POST-SETTLEMENT INVASION OF WOODY SPECIES IN KANSAS TALL-GRASS PRAIRIE

by

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INTRODUCTION

Settlement of Geary County, Kansas began in 1854. A General Land Office Survey of the county was conducted from 1856 to 1857 and the field notes describe the region as consisting of grasslands with trees along river and creek valleys. In the early and mid-1800's military expeditions described the area similarly (Bradbury 1819, Beckwith 1855) and as long ago as 1541 Francisco Vasques de Coronado travelled through the region that is now Geary County (Day 1940) and wrote of the area in general that "there is not any kind of wood in all these plains away from the gullies and rivers..." (Webb 1931).

Geary County's bluestem prairie has been grazed since the early 1880's when it became generally realized that they provided ideal grazing for cattle. Many, but not all, land owners of the county have intentionally burned the grasslands in the spring to improve grazing conditions. In so doing they have continued a process that is widely considered to be a major environmental factor in the formation and maintenance of prairies (Gleason 1913, Buell and Facey 1960). The use of herbicidal sprays as a control was introduced in the early 1940's with increasing occurrences of woody species in unburned portions of the grasslands; by 1947 a shared expense spray program, which continues today, was sponsored by the U. S. Government through the Agricultural Stabilization and Conservation Service.

The purpose of this study was to understand the invasion of woody species in Geary County under the following management conditions: (1) no burning or spraying, (2) burning and (3) spraying.

AREA AND METHODS

Area Studied

Geary County, Kansas was selected for this study because it is (1) characteristic of the Flint Hills, the largest remaining unplowed area of bluestem or tall-grass prairie in the country, (2) has a published, modern soil survey, and (3) is convenient to Kansas State University.

The climate is typified by hot summers and moderately cold winters (the maximum and minimum three-month averages being 77.8 degrees Fahrenheit and 31.3 degrees Fahrenheit respectively). Precipitation is heaviest in the early summer, resulting principally from thunderstorm activities, while winters are generally clear and dry. The amount of precipitation across the country varies from 15 to 60 inches annually, the eastern portion averaging about three inches more than the western. This difference did not appear to alter the conclusions of this study. Prevailing winds are from the south (Climatic data from Dunmire and Bidwell 1959).

Geary County soils are in the Mollisol soil order, suborders Udoll (Prairie or Brunizem soils and some Reddish Prairie and Regosol soils) and Ustoll (Chernozem soils). They range from deep, alluvial, bottomland soils through slope and upland soils of varying depth and degree of rockiness (Table 1).

TABLE 1. Description of Geary County soils studied, listed approximately by topographic position from ridge to lowland[1]

Symbol	Name	Description
La	Ladysmith silty clay loam	deep soils over dense, compact, slowly permeable, clay subsoil; on nearly level uplands (0 to 1-percent slopes); range site, Clayey upland.
Lb	Ladysmith silty clay loam	deep soils over dense, compact, slowly permeable, clay subsoil; on gently sloping uplands (1 to 4-percent slope); range site, Clayey upland.
Db	Dwight silty clay loam	shallow soil over claypan on nearly level upland ridges (0 to 3-percent slope); subsoil very slowly permeable; range site, Claypan.
Ia	Irwin silty clay loam	deep soils over dense, compact, slowly permeable, clay subsoils; on gently sloping uplands (1 to 4-percent slope); range site, Clayey upland.
Ib	Irwin silty clay loam	moderately deep to shallow soils over dense, compact, slowly permeable clay subsoils; on gently sloping to rolling uplands (4 to 8-percent slope); range site, Clayey upland.
Ic	Irwin silty clay loam	shallow soil over dense, compact, slowly permeable, clay subsoils; on rolling uplands (8 to 12-percent slope); range site, Clayey upland.
Fc	Florence cherty clay loam	moderately deep to shallow, permeable soil over cherty clay subsoil of variable thickness; on nearly level to moderately sloping uplands (0 to 8-percent slope); range site, Loamy upland.
Sf	Sogn rocky clay loam	very shallow, rocky soil over limestone; on gently to moderately rolling uplands (0 to 8-percent slope); bedrock exposed in places, range site, Shallow.

TABLE 1. (continued)

Symbol	Name	Description
Sg	Sogn complex	deep to very shallow soil over limestone; on steeply sloping uplands (15 to 40-percent slope); an intricate pattern of narrow bands and outcrops; average composition: 30-percent Sogn rocky clay loam, 20-percent Tully silty clay loam and 50-percent unnamed Regosols developed from calcareous shale; dominant range site, Limestone breaks.
Td	Tully silty clay loam	deep, permeable soil with clayey subsoil; on steep slopes (8 to 20-percent slope); range site, Loamy upland.
Tc	Tully silty clay loam	deep, permeable soil with clayey subsoil on moderate to steep slopes (4 to 8-percent slope); range site, Loamy upland.
Tb	Tully silty clay loam	deep, permeable soil with clayey subsoil on nearly level to moderate colluvial slopes (1 to 4-percent slope); range site, Loamy upland.
Wb	Hastings silty clay loam	deep, well drained soil on gently sloping, convex ridgetops and lower slopes (1 to 4-percent slope); range site, Loamy upland.
Ha	Hobbs silt loam	deep, permeable soil on nearly level first bottoms (0 to 2-percent slope); range site, Loamy lowland.

[1]Adapted from original tables and descriptions in Geary County Soil Survey (Dunmire and Bidwell 1959).

Site Selection

Sites were selected by field observations and talking to landowners or managers. Of many sites checked, the twelve sites studied most closely met the following characteristics: (1) known management history longer than 20 years, and (2) type of management constant throughout the 20 years (Table 2).

Grazing Treatment

All sites except Site 5 were grazed by cattle during the time of the study; grazing rates were reported by owners and managers to be generally moderate but insufficient information was available to determine specific rates with any accuracy. No information on grazing was available for Site 5 although from field observations it appears to have been ungrazed in recent years. Portions of each site not invaded by woody plants were dominated by native prairie species, the most abundant being big bluestem, Andropogon gerardii, indicating that grazing has not been excessive.

