrosia psilostachya*	0.8	15.0	1.0	1.1	8.3	6.4
Korean clover	*Lespedeza stipulacea*	25.5	0.1			3.0	3.3
Prairie threeawn	*Aristida oligantha*	50.1	5.3			3.9	2.3
Other species		1.9	12.7	12.1	7.1	6.9	6.3
Number of species		28	22	31	27	30	27
Total % cover		74.4	24.7	42.4	38.0	61.3	35.2

The most important aspect of plant succession in the protected prairie since 1954 was the notable invasion of woody species (Figure 2, right). This has involved a great increase of native woody species of the prairie, especially of coralberry. In addition, several typical forest shrubs and trees have invaded. At present, eighteen different woody species have been found in the protected prairie. If this invasion continues at the present rate, it is probable that the prairie will have been eliminated by 1980.

The major dominant in the grazed prairie in 1950 was little bluestem. In 1959, the dominants in the grazed prairie comprised one midgrass (little bluestem) and one forb (western ragweed). By 1962, dominance was shared by little bluestem, western ragweed and sideoats grama. The other three prairie dominants and coralberry were present in the grazed prairie but not dominant (Table 1).

FIGURE 1. The grazed prairie is characterized by the uneven nature of the stand and the dominance of *Andropogon scoparius*.

Table 3. Average temperature and precipitation of growing season April through October, based on average monthly data of Weather Bureau at Oklahoma City.

Datum	Year			
	1950	1954	1959	1962
Average monthly temp.	70.5	74.7	70.4	72.7
Departure from normal	− 0.70	+ 2.21	− 2.01	+ 1.20
Average monthly precip.	3.82	2.09	5.70	3.16
Departure from normal	+ 0.47	− 1.06	+ 2.54	− 0.15

The major dominants in the protected cropland at the start of the study were prairie threeawn and Korean clover (Table 2). By 1954, these species had been replaced by two forbs (western ragweed and heath aster) and two short grasses (Scribner panicum and fall witchgrass). Both forbs, however, exhibited very low relative cover in the previous (1950) and subsequent sampling periods (1959, 1962). This is another case where species suddenly attained prominence and later reverted to insignificance without apparent cause. By 1959, the midgrass (little bluestem) and two short grasses (Scribner panicum and fall witchgrass) were the important species in the protected cropland (Table 2). During the next three years, two of the prairie dominants: little bluestem and indiangrass increased in relative cover, primarily at the expense of the short grasses.

Prairie threeawn and Korean clover were the dominants in the grazed cropland in 1950. By 1959, these species were replaced largely by little bluestem, silver bluestem and Scribner panicum. This was the only plot and period where this midgrass (silver bluesteam) was important. By 1962, however, it had declined somewhat and little bluestem had become the sole dominant.

Apparently the effects of undergrazing, and of no grazing, are due to prodigious mulch. Much of this mulch lies flat on the ground and is of sufficient thickness to prevent the emergence of seedlings and culms of the dominant grasses. The open (dead) spaces that are produced allow the ecesis of annual forbs and the seedlings of woody plants. In the study of a protected prairie in an abandoned roadway northwest of Lincoln, Nebraska, no invasion of woody species was reported by Weaver and Rowland (1952). In southwestern South Dakota, the virgin grassland, long protected from fire and grazing, did not accumulate sufficient mulch to prevent the continuing dominance of grass (Larson and Whitman, 1942). It seems probable, therefore, that the establishment of trees, even in areas completely protected from fire and grazing, is unlikely when the annual precipitation is much less than 20 inches.

The rate of succession is related to the amount of grazing. Overgrazing causes retrogression, moderate grazing decelerates the rate of succession whereas light grazing and complete protection accelerate the successional process. During the 13 years of the study, the major dominant of the grazed prairie remained the same, presumably because the community had reached stability under the practiced grazing regime. In the grazed cropland the composition changed from an annual grass stage through a short grass-midgrass status to a midgrass type, essentially the same as in the grazed prairie.

In the protected prairie, the vegetation changed from midgrass to midgrass-tall grass to midgrass-tall grass-woody plants in 13 years. Booth (1941) reported that, under favorable conditions, the oldest field with bunch grass was 30 years of age but ". . . did not appear to be

FIGURE 2. *Left:* After seven years of protection, the formerly grazed prairie exhibited a very even grass cover of typical tall grass prairie dominants. *Right:* After thirteen years of protection, the formerly grazed prairie had been invaded by many woody species. Present grazed prairie in background.

nearing the fully-developed prairie stage." In the current investigation, however, the succession had proceeded past the prairie stage to incipient woodland in 13 years. It appears that elm and hackberry may be the most important tree dominants as was the case in central Tennessee (Quarterman, 1957). In the protected cropland the succession proceeded through the following stages in the 13-year period: annual grass to forb-short grass to short grass-midgrass to short grass-midgrass-tall grass. These facts suggest that plant succession in tall grass prairie is much more rapid than is usually reported.

As indicated previously, there were several examples in our investigation in which a given species, which had been uncommon, suddenly attained important status in a given growing season, only to return to an insignificant role in the following year. In the prairie plots this was true for big bluestem, hairy paspalum and sideoats grama. In the cropland plots, this phenomenon was exhibited by western ragweed and heath aster. Dr. G. J. Goodman (personal correspondence) has observed this 'pulse phenomenon' in six native species at the University of Oklahoma Biological Sation on Lake Texoma. I have observed this same phenomenon in the marsh fleabane, *Pluchea purpurascens*, along the Lake Texoma shoreline. This species was a predominant plant in 1959 but was present only sporadically in 1958 and 1960.

Summary

The effects of complete protection from grazing upon plant composition and plant succession in tall grass prairie and revegetating cropland are reported herein. These grassland plots, located about ten miles southwest of Norman, Oklahoma, have been protected from grazing since 1949. They were designated as follows: protected prairie, grazed prairie, protected cropland and grazed cropland. In all plots, autumnal composition was determined by means of 25 quadrats of 0.1 sq. m. each.

In the protected prairie, the vegetation changed from midgrass (1950) through representative tall grass prairie (1959) to tall grass prairie with many woody species (1962). If protection continues, it seems probable that much of the protected prairie will be taken over by woody plants. In the grazed prairie the vegetation remained nearly constant since the midgrass (little bluestem) was the major dominant throughout.

In the protected cropland the vegetation changed rapidly through the following stages: annual (1950), forb-short grass (1954) to short grass-midgrass-tall grass (1962). In the grazed cropland the plant population shifted from annual grass (1950) through short grass-midgrass (1959) to a midgrass type (1962).

The most important species in all four tracts was the little bluestem. Considerable plant succession occurred in all plots but was much more rapid in the protected units.

LITERATURE CITED

Booth, W. E. 1941. Revegetation of abandoned fields in Kansas and Oklahoma. Am. Jour. Botany 28: 415-422.

Drew, W. B. 1942. The revegetation of abandoned cropland in the Cedar Creek area, Boone and Calloway Counties, Missouri. Univ. Missouri Coll. Agr. Exp. Sta. Res. Bull. 344, 52 p.

Kelting, R. W. 1954. Effects of moderate grazing on the composition and plant production of a native tall-grass prairie in central Oklahoma. Ecology 35: 200-207.

Larson, F. and W. Whitman. 1942. A comparison of used and unused grassland mesas in the Badlands of South Dakota. Ecology 23: 438-445.

Penfound, Wm. T. and E. L. Rice. 1957. Effects of fencing and plowing on plant succession in a revegetating field. Jour. Range Mangt. 10: 21-22.

Quarterman, Elsie. 1957. Early plant succession on abandoned cropland in the central basin of Tennessee. Ecology 38: 300-309.

Smith, C. C. 1940a. Biotic and physiographic succession on abandoned, eroded farmland. Ecol. Monographs 10: 421-484.

Smith, C. C. 1940b. The effect of overgrazing and erosion upon the biota of the mixed-grass prairie of Oklahoma. Ecology 21: 381-397.

Tomanek, G. W. 1948. Pasture types in western Kansas in relation to intensity of utilization in past years. Fort Hays Kansas State Coll. Studies No. 13: 171-196.

Waterfall, U. T. 1952. A catalogue of the flora of Oklahoma. The Research Foundation, Stillwater, Oklahoma. 91 pp.

Weather Bureau, U. S. Department of Commerce. 1963. Local climatological data for 1963. Oklahoma City, Oklahoma.

Weaver, J. E. 1954. A seventeen-year study of plant succession in prairie. Am. Jour. Botany 4: 31-38.

Weaver, J. E. and T. J. Fitzpatrick. 1934. The prairie. Ecol. Monographs 4: 108-295.

Weaver, J. E. and N. W. Rowland. 1952. Effects of excessive natural mulch on development, yield, and structure of native grassland. Bot. Gaz. 114: 1-19.

REMINDER

1965 dues are $10.00 regular and $5.00 for students. Add 50¢ for postage to countries other than USA, Canada, and Mexico. All dues payable in U.S. Funds.