# Woody Plant Invasion of Unburned Kansas Bluestem Prairie

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**Highlight**: *Postsettlement invasion of trees and shrubs on the bluestem prairie of Geary County in the Kansas Flint Hills was assessed using aerial photos, General Land Office survey data, and field observations. Tree cover increased 8% from 1856 to 1969 throughout the county, although on regularly burned sites combined tree and shrub cover was effectively maintained at presettlement amounts. On unburned sites, aerial photographs showed that combined tree and shrub cover increased 34% from 1937 to 1969; section-line data showed that tree cover alone increased 24% from 1856 to 1969. Data from two sites suggested that herbicide spraying only slowed the invasion rate. Woody plants increased only slightly on shallow, droughty clay loam soils located on level uplands, ridgetops, and upper slopes. On deeper and more permeable middle- and lower-slope soils, woody plants increased more than 40% from 1937 to 1969. In 1937 trees covered 64% of the unburned, deep, permeable, lowland soils; by 1950 they had increased to 89%; change was slight thereafter. The increase in coverage of the lowland soils from 1856 to 1937 suggests that these soils are rapidly invaded. We conclude that on the Flint Hills bluestem prairie rangeland, (1) burning has been effective in restricting woody plants to natural, presettlement amounts and (2) soil type and topography affect the rate of woody-plant invasion.*

Bluestem prairie (*Andropogon-Panicum-Sorghastrum*) (Küchler, 1964), also referred to as true or tallgrass prairie, once covered large areas from Canada to Oklahoma. That part of eastern Kansas known as the Flint Hills is the only extensive, unplowed tract of bluestem or true prairie remaining in the United States. It has not been widely cultivated because of the characteristic steep slopes and shallow upland soils.

Burning was an essential component of the natural bluestem prairie ecosystem (Buell and Facey, 1960; Anderson, 1970). Climatic and topographic characteristics of the central United States grassland were conducive to periodic and widespread burning during prairie development (Borchert, 1950; Sauer, 1950). Lewis (1814) and Catlin (1848) reported the occurrence of natural fires in presettlement times, and recent studies also suggest the potential for natural, lightning-caused fires (Komarek, 1966 and 1968; Daubenmire, 1968; Rowe, 1969). In addition, American Indians started fires to assist in their movement and to establish buffalo grazing areas (Lewis, 1814; Gleason, 1913). Fires occurred frequently, perhaps almost annually, and both during spring and fall (Catlin, 1848; Newberry, 1873; Shimek, 1911).

**Fig. 1.** *Contrast in woody plant occurrence on Flint Hills bluestem prairie, left side regularly burned, right side unburned for at least 35 years. Photograph taken in early spring of 1974, 1 mile south of Manhattan, Kans.*

Kucera (1960) and Blan (1970) reported that without fire, forest species invade and often dominate former bluestem prairie areas (Fig. 1), but the rate and the extent of such invasion have not been previously ascertained. The decreased number and extent of prairie fires is explained, in part, by the construction of roads, expansion of towns, plowing of land for agriculture, suppression of wildfires, and local recommendations against burning Flint Hills prairie which were followed by some land managers during the mid-1900's. Additionally, it is probable that with cattle grazing every year in confined ranges the grasses are shorter and hence fires are less intense now than on those same areas before settlement when bison and elk probably grazed more erratically and so some years left much more fuel. For these reasons, the extent, frequency, and intensity of fires is thought to be less now than before settlement, thus allowing woody plants to increase in much of the bluestem prairie of the Flint Hills.

The objective of this study was to ascertain the rate of woody plant invasion on various soils of burned and unburned bluestem prairies to help evaluate the role of fire in the prairie ecosystem.

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## Description and History of Study Area

Geary County, Kansas, was selected for this study because it (1) is characteristic of the northern Flint Hills, (2) has a published soil survey, and (3) is near Kansas State University. Summers are hot and winters moderately cold. About 75% of the annual precipitation, heaviest in early summer, falls during the growing season and results principally from thunderstorms; winters are generally clear and dry. The amount of precipitation varies from 84 cm (33 inches) in the eastern part to 76 cm (30 inches) in the western part of Geary County.

In 1541 Coronado, in describing the prairie near the Flint Hills, noted: "There is not any kind of wood in all these plains, away from the gullies and rivers, which are very few." (Webb, 1931; Day, 1940). Field notes taken during the General Land Office survey of the County in 1856 and 1857, approximately the time that settlement of the region began, describe the area as consisting of grasslands with trees principally along river and creek valley. Reports from military expeditions in the early and mid-1800's describe the area similarly (Bradbury, 1809; Beckwith, 1855).

Vegetation of regularly burned bluestem prairie is predominantly big and little bluestem (*Andropogon gerardi* and *A. scoparius*)[1] and Indiangrass (*Sorghastrum nutans*), with lesser amounts of switchgrass (*Panicum virgatum*), sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), hairy grama (*B. hirsuta*), buffalograss (*Buchloë dactyloides*), and Kentucky bluegrass (*Poa pratensis*). The remainder of the vegetation consists of many perennial and some annual forbs and a few woody plants, including leadplant (*Amorpha canescens*) and inland ceanothus (*Ceanothus ovatus*). Total woody plant cover comprises from 1% to 5% of the total vegetative cover on regularly burned bluestem prairie (Anderson and Fly, 1955).

Forests of the Flint Hills today are situated (1) along steep sides of deep valleys, (2) in generally narrow bands and patches along small creeks and ravines, and (3) on alluvial soils along large streams. Those on alluvial soils were not included in this study. Slope forests are dominated by chinquapin oak (*Quercus muehlenbergii*) with lesser amounts of American elm (*Ulmus americana*) and redcedar (*Juniperus virginiana*). Valley forests are dominated by common hackberry (*Celtis occidentalis*) and American elm (*Ulmus americana*), but bur oak (*Quercus macrocarpa*), eastern redbud (*Cercis canadensis*), bitternut hickory (*Carya cordiformis*), and others, also are present.

Extensive cattle grazing in the Flint Hills during the late 1800's resulted in the fencing of extensive tracts of upland areas for locally owned grazing operations (Malin, 1942). By the end of the 19th century, the usual pattern was summer grazing, from April or May to late summer; recent trends, however, are toward year-long grazing of the prairie (Owensby et al., 1973). The summer-grazing leases, which required maintenance of the prairie, usually specified the amount of acreage per animal and that the pastures be burned (Kollmorgen and Simonett, 1965). Virtually all unplowed prairie has been grazed by cattle for most or all of the last 100 years (Owensby et al., 1973), except that small acreages have been cut for native hay. Different grazing pressures among range sites, such as reported by Herbel and Anderson (1959), may affect rates of invasion.

## Principal Geary County Soils

The Flint Hills region is composed of rocks of Permian period, principally shales and limestones of the Chase and Council Grove groups (Dunmire and Bidwell, 1959). Abundance of chert ("flint") in the rock units increases their resistance to weathering and also explains the name "Flint Hills." Weathering of the alternating layers of predominantly cherty limestones and loose shales has produced upland plateaus and irregular, steep slopes on which the resistant limestone strata may form ledges or may be exposed and form bands of rock outcrops. Residuum from bedrock is the parent material of most of the region's soils. The soils are in the Mollisol soil order, suborders Udoll (Prairie or Brunizem soils and some Reddish Prairie and Regosol soils), Ustoll (Chernozem soils), and Rendoll (Rendzina soils). Under the native bluestem vegetation, the soils have developed dark, well-granulated silt loam or silty clay loam surface horizons. The soils vary widely in ability to support prairie vegetation. The following soil descriptions were adapted from the Geary County Soil Survey (Dunmire and Bidwell, 1959).

*Level-upland and ridge-top soils* are more droughty than other soils of the study sites because of their higher clay content and their topographic position. Dwight silty clay loam is a shallow soil with a slowly permeable claypan subsoil; it is situated on nearly level, upland ridges. Ladysmith silty clay loam is a deep, extensively cultivated soil situated on nearly level to gently sloping uplands (0 to 4% slopes). Irwin silty clay loam, situated on gently sloping to rolling uplands (1 to 12% slopes), is a shallow to deep soil with a slowly permeable subsoil.

*Upper-slope soils* are rocky, generally uncultivated soils located on nearly level to moderately sloping uplands (0 to 8% slopes). The Florence cherty clay loam is a permeable soil of variable depth over cherty clay subsoil. The Sogn rocky clay loam is a very shallow soil located over limestone.

*Mid-slope soils* of the study sites were all classified as Sogn complex. The complex is located on sloping uplands (15 to 40% slopes) and is made up of narrow bands of soils of variable depth and many rock-outcrops. The average composition of the Sogn complex is 30% Sogn rocky clay loam, 20% Tully silty clay loam, and 50% unnamed Regosols.

*Lower-slope soils* are deep, permeable, extensively cultivated soils. The Tully silty clay loam is situated over clayey subsoil on nearly level to steep, colluvial slopes (1 to 20% slopes). The Hastings silty clay loam of the study sites is a well-drained soil located on gently sloping lower slopes (1 to 4% slopes). The Geary silt loam is primarily developed from loess and is found on gently sloping areas near major streams.

*Lowland soils* are deep, permeable, extensively cultivated soils on first and second bottoms. The Muir silty clay loam is situated on nearly level second bottoms along major rivers. The Hobbs silt loam and the Humbarger clay loam and loam are found on nearly level first bottoms, particularly along the smaller streams. Humbarger soils are occasionally flooded.

## Methods and Materials

The management history of many potential study sites was determined by discussion with land managers and by field observations. Twelve sites were selected that most closely met these characteristics: (1) management history was known for at least the last 20, and usually 30, years and the grazing intensity during that time was not heavy; (2) management had been relatively constant throughout that time; and (3) the site contained a range of soil types. Five sites had been burned regularly (three burned annually, one burned every 2 to 3 years, and one once every 5 years), five sites had been unburned (three for at least 50 years and two for at least 20 years; two of the 50-year sites were sprayed with herbicides in the mid-1960's and thus excluded from 1969 data), and two sites had been sprayed with herbicides two consecutive years out of every 6 years, beginning in 1943.

### Measuring Woody Plant Coverage

Woody plant coverage was estimated on the various soils of each site using (1) areal data for the last 30 years; the

[1] Scientific names of plants are taken from Barkley (1968).

land-surface area occupied by both trees and shrubs as determined from 1937 to 1969 aerial photos; and (2) section-line data over a 114-year period; coverage of trees only along section-lines as determined from 1937 to 1969 aerial photos and from 1856 General Land Office survey records. Section-line data were used to supplement the more comprehensive areal data by providing information over a longer period of time.

*Areal Data*

Aerial photographs of sites of known management were used to obtain areal data on tree and shrub coverage in relation to various soils. The earliest aerial photos were taken in 1937 for some study sites and in 1939 for the remainder. For convenience, both are referred to as 1937. Complete photo coverage of the county was made in 1950, 1956, and 1969. For 1937, 1939, 1950, and 1956, contact prints at a scale of 1:20,000 and for 1969, enlargements at a scale of 1:7,800 were used. Woody plant coverage on various soils of the twelve study sites was obtained from each set of photographs by using an acetate grid overlay on which each grid square represented a 20 X 20-m ground area. Variously sized grid overlays were used on different aerial photos because of slight differences in photo scale. Soil boundaries, as determined from the Geary County Soil Survey (Dunmire and Bidwell, 1959), were outlined on the overlay to permit separate measurement of woody plants on each soil type. Woody plant coverage within a grid square was classified as: absent; less than 5%; 5 to 50%; 50 to 95%; or 95 to 100%. 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.

*Section-line Data*

These data, measuring tree cover only, were separately obtained for (1) the 12 study sites used above, for which the history of management was known, and (2) the southern portion of Geary County, for which land management was not separately differentiated. Tree coverage shown on 1937, 1950, 1956, and 1969 aerial photographs was measured along section-lines. Section-line tree coverage for 1856 was obtained from General Land Office survey records.

On sites for which the management history was known, the same 6 km of burned and 14 km of unburned section-lines were evaluated for each of 1856, 1937, 1950, 1956, and 1969. In 1856, prior to extensive settlement of the area, the General Land Office commissioned surveyors (1) to locate and set markers along the boundaries of mile-square sections, and (2) to note construction materials (timber and rock) and quality of soil. Distances along the section-lines at which the surveyors entered and left timber were recorded. From these records we estimated presettlement tree coverage. Post-settlement tree coverage along section-lines was measured from aerial photographs taken in 1937, 1950, 1956, and 1969. Only the presence of trees was recorded because the 1856 survey teams made no records of shrub cover. Timbered and scattered-timber portions were measured separately because the 1856 field notes indicated both. Assuming that scattered-timber regions were 25% covered by trees, total tree coverage was approximated by adding 25% of the

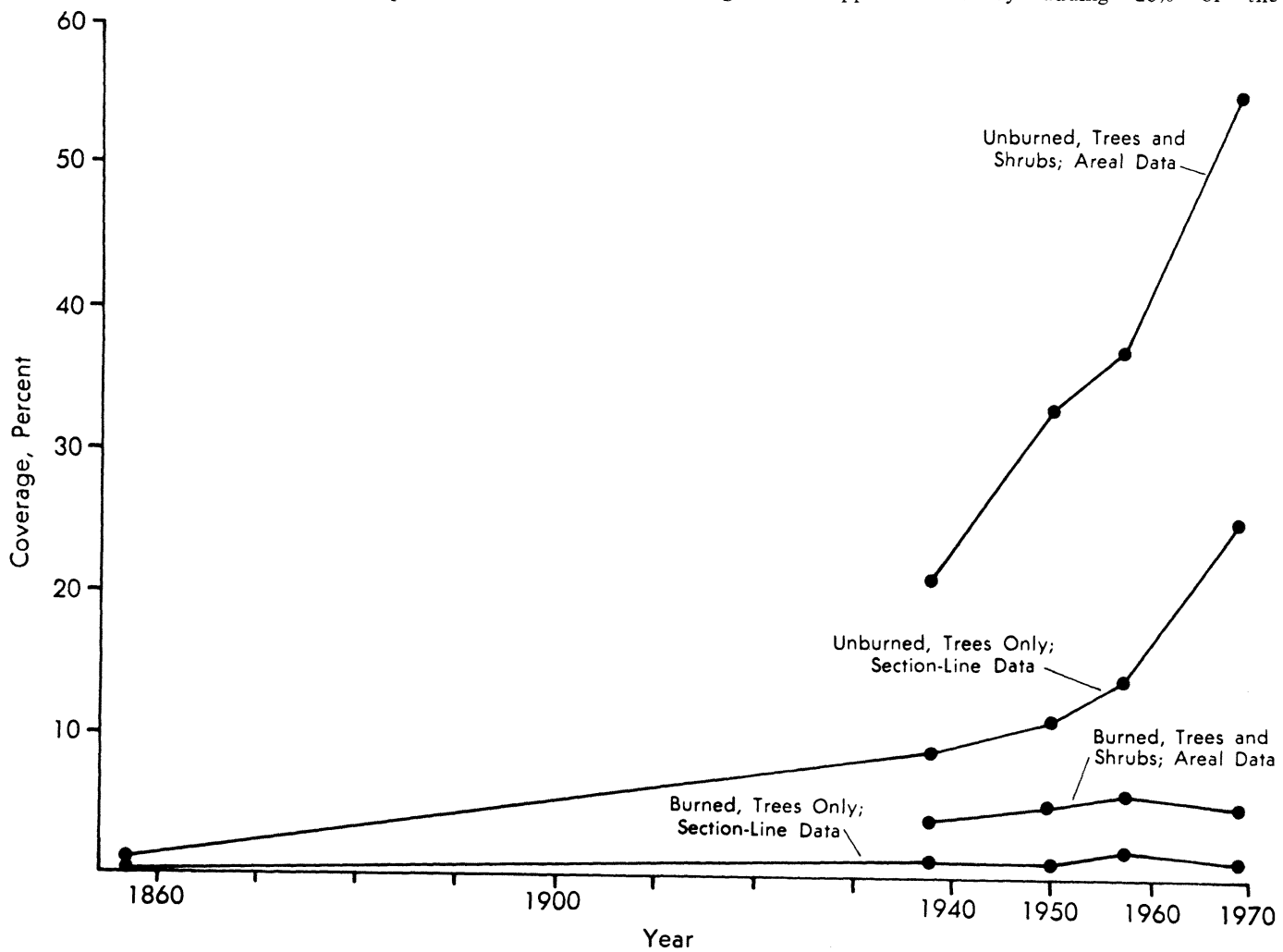


**Fig. 2.** *Average percent coverage of woody-plants on burned and unburned prairie sites, 1856 to 1969.*

Table 1. Average percent woody plant coverage ($\bar{x}$) from areal and section line data. n = number of sites.

| | | 1856 | 1937 | 1950 | 1956 | 1969 |
|---|---|---|---|---|---|---|
| Areal data: trees and shrubs | | | | | | |
| Unburned | $\bar{x}$ | – | 21 | 33 | 37 | 55 |
| | n | – | 5 | 5 | 5 | 3 |
| Periodically burned | $\bar{x}$ | – | 4 | 5 | 6 | 5 |
| | n | – | 5 | 5 | 5 | 5 |
| Sprayed beginning 1943 | $\bar{x}$ | – | – | 22 | 22 | 26 |
| | n | – | – | 2 | 2 | 2 |
| Section line data: trees only | | | | | | |
| Unburned (6 km) | $\bar{x}$ | 1 | 9 | 11 | 14 | 25 |
| | n | 4 | 4 | 4 | 4 | 2 |
| Periodically burned (14 km) | $\bar{x}$ | 0 | 1 | 1 | 2 | 1 |
| | n | 2 | 2 | 2 | 2 | 2 |
| Sprayed beginning 1943 (3 km) | $\bar{x}$ | 12 | 34 | 46 | 41 | 45 |
| | n | 2 | 2 | 2 | 2 | 2 |
| Undifferentiated (211 km) | $\bar{x}$ | 2 | – | – | – | 10 |

scattered-timber distance to the fully timbered distance.

Tree cover in 1856 and 1969 was obtained from 211 km (131 miles) of alternate, east-west section-lines to assess general trends in tree coverage on various soils since settlement. The section-lines evaluated were not differentiated into types of land-management (burning, spraying, grazing, etc.). Only that portion of Geary County south of the Kansas River was evaluated and cultivated or disturbed portions of the area were eliminated from consideration. Small portions of the study sites for which the management history was known were included in these data.

## Results and Discussion

### Effects of Burning

On periodically burned sites, woody plant cover is essentially restricted to presettlement amounts according to section line data for 114 years and areal data for 30 years (Fig. 2, Table 1). The slight increase in woody plants may have been permitted by less destructive fires resulting from reduced fuel as a consequence of cattle grazing.

Section-line data from uncultivated land in the southern portion of Geary County (not differentiated into burned, unburned, or other management practice) indicated that tree cover alone increased an average of 8% from 1856 to 1969 (Table 1). It is estimated that, since settlement, more than half the county has been burned intentionally, at least occasionally, but more than a third has been burned rarely, if at all.

Section-line data on prairie unburned for at least the last 30 years showed that tree cover alone increased 16%; areal data from the same sites indicated that tree and shrub cover combined increased 34%. Areal data from 1937 to 1969 indicated that, on unburned areas, increases in woody plant cover involved (1) increased density of woody plants on areas partially invaded in 1937, and (2) invasion of new area, as suggested by a 30% increase in the number of grid squares indicating some woody plant coverage; 35% of the grid squares indicated woody plant coverage in 1937 as compared to 65% in 1969. Grid squares with woody plants on regularly burned sites increased by only 2% during the same 30-year period.

These various findings support the hypothesis that burning, as a natural component of the Flint Hills environment, kept woody plants from invading the prairie.

Field observations indicate that invading woody plant species generally include many found in adjacent areas. American elm, redcedar, and chinquapin oak were found on many invaded areas. On all sites, major shrub invaders were smooth sumac (*Rhus glabra*), roughleaf dogwood (*Cornus drummondii*), and buckbrush (*Symphoricarpos orbiculatus*).

### Effects of Spraying

Two unburned study sites were sprayed with phenoxy herbicides in 1943 and 1944 and subsequently two consecutive years out of each six. Initial spraying considerably reduced the area covered by woody plants, but subsequent spraying did not result in substantial reductions (Table 1). Regrowth or resprouting of some species was observed while other species, notably redcedar, did not appear to be affected.

### Effect of Soil on Invasion of Unburned Sites

Woody plant invasion was strikingly greater on some unburned soils than on others (Figs. 3 and 5), but invasion was negligible on every soil when regularly burned (Fig. 4).

#### *Level-upland, Ridge-top, and Upper-slope Soils*

From 1937 to 1969, woody plant coverage increased only slightly on these nearly level to gently sloping, high-clay-content soils, indicating that invasion of these soils is very slow. Small redcedar and smooth sumac were found in a few areas on both Dwight and Irwin silty clay loam soils, indicating the potential for invasion. Shallowness and droughtiness of these soils probably accounted for the slow rate of invasion, although the great distance to established trees, and therefore a source of seeds, may also have had some effect. The decrease in coverage in 1969 resulted because we excluded two sites sprayed with herbicides after 1956 and on which woody plant coverage was greater than that on the other sites.

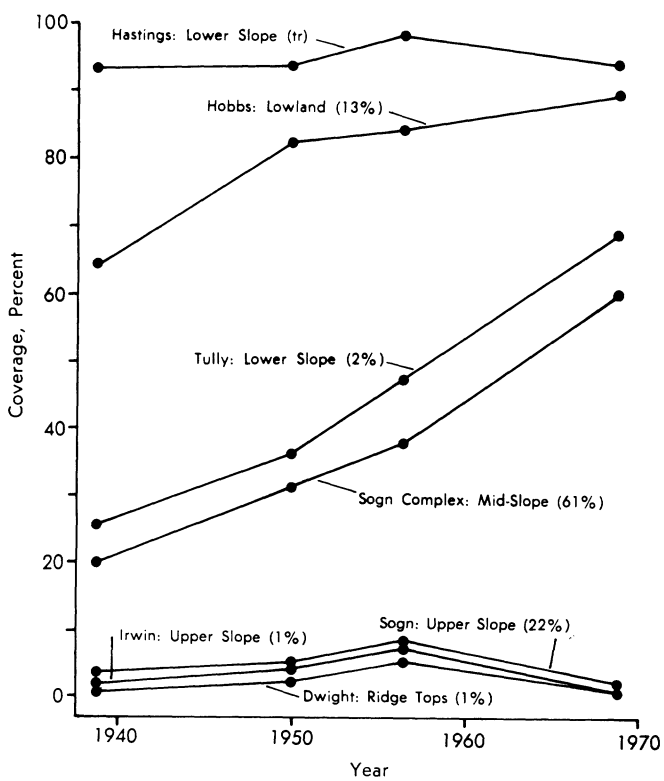


**Fig. 3.** *Average percent coverage of trees and shrubs on soils of unburned prairie sites. Numbers in parentheses indicate the average percent of all unburned sites occupied by the soil type.*

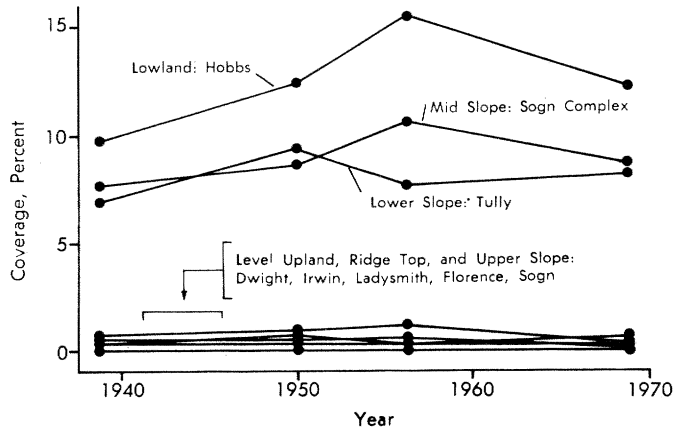


**Fig. 4.** *Average percent coverage of trees and shrubs on soils of regularly burned prairie sites.*

### *Mid-slope Soils*

Woody plant cover on Sogn complex soils increased by 40% from 1937 to 1969. Invasion of these soils represents the principal woody plant invasion in Geary County in that Sogn complex soils were common, averaging more than 50% of the total area of all study sites. Steep slopes with many rock outcrops characterize the soil complex. Occasional springs and generally permeable soils which facilitated water intake may have aided invasion. Other differences between mid-slope and upland soils that may encourage invasion are that (1) cattle graze steep areas much less than they do level areas, (2) mid-slope soils are closer to sources of woody plant seeds, and (3) rock outcrops on the slopes offer some protection for woody plants from grazing and fire.

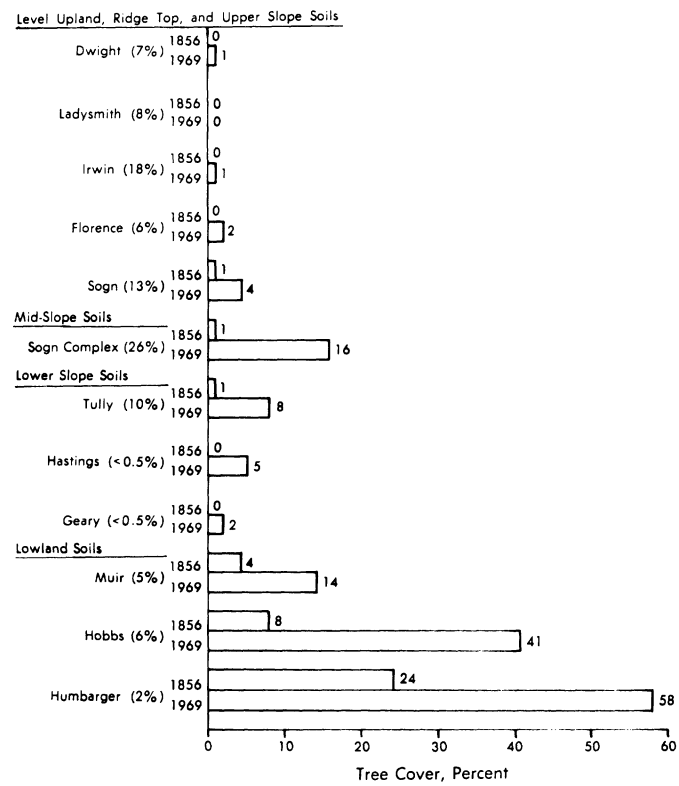


**Fig. 5.** *Tree cover in 1856 and in 1969 on various uncultivated soils along 211 km (131 miles) of section-lines in Geary County, Kans.; undifferentiated as to management. Percentage of total section-line is indicated in parentheses. Number after bar graph indicates actual percentage of tree cover. Not included in the bar graph under lowland soils were 7% of Muir, 3% of Hobbs, and 11% of Humbarger soils, which were forested in 1856 but cultivated in 1969.*

### *Lower-slope Soils*

Tully silty clay loam soil on unburned sites showed the greatest rate of increase in woody plant cover, increasing 42% from 1937 to 1969. Tully soils, which occupied only 2% of the rated area, were commonly located in small pockets or long, thin strips between lowland and mid-slope soils, and were close to seed sources: characteristics favorable for rapid invasion. The uncultivated Hastings silty clay loam, found only on one site, was already more than 93% covered by woody plants in the late 1930's when the first aerial photographs were taken; this suggests that it was rapidly invaded.

### *Lowland Soils*

Trees and shrubs covered 64% of the uncultivated Hobbs silt loam in 1937, had increased to 82% by 1950, and changed only slightly thereafter. Closeness of this soil to both forested areas and water explains the apparently rapid rate of invasion.

## Summary and Conclusions

This study in the Kansas Flint Hills showed that on unburned and unsprayed bluestem prairie, woody plants increased 34% from 1937 to 1969, in contrast to a 1% increase on burned areas. These results support the contention that burning was a natural factor in establishing and maintaining natural, bluestem prairie. Results on two sites aerially sprayed about seven times in 20 years indicate that without burning, herbicides would need to be applied more frequently to reduce woody plant coverage to presettlement amounts.

Soils and topography markedly affected the rate of woody plant establishment. Invasion was rapid on lowland, lower-slope, and steep, rocky soils; rate of invasion was slowest on upland soils having the highest clay content. Variations in soil textural characteristics, as well as distance to seed source, apparently control rate of woody plant establishment.

The results of this study show that controlled burning is a good management technique for preventing woody plants from invading bluestem prairie range.

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# Vegetation of a 25-Year Exclosure on the Edwards Plateau, Texas

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**Highlight**: *An evaluation was made of current species composition, production and 25-year vegetation trends within an exclosure on the Texas A&M University Agricultural Research Station at Sonora, Texas. Community composition was variable and most species responded individually to soil variables, particularly soil depth and degree and kind of stoniness. Common curlymesquite (*Hilaria belangeri*) was the most characteristic and widespread species of the area. Communities dominated by Texas cupgrass (*Eriochloa sericea*), on soils greater than 25 cm in depth, produced 4,330, 2,235, and 504 kg/ha in June and August 1972 and January 1973, respectively. Wright threeawn (*Aristida wrightii*) dominated communities with soil depths of 15 cm, produced 1,318, 1,349, and 413 kg/ha for the same dates; and hairy tridens (*Erioneuron pilosum*) sites with soil depths of 10 cm yielded 970, 1,456, and 84 kg/ha. Vegetation change over the past 25 years has been primarily adjustment in relative dominance of species rather than addition or loss of species. Following establishment of the exclosure some species adjusted to previous grazing history, and thereafter primary changes followed precipitation variation.*

Relict areas and historical documents are sources commonly used to ascertain the pre-settlement vegetation of an area (Clements, 1934; Larsen and Whitman, 1942; Dyksterhuis, 1958). Use of the relict concept, however, requires qualifications of specific climatic, edaphic, pyric, and biotic factors. Unless these factors are clearly defined, status of the vegetation may be subject to misinterpretations. For example, ecosystems known to have been influenced by large grazing animals and fire in the past are questionable representatives of the original vegetation if these factors are removed (Larsen, 1940; Daubenmire, 1968; Mason, 1970; Beetle, 1974).

Often native vegetation is significantly altered by man's activities before a detailed documentation is made of its characteristics. In these cases an alternative to the relict method is to establish exclosures which are protected against influences such as grazing and fire. Two major problems exist with interpretations of exclosures. Firstly, protection, as with relict areas, does not necessarily represent natural or optimum conditions. Secondly, an area once subjected to change by man may not, upon protection, revert to its original state. Kind, degree, and duration of the disturbance may profoundly affect vegetation changes that occur upon protection.

This investigation was designed to quantitatively evaluate the vegetation of a 25-year-old (established 1948) 16-ha livestock and deer exclosure on the Edwards Plateau, Texas. Specific objectives of the study were: (1) to determine herbaceous species composition and seasonal production for selected communities within the exclosure; (2) to relate plant distribution and abundance to edaphic variables; and (3) to construct patterns of vegetation change from records of the past 25 years.

## Study Area and Methods

The Sonora Research Station is located 56 kilometers south of Sonora, Tex., at an elevation of approximately 735 m. It is within the Edwards Plateau Resource Area of Texas (Godfrey et al., 1970). Average annual rainfall for 44 years at the Station is 55.7 cm, with peaks in May and September. Summers are hot with an average July temperature of 28.5°C, and winters are mild with an average Janaury temperature of

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The study was approved by the director, Texas Agr. Exp. Sta. as TA-11344.

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