Summer grazing of steers at one time constituted the principal use of Geary County rangeland (Anderson 1953), particularly that in the eastern half. In recent years, however, the emphasis has shifted to cow-calf operations in which the grasslands are grazed most of the year, the cattle receiving supplemental feedings during the severe winter months, frequently in smaller, separate pastures. Annual burning was and is standard practice on land leased for summer steer grazing whereas cow-calf operators often do not burn. Steer grazing, and hence burning,

TABLE 2. Description of study sites

Site	Location (section, township and range)	Size (hectares) (1 ha. = 2.47 acres)	Known management begins (year)	Treatment
1	NW¼ 16-12S-6E NE¼ 17-12S-6E	77	1948	unburned and unsprayed; grazed all year.
2	NE 2-13S-5E N½ 1-13S-5E SW 36-12S-5E NW 6-13S-6E	186	1920	unburned and unsprayed; grazed all year until 1969 when grazing was stopped.
3	S¼ 25-12S-5E	184	1920	unburned and unsprayed until ca. 1966 when sprayed once; grazed all year.
4	NE 11 and NW¼ 12 13S-5E	57	1920	unburned and unsprayed until ca. 1965 when sprayed once; grazed all year.
5	SE 19-12S-8E	3	Before 1940	unburned and unsprayed; grazing unknown.
6	NE¼ 11-12S-7E	92	1943	sprayed two consecutive years out of every six, much of area accidentally burned in early 1969; grazed all year.
7	NW¼ 12-12S-7E	24	1943	sprayed two consecutive years out of every six, grazed all year.
8	25-11S-7E N½ and E½ 30-11S-8E NW¼ 31-11S-8E	590	Before 1937	burned annually, grazed in summers.
9	23-13S-7E	156	Before 1937	burned annually; grazed in summers.
10	S. Central 31-11S-8E	51	1945	burned every one to three years, sprayed twice ca. 1964 and 1965; grazed all year.

TABLE 2. (continued)

Site	Location (section, township and range)	Size (hectares) (1 ha. = 2.47 acres)	Known management begins (year)	Treatment
11	E 3/4 31-12S-8E	245	Before 1937	burned annually; grazed all year.
12	W. Central 30-12S-8E	44	1940	burned once in each five years, sprayed once ca. 1967; grazed all year.

has been concentrated in the eastern part of the county, while cow-calf operations, without burning, have been mostly in the western part.

Measurement of Coverage by Woody Species

The General Land Office Survey records for Geary County, Kansas, located at the state capitol in Topeka, were used in estimating pre-settlement coverage. Land office surveyors were commissioned to locate and set markers at section and quarter-section corners. In addition they were instructed to make notes on the occurrence of timber, soil, building stone and water. Witness trees at section and quarter-section corners and distances from section corners at which they entered and left timber were usually recorded. Presettlement coverage was estimated from these records of woody species coverage in 1856 and 1857.

Aerial photos provided the majority of the information for this study. The earliest photos of the northern half of the county were taken during 1937 and of the southern half in 1939. The entire county was photographed in each of 1950, 1956 and 1969. Photo scales, as flown, were approximately 1:20,000 and contact prints were used for the 1937, 1939, 1950 and 1956 photos. The prints used of the 1969 photos were enlarged to a scale of approximately 1:7800. The scale varied slightly between photos of a single year and from year to year, requiring frequent checking to reduce errors.

Section-line data were used to compare the changes in woody species coverage since settlement. Total section line distances within or along the boundaries of study sites and the percent of that total that was timbered was obtained using distances recorded in the 1856 and 1857

General Land Office Survey records. These distances were compared with distances measured from aerial photos of all available years from the same section lines. Only eight of the twelve sites involved section lines so only these eight were included in this portion of the study. Timbered and scattered timber portions of section lines were separately measured on aerial photos since both notations were used in the 1856 and 1857 survey field notes. Total coverage was obtained by adding 25% of the scattered timber distance to the fully timbered distance. Cultivated portions of section lines were eliminated from all years as was the small area bordering fence lines. Only the presence of trees was recorded from aerial photos since shrubs were not noted by the survey teams.

Changes during the last 30 years were obtained by measuring area occupied by woody plants on aerial photos. The area covered by woody species was rated for each soil type using a grid acetate overlay on which each grid square approximated a 20 meter by 20 meter area. Woody species coverage was estimated in each grid square using the following coverage classes: none, 0 to 5%, 5 to 50%, 50 to 95% and 95 to 100%. Woody species could be distinguished when they were distinctly taller or darker than surrounding grasses or when grouped together. Individual woody plants no taller than the surrounding grasses were not detectable.

Soils were incorporated in the ratings by outlining each soil type on acetate using soil maps from the Geary County Soil Survey (Dunmire and Bidwell 1959). A LUCYGRAF was used to trace soil boundaries in the same scale as that of the aerial photograph being used.

Reference points such as road junctions and fence lines were noted to permit uniform and accurate placement of the soil overlay on the aerial photos. Initially sites were rated using stereo pairs of aerial photos but after some preliminary familiarization it was found to be faster and as accurate using single photographs. The overlays were placed as similarly as possible over aerial photos of different years. Cultivated areas and squares along fence lines were excluded and squares on soil boundaries were not counted unless more than 75% of their area was included in the soil type. No ratings were made during years for which the history of a site was unknown except for Sites 1 and 10. Management for these sites was unknown from 1939 to 1950 but a comparison of 1939 and 1950 data indicated that, compared to known treatment, it was probably similar. Data for 1937 or 1939 on all sites were needed to best show treatment effects, therefore, these data for Sites 1 and 10 were included in the study.

RESULTS AND DISCUSSION

Effect of Burning

Section-line data for 115 years, supplemented by area data for approximately 30 years, show that burning maintained the woody species essentially at presettlement amounts (Fig. 1, Table 3); the slight increase may be the result of cooler and less destructive fires due to reduced litter as a consequence of cattle grazing. The increases shown are quite small, however, when compared to the 24% increase shown from section-line data and the 33% increase shown from area data on unburned

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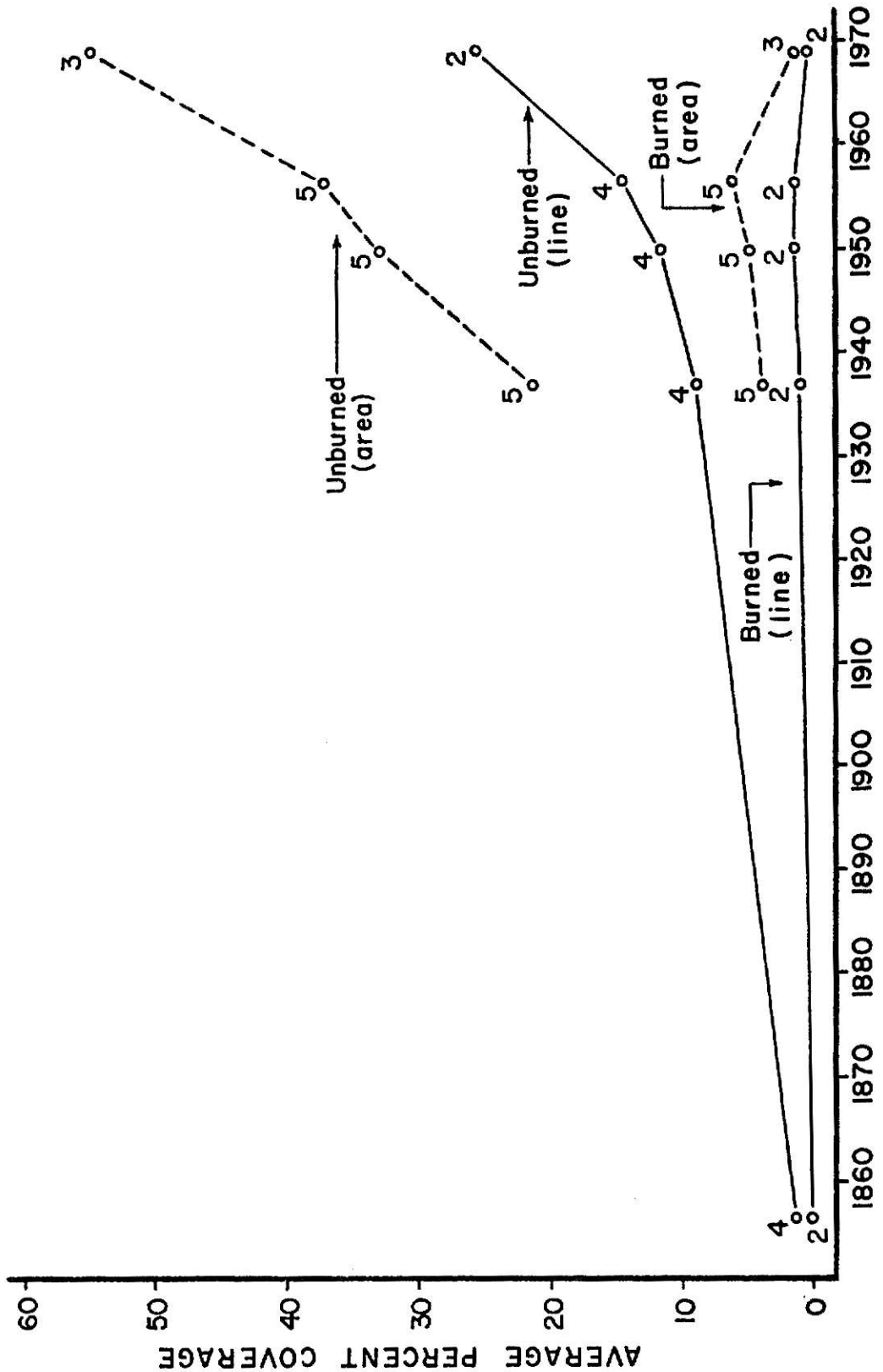

FIG. 1. Average woody species coverage from area and section-line data on burned and unburned sites. Numbers by points indicate total number of sites averaged.

TABLE 3. Percent woody species coverage from area and section-line data

Year and date	Percent coverage											
	Unburned and unsprayed					Sprayed		Burned				
	1	2	3	4	5	6	7	8	9	10	11	12
1856/57												
Line	0	5	0	0	-	1	23	0	0	-	-	-
Area	-	-	-	-	-	-	-	-	-	-	-	-
1937/39												
Line	19[a]	9	5	2	-	5[a]	62[a]	tr	2	-	-	-
Area	26[a]	16	12	25	27	-	-	1	1	9[a]	1	7
1950												
Line	23	12	8	3	-	6	87	1	2	-	-	-
Area	33	31	21	35	43	11	34	1	1	11	1	10
1956												
Line	25	13	13	7	-	5	77	1	2	-	-	-
Area	36	35	26	42	47	12	33	2	2	14	2	10
1969												
Line	33	18	7	8	-	19	71	1	tr	-	-	-
Area	37	39	24	34	88	14	37	1	2	9	1	11

[a] Not present managers.
tr(trace): less than 0.5

(and unsprayed) sites. These results support the hypothesis that burning was indeed a natural part of the prairie environment of this region, whether the fires were of natural origin (Humphrey 1958, Komarek 1966 and 1968, Daubenmire 1968, Rowe 1969) or caused by Indians (Gleason 1913, Humphrey 1958).

The coverage differences, for burned sites, between section-line and area data probably result from the lower frequency of burning on two of five sites used in determining the area data. Sites 10 and 12 were not burned annually and consequently, the woody species coverage was higher than on the remaining annually burned sites. When these sites were sprayed in 1965 and 1966 and therefore eliminated from 1969 data, the average coverage dropped to one more closely approximating that of section-line data. The effects of the few sites studied indicate that annual burning of grazed range will maintain woody species coverage at a lower level than will burning every three to five years. If, as a result of more fuel, fires were hotter in presettlement times, they need not have occurred annually to maintain the small amounts of woody species indicated by section-line data, but certainly these findings support the conclusion that fires averaged more than one a decade.

The difference between section-line and area coverage on unburned and unsprayed sites appears to have resulted from the chance location of the section lines along narrow, wooded places thus underrepresenting the area occupied by woody species. The amount of useable section lines on the sites for which management was known was too small to give as true a representation as did the area method.

The woody species increase shown in Fig. 1 and Table 3 involves both invasion of new territory and increase in density in areas already possessing trees. The area invaded was assessed by comparing changes in the amount of increase in number of grid squares containing trees during each of the years studied. The results show that woody species did invade new territory (Fig. 2, Table 4). In fact, invasion of new territory was a major cause of the increase in total woody plant coverage on unburned and unsprayed sites. In contrast, burned sites showed only a small invasion of new area reflecting the trend indicated by coverage information.

Field observations showed that invading species varied slightly with the site but generally included many of the woody plants found in the adjacent lowland areas. American elm (Ulmus americana) constituted a large percent of the invaders, particularly on Site 5. Juniper or red cedar (Juniperus virginiana) was found on many of the invaded areas and was also noted on some upland soils (not on the study sites) which generally seem to resist invasion of woody plants. The two principal oaks of the sites were bur oak (Quercus macrocarpa) and chinquapin oak (Quercus prinoides). Bur oak seedlings were found on lower slopes near mature trees whereas chinquapin oak more commonly spread upslope. The major shrub invaders on all sites were smooth sumac (Rhus glabra), roughleaf dogwood (Cornus drummondi) and buckbrush (Symphoricarpos orbiculatus). Smooth sumac was found on both upland and slope soils.

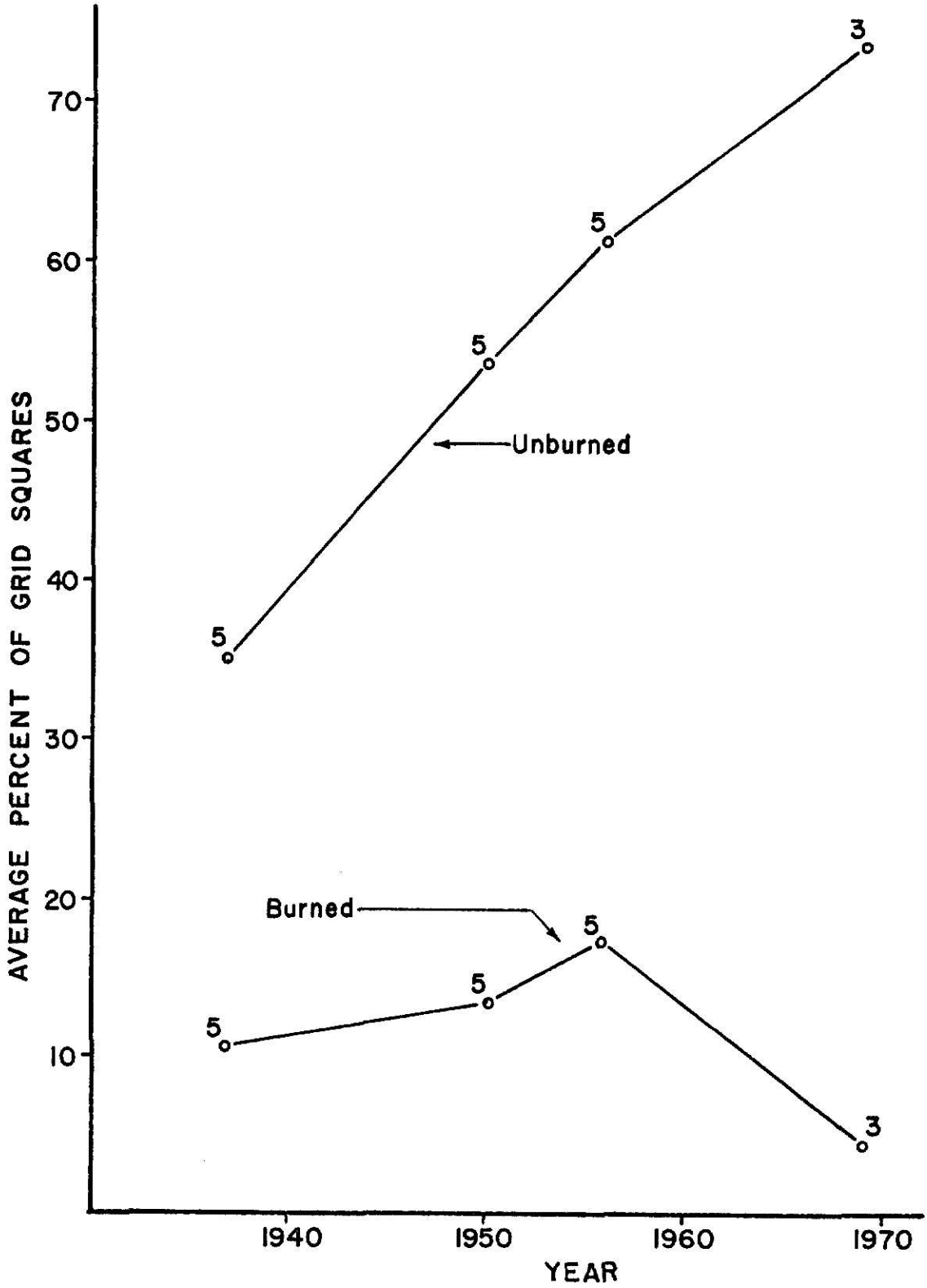

FIG. 2. Change in percent of grid squares containing woody species. Numbers by points indicate the number of sites averaged.

TABLE 4. Percent of grid squares with woody species coverage

Site	Treatment	Percent with woody species coverage			
		1937/39	1950	1956	1969
1	unburned, unsprayed	38[a]	52	57	58
2	unburned, unsprayed	35	56	63	62
3	unburned, sprayed ca. 1966	24	40	50	45
4	unburned, sprayed ca. 1965	49	67	80	62
5	unburned, unsprayed	31	54	58	100
6	sprayed	-	29	32	27
7	sprayed	-	43	54	55
8	burned annually	2	4	6	5
9	burned annually	4	5	5	7
10	burned every 1 to 3 years, sprayed ca. 1964 and 1965	24[a]	29	42	19
11	burned annually	2	4	5	2
12	burned every 1 to 5 years, sprayed ca. 1967	20	26	28	28

[a] Not present managers

Effect of Soil

Woody species coverage has remained approximately the same on all soils in burned areas during the last 30 years but woody plant coverage among soils differed markedly on unburned and unsprayed sites (Fig. 3, Table 5).

The Hobbs silt loam (Ha) was covered at a relatively rapid rate from 1937/1939 to 1950, at which time 82% of it contained woody plants. After 1950 increases were slower as woody species coverage approached saturation.

The Hastings silty clay loam (Wb), located on only one unburned site and constituting but 1% of that site's soils (Table 6), was situated next to the Hobbs silt loam on lower slopes. It was 94% covered by woody species in the late 1930's when first recorded and has remained mostly forested since that time.

The Tully silty clay loams (Tb, Tc and Td) on unburned sites showed the greatest change with an increase averaging more that 56% from 1937 to 1969 (Fig. 3, Table 5). These soils, located on lower slopes, averaged less than 2% of the soils of unburned sites (Table 6) and were frequently located in small pockets or long, thin strips between the Hobbs and the Sogn complex soils which may partly explain the rapid rate of invasion. The somewhat erratic changes in coverage of the 8 to 20-percent slope Tully soil (Td) probably results from its small area. Slightly different placement of the overlay might include some woody species one time and not the next; when only a few squares are involved this can cause drastic changes in percent coverage.

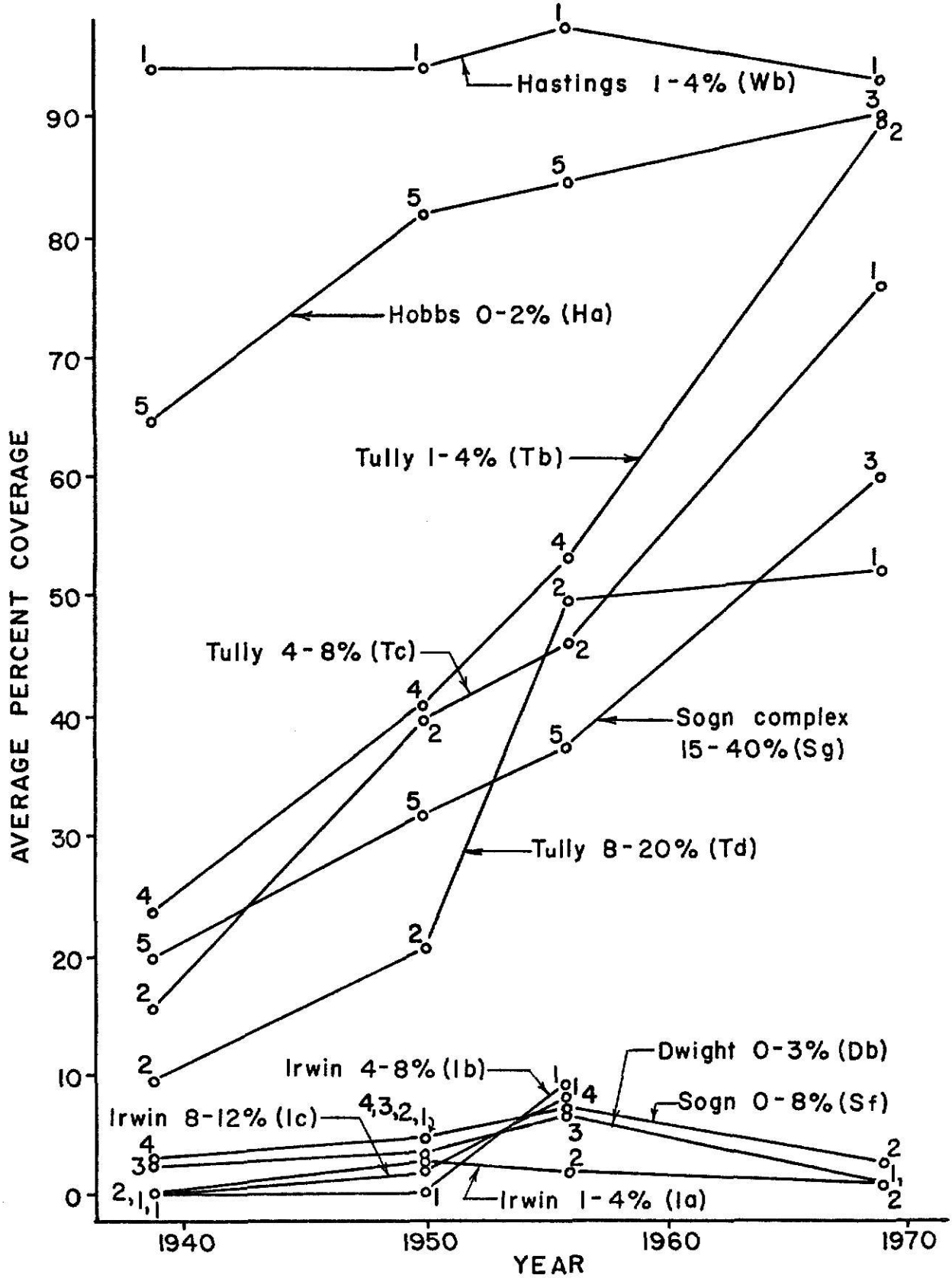

FIG. 3. Average percent coverage by woody species for soils of unburned sites. Numbers near points indicate the number of sites averaged. Numbers following soil name indicate slope.

TABLE 5. Percent of each soil type covered by woody species

Site	Year	Percent coverage													
		Ha	Wb	Tb	Tc	Td	Sg	Sf	Fc	Ic	Ib	Ia	Db	Lb	La
1	1939[a]	81	94	73	-	-	29	tr	-	-	-	0	-	-	-
	1950	94	94	72	-	-	37	2	-	-	-	0	-	-	-
	1956	88	98	82	-	-	43	2	-	-	-	0	-	-	-
	1969	90	93	81	-	-	45	2	-	-	-	0	-	-	-
2	1937	46	-	13	12	19	19	2	-	-	-	0	0	-	-
	1950	78	-	64	28	33	39	4	-	-	-	6	1	-	-
	1956	81	-	69	49	34	44	6	-	-	-	3	5	-	-
	1969	86	-	98	76	52	50	3	-	-	-	2	1	-	-
3	1937	34	-	0	19	0	17	1	-	tr	-	-	0	-	-
	1950	52	-	8	51	8	29	2	-	2	-	-	1	-	-
	1956	63	-	34	43	65	34	4	-	8	-	-	1	-	-
	1969	43	-	13	45	98	33	tr	-	0	-	-	1	-	-
4	1937	98	-	8	-	-	32	8	-	-	0	-	7	-	-
	1950	98	-	19	-	-	46	10	-	-	0	-	8	-	-
	1956	98	-	28	-	-	53	17	-	-	9	-	15	-	-
	1969	98	-	25	-	-	46	8	-	-	8	-	3	-	-
5	1939	63	-	-	-	-	2	-	-	-	-	-	-	-	-
	1950	89	-	-	-	-	6	-	-	-	-	-	-	-	-
	1956	91	-	-	-	-	12	-	-	-	-	-	-	-	-
	1969	93	-	-	-	-	84	-	-	-	-	-	-	-	-
6	1950	20	-	44	-	67	9	15	2	-	-	0	tr	-	-
	1956	39	-	43	-	68	9	19	5	-	-	0	tr	-	-
	1969	12	-	42	-	70	11	29	3	-	-	3	0	-	-

TABLE 5. (continued)

Site	Year	Percent coverage												
		Ha	Wb	Tb	Tc	Td	Sg	Sf	Fc	Ic	Ib	Ia	Db	Lb	La
7	1950	88	-	-	-	90	17	-	0	-	-	-	-	-	-
	1956	89	-	-	-	98	18	-	0	-	-	-	-	-	-
	1969	93	-	-	-	83	21	-	0	-	-	-	-	-	-
8	1939	13	-	5	tr	tr	tr	-	0	-	0	0	0	-	-
	1950	17	-	8	tr	1	1	-	tr	-	0	tr	tr	-	-
	1956	17	-	9	tr	1	1	-	tr	-	2	tr	0	-	-
	1969	17	-	9	0	1	1	-	tr	-	0	tr	tr	-	-
9	1937	7	-	0	6	-	7	1	-	0	1	tr	1	-	-
	1950	10	-	2	0	-	6	tr	-	0	1	tr	1	-	-
	1956	11	-	9	2	-	7	tr	-	0	1	tr	1	-	-
	1969	13	-	4	0	-	6	1	-	18	tr	tr	1	-	-
10	1939[a]	-	-	-	-	-	17	-	1	-	-	1	0	-	-
	1950	-	-	-	-	-	20	-	1	-	-	1	tr	-	-
	1956	-	-	-	-	-	25	-	3	-	-	2	tr	-	-
	1969	-	-	-	-	-	16	-	1	-	-	0	0	-	-
11	1939	10	-	14	0	tr	3	tr	0	-	0	0	0	0	0
	1950	10	-	7	tr	tr	3	1	tr	-	tr	0	tr	0	0
	1956	18	-	21	tr	1	5	tr	tr	-	tr	0	tr	tr	0
	1969	6	-	tr	0	0	3	0	0	-	0	0	0	0	0
12	1939	-	-	26	21	-	12	-	1	-	-	-	-	-	-
	1950	-	-	59	24	-	14	-	2	-	-	-	-	-	-
	1956	-	-	28	16	-	16	-	1	-	-	-	-	-	-
	1969	-	-	47	22	-	17	-	1	-	-	-	-	-	-

[a] Not present manager
tr (trace): less than 0.5

TABLE 6. Average percent of total area of each site occupied by each soil type

Site	Average Percent Coverage													
	Ha	Wb	Tb	Tc	Td	Sg	Sf	Fc	Ic	Ib	Ia	Db	Lb	La
1	8	1	2	-	-	62	27	-	-	-	1	-	-	-
2	9	-	tr	tr	5	55	27	-	-	-	1	3	-	-
3	4	-	1	tr	tr	64	30	-	1	-	-	1	-	-
4	1	-	1	-	-	66	28	-	-	tr	-	3	-	-
5	41	-	-	-	-	59	-	-	-	-	-	-	-	-
6	1	-	5	-	3	52	12	19	-	-	tr	8	-	-
7	22	-	-	-	2	74	-	3	-	-	-	-	-	-
8	3	-	1	2	25	44	-	16	-	tr	7	1	-	-
9	10	-	tr	tr	-	4	16	-	tr	4	55	10	-	-
10	-	-	-	-	-	52	-	33	-	-	13	2	-	-
11	2	-	1	2	6	20	13	14	-	15	1	21	4	1
12	-	-	2	5	-	48	-	44	-	-	-	-	-	-

tr (trace): less than 0.5

The Sogn complex (Sg) soils of the upper slopes averaged more than 61% of the area of unburned sites. Almost 40% of these soils were invaded by woody plants during the 30 years of the study, the majority of invasion on all sites occurring on this soil type.

The upland, shallow, Sogn rocky clay loam (Sf), adjacent to the Sogn complex, showed no substantial increase in coverage; an important point considering that the soil represented 28% of the total soils on unburned and unsprayed sites. Sogn rocky clay loam soil on burned sites also showed no substantial increase.

The Irwin soils (Ia, Ib and Ic) were generally located above the Sogn rocky clay loam. The 1 to 4-percent slope Irwin soils (Ia) showed little change in woody-plant coverage from 1937 to 1969 but those of the 4 to 12-percent slopes (Ib and Ic) did begin to show evidence of invasion from 1950 to 1956 (Fig. 3). Subsequent data on 4 to 12-percent slope soils, however, were not available due to spraying of the sites on which these soils occurred. The greater increase of woody species on the 4 to 12-percent slope of unburned sites may be real or it may be that the small amount of that soil increased experimental error as mentioned with the Tully soils.

The Dwight silty clay loam (Db) of the upland ridges also showed little increase in woody species coverage. Field observations, however, showed a few sites where small juniper and smooth sumac were invading Dwight soils, indicating the potential for invasion.

The Florence cherty clay loam (Fc) and the Ladysmith silty clay loam (La and Lb), both upland soils, were not found on unburned sites; no invasion was noted on the burned sites on which they did occur.

On unburned and unsprayed sites, upland soils were shown to long resist invasion by woody species while increases in lowland and slope soils were substantial. A combination of many factors is probably responsible for the differences in invasion of the various soils but it seems reasonable to suggest that water availability may be of major importance in preventing young woody plants from surviving on upland soils and in encouraging their survival on lowland and slope soils. Shallowness, low permeability and other limiting characteristics of some upland soils could have various effects, one being to reduce the water available for plants. Characteristics of lowland and slope soils, including greater permeability and outcropping aquifers, appear to make these soils more favorable for woody species establishment. Whatever the cause, the evidence indicates that woody plants will invade unburned lowland and slope soils many times more rapidly than upland soils.

Effect of Spraying

The effect of spraying for several years is unclear because insufficient sites were available for good comparisons. The data, however, suggest that regular spraying in lieu of burning slows invasion but does not eliminate some increase in woody plants (Fig. 4). Prior to 1943 Sites 6 and 7 were apparently unburned as suggested by woody plant increases characteristic of such treatment (Fig. 1). By 1950 spraying had begun on the two sites with resulting stabilization of the woody species coverage. A single year's spraying on Sites 3 and 4, not previously sprayed (or burned), reduced the woody species (Fig. 4),

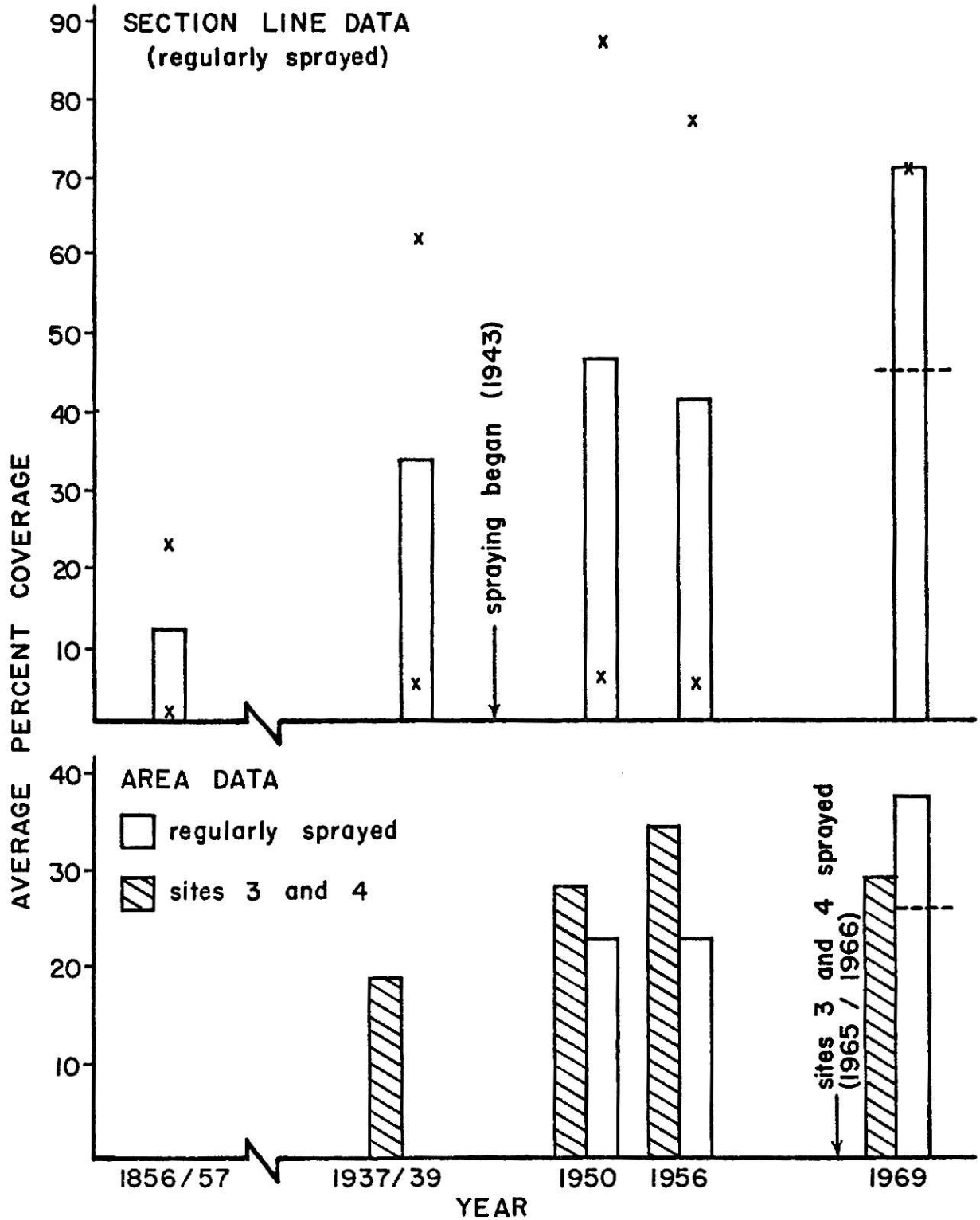

FIG. 4. Average percent woody species coverage on two sites sprayed with herbicides. One site accidentally burned in 1969 therefore bar for that year represents only one site. Regularly sprayed sites were sprayed two consecutive years out of every six. Points shown by an x represent the actual percent coverage of each of the sites averaged.

however, it is not clear if this is only a temporary reduction. Initial spraying may considerably reduce the area covered by woody species but subsequent sprayings over a period of time may not result in further reductions particularly if species less susceptible to spraying increase or if regrowth or resprouting by initially damaged woody plants can rapidly replace itself after each subsequent spraying; reactions of this nature could lead to an increase in woody species coverage. More sites, a longer history of spraying and more information on each spraying would have been required to adequately evaluate the spraying effects but such information was not available.

SUMMARY

Results of this study on bluestem or tall-grass prairie showed that without burning or spraying woody species increased from 24 to 33% whereas burning was shown to effectively maintain woody species coverage at amounts approximating presettlement conditions. These results support the contention that burning was a natural factor in the establishment and maintenance of the natural prairie.

The rate of invasion differed markedly among soils on unburned and unsprayed sites. Soils most rapidly invaded were the Tully silty clay loam and the Sogn complex; an average of more than 52% of these slope soils was invaded by woody species from 1937 to 1969. The Hobbs silt loam and the Hastings silty clay loam of the lowlands and slopes respectively had many trees at the time of the first aerial photos, therefore it is logical that they had smaller percent increases than

the Tully and Sogn complex soils. The Dwight and Irwin silty clay loams and the Sogn rocky clay loam, all upland soils, appeared to resist invasion but given time and proper conditions, these may be invaded at a much slower rate.

Available sprayed sites were inadequate for proper comparisons but results indicated that the rate of invasion is reduced by spraying. These results also indicate that more frequent applications of herbicides would be needed to reduce woody plant coverage and to maintain them in low amounts. Side effects of such applications on the prairie environment are not known.

From this study it appears that fire is the best available treatment to maintain presettlement amounts of woody species coverage on the Geary County tall-grass or bluestem prairie.

LITERATURE CITED

Anderson, Kling L. 1953. Utilization of Grasslands in the Flint Hills of Kansas. J. Range Manage. 6(2):86-93.

Beckwith, E. G. 1855. Reports of Explorations and Surveys 1853-4. U. S. War Department. vol. 2 of 12 vol.

Bradbury, John. 1809. Travels in the Interior of America. Ann Arbor, Mich. Univ. Microfilms. 1966. 364 p.

Buell, Murray F. and Vera Facey. 1960. Forest-Prairie Transition West of Itasca Park, Minnesota. Bull. Torrey Bot. Club. 87(1):46-58.

Daubenmire, R. 1968. Ecology of Fire in Grasslands. Advance. Ecol. Res. 5:209-266.

Day, Arthur Grove. 1940. Coronado's Quest. Univ. Calif. Press, Berkeley. 419 p.

Dunmire, R. G. and O. W. Bidwell. Soil Survey of Geary County, Kansas. Soil Conservation Service, U. S. Dep. Agr. Series 1955, No. 6. Issued Feb., 1960.

Gleason, Henry Allan. 1913. The Relation of Forest Distribution and Prairie Fires in the Middle West. Torreya. 13(8):173-181.

Humphrey, Robert R. 1958. The Desert Grassland: A History of Vegetational Change and an Analysis of Causes. Bot. Rev. 24(4):193-252.

Komarek, E. V., Sr. 1968. Lightning and Lightning Fires as Ecological Forces. Proc. Eighth Annu. Tall Timbers Fire Ecol. Conf. No. 8., Tall Timbers Res. Sta., Tallahassee, Florida. 8:169-197.

Komarek, E. V., Sr. 1966. Meteorological Basis for Fire Ecology. Proc. Fifth Annu. Tall Timbers Fire Ecol. Conf., Tall Timbers Res. Sta., Tallahassee, Florida. 5:85-123.

Rowe, J. S. 1969. Lightning Fires in Saskatchewan Grassland. Can. Field Natur. 83(4):317-324.

Webb, Walter Prescott. 1931. The Great Plains. Ginn and Co., Boston. 398 p.

POST-SETTLEMENT INVASION OF WOODY SPECIES IN KANSAS TALL-GRASS PRAIRIE

by

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Aerial photos, general land office survey data and field observations were used to assess the post-settlement invasion of trees and shrubs in the bluestem or tall-grass prairie of Geary County, Kansas. Burning was shown to effectively maintain presettlement woody species coverage while lack of burning or spraying allowed an increase in the coverage for all soils of 24% from 1857 to 1969, as shown by section-line data, and of 33% from approximately 1939 to 1969, as shown by area data. The increase was mostly due to invasion of new area. Woody species on the Hobbs silt loam in the lowlands of unburned sites increased from 64% to 90% from 1937/1939 to 1969. The Tully silty clay loam and the Sogn complex soils of the lower and upper slopes respectively, showed the greatest increase in coverage; the Tully increased from 16% to 72% while the Sogn complex increased from 20% to 60%. Dwight and Irwin silty clay loams and Sogn rocky clay loam soil of unburned, upland sites showed no substantial change from the average coverage of slightly more than 1% in 1937. The potential for slow invasion of some of these upland soils, however, is indicated by small, individual increases and was also noted in field observations. In the few areas found which had been regularly sprayed, the rate of increase of woody species was slowed but the amount of area occupied was not reduced. On two previously unburned and unsprayed sites, however, one spraying reduced the average woody species coverage by at least 5%. These results indicate that more frequent applications of herbicides than have been used would be needed to reduce woody plant coverage to presettlement amounts and to maintain coverage at this level. The unknown environmental effects of

herbicides and the higher cost of spraying, however, discourage this procedure. It therefore appears that burning is the best available method of maintaining the original woody species coverage on bluestem or tall-grass prairies of Geary County.