CLIMAX VEGETATION AND SOILS OF THE BLACKLAND PRAIRIE OF TEXAS

A Thesis

By

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ABSTRACT

Climax Vegetation and Soils of the Blackland Prairie of Texas
(August 1972)

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In 1971 an extensive study was conducted of the climax vegetation of the Blackland Prairie of Texas. Eighty-three native hay meadows were sampled with quadrats and point quadrats during the summer of 1971. Twenty-four of these meadows were sampled for end-of-season production in November of 1971.

Three soil associations were recognized: the shallow Austin-Stephen-Eddy association; the vertic Houston Black-Heiden-Ferris; and the acidic Wilson-Crockett-Burleson.

Dominant grasses were determined to be *Andropogon gerardii*, *Eriochloa sericea*, *Paspalum floridanum*, *Schizachyrium scoparium*, *Sorghastrum nutans*, *Sporobolus asper* var. *asper*, *Tridens strictus* and *Tripsacum dactyloides*. It was determined that the majority of species populations produced a normal curve of distribution along a continually varying precipitation gradient. Since discontinuities existed between soil associations, species distribution tended to be generally discontinuous.

The Blackland Prairie was divided into seven major community types and a map of their location prepared. Based on dominant species distribution and production, east-west boundaries were

established by soil associations. The north-south boundaries tended to coincide with divisions produced by major streams. The Blackland Prairie was considered True Prairie, however, the two most mesic community types were identified as Tall Grass Prairie.

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INTRODUCTION

The vegetation of Texas is among the most diverse of any area in North America. Climates from humid subtropical to arid desert, numerous geologic substrates and related soils, as well as one of the longest settlement histories on the continent, all contribute to this diversity. The state is divided into 16 land resource areas based on similarity of soils, climate, topography and native vegetation (Godfrey, Carter, and McKee 1969). The vegetation of a few of the areas has been studied in detail, but there is a lack of systematic, quantitative ecological data for most. As a result of cultivation, overgrazing and other land use practices most areas have few, if any, remnants of climax vegetation.

It therefore seems desirable to obtain, where possible, ecological information about these native vegetation remnants before they are completely altered or eliminated. These data may prove useful in the maintenance and reestablishment of native communities.

The purpose of this study was to provide a systematic, quantitative description of the rapidly disappearing (Black 1969) climax vegetation of the Blackland Prairie (Fig. 1).

Specific objectives were: 1) to quantitatively describe species composition; 2) to determine end-of-season green herbage

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This thesis follows the style and editorial requirements of Ecological Monographs.

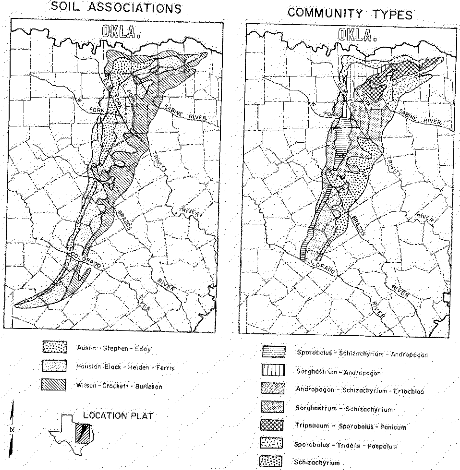


Fig. 1. Soil associations and plant community types of the Blackland Prairie of Texas.

production and 3) to relate composition and production to soil, climate and land use patterns. The study was conducted during 1970 and 1971.

LITERATURE REVIEW

Historical Resume

Presettlement

The Blackland Prairie was not often traversed by European expeditions because: 1) proposed routes for a railroad from the Mississippi River to the Pacific Ocean generally passed north of the Red River, and 2) most other expeditions in the state were to survey the Texas-Mexico boundary, which is considerably south of the Blackland (McKelvey 1955).

The earliest European to view the Blackland Prairie was De Mezieres who reported on an 1878 expedition to the Indian nations along the Trinity, Brazos and Red Rivers. He noted, "This is the best locality I have seen, because of the fertility of the soil and the abundance of pasturage. . ." (Bolton 1914).

The first American to write of the Blacklands was Dr. Henry Connelly on his Santa Fe Expedition in 1839: "Between the Brazos and the Red River, there is surely the most beautiful and picturesque region I have ever beheld. . . . The fertility of the soil is not to be exceeded by any I have ever seen; and, from the high and undulating character of the country, there can be no doubt of its being very healthy. . . ." (Moorehead 1954). Unfortunately, the only descriptive memoranda on the Blacklands from this expedition are aforementioned observations which were given to Josiah

Gregg for inclusion in Commerce of the Prairies. An extensive search for any remaining memoranda of Connelly on the Santa Fe Expedition has been unsuccessful.

Lt. R. B. Marcy led an expedition across the Blackland Prairie in 1854. Parker (1856) gives this account of their first impressions.

> After leaving Preston, we entered upon the vast plains, which stretching to the Cross Timbers, gave us a foretaste of our home.... From this point, there is but a house here and there and the little village of Gainesville, until we reach the Upper Cross Timbers.. . . Our road from the stream was gradually ascending and bounded on both sides by timber, when of a sudden we reached the top of the ridge.. . . O, the glorious beauty of that scene. Fancy would in vain attempt to paint it. Below ... lay a sea of pale green, hemmed in by timber of a darker hue; flowers of every variety, shade and form interspersed over the surface; a dark green belt of verdure here and there marking the ravines and watercourses and groves of trees, or clumps, or single trees, scattered in such perfect arrangement over the whole, as to seem as though some eminent artist had perfected the work.

Pope (1854) stated: "The most beautiful country I have seen . . . is watered by the Trinity and its tributaries . . . with a gently undulating surface of prairie . . . you are startled at the summit of each swell with a propensity of groves, parks and intervening plains of luxuriant grass.. . ."

Parker (1856) noted several different species: "I have frequently alluded to the beauty and variety of the prairie flowers. It is a treat to roam amongst them.. . . The Texas plume--gorgeous flower of a brilliant scarlet--the red and white rose, the prairie pink, the verbena, the marygold of many varieties, the convolvulus, "the ranunculus, the sensitive and other leguminous plants, the flag, the sunflower and the wild pea--all bloom together."

Hubbard (1885) wrote concerning vegetation in Lamar County: "Calimus grass is indigenous to the soil. Originally the blades averaged 4 ft. in height and the seed stems from 6 to 8 and covered the entire prairie region." Calimus grass is a name applied to *Tripsicum dactyloides*.

As early as the mid and late 1800's much of the prairie was mowed for hay. Hubbard (1885) wrote: "Messrs Berry Bros. producted [sic] and shipped from Lamar County, during 1884, 2,000 carloads of wild hay of excellent quality."

The unique characteristics and topographic features associated with certain soils in the Blackland Prairie were noted by early explorers. Kendall (1845) found gilgai (hog wallow) a hinderance when pursuing Indians: "We gave chase at once; but finding, after a race of some ten minutes, that they were going at least three yards to our two on the hog-wallow prairies . . . so-called from the roughness of the prairie in many parts. In some places, the ground has every appearance of being torn up by hogs--'rooted', I believe, is the expression--and hence the name."

McDanield and Taylor (1877) while traveling 2,000 miles across Texas on horseback had occasion to travel on gilgai soils and made some rather penetrating observations.

> The Prairie which has been seized upon . . . has also a peculiarity new to me. It is filled with saucer-like depressions, from the size of a wash-bowl to many feet

> in diameter. These are thought to resemble the wallows made by hogs in muddy places and hence this peculiar style of prairie is called 'hog-wallow' prairie. The depressions are so numerous that it looks as if the earth had suffered from a severe case of small-pox, but the pits rarely if ever run into each other. The soil upon this, as upon all other hog-wallow prairies, is the consistency and quite as sticky as tar. When in the hand it is of a sleek and unctuous feel, and has not a trace of sand. It is the very *creme de la creme* of fertility. It has a capacity for resisting drought beyond that of all other lands. When the crops on adjoining lands are withering under the scorching sun they still laugh with merriment on hog-wallow prairie.

Gregg (Fulton 1941) recognized the droughty character of soils of the present-day Wilson-Crockett Burleson association when compared with the Houston Black-Heiden-Ferris association: "The soil of the high prairies is very black and deep. Some of the prairies it is true are of a grayish soil which generally produces badly--some of them are singularly listed with narrow streaks of yellow clayish soil which produce badly, whilst the interstices of black soils are rich and fertile."

Gregg in 1841 wrote of grass on soils now known as the Wilson-Crockett-Burleson association: "A good deal . . . . is cold gray unproductive soil inclined to be covered with *wire grass*." (Fulton 1941). Wire grass is the local name for *Sporobolus silveanus*.

Bailey (1892) described the mima mounds in the northern portion of the Blackland Prairie: "Left Texarcana . . . good prairie, broad smooth and grassy, yellow with flowers.. . . From New Boston and Anona circular mounds are scattered all along irregularly. They are 30 to 60 feet across and 4 to 6 feet high, circular and even in "outline, often cover a third of the land.. . . I can suggest no good origin for these mounds."

Postsettlement

Riverbottom overflow areas had certain characteristics which made them choice homesteads for early settlers. The alluvial soil was sandy and did not present the cultivation problems of upland soils. Moore (1840) reported other advantages.

> In the bottoms . . . are many prairies which are covered with a dense growth of weeds, instead of grass; from this fact, they are styled weed prairies. The soil of these prairies is extremely fertile, and is so light and friable that after the weeds have been burned off, a person may easily plant it merely by kicking it open with the shoe. The settlers prize these prairies very highly on account of the fertility of the soil and the facility of cleaning them. They merely burn off the weeds, and then with a light hoe plant the maize, without ploughing.. . . The weeds which cover them, chiefly belong to a species of Indian hemp or flax.

De Cordova (1858) reported on the weed prairies, ". . . it being of class known both far and wide as the celebrated weed-prairie for which, facility of cultivation and immense yield is not to be surpassed . . . valuable as the weed-prairies were for cultivation, it was almost folly for any person to attempt to build his habitation near them . . . but build their houses on the sides of the beautiful hills which surrounded them--thus obtaining the advantages of pure air, uncontaminated with malaria.. . ."

These weed-prairies probably resulted from the yearly stream flooding and from overgrazing by cattle herds mentioned by

De Mezieres (Bolton 1914): "I crossed the Colorado and Brazos where there are . . . incredible numbers of Castilian cattle, and herds of mustangs that never leave the banks of these streams."

When tillage equipment advanced to the point the soils of the Blacklands became arable, settlers found the soil highly productive and cultivated the land for production of wheat, corn, and other food crops (Roemer 1849, Bizzell 1924). By 1880, intensity of land use had advanced to the point the Blacklands were no longer considered cattle range (Nimmo 1885). Improved tillage methods soon made possible introduction of fiber crops, primarily cotton (Bolton 1914).

A steady influx of people occurred, and by 1910 the region supported a higher population density than any other area of comparable size west of the Mississippi River (Goldenweiser 1919). The Blackland Prairie continued to sustain a large rural population through the early 1900's (Bonnen and Thidobeaux 1937), but the great drought of the 1930's forced many people to move to urban areas. This migration spawned an urban growth that continues today (Chambers 1946). In all, slightly over 10% of the land area is classified as urban (Texas Soil and Water Conservation Needs Committee 1970a). Current figures indicate 1,725,000 ha or 68% of the land is cultivated with an additional 850,000 ha or 22% in tame pasture (Texas Soil and Water Conservation Needs Committee 1970b).

Vegetation Classifications

The Blackland Prairie, because of its extent, has been included in numerous treatments of North American Midcontinental Grasslands. Merriam (1898) included the Blackland Prairie in his Austroraparian or Humid Division of the lower Austral Zone. Bailey (1905) provided a detailed description of the fauna coupled with a general vegetational treatment. In a more recent study, Blair (1950) included the Blackland Prairie in his Texian Life Zone. Tharp (1926) in a general description of Texas vegetation east of the 98th meridian referred to the Blackland Prairie as an *Andropogon-Stipa-Aristida* Association, based on dominants of successional stages. A recent treatment by Küchler (1964) recognized the Blacklands as an *Andropogon-Stipa* Association. The classification scheme of Shantz and Zon (1924) delineated the Blackland Prairie as Tall Grass Prairie as did a broad physiognomic treatment by Penfound (1967).

Carpenter (1940) recognized the Blacklands as Tall-Grass Prairie and considered *Sorghastrum nutans* the binding dominant. In the gradient classification system of Livingston and Shreve (1921) the Blackland Prairie was considered grassland-deciduous forest transition. Some general classification systems included the Blacklands as a component of the Coastal Prairie (Weaver and Clements 1928, Clements and Shelford 1939). Dodd (1968) in a general treatment of North American grassland associations included the Blackland Prairie as an extension of the True Prairie, as did

Allred and Mitchell 1954, Allred 1956) in more restricted descriptive works. The San Antonio Prairie, a large island of the Blackland Prairie in the Oak-Hickory Association (McCaleb 1954), has been identified as a part of the True Prairie (Launchbaugh 1955) and similar to the Fort Worth Prairie as described by Dyksterhuis (1946). No quantitative studies of the climax vegetation of the Blackland Prairie have been conducted.

STUDY AREA

Location and Extent

The Blackland Prairie is one of the major land resource areas of Texas (Godfrey, Carter, and McKee 1969) (Fig. 1). It is generally described as a narrow band bordered on the north by the Red River and the east by the East Texas Timberlands. The Eastern Cross Timbers clearly define the western boundary as far south as the Brazos River, but the delineation is geologic rather than topographic between the Brazos and Colorado Rivers (Hill 1901, Carter 1931, Johnston 1931). It extends southward into Bexar County, but the Colorado River will be recognized as the southern boundary in this study. The Prairie is approximately 70 km across the north between the Trinity and Red Rivers, while southward it narrows to about 12 km. It covers an area of over 4,260,000 ha (Godfrey, Carter, and McKee 1969, Gould 1969, Austin 1970, Texas Soil and Water Conservation Needs Committee 1970a). Inventories often include with the main Prairie several outlier prairies, the largest of which are the Fayette and San Antonio Prairies (Johnston 1931). Only the main belt is included in this investigation and will be referred to as the Blackland Prairie or Blacklands.

The Blackland and Grand Prairies, because of similar soil texture and coloration were considered a single unit for some time. However, while the Blackland Prairie sustained a farming culture, the soils of the Grand Prairie were too rocky and shallow for agronomic purposes and a ranching economy developed. Primarily because of land use differences the two areas were soon recognized as separate land resource areas (Bray 1901, Hill 1901, Greer 1935).

Climate

Climatic gradients are distributed north to south in the Blackland Prairie. Average annual precipitation varies from 135 cm in the north to 75 cm in the south. Probability of receiving 100 cm or more precipitation decreases from 65 to 30% along the same gradient (Tucker and Griffiths 1965). Virtually all precipitation occurs as rain with May and September peaks (Carr 1967). The growing season decreases from north to south and varies from 260 to 290 days (Blood and Hildreth 1958). January and July mean temperatures vary from 19°C and 52°C in the northernmost portion to 23°C and 53°C along the Colorado River (Carr 1967).

Topography

The Blackland Prairie, because of the vectorial effect of dip plains influenced by both the eastward continental slope from the Rocky Mountains and southward tilt of the Red River tip plain, has a coastward or southeastward orientation. The relief of the Blackland Prairie is gently undulating and is marked by numerous mammillary hills with gently rounded slopes. Hill (1901) commented: "When the wide extent of the Blackland Prairie as a whole is considered, the general slope is remarkably uniform--more so than any "other large area in the country.. . ." The elevation gradient across the Blacklands reflects this uniformity. It ranges from 250 m on the western boundary to 130 m in the east and represents an average change of 0.4 m/km compared to 8 m/km in the Fort Worth Prairie to the west of the Blacklands (Dyksterhuis 1946).

Four major streams dissect the summit slope of the Blacklands. From north to south they are the Red, Trinity, Brazos and Colorado Rivers. These streams may be segregated into two general types: 1) through-flowing rivers--the Red, Brazos, and Colorado, which enter the region from the west and flow across; and 2) a system of less copious locally developed streams, the largest of which is the Trinity. The through-flowing rivers, which descend from the Grand Prairie, cross the Blacklands in deeply indented valleys cut far below the general flat-topped upland divides and have a low profile and flattened gradient. Short tributaries fringe these streams, but have not made sufficient headward progress to the divides of the original plain to destroy the summit level. It should be noted that the riverbottoms are not considered part of the Blackland Prairie (Carter 1931, Godfrey 1964).

Geology

A large inland sea covered the Blackland Prairie during Cretaceous times. As the Laramide Uplift occurred during the Late Cretaceous the sea receded to the south and east, alternately depositing strips of arenaceous and calcareous materials. Thus, the

Western and Eastern Cross Timbers (arenaceous material) represent the basal sands of the Grand and Blackland Prairies (calcareous material), respectively. Geologic sediments are more recent from west to east, due to the retreat of the sea in that general direction to form the Gulf of Mexico (Hill 1887).

Geologically, the Blackland Prairie may be longitudinally subdivided into five parallel north-south units. These divisions, from west to east are the Eagle Ford, Austin, Taylor, Navarro and Midway Groups (Hill 1901).

The Eagle Ford Group forms a thin band extending from the Red to the Brazos River. South of the Brazos River it becomes intermittent, gradually narrowing and disappearing at the Colorado River (Hill 1901). This is the lowest Upper Cretaceous formation in central Texas (Cuyler 1931) and consists of well laminated shales (Sellards, Adkins, and Plummer 1966).

Bordering the Eagle Ford Group on the east is the Austin Group. This area of hard rock is known as the Austin Chalk and extends from Sherman to Austin as a narrow strip a few miles in width (Hill 1901). This group consists of irregular strata of unlaminated, indurated gray-white limestone and softer layers of dark blue marly limestone (Sellards, Adkins, and Plummer 1966).

The Taylor Group forms a transitional eastern boundary with the Austin Group. This formation is the largest geologic subdivision of the Blackland Prairie and forms the center of the Blacklands south of Red River County. It gives the Prairie its general configuration and lesser groups on the east and west merely define its features. The Taylor Group is characterized by light blue chalk, called "soapstone" and "joint clay" by area residents because of its jointed and laminated structure (Roark 1921).

The Navarro, uppermost group of the Upper Cretaceous, borders the Taylor Group on the east and is comprised primarily of calcareous shaly clays, sandy clays, fine grain sands and argillaceous sands with indurated portions in the form of calcareous septaria of concretionary sandstone layers (Stephenson 1918). This division extends along a narrow belt from the Red River to Williamson County.

Forming the easternmost geological subdivision of the Blacklands, the Midway Group extends from Red River to Travis County. This group is characterized by medium to fine-grained calcareous sandstone, soft gypsiferous clays, and hard indurated limestone lentils (Sellards, Adkins, and Plummer 1966)

Soils

The great variety of parent materials within the Prairie results in associated soil diversity. To facilitate discussion, soil series possessing similar physical and chemical properties and exhibiting like behavior are grouped to form associations. These associations generally correlate with parent material. They are from west to east: Austin-Stephen-Eddy, Houston Black-Heiden-Ferris, and Wilson-Crockett-Burleson (Fig. 1).

Austin-Stephen-Eddy Association

Derived from the Austin and Eagle Ford Groups, soils of this association are brown silty clays and clay loams and are thermic, carbonatic and shallow. They are basic with a $CaCO_3$ equivalent of 24%. Cation exchange capacity varies between 35 and 40 me/100 g. The principle exchangeable cations are magnesium (1.0 me/100 g) and potassium (1.0 me/100 g) (Carson 1970). The "A" horizon has a maximum depth of 37.5 cm and the "C" horizon occurs within 75 cm of the surface. Differentiating characters are chalk fragments and $CaCO_3$ concentrations in lower portions of the control section (solum). These soils are considered "droughty" (Brooks et al. 1964) and plants may experience severe moisture stress during summer months. This association represents the shallowest and least productive soils of the Blackland Prairie. The Austin series is used to typify this association.

Houston Black-Heiden-Ferris Association

This association includes the soils from which the Blackland Prairie derived its name. These are Vertisols developed from the Taylor Marl and Navarro Groups. These soils have no "B" horizon. The transition is from "A" to "AC." They share fine montmorillonitic, thermic and ustertic properties. Soils of this association are basic with a $CaCO_3$ equivalent of 6%. Cation exchange capacity varies from 60 to 65 me/100 g. Magnesium (4.2 me/100 g) is the most abundant exchangeable cation, with potassium (0.8 me/100 g) the least abundant (Carson 1970). These soils are very hard when dry, becoming extremely plastic when wet. Moisture stress conditions are somewhat buffered by these soils. Moisture extremes do not induce a marked response--crops produce only slightly more in years of above average rainfall than in years of below average rainfall (Brooks et al 1964). This association covers by far the largest percentage of the Blackland Prairie (Texas Soil and Water Conservation Needs Committee 1970b) and has long been considered typic of and the standard for the region (Parker 1856, Bizzell 1924, Carter 1931, Godfrey 1964). This association also represents the largest continuous assemblage of Vertisols in the world (Dudal 1965).

Montmorillonite is the dominant clay mineral in these soils and the 2:1 lattice structure gives them high shrink-swell potential. When dry, the clays contract (shrink) resulting in development of broad, deep cracks. Studies have shown that evaporation from shrinkage cracks may equal or exceed that from surface soil (Adams and Hanks 1964). Soil particles fall or are washed by rain into these fissures and partially fill them. The soil mass expands again when wet, but cannot reoccupy the cracks, so some part of the soil mass is forced upward. Pressures resulting from the force exerted by expansion cause the sliding of one mass of soil past another which produces polished and grooved surfaces called "slickensides". A parallelepiped structure forms. This movement of soil gives rise to a characteristic microrelief of low mounds and shallow depressions referred to as gilgai. On slopes of less than 5% gilgai topography is characterized by circular micro-depressions while on slopes greater than 5% it consists of continuous curving banks and depressions aligned approximately parallel to the maximum slope (Beckman, Hubble, and Thompson 1970).

Contraction and expansion of these soils bring about a slow churning of the whole soil mass to the depth of the fissures. Thus, the soil is gradually overturned to some depth and is said to "plow itself" or be "self-mulching" or "self-swallowing". For this reason Oakes and Thorp (1950) suggested these soils be called Grumusols (*grumus*, low hill + *sol*, soil), but in the mnemonic system of naming soils employed in the 7th Approximation (Soil Survey Staff 1960) they are referred to as Vertisols (*verto*, to invert or turn).

For gilgai formation the material must be capable of movement in the plastic state. Chemical properties, particularly sodium ion concentration, clay content and amount of organic matter all influence plasticity (Winterkorn and Moorman 1941, Aitchison 1953, Winterkorn 1953, Hallsworth, Robertson, and Gibbons 1955, Mielenz and King 1955, Page 1955).

Contact between the "A" and "AC" horizons is cyclic due to gilgai formation. This boundary is well-defined in upland soils because the "A" horizon, stained with organic matter, appears dark while the "AC" horizon, lacking organic matter is of a lighter hue. Where these soils have been transported to form floodplains or "bottomlands" slickensides and parallelepiped structure are encountered but because the entire soil mass consists of dark surface soil the subsurface waviness is difficult to detect visually. The Houston Black series typifies this association.

Wilson-Crockett-Burleson Association

These soils, derived from the Midway Group, are dominant in the northern and eastern portion of the Prairie. The area covered by this association is called "Graylands" (Godfrey 1964) because of neutral to slightly acid gray, loamy and clayey soils usually characterized by massive, very hard fine sandy loam "A" horizon. An abrupt change to an extremely hard mottled clay "Bt" horizon and an olive "C" horizon occur. Although deep, soils of this association are considered "droughty" and have limited water-holding capacity (Brooks et al. 1964). These soils are acid in the surface layer with a cation exchange capacity of approximately 20 me/100 g. Exchangeable cation content ranges from 12.6 me/100 g for calcium to 0.4 me/100 g for potassium (Carson 1970). The Wilson series typifies the soils in this association which are loamy in the surface; the Burleson series typifies the ones which are clayey throughout.

In the northern parts of this association irregular rounded mounds are encountered. These "mima mounds" are totally different from gilgai topography and may be 3 or 4 m high and 9 meters wide. The name is derived from a county in ~~Oregon~~ wash where they were first intensively studied (Ritchie 1953, Olmstead 1963). Although these mounds occur extensively in western North America

(Barnes 1879, Nikiforoff 1941, Arkley and Brown 1954), they have never been reported east of the Mississippi River. Despite their wide geographical distribution, mima mounds found in all areas are similar (Kritinitzsky 1949). Studies of the origin of mima mounds have resulted in a myriad of theories; none are commonly accepted.

METHODS AND MATERIALS

Stand Selection

With the assistance of the U. S. Soil Conservation Service (SCS), a survey employing the Relict Method described by Clements (1934) was conducted the winter of 1970 to determine the extent and distribution of native vegetation in the Blacklands. All vegetation remnants reported were native hay meadows. These hay meadows were noted by Tharp (1926): "A few native hay meadows have been preserved and constitute accurate representation of the composition of the original prairie vegetation as the pioneer first saw it." Similar observations were made by Bailey (1890) and Johnston (1931).

Each remnant reported by the SCS as well as those located through a reconnaissance of the area were considered for study. Each remnant was considered to be one stand unless topographic or edaphic factors warranted its division into more than one stand. Only upland sites were used; bottomlands and overflows were excluded. To be selected a stand must: 1) have unbroken native sod; 2) be large enough that vegetation was not affected by agronomic treatments or other edge effects; 3) exhibit visual homogeneity of vegetation; 4) be ungrazed during the growing season; 5) not be mowed more than once during the growing season; 6) never have been interseeded; and 7) have no history of pesticide treatment. Areas satisfying these requirements were accepted as stands. Of the 360 remnants reported, 83 satisfied these criteria and were representative of climatic and edaphic variations across the Blacklands. Stand size varied from 2 to 500 ha but most were about 20 ha.

Many factors such as mowing, grazing and fire have differential effects upon vegetation composition and production (Dix 1964). However, there is little doubt that hay meadows are the best remaining approximation of the climax vegetation of the Blackland Prairie (Bailey 1892, Tharp 1926, Johnston 1931). All meadows are mowed annually in late June or early July. This time of cutting not only allows most of the vegetation to develop beyond the critical early spring growth period, but is prior to seedstalk formation of the major grasses so that after removal of the hay crop plants make new growth and complete their life cycle.

Vegetation Measurements

Species frequency and basal cover were measured in each stand. All samples were taken between May 10 and July 20, 1971. Sampling was initiated in the southernmost portion of the Blacklands and progressed northward to minimize phenological variation. Frequency was determined by taking 30 rectangular 0.5 m^2 (100 × 50 cm) quadrats per stand similar to techniques employed by Dix and Smeins (1967) and Nicholson and Hulett (1970). Basal cover was measured with 300 single vertical point quadrats per stand (Goodall 1952). Quadrats and point quadrats were positioned in a stratified random manner throughout each stand. For example, transects were arbitrarily established at equidistant intervals so all portions of a stand were traversed. Point quadrats and quadrats were located at random along these transects.

Samples of 30 quadrats and 300 points were arrived at by intensively sampling one stand to determine the optimum sample number. For quadrats successive intervals of 10 quadrats up to 50 were analyzed and it was shown that absolute frequency did not change appreciably after 20 quadrats and few additional species were encountered. Likwise, successive samples of 50 points showed that after 250 points species composition for the top 3 species exhibited little change. Since point quadrat sampling was designed to determine only dominant species, it was felt that 300 points was an adequate sample.

Twenty-four stands were sampled for end-of-season production in a manner similar to that of Ralston and Dix (1966). Five 0.125 m^2 (50 × 25 cm) quadrats placed randomly along a transect through the center of the stand were clipped. Clipping was conducted the first week in November 1971. Plants were clipped at ground level and segregated, in the field, into species for the grasses while forbs were segregated into annuals and perennials. Samples were oven-dried for 48 hours at 70°C. Values are reported as kilograms (kg) of oven-dry weight per hectare (ha).

Quadrat data provided a measure of species distribution and species diversity, while basal cover and production values provided measures of species dominance within each stand.

Taxomonic nomenclature follows Gould (1969). Varietal

Soils Measurements

Soil samples approximately 10 × 10 × 38 cm were taken of the solum from a representative location in each stand and analyzed for texture by the hydrometer method, pH, available water (1/3-15 bars) using matrix suction and bulk density by the weight to volume ratio (Black 1965). Soil profiles for selected stands within each soil association were described in the field with the help of SCS soil scientists.

RESULTS

Soils

Pits were excavated and soil profiles described for typic soils in each association (Fig. 1). These profiles did not significantly differ from those published by the Soil Conservation Service. Physical characters measured were similar to those previously reported (Carson 1970) and are summarized in Table 1.

Austin-Stephen-Eddy Soils

For the 15 surface (10 × 10 × 38 cm) samples collected, sand content was negligable (Table 1). Average moisture retention was 14%, varying from 35% at 1/3 bar to 21% at 15 bars. Average pH was 7.8. Few samples deviated more than 20% from the mean values. Average chroma for this soil (surface) was 10 YR 6/1. A pit was excavated in Bell County to describe an Austin profile.

Horizon	Description
A1	0-38 cm -- Dark grayish brown (10 YR 4/2) silty clay, very dark grayish brown (10 YR 3/2) moist; weak fine granular and subangular blocky structure; hard, firm but crumbly, sticky, plastic; many roots; many fine and very fine pores; many worm casts; few fine $CaCO_3$ concretions; calcareous moderately alkaline; gradual smooth boundary.
B21	39-66 -- Brown (10 YR 5/3) silty clay, dark brown (10 YR 4/3) moist; moderate fine subangular blocky structure; hard, firm crumbly, sticky, plastic; few roots; many fine pores; many light yellowish brown (2.5 Y 6/4) worm casts; common fine $CaCO_3$ concretions; few fine chalk fragments; calcareous, moderately alkaline; clear smooth boundary.

TABLE 1. Some physical characteristics of Blackland Prairie soils

	Soil associations					
	Austin-Stephen-Eddy		Houston Black-Heiden-Ferris		Wilson-Crockett-Burleson	
Number of samples	15		37		31	
Soil characteristics	Mean	Range	Mean	Range	Mean	Range
Texture (%)						
Sand	2	0- 5	2	0- 4	14	9-24
Silt	43	37-48	37	29-41	55	48-60
Clay	55	48-61	61	56-66	31	27-34
Moisture retention (%)						
15 bars	21	16-27	43	34-50	13	8-20
1/3 bars	35	32-40	60	54-67	28	22-31
Available	14	12-16	17	15-21	15	13-19
pH	7.8	7.7-7.8	7.7	7.6-7.9	5.4	5.0-5.9
Chroma	10 YR 6/1		10 YR 3/1		10 YR 5/2	

B22	66-75 cm -- Brown (10 YR 5/3) silty clay, dark brown (10 YR 4/3) moist; moderate fine subangular blocky structure; hard, firm, sticky, plastic; few roots; common worm casts, about 30 per cent platy chalk fragments less than 3 inches in the axis; calcareous, moderately alkaline; clear irregular boundary.
C	75-90 cm -- White (10 YR 8/2) and very pale brown (10 YR 8/4) platy chalk that is less hard than 3, Moh's scale; few thin tongues of brown silty clay in crevices between chalk plates.

Houston Black-Heiden-Ferris Soils

Thirty-seven samples of these soils were analyzed (Table 1). Clay was the dominant component (61%) and sand negligable (2%). Available moisture averaged 17%, from a 1/3 bar capacity of 60% to 43% at 15 bars. These samples had a mean pH of 7.7 and chroma of 10 YR 3/1. A pit was excavated in Bell County to describe a Houston Black profile.

Horizon	Description
A11	0-20 cm -- Very dark gray (10 YR 3/1) clay, black (10 YR 2/1) moist; moderate fine subangular blocky and moderate medium granular structure; extremely hard, very firm, very sticky and plastic; many fine roots; common worm casts; few snail fragments; shiny ped faces; few fine black weakly cemented iron manganese concretions; few fine strongly cemented $CaCO_3$ concretions; calcareous in matrix; moderately alkaline; clear wavy boundary.
A12	21-60 cm -- Very dark gray (10 YR 3/1) clay, black (10 YR 2/1) moist; moderate fine and very fine angular blocky structure remaining characteristics same as horizon above; gradual wavy boundary.
A13	61-95 cm -- Dark gray (10 YR 4/1) clay, very dark gray (10 YR 3/1) moist; coarse grooved intersecting slickensides that form parallelepipeds; common

fine roots; remaining characteristics same as horizon above.

AC1 96-200 cm -- Grayish brown (10 YR 5/2) clay, dark grayish brown (10 YR 4/2) moist; with few medium distinct mottles of olive brown (2.5 Y 4/4), and many coarse faint mottles of gray (10 YR 5/1); structure and consistence same as horizon above; few fine roots; few worm casts; shiny ped faces; few streaks of dark gray from above, few fine black weakly cemented concretions and fine brown masses of iron-manganese; few fine and medium strongly and weakly cemented $CaCO_3$; calcareous in matrix; moderately alkaline; gradual wavy boundary.

AC2 201-265 cm -- Distinctly and coarsely mottled light olive brown (2.5 Y 5/4) and gray (10 YR 6/1) clay; common fine mottles of olive brown; weak medium and coarse angular blocky structure; few intersecting slickensides that form parallelepipeds; very hard; very firm; very sticky and plastic; few fine roots; few fine brown masses of iron-manganese; few powdery masses of $CaCO_3$; calcareous in matrix; moderately alkaline.

Wilson-Crockett-Burleson Soils

The 31 samples collected from the Wilson-Crockett-Burleson association were markedly different from other samples (Table 1). Silt was the primary constituent (55%) and sand the least abundant (14%). However, this sand value represented a considerable increase over the other soils. Available moisture values averaged 15%; from 28% at 1/3 bar to 13% at 15 bars. The average pH value was 5.4 and chromas averaged 10 YR 5/2. These soils deviated only slightly from the mean, with the exception of two Burleson collections (Table 1). These are physically similar to the Houston Black-Heiden-Ferris type soils, but chemically similar to the Wilson-

Crockett soils. While textural values were different from the Wilson and Crockett samples, the moisture retention was not appreciably different. A pit was excavated in Lamar County to describe a Wilson profile.

Horizon	Description
A1	0-13 cm -- Dark gray (10 YR 4/1) clay loam, very dark gray (10 YR 3/1) when moist; weak, fine, granular structure; friable when moist, very sticky and plastic when wet; many worm casts; many medium pores; many fine, fibrous roots; pH 6.3; abrupt boundary.
B21tg	14-80 cm -- Very dark gray (10 YR 3/1) silty clay, gray (10 YR 5/1) dry; moderate medium blocky structure; extremely hard, very firm; few fine pores; continuous clay films 1/2 unit of value darker than ped interiors; vertical cracks are filled with material from the A1 horizon slightly acid; gradual wavy boundary.
B22tg	81-125 cm -- Grayish brown (2.5 Y 5/2) silty clay, light brownish gray (2.5 Y 6/2) dry; moderate medium blocky structure; extremely hard, very firm; few fine pores; continuous thin clay films on peds; few small pressure faces; vertical cracks partly filled with material from above; few fine gypsum crystals; few fine strongly cemented $CaCO_3$ concretions; mildly alkaline; diffuse wavy boundary.
B3tg	126-163 cm -- Grayish brown (2.5 Y 5/2) silty clay, light brownish gray (2.5 Y 6/2) dry; weak coarse blocky structure; extremely hard, very firm; patchy clay films on peds; common fine gypsum crystals; few soft bodies of $CaCO_3$; mildly alkaline; gradual smooth boundary.
C	164-235 cm -- Olive gray (5 Y 5/2) silty clay, light gray (5 Y 7/2) dry; massive; extremely hard, very firm; few soft coarse bodies of $CaCO_3$; few small shale fragments; calcareous, moderately alkaline.

It should be noted that sand content for the Austin-Stephen-Eddy and Houston Black-Heiden-Ferris soils may exert even less influence since the vast majority of the sand is < 0.25 mm and behaves as silt (Carson 1971).

Vegetation

One hundred and twenty-three species and varieties were identified in this study. There were an average of 41 species per stand encountered in quadrats. Average basal cover for all stands was 29% (13-44%) and end-of-season above ground production averaged approximately 6,500 kg/ha (1,500-10,000) of oven-dry forage (Table 2, Fig. 2).

A regression of percent composition based on end-of-season production and on percent composition based on basal cover for dominants in 24 stands was calculated to determine if the values could be used interchangeably to describe dominant species (Fig. 3). The regression had an r value of 0.966 ($p < 0.0$)

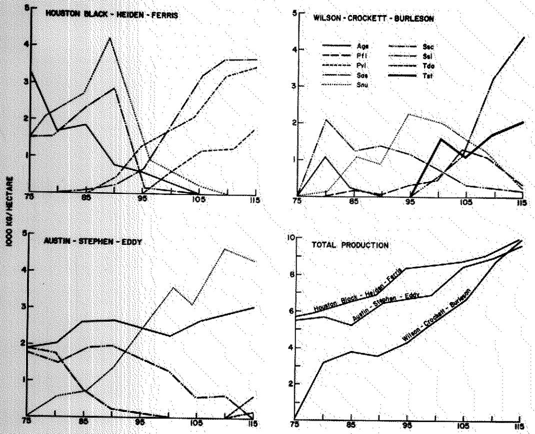
This relationship showed that not only could basal cover and production be used more or less interchangeably to describe dominant species, but also indicated that early season basal cover values can be used to predict late season production values. Because of this high correlation, basal coverage (Table 2) will be used to describe dynamics of dominant species since this measure is available for all 83 sampled stands.

Dominant species of the Prairie were defined as those with a

TABLE 2. Average species composition (%) based on basal cover in relation to soil associations and precipitation. Only species with greater than 20 percent basal cover in at least one stand are included.

	Soil associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average annual precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115
Number of stands	15				37				31			
SPECIES												
Andropogon gerardii												
Mean	31	39	32	44	33	9	--	1	4	--	--	--
Range	28-36	33-48	18-45	36-48	27-42	6-15	--	0- 3	0- 6	--	--	--
Eriochloa sericea												
Mean	--	--	--	--	22	4	--	--	--	--	--	--
Range	--	--	--	--	12-27	0-15	--	--	--	--	--	--
Panicum virgatum												
Mean	--	--	--	1	--	--	14	16	--	--	--	--
Range	--	--	--	0- 6	--	--	0-30	9-21	--	--	--	--
Paspalum floridanum												
Mean	--	--	--	--	--	--	--	--	5	9	9	17
Range	--	--	--	--	--	--	--	--	1- 9	3-18	0-24	6-27
Schizachyrium scoparium												
Mean	27	35	16	4	37	23	--	--	81	37	26	--
Range	21-33	30-42	6-24	0-9	30-48	9-36	--	--	[illegible]-92	33-48	21-30	--
Sorghastrum nutans												
Mean	4	23	45	49	5	40	3	--	[illegible]	43	54	4
Range	0- 6	21-27	42-52	45-57	0-18	27-59	0-12	--	0-24	32-57	45-66	0-15
Sporobolus asper var. *asper*												
Mean	35	2	--	--	--	12	45	43	--	--	--	--
Range	27-42	0- 9	--	--	--	0-33	27-60	36-57	--	--	--	--
Sporobolus silveanus												
Mean	--	--	--	--	--	--	--	--	--	--	1	57
Range	--	--	--	--	--	--	--	--	--	--	0- 6	15-82
Tridens strictus												
Mean	--	--	--	--	--	--	--	--	--	--	3	21
Range	--	--	--	--	--	--	--	--	--	--	0- 6	12-33
Tripsacum dactyloides												
Mean	--	--	--	1	--	9	27	30	--	--	--	--
Range	--	--	--	0- 6	--	0-24	18-39	23-48	--	--	--	--
Total species composition	97	99	93	99	97	97	89	98	96	89	93	99
Average % basal cover	34	29	30	24	28	25	27	30	35	28	26	29

Fig. 2. Total production and dominant species production for each soil association in relation to precipitation. Each point represents data for only one stand. Species associated with abbreviations are: Age, *Andropogon gerardii;* Pfl, *Paspalum floridanum;* Pvi, *Panicum virgatum;* Sas, *Sporobolus asper* var. *asper;* Snu, *Sorghastrum nutans;* Ssc, *Schizachyrium scoparium;* Ssi, *Sporobolus silveanus;* Tda, *Tripsacum dactyloides;* Tst, *Tridens strictus*.


1000 KG/HECTARE
HOUSTON BLACK - HEIDEN - FERRIS
WILSON - CROCKETT - BURLESON
Age
Pfl
Pvl
Sos
Snu
Sac
Sal
Tdo
Tsf
AUSTIN - STEPHEN - EDDY
TOTAL PRODUCTION
Houston Black - Heiden - Ferris
Austin - Stephen - Eddy
Wilson - Crockett - Burleson
0
1
2
3
4
5
6
8
10
75
85
95
105
115

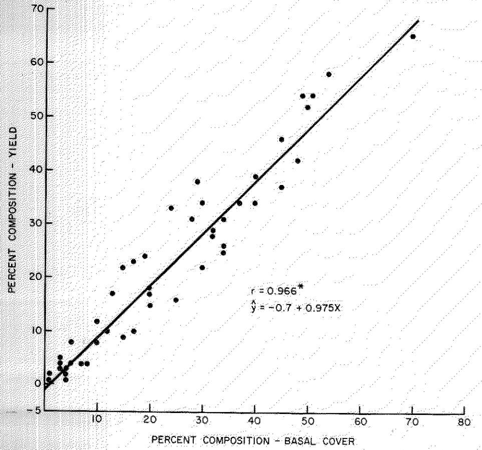


Fig. 3. Regression between percent composition-basal cover and percent composition end-of-season yield for dominant grasses.

basal cover percent composition of 20% or greater in at least one stand. Included were *Andropogon gerardii, Eriochloa sericea, Panicum virgatum, Paspalum floridanum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper* var. *asper, Sporobolus silveanus, Tridens strictus,* and *Tripsacum dactyloides* (Table 2).

In addition to the dominants, some widely distributed species with 50% or greater absolute frequency in three or more stands, included *Carex microdonta, Carex crus-corvi, Coreopsis basalis, Centaurea americana, Chaerophyllum tainturieri, Eleocharis acutisquamata, Helianthus hirsuta, Helianthus maximiliani, Polytaenia nuttallii* and *Sisyrinchium varians* (Table 3).

Species that occurred in the highest percentage of stands were *Sorghastrum nutans* (95%), *Schizachyrium scoparium* (92%), *Sisyrinchium varians* (75%) and *Bouteloua curtipendula* (66%) (Table 3).

Species-Environmental Relationships

The east-west soils gradient and north-south precipitation gradient across the Blacklands provided excellent contrasts of the influence of environmental factors in plant distribution and production. Vegetation and floristic transitions were generally more abrupt when related to soil differences. This was due to sharp changes in soil characteristics over short distances. In contrast, the precipitation variable represented a gradual change over distance. Many species, such as *Gaillardia aestivalis, Manisuris cylyndrica, Asclepias brachystephana* and *Baptisia australis*

TABLE 3. Average absolute frequency values (%) for all species encountered in quadrats in relation to soil associations and precipitation. The first number in each column represents stands of occurrence; the second is the average absolute frequency for stands of occurrence.

	Soil Associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average Annual Precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115
Number of Stands	3	4	3	5	11	12	10	4	5	6	6	14
Species												
Achillea millefolium	-	-	-	-	-	-	-	-	-	2-3	4-18	1-6
Agrostis hiemalis	-	-	-	-	-	-	-	-	-	1-3	1-6	-
Aira elegans	-	-	-	-	-	-	-	1-6	-	1-6	1-12	5-18
Andropogon gerardii	3-72	4-60	3-46	5-81	11-83	8-42	2-10	1-13	5-36	1-3	3-15	4-9
A. ternarius	-	-	-	-	-	-	-	-	-	-	-	3-12
Argythamnia humilis	-	-	-	-	11-63	5-27	-	-	-	-	-	-
Asclepias brachystephana	-	-	-	-	3-3	4-3	-	-	-	-	-	-
A. oenotheroides	1-3	1-3	1-3	-	3-3	1-3	-	2-6	-	-	-	-
A. stenophylla	-	-	-	-	-	-	-	-	1-3	2-9	-	6-9
Aster ericoides	-	1-6	4-3	-	1-3	4-6	6-19	3-18	-	1-3	-	7-15
A. eulae	-	-	-	-	-	-	-	1-3	-	2-3	1-3	3-6
A. oblongifolius	-	-	-	2-3	-	-	-	-	-	1-3	1-3	2-9
A. praealtus	-	-	-	-	-	-	-	-	-	-	1-3	1-3
Astragalus crassicarpus	-	-	-	-	3-12	1-4	7-6	2-12	-	-	-	-
Baptisia australis	-	1-3	3-28	5-36	-	-	-	-	-	-	-	-
B. nuttalliana	-	-	-	-	-	-	1-6	-	-	1-6	3-9	9-14
Bifora americana	-	-	-	-	-	-	-	-	1-3	2-9	1-6	3-9
Bothriochloa saccharoides	3-7	-	-	-	1-3	-	-	-	-	-	-	-
Bouteloua curtipendula	3-51	4-30	3-23	5-23	11-39	11-30	6-18	1-3	5-27	4-12	2-3	-
B. hirsuta	1-6	-	-	-	-	-	-	-	-	-	-	-
Brazoria scutellarioides	-	-	1-3	3-3	9-29	7-19	7-10	1-3	1-3	2-6	2-6	1-3
Cacalia plantaginea	1-3	-	3-7	5-17	2-3	3-14	4-10	4-3	-	-	-	-
Callirhoe alcaeoides	-	-	1-3	-	-	1-3	3-6	2-13	-	1-3	-	10-18
Castilleja indivisa	-	-	-	-	4-5	3-3	1-3	1-3	2-3	3-11	-	7-12
C. purpurea	-	-	-	-	-	1-3	2-3	-	-	-	-	-
Carex brittoniana	-	-	-	-	-	-	-	-	2-11	3-9	-	-
C. crus-corvi	-	-	-	-	--	-	-	-	-	1-3	-	14-50
C. microndonta	3-14	4-39	3-73	5-57	8-15	12-46	10-66	4-45	-	-	-	-
Centaurea americana	3-77	4-74	3-54	5-23	11-46	12-58	7-31	2-16	-	1-3	5-12	-
Chaerophyllum tainturieri	-	3-26	3-41	5-17	4-3	12-51	10-57	4-55	4-26	4-21	-	1-3
Cirsium helleri	-	-	-	-	-	3-3	1-6	-	-	-	-	-
C. iowense	-	1-3	3-9	3-8	3-9	4-6	3-19	2-12	-	2-6	4-20	4-6
C. ochrocentrum	2-3	-	-	-	-	-	-	-	-	-	-	-
C. texanum	2-3	-	3-17	3-8	6-19	10-24	2-21	4-24	2-3	1-6	2-9	6-6
Coreopsis basalis	-	-	-	-	-	-	1-3	1-3	2-3	3-12	6-35	14-52

TABLE 3. Continued.

	Soil Associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average Annual Precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-106	106-115
Number of Stands	3	4	3	5	11	12	10	4	5	6	6	14
Species												
Delphinium virescens	-	-	2-7	1-6	1-3	6-17	5-12	4-24	-	-	2-12	1-9
Desmanthus illinoensis	-	-	-	2-3	-	-	-	-	-	1-6	4-15	3-17
D. leptolobis	-	-	3-16	5-10	1-6	9-25	6-10	1-21	-	-	1-3	-
Echinacea pallida	-	-	1-3	-	-	-	2-6	2-9	-	-	1-6	4-6
Eleocharis acutisquamata	-	-	-	-	-	11-21	9-33	4-39	-	1-3	4-21	10-41
Elymus canadensis	-	-	-	-	-	1-3	1-3	1-18	-	-	-	-
Engelmannia pinnatifida	-	-	-	-	5-15	8-12	3-15	-	1-6	4-12	2-9	-
Eragrostis capillaris	-	-	-	-	-	-	-	-	-	-	1-3	-
E. hirsuta	-	-	-	-	-	-	-	-	1-3	1-6	2-6	6-9
Erigeron pulchellus	-	-	+	-	-	1-3	6-18	1-6	1-12	1-9	6-45	14-50
Eriochloa sericea	3-19	1-3	-	-	11-30	6-14	1-3	-	2-18	1-3	-	-
Eryngium yuccifolium	-	-	3-18	4-16	-	-	-	-	-	1-3	5-9	9-21
Erythonium rostratum	-	-	-	-	-	-	-	1-6	-	-	-	-
Euphorbia corollata	-	1-3	3-12	2-3	-	2-3	4-11	4-18	-	2-6	4-12	7-6
E. spathulata	3-16	4-21	3-16	-	6-8	7-10	2-6	-	-	-	-	-
Gaillardia aestivalis	-	-	-	-	-	-	-	-	-	-	1-3	9-15
G. pulchella	3-31	4-14	-	-	4-10	9-12	2-6	-	-	-	-	-
Galium virgatum	2-6	4-17	-	-	6-13	4-10	6-10	-	-	2-6	3-21	1-3
Hedyotis nigricans	1-3	3-3	3-12	1-3	1-6	3-12	4-3	1-6	1-3	1-9	-	1-3
Helianthus hirsutus	-	2-6	3-26	5-18	-	-	-	1-6	-	1-3	-	6-34
H. maximiliani	-	1-3	1-3	1-12	1-3	8-12	9-34	4-50	-	-	-	2-6
Hymenopappus artemisiaefolius	2-12	1-3	-	-	4-11	5-19	3-12	1-3	-	-	-	-
Hypoxis hirsuta	-	-	-	-	-	-	-	-	-	-	1-3	1-6
Krigia dandelion	-	-	-	-	-	-	-	1-3	-	3-9	4-18	2-3
K. gracilis	-	1-3	2-13	3-5	-	1-3	-	-	-	-	-	-
Kuhnia eupatorioides var. *texana*	-	1-6	3-3	1-3	2-3	9-10	5-16	4-22	-	-	-	-
Lesquerella gordoni	3-24	4-8	-	-	1-3	1-6	2-10	3-12	4-3	5-27	-	1-3
Liatrus aspera	-	-	-	-	-	-	-	-	-	-	1-3	1-13
Linaria texana	-	-	1-3	2-3	-	1-4	4-21	3-19	-	2-9	-	8-21
Lindheimera texana	-	-	-	-	-	-	1-3	-	2-11	6-26	4-21	11-28
Linum rigidum	-	-	2-3	1-6	-	-	-	-	-	2-3	2-9	9-26
Lithospermum incisum	-	-	1-3	-	2-3	8-21	2-9	-	-	2-3	-	2-3
Lobelia puberula	-	-	-	-	-	-	4-6	1-3	-	-	1-3	1-3
Lupinus texensis	3-19	-	1-3	-	7-19	5-14	1-3	-	-	-	-	-
Manisuris cylindrica	-	-	-	-	-	-	-	-	-	1-6	-	3-6

TABLE 3. Continued.

	Soil Associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average Annual Precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115
Number of Stands	3	4	3	5	11	12	10	4	5	6	6	14
Species												
Marshallia caespitosa	-	-	-	-	-	-	-	-	1-6	6-22	6-33	12-27
Melilotus indicus	-	-	-	-	-	-	1-3	-	-	-	-	2-6
Monarda citriodora	3-15	-	-	-	1-3	1-12	1-6	-	2-3	1-3	1-3	1-3
Nemastylis purpurea	-	-	-	-	1-3	2-6	1-6	2-3	-	1-3	4-9	3-3
Neptunia lutea	1-3	2-3	-	-	3-9	1-6	-	-	-	-	-	-
Nothoscordum bivalve	3-19	4-16	3-7	2-3	4-11	6-15	4-3	1-3	-	1-3	-	3-12
Oenothera speciosa	-	2-3	3-11	3-8	7-3	3-7	8-20	3-12	-	1-3	2-6	-
Oxalis violacea	3-12	3-3	-	-	2-6	1-3	2-3	1-6	4-18	3-15	-	9-15
Panicum angustifolium	-	-	-	-	-	-	-	-	-	-	-	2-6
P. lanuginosum	-	-	-	-	-	-	-	2-3	-	-	-	-
P. linearifolium	-	-	-	-	-	-	-	1-3	-	-	4-13	3-12
P. oligosanthes	-	-	-	-	-	-	-	2-6	-	-	4-21	-
P. virgatum	-	-	1-3	3-4	-	1-3	6-21	4-61	-	-	1-6	4-12
Paspalum floridanum	-	-	-	-	-	-	-	-	1-3	1-6	6-21	13-33
Petalostemum multiflorum	-	-	-	-	-	-	3-10	1-3	-	-	-	-
Phalaris canariensis	-	-	-	-	-	-	1-3	2-6	-	-	1-3	1-3
Phlox divaricata	-	-	-	-	-	-	5-16	2-12	-	1-3	3-18	-
Physalis angulata	-	-	2-11	4-7	1-3	3-3	2-6	4-27	-	-	-	-
P. viscosa var. mollis	-	-	-	-	-	-	1-6	-	-	3-3	1-3	9-5
Plantago lanceolata	-	-	-	-	-	2-14	1-6	-	-	1-9	-	11-15
Poa arachnifera	-	-	-	-	5-7	1-10	1-3	-	-	-	1-6	1-3
Polytaenia nuttallii	3-19	4-11	3-22	1-3	11-21	6-15	6-19	4-6	5-40	6-34	3-18	3-3
Psoralea tenuiflora	-	1-3	1-3	2-3	-	3-6	4-15	3-14	-	2-3	-	4-5
Pyrrhopappus carolinianus	1-6	1-6	1-6	-	2-6	9-14	1-10	-	1-3	3-12	1-3	-
P. geiseri	-	-	1-3	-	-	2-6	-	-	-	-	-	1-3
Rosa foliosa	-	1-3	3-12	3-8	-	-	-	-	-	-	-	-
Rudbeckia amplexicaulis	-	-	-	-	-	-	2-3	1-6	1-3	3-14	-	-
R. maxima	-	-	-	-	-	-	-	-	-	-	1-3	1-6
Ruellia nudiflora	-	2-3	3-8	1-3	6-14	8-11	1-3	-	-	1-3	-	2-6
Salvia azurea	2-3	3-12	3-22	2-9	1-3	5-10	1-14	1-6	-	2-3	4-18	-
Schizachyrium scoparium	3-89	4-76	3-75	-	11-92	12-81	10-86	4-21	5-97	6-71	6-45	12-30
Schrankia uncinata	3-17	3-10	1-6	-	9-7	9-10	8-15	-	2-6	-	3-18	7-18
Scutellaria drummondii	3-1	4-9	3-24	2-9	1-3	2-6	1-3	1-3	-	-	1-6	-
Senecio imparipinnatus	-	-	1-3	-	-	-	2-3	2-6	4-28	2-18	2-9	-
S. obovatus	-	4-6	3-20	3-5	7-3	11-31	5-21	2-15	-	-	-	-

TABLE 3. Continued.

	Soil Associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average Annual Precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115
Number of Stands	3	4	3	5	11	12	10	4	5	6	6	14
Species												
Setaria geniculata	-	-	-	-	-	-	-	-	-	-	2-15	-
Silphium laciniatum	-	-	1-3	1-3	-	-	2-3	1-3	-	-	2-6	-
Sisyrinchium varians	3-9	4-33	3-34	5-10	9-15	12-69	10-34	2-17	-	1-3	6-27	5-12
Solidago altissima	-	-	-	-	-	-	1-3	1-9	-	-	2-3	-
Sonchus asper	-	-	-	-	4-3	1-6	-	-	3-3	-	-	-
Sorghastrum nutans	3-21	4-30	3-62	5-90	11-25	12-54	10-66	4-48	5-28	6-42	6-35	10-26
Spiranthes longilabris	-	-	-	-	-	-	-	-	-	-	-	1-3
Sporobolus asper var. *asper*	3-34	4-24	3-16	4-9	10-9	12-79	10-68	4-81	3-11	-	-	-
S. silveanus	-	-	-	-	-	-	-	-	-	2-6	6-53	14-97
Stipa leucotricha	3-15	1-6	2-3	-	10-28	4-19	8-15	1-6	-	1-6	4-9	1-3
Tragia brevispica	-	1-3	2-14	3-7	1-3	1-6	-	2-9	-	-	1-6	3-3
Tridens flavus	-	-	-	-	-	-	-	-	-	2-3	-	1-3
T. strictus	-	-	-	-	-	-	-	-	-	1-6	5-18	14-39
Tripsacum dactyloides	-	-	1-3	1-3	-	1-6	4-14	4-32	-	-	1-6	5-17
Valerianella radiata	3-15	1-3	2-3	-	11-23	1-3	2-3	1-21	-	1-6	3-18	1-6
Verbena bipinnatifida	3-12	4-24	3-21	-	11-12	2-6	1-3	-	-	-	-	-
Vicia ludoviciana	-	-	-	-	-	-	-	-	-	1-6	1-3	-
Zygadenus leimanthoides	-	-	-	-	-	-	-	-	-	-	-	2-3

were restricted to one soil association, but few were similarly restricted by rainfall. Some species such as *Tripsacum dactyloides* occurred only in a limited portion of the precipitation range (Tables 2, Fig. 4).

To illustrate behavior of some dominant and major secondary species in relation to environmental variables, three factors were chosen to describe the behavior of species within the Blacklands. Frequency, basal cover and production values for species were related to all measured environmental factors in an attempt to determine which factors best explained species dynamics. It was found that most species related to one or a combination of three factors: average annual precipitation, % silt and soil pH. These factors were displayed on independent, linear axes. The three axes were arranged into a three-dimensional diagram and species behavior plotted simultaneously against the three variables (Fig. 4, 5). Factors selected and order of arrangement in the diagram was arbitrary, however, the diagram did tend to effectively show the behavior of species within the Blacklands. Dominant and major secondary species are described in relation to the three-dimensional diagram and other factors of significance (Tables 2, 3; Fig. 4, 5).

Dominants

Sorghastrum nutans. This species was the most ubiquitous species in the Blackland Prairie, as exhibited by its diverse

Fig. 4. Behavior of six grasses in relation to gradients of precipitation, soil pH and silt content. Circles of increasing size represent 0-5%, 6-20%, 21-35%, 36-50% and greater than 50% species composition based on basal cover.

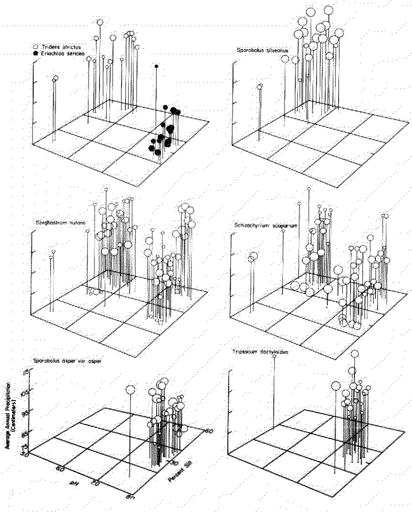
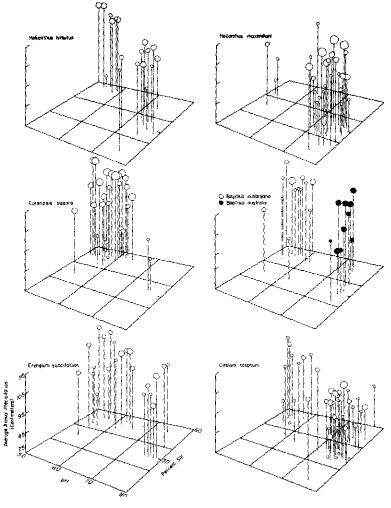

○ Tridens strictus
● Eriochloa sericea
Sporobolus silveanus
Sorghastrum nutans
Schizachyrium scoparium
Sporobolus asper var. asper
Tripsacum dactyloides
Average Annual Precipitation (Centimeters)
115
105
95
85
75
5.0
6.0
pH
7.0
8.0
30
60
Percent Silt

Fig. 5. Behavior of six forbs in relation to gradients of precipitation, soil pH and silt content. Circles of increasing size represent 0-10%, 11-25%, 26-50%, 51-80% and greater than 80% absolute frequency.


Helianthus hirsutus
Helianthus maximiliani
Coreopsis basalis
○ Baptisia nuttalliana
● Baptisia australis
Eryngium yuccifolium
Cirsium texanum
Average Annual Precipitation (Centimeters)
75
85
95
105
115
50
60
70
80
pH
30
60
Percent Silt

responses to environmental variables. *S. nutans* increased from 5% of the vegetation (basal cover) at the 75 cm/yr isohyet to 35% at the 95 cm/yr isohyet and then decreased to less than 1% at the 115 cm/yr isohyet on the Houston Black-Heiden-Ferris association with a range of production from 0 to 4,300 kg/ha (Table 2; Fig. 2). On Wilson-Crockett-Burleson soils *S. nutans* increased with increasing precipitation up to 95 cm/yr, but declined rapidly thereafter. On the Austin-Stephen-Eddy soils *S. nutans* increased continuously with rainfall. Thus, it exhibited similar patterns on the Wilson-Crockett-Burleson and Houston Black-Heiden-Ferris soils, but continued to increase with increased precipitation on the Austin-Stephen-Eddy soils.

Schizachyrium scoparium (Andropogon scoparium of Hitchcock 1950). This species occurred throughout the Prairie in a variety of growth forms. In areas of low precipitation, heights of one meter were observed and dominance occurred within some communities. In high rainfall areas, where tall grasses dominated, *S. scoparium* occurred as a minor understory component and was seldom observed to attain a flowering height of more than 45 cm. For example, on the Wilson-Crockett-Burleson soils absolute frequency of *S. scoparium* varied from 97 to 30% from south to north (Table 3). Yield composition for the same soil association varied from 70 to less than 3% along the same gradient (Table 4). This behavior was exhibited by several other species, notably *Sorghastrum nutans*. *Schizachyrium scoparium* commonly decreased as precipitation

TABLE 4. Species composition (%) based on end-of-season production in relation to soil associations and precipitation. The value in each column is the average composition for two stands.

	Soil associations											
	Austin-Stephen-Eddy				Houston Black-Heiden-Ferris				Wilson-Crockett-Burleson			
Average annual precipitation (cm)	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115	75-85	86-95	96-105	106-115
SPECIES												
Andropogon gerardi	32	18	35	35	40	18	--	--	37	--	--	--
Eriochloa sericea	--	--	--	--	17	--	--	--	--	--	--	--
Panicum virgatum	--	--	--	4	--	--	13	17	--	--	--	--
Paspalum floridanum	--	--	--	--	--	--	--	--	3	4	17	13
Schizachyrium scoparium	29	34	16	3	32	21	--	--	--	49	55	--
Sorghastrum nutans	5	17	48	54	8	35	6	--	6	40	45	5
Sporobolus asper var. *asper*	33	9	--	--	--	15	42	43	--	--	--	--
Sporobolus silveanus	--	--	--	--	--	--	--	--	--	--	8	55
Tridens strictus	--	--	--	--	--	--	--	--	--	--	26	23
Tripsacum dactyloides	--	--	--	--	--	10	38	38	--	--	--	--
Total % composition	99	78	99	96	97	99	99	98	95	99	96	96

increased, but showed no preference for pH or texture. On soils of the Austin-Stephen-Eddy association it occurred as a major component in isohyets of less than 100 cm/yr but declined rapidly above 100 cm/yr. A similar behavioral pattern was exhibited on the Houston Black-Heiden-Ferris soils. *S. scoparium* was the dominant species in lower precipitation zones on Wilson-Crockett-Burleson soils, composing more than 90% of the basal cover composition in some stands. The average basal cover at 75 cm/yr of precipitation was 81% (Table 2).

Andropogon gerardii. Reports of prairie vegetation indicated *A. gerardii* increased as conditions became more mesic (Weaver and Fitzpatrick 1934, Carpenter 1940). On the Houston Black-Heiden-Ferris soil association this species decreased in basal cover composition from 33% at 75 cm/yr average annual precipitation to 1% at the 115 cm/yr isohyet (Table 2). Production was approximately 3,000 kg/ha at the 75 cm/yr isohyet, but decreased as precipitation increased (Fig. 2). On Wilson-Crockett-Burleson soils it was present exclusively in lower precipitation zones, producing a maximum of 1,000 kg/ha. *A. gerardii* remained constant with increased precipitation on the Austin-Stephen-Eddy soils.

Sporobolus asper var. *asper*. This species was a major component of the vegetation in the southern part of the Austin-Stephen-Eddy soil association and in the northern portion of the Houston Black-Heiden-Ferris soil association. The southern part of the Austin-Stephen-Eddy association was characterized by droughty conditions and shallow soils. Co-dominants in this area were *Andropogon gerardii* and *Schizachyrium scoparium*. In the 115 cm/yr precipitation zone on the Houston Black-Heiden-Ferris association *Sporobolus asper* var. *asper* was a co-dominant with *Tripsacum dactyloides* and often comprised more than 40% of the composition based both on yield and basal cover (Tables 2, 4).

Tripsacum dactyloides. This species was found in varying quantities in high precipitation zones of all soil associations. On Austin-Stephen-Eddy soils it occurred as scattered clones of low abundance and did not form a major vegetational component. *T. dactyloides* was most abundant in high rainfall areas of the Houston Black-Heiden-Ferris soils, often composing over 40% of basal cover (Table 2). It extended southward in this soil association in gilgai microlows, until average annual precipitation decreased below 85 cm/yr. Although generally considered a warm-season species (Gould 1969, Leithead, Yarlett, and Schiflet 1971) *T. dactyloides* behaved as a cool-season species throughout the Blackland Prairie. It maintained green shoots and leaves yearlong, flowering and reaching peak production in May. In the northern portion of the Houston Black-Heiden-Ferris soil association *T. dactyloides* often occurred as almost pure stands, covering large areas with a continuous clonal mat. When mowed it constitutes a sought-after hay.

sought-after hay.

Paspalum floridanum. This species occurred on the acid soils of the Wilson-Crockett-Burleson association. Production increased with rainfall, but *P. floridanum* seldom constituted more than 20% of the composition by either basal cover or production. Generally, it occurred as occasional large mat-like circular clones. When mowed too frequently or too close, these clones widened, but the center portion died. As a dominant, it was restricted to the most mesic extension of the Wilson-Crockett-Burleson soils. Although pH restricted distribution, precipitation largely determined abundance (Fig. 4).

Sporobolus silveanus. Although not recognized as a separate species until 1941 (Chase and Niles 1962) *S. silveanus* occurred as monodominant stands, restricted to the northeastern portion of the Blackland Prairie on soils of the Wilson-Crockett-Burleson association. Distribution was restricted by precipitation, probably more than any other species (Fig. 4).

Tridens strictus. This species peaked in production near the northernmost portion of the Prairie. Although seedheads were very abundant in the autumnal phase, *T. strictus* seldom comprised over 30% of the composition (Table 2).

Eriochloa sericea. The only cool-season grass recognized as a dominant was restricted to the southern portion of the Houston Black-Heiden-Ferris soil association (Table 2). Often the stands were characterized by both pre-vernal and autumnal flowering periods.

E. sericea was observed to be especially abundant in soil of high gravel content.

Major Secondary Species - Vernal

Baptisia australis and *B. nuttallii.* Restricted to higher isohyets on Austin-Stephen-Eddy soils, *B. australis* was perhaps the best single vernal plant characteristic of this association. Plants were often found growing near *Rosa foliosa*, an autumnal species, characteristic of the same soil and precipitation zones. *Baptisia nuttallii* was restricted to the northeastern portion of the Wilson-Crockett-Burleson soils and was characteristic of the vernal phase of this portion of the Prairie. The growth form and phenology of the two species, *B. australis* and *B. nuttallii*, were similar but it was interesting to note that each was restricted to one soil association (Table 3; Fig. 5).

Chaerophyllum tainturieri. This species occurred throughout the Blacklands, but was most prominent in the central portion of the Houston Black-Heiden-Ferris soil association (Table 3). *C. tainturieri* dominated the vernal aspect of meadows in this region. Flowers formed a blanket of white which often extended unbroken over many acres. Even though it was locally very abundant, *C. tainturieri* contributed only a small amount to end-of-season production.

Carex crus-corvi and *C. microndonta.* Rigidly restricted by both soil and rainfall, *C. crus-corvi* was abundant only in mesic portions of the Wilson-Crockett-Burleson association (Table 3). It disappeared rapidly to both the south and west. *C. microndonta* was found on virtually all remnants occurring on calcareous soils, and formed a considerable portion of the vernal aspect.

Centaurea americana. This species, more than any other, characterized the vernal phase in the southern region of the Blacklands. It was found in such abundance that, although it reached senescence in mid-August, the stems formed a large part of the end-of-season annual forb production. It was the primary reason annual forb production was higher than perennial forb production in the more xeric portions of the Blackland Prairie (Fig. 6).

Cirsium texanum. While most abundant on Houston Black-Heiden-Ferris soils, this species was not restricted in distribution by soil and precipitation zones within the Blacklands (Table 3; Fig. 5). Based on observations it appeared that *C. texanum* attained a flowering height of up to 2 m. *C. texanum* was an integral vernal component on the Houston Black-Heiden-Ferris type soils. It was obvious because of size and not density. This species, like most other vernal components of the Blackland Prairie, set seed before mowing.

Desmanthus leptolobis. Encountered most frequently in xeric portions of Houston Black-like soils, *D. leptolobis* was one of the most noticeable vernal components. It was observed that in some meadows plants would not exceed 0.3 m in height because all leaves were eaten by insects. Where this insect pressure was not a factor, plants commonly attained a height of near 1 meter. *D. leptolobis*

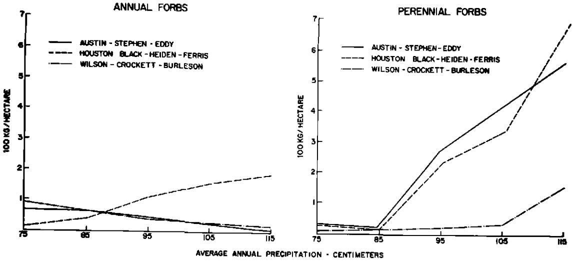


Fig. 6. Total production of annual and perennial forbs for all soil associations in relation to precipitation. Each point represents data for only one stand.

declined gradually with increasing rainfall and should be considered a sign of disturbance when found in abundance on remnants in mesic portions of the Blacklands.

Galium virgatum. This species decreased with increasing precipitation on basic soils, but increased with increasing precipitation on the acid Blackland soils (Table 3). *G. virgatum* and *Brazoria scutellaroides* were the most abundant understory vernal components of the Blacklands.

Psoraelia tenuiflora. Encountered on all soil associations, this species was most abundant in the central and northern portions of the Houston Black-Heiden-Ferris association (Table 3). It appeared to be ecologically similar to *Psoraelia argophylla* (Weaver and Fitzpatrick 1934) and occurred as scattered solitary plants with no discernable grouping or aggregation. *P. tenuiflora* was most often found on gilgai microridges and was never observed in microlows It formed the dominant vernal forb component in the central region of the Houston Black-Heiden-Ferris association. On acid soils this species was observed to be an indicator of soil natural fertility.

Coreopsis basalis. This species was restricted to some extent by precipitation, but primarily by soil associations. On mesic portions of the Wilson-like soils it dominated the vernal aspect of remnants (Table 3; Fig. 5). The entire meadow appeared orangish-yellow. *C. basalis* grew in harmony with all other species encountered on mesic portions of acid soils of the Blacklands.

Delphinium virescens. Scattered throughout the Prairie, and especially noticeable because of its white flowers, *D. virescens* was the only poisonous species encountered as a climax component of the vegetation (Table 3).

Eleocharis acutisquamata. This species occurred extensively in mesic portions of the Houston Black-Heiden-Ferris and Wilson-Crockett-Burleson soil associations (Table 3) and was observed to be especially abundant in gilgai microlows. Easily observed in the pre-vernal phases it was absent from the above-ground herbage during the late aestival and early autumnal phases. However, rhizomes were easily found during the late aestival and early autumnal periods.

Lindheimera texana. Encountered almost exclusively on Wilson-like soils, *L. texana* was observed to be a reliable indicator of acid soils. In the southern portion of the Prairie it was virtually the only indicator forb and was more obvious than in the northern portion. This occurred despite increased abundance with increased precipitation (Table 3).

Linum rigidum. Restricted to high-silt soils, this species was more abundant in acidic situations (Table 3). This species was one of the few vernal understory components commonly found in mesic Wilson-Crockett-Burleson soils.

Lupinus texensis. This species was most commonly found in xeric regions on both the Austin-Stephen-Eddy and Houston Black-Heiden-Ferris soil associations. In instances where mowing was done on a biannual basis, this species was especially abundant. In such situations many seeds germinated in the mulch layer rather than in the mineral soil. *L. texensis* increased with soil disturbance.

Marshallia caespitosa. Found on acidic soils and increasing in abundance as precipitation increased, this species was most abundant on Wilson-Crockett-Burleson soils just north of the Sabine River (Table 3).

Oenothera speciosa. Found on all soil associations this species increased with increasing precipitation and was most abundant in the central portion of the Houston Black-Heiden-Ferris association (Table 3). It often grew in association with *Chaerophyllum tainturieri.* Excepting *Anemone caroliniana* this was the first pre-vernal plant to bloom on the meadows.

Phlox divarcata. Encountered in the central portion of the Wilson-Crockett-Burleson soil association and in the northern portion of the Houston Black-Heiden-Ferris association, *P. divarcata* was abundant on some meadows while on similar meadows it was absent. This was one of the few species that did not have a predictable pattern of distribution or abundance (Table 3).

Polytaenia nuttallii. Often observed to attain a flowering height of 1 m, this was the first large species to flower during the pre-vernal season. It had no discernible pattern, except to increase in abundance as precipitation decreased (Table 3). It was one of the few perennial forb species not adversely affected by summer mowing, possibly because it was a pre-vernal vegetation component.

Major Secondary Species - Aestival

Astragalus crassicarpus. Most often encountered on Houston Black-Heiden-Ferris soils, this species has long been recognized as a component of the True Prairie (Weaver and Fitzpatrick 1934). While forage obtained from this species was not appreciable, seed production was often observed to exceed forage production. This was especially noticeable in high precipitation zones.

Argythamnia humilis. Found as an understory component and attaining a flowering height of only 15 to 20 cm, this species was most prominent following mowing in mid-June or early July. *A. humilis* was restricted to the southern portion of the Houston Black-Heiden-Ferris association (Table 3).

Brazoria scutellaroides. Found throughout the Blacklands, this species was most abundant in the southern portion of the Houston Black-Heiden-Ferris soil association. It was observed that *B. scutellaroides* seldom attained a flowering height of 20 cm, and was most often found growing in *Andropogon gerardii* clones. It was most often found on microknolls, seldom growing in microlows or similar mesic situations. Another mint, *Scutellaria drummondii*, appeared to fill a similar niche to *Brazoria scutellaroides*, however, it occurred in northern, high rainfall areas of the prairie.

Ruellia nudiflora. Commonly encountered throughout most of the Blackland Prairie this species was most abundant in the xeric southern portion of the Houston Black-Heiden-Ferris association

(Table 3). *R. nudiflora,* like *Argythamnia humilis,* was most easily observed soon after mowing. *Ruellia nudiflora* was easily distinguished by violet flowers.

Schrankia uncinata. On Austin-Stephen-Eddy soils this species decreased as precipitation increased. On the other soil associations the reverse was true. Despite its decumbent growth habit, *S. uncinata* was observed to be adversely affected by mowing.

Sisyrinchium varians. Found extensively throughout the Blackland Prairie, *S. varians* was most abundant in intermediate precipitation zones on all soils (Table 3). On the vertic soils it was observed most often on microridges.

Major Secondary Species - Autumnal

Aster ericoides. Scattered throughout the Prairie, this species was most abundant on the Houston Black-Heiden-Ferris soils. Primarily found in high precipitation zones, *A. ericoides* was observed to frequent microlows and be locally (within the microlow) abundant. This was the only member of the genus *Aster* commonly found on basic soils in the Blackland Prairie. This species was found throughout the central North American Grassland (Weaver and Fitzpatrick 1934, Weaver and Albertson 1956).

Kuhnia eupatoriodes. Occurring extensively throughout the calcareous portion of the Blackland Prairie, *K. eupatoriodes* was one of the most widely distributed autumnal species (Table 3). In gilgai soils it preferred microlows and occurred as scattered, dense aggregations. On level soils the distribution was observed to be more random with scattered solitary plants.

Salvia azurea. A major species on all soil associations, *S. azurea* was most abundant in intermediate precipitation zones (Table 3). It was the tallest autumnal forb observed in the southern region on all soil associations. Based on observation *S. azurea* disappeared rapidly as mowing intensity or frequency increased.

Species Coordination

Species within the same genus or family tended to replace one another along precipitation and soil gradients. Along rainfall gradients within soil associations *Euphorbia spathulata* occurred most often in isohyets of less than 95 cm/yr annual precipitation while *Euphorbia corollata* was seldom encountered. Both species had almost identical growth habits and flowered at the same time. However, the reverse was true when annual average precipitation exceeded 100 cm. *Brazoria scutellaroides*, a mint, occurred as a low-growing vernal forb on basic soils and decreased with increasing precipitation while the reverse was true of another mint, *Scutellaria drummondii*. *Senecio imparipinnatus* occurred on the Wilson-Crockett-Burleson soils in isohyets of less than 95 cm/yr while *Senecio obovatus*, which is similar in growth form and season of flower, was found on the Houston Black-Heiden-Ferris association, primarily in isohyets of less than 105 cm/yr.

Some species were restricted by both precipitation and a particular soil character. *Eryngium yuccifolium* was found in areas of greater than 105 cm/yr precipitation on both the Wilson-Crockett-Burleson and Austin-Stephen-Eddy soils, but was absent from the Houston Black-Heiden-Ferris soils. The pH range on soils of occurrence was from 5.2 to 7.6 while in the Houston Black-Heiden-Ferris association it was 7.6 to 7.9. Thus, pH was probably not a controlling factor in its distribution. These soils had few similar chemical characteristics and had different water retention properties (Table 1). The character these soils share is silt content; both have between 50 and 60% silt. Silt content was the controlling factor in the distribution of *Helianthus hirsutus*. It and *Eryngium yuccifolium* were commonly found only in high-precipitation, high-silt areas (Fig. 5). On the Houston Black-Heiden-Ferris soils association, where silt content was less than 35%, *Helianthus maximiliani* was found occupying a place in the community much like that of *Helianthus hirsutus* on the other soil association in similar rainfall belts (Table 3).

Although extremes were not as great as those encountered by Billings (1950) and Salisbury (1964) this relationship would seem to support the hypothesis of Kruckeberg (1969) that, "Speciation within a regionally contiguous genus is largely a response to environmental diversity within the confluent area. Sharp discontinuities in soil chemistry can serve as isolating phenomena to bring about species diversification."

Production

End-of-season above ground production was sampled in 24 stands (Fig. 5, 6). Due to lack of stands and large travel distances, one stand was selected for each 5 cm isohyet within each of the three soil associations. Consequently, statistical variation within a precipitation zone could not be determined. However, these data did plot more or less normal curves against precipitation and probably the 24 values are representative of production across the Prairie. Certainly they show the trends in relation to precipitation and soil, if not variation within soil or precipitation zones.

Total foliar end-of-season, oven-dry production at the Colorado River on the Austin-Stephen-Eddy soils was approximately 5,500 kg/ha (Fig. 2). Major constituents of the production were *Sporobolus asper* var. *asper*, *Schizachyrium scoparium* and *Andropogon gerardii*. At the Red River in a 115 cm/yr precipitation zone end-of-season total production exceeded 9,000 kg/ha. Major yield components were *Andropogon gerardii* and *Sorghastrum nutans* (Table 4; Fig. 2).

On the Houston Black-Heiden-Ferris soils association at the southern extension, production was approximately 5,800 kg/ha and primary yield constituents were *Andropogon gerardii*, *Schizachyrium scoparium* and *Eriochloa sericea*. Near the Red River, in the 115 cm isohyet, production reached 10,000 kg/ha. Comprising most of this were *Tripsacum dactyloides*, *Sporobolus asper* var. *asper* and *Panicum virgatum* (Table 4; Fig. 2).

Production on the Wilson-Crockett-Burleson soils was approximately 3,000 kg/ha in the 80 cm/yr isohyet. *Andropogon gerardii* and *Schizachyrium scoparium* were the major components. Production increased sharply to 10,000 kg/ha in the 115 cm/yr precipitation zone along the Red River. In this isohyet, *Sporobolus silveanus, Tridens strictus* and *Paspalum floridanum* composed most of the forage (Table 4; Fig. 2).

Total grass production increased with precipitation in all soil associations, although individual species exhibited independent responses. A 40 cm/yr increase in precipitation resulted in a 100% increase in production on the Austin-Stephen-Eddy and Houston Black-Heiden-Ferris soil associations. However, on the Wilson-Crockett-Burleson soil association the increase in production was 300%. Water retention properties may well have been the primary factor effecting this difference in yield increases among soil associations. The Wilson-Crockett-Burleson soils have an average available moisture content somewhat less than the others (Table 1). Increased precipitation would compensate for the lower moisture retention qualities and may cause the sharp yield increase. While water is acknowledged as the primary limiting factor in grassland production a point may be reached where precipitation is no longer limiting.

End of season, oven-dry production of annual forbs decreased from approximately 100 kg/ha at the 75 cm/yr isohyet on the Austin-Stephen-Eddy and Wilson-Crockett-Burleson soil associations. On Houston Black-Heiden-Ferris soils production increased from less than 25 kg/ha at the 75 cm/yr isohyet to 200 kg/ha at the 115 cm/yr precipitation zone (Fig. 6).

End-of-season, oven-dry, perennial forb production increased from less than 100 kg/ha at the Colorado River to maximum of 175 kg/ha on the Wilson-Crockett-Burleson, 550 kg/ha on the Austin-Stephen-Eddy, and 700 kg/ha on the Houston Black-Heiden-Ferris soils (Fig. 6).

Although annual forb production increased with increased precipitation on the Houston Black-Heiden-Ferris soils, the ratio of annual to perennial forb production decreased (Fig. 6). Thus it may be generalized that both annual and perennial forb production increased with increasing precipitation.

Vegetation Stability

A study of stability involved movement of a segregated *Sorghastrum nutans* clone in the southern portion of the Houston Black-Heiden-Ferris soils association. Movement was investigated using a permanent line transect. In 1946 Dr. E. J. Dyksterhuis and several other Soil Conservation Service personnel established a line transect on a native hay meadow in Bell County sampled during the current study (Dyksterhuis 1970). In 1971 both stakes were relocated and the transect was again sampled.

In 1946 *Sorghastrum nutans* constituted 34% of the vegetation along the transect and was recorded only in the central portion. In 1971 *S. nutans* composed 33% of the vegetation and was encountered only in the middle portion of the transect. These data would indicate that these clones migrated little over time. Soil samples were collected from the upper 1 m in an effort to determine causes for segregation. No physical soil characters changed along the line or on either side of the segregated *S. nutans* clone. There also was no correlation between the gilgai microrelief and occurrence of clones.

Fire must have had a role in maintaining the pristine vegetation throughout the Blacklands. Every explorer noted traversing much land where the vegetation had been burned or was burning (Moore 1840, Kendall 1845, Parker 1856, Decordova 1858, Greer 1935, Fulton 1941, De Wees 1968).

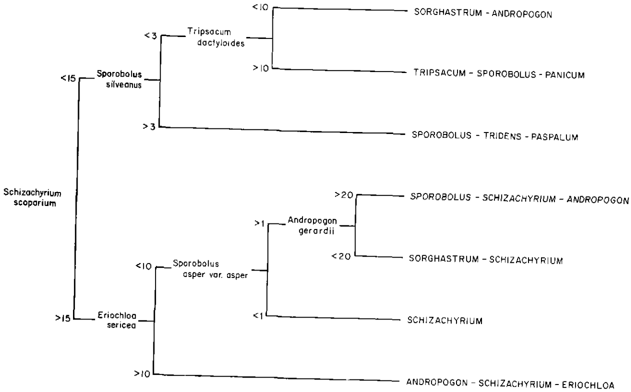
To investigate effects of the removal of fire and mowing influences, a cemetery located in a hay meadow in the northern portion of the Wilson-Crockett-Burleson soils association was observed. The cemetery had been located in the center of the meadow some 80 years. Residents of the area indicated the cemetery was treeless and did not obviously differ from the remainder of the meadow at the time of establishment. Today the cemetery supports a mott of *Maclura pomifera*. The oldest tree is one that sprouted from a log cut for a cornerpost of the cemetery fence. This tree still forms a cornerpost. End-of-season clippings from the cemetery and associated meadow were very different. Total production on the meadow was over 8,500 kg/ha, with *Sporobolus silveanus* and *Paspalum floridanum* producing a majority of the forage. Total production in the cemetery was 3,500 kg/ha dominated by *Symphoricarpos orbiculatus, Aster euale* and *Elymus canadensis*. This difference in both composition and production may indicate the role that fire and, more recently, mowing have had in reducing woody encroachment on climax hay meadows in this community type. Where meadows have been fenced for grazing, and mowing and fire eliminated, woody invasion has been more rapid in this area than on any other portion of any soil associations.

Community Types

Field observations, distribution, production, and basal cover values of dominants in relation to soil characteristics and precipitation (Tables 1, 2, 3, 4), and distribution of secondary species (Table 3; Fig. 5) suggested existence of several more or less distinct community types within the Blackland Prairie. A number of vegetation variables were considered in an attempt to quantitatively delimit these types. Percent composition of dominant species based on basal cover produced an effective single factor mechanism for consistent and rapid recognition of communities in the field. A key was developed utilizing this variable to distinguish seven community types which were named after dominant genera (usually only one species per genus) in the community type (Fig. 7). Community types occurred along a gradient from xeric to mesic in each soil association (Fig. 1). Map units were to some extent artificial and served primarily to show the area within which a particular community is the prevalent kind of vegetation. A type may occur outside the mapped

Fig. 7. Key to Blackland Prairie Community Types. Numbers represent percent composition based on basal cover.

BLACKLAND PRAIRIE COMMUNITY TYPES



boundary, but in this case it would be a minor part
vegetation.

The north-south boundaries for the community types are
major streams since species distributions tended to coincide with the position of rivers. East-west divisions are established by soil association boundaries, and community boundaries are more distinct than in relation to the north-south divisions.

Sporobolus-Schizachyrium-Andropogon type. This type was found between the Colorado and Trinity Rivers on soils of the Austin-Stephen-Eddy association (Fig. 1). It was the most xeric type in the Blackland Prairie. Average annual precipitation varied from 75 cm/yr on the southern boundary to 96 cm/yr along the Trinity. Basal cover values for *Andropogon gerardii* (35%), *Schizachyrium scoparium* (31%) and *Sporobolus asper* var. *asper* (19%) indicated that these species were dominant in this community type (Table 2).

Production varied from slightly over 5,500 kg/ha in the south to about 6,700 kg/ha in the north (Fig. 2). *Sporobolus asper* var. *asper* and *Schizachyrium scoparium* decreased in composition as precipitation increased and were replaced by *Sorghastrum nutans* and *Andropogon gerardii* (Table 2; Fig. 2).

Scattered clones of *Sorghastrum nutans* were encountered, but rarely covered a significant area. *Bouteloua curtipendula* was more abundant (3%) than in any other area within the Prairie. This was the only community type were *Bothriochloa saccaroides*, *Bouteloua curtipendula*, and *Cirsium ochrocentrum* could be considered climax components.

In early spring combinations of *Centaurea americana*, *Euphorbia* *spathulata*, *Lesquerella gordoni* and *Verbena bipinnatifida* were the best indicators of this type. *Schrankia uncinata* and *Gaillardia pulchella* were spring-flowering forbs which preferred slope and knoll locations, respectively. The cool season grasses *Eriochloa sericea* and *Stipa leucotricha* flowered in both spring and fall, but did not produce appreciable forage. This was a fragile community type in that the shallow soils of occurrence were subject to erosion once the climax vegetation had been removed.

It was observed that grazing or mowing too close or too often was followed by a marked increase in composition of *Bothriochloa saccaroides* and *Stipa leucotricha*, similar to their behavior as increasers in the Fort Worth Prairie (Dyksterhuis 1946).

Sorghastrum-Andropogon type. This type occupied the Austin-Stephen-Eddy soils north of the Trinity River and was dominated by *Sorghastrum nutans* (47% basal cover) and *Andropogon gerardii* (36% basal cover) (Table 2). Average annual precipitation varied from 95 cm/yr at the southern boundary to 115 cm/yr near the Red River. *Schizachyrium scoparium* and *Sporobolus asper* var. *asper* decreased rapidly as precipitation increased and were replaced by *Sorghastrum nutans* and *Andropogon gerardii* (Table 2). Production increased from approximately 6,000 kg/ha in the south along the Trinity River to about 10,000 kg/ha along the northern boundary (Fig. 2). *Baptisia australis* has the most striking spring-flowering species, but *Euphorbia corollata* and *Krigia lanceolata* also characterized this community type in the spring. The most noticeable fall-flowering forb was *Eryngium yuccifolium*. *Helianthus hirsutus* and *Desmanthus* *leptolobis* also were prominent and to a lesser degree, *Salvia azurea*. Scattered plants of *Kuhnia lanceolata* and *Helianthus maximiliani* also were observed. *Panicum virgatum* and *Tripsacum dactyloides* occurred as infrequent clones in swales or low areas. *Cacalia plantigenia* and *Tragia brevispica* occurred commonly, but were most often restricted to clones of *Sorghastrum nutans*; seldom occurring with other grass species. *Maclura pomifera* was common along ravines and in scattered motts throughout this type. *Bouteloua curtipendula* and, to a lesser degree, *Schizachyrium scoparium*, increased rapidly with disturbance and were observed to be characteristic of meadows mowed too close or too frequently.

Schizachyrium-Andropogon-Eriochloa type. This type extended from the Colorado to the Brazos Rivers on the Houston Black-Heiden-Ferris soils and was dominated by *Andropogon gerardii* (33% basal cover), *Schizachyrium scoparium* (37% basal cover), and *Eriochloa sericea* (22% basal cover) (Table 2). Average annual precipitation varied from 75 to 85 cm/yr. End-of-season production increased from near 5,500 kg/ha along the Colorado to 6,200 kg/ha along the Brazos (Fig. 2). *Andropogon gerardii* decreased as precipitation increased, while *Sorghastrum nutans* increased with increased precipitation. It is noteworthy that *Eriochloa sericea*, a cool-season grass, provided an appreciable portion (17%) of the annual herbage production collected following the most stressful period of the year for this species (Table 4).

In the spring, the *Andropogon-Schizachyrium-Eriochloa* community type was readily identified by the presence of *Poa arachnifera* and *Tradescantia gigantia*; neither was commonly observed elsewhere. A cursory observation in springtime revealed *Engelmanii pinndifita, Ruellia nudiflora* and *Valerianella radiata*. More intensive observation commonly revealed *Brazoria scutellaroides* and *Neptunia lutea* in flower. When *Sorghastrum nutans* was observed in this community type it occurred as segregated clones. The delineation between clones of *Sorghastrum nutans* and a mixture of *Andropogon gerardii* and *Schizachyrium scoparium* clones was quite pronounced. *Baccaris salicina* and *Bothriochloa saccaroides* were observed to be reliable indicators of overgrazing or mowing too close within this community type.

Sorghastrum-Schizachyrium type. This type extended from the Brazos to the Sabine River on the Houston Black-Heiden-Ferris soils and from the Trinity to the Sabine River on the Wilson-Crockett-Burleson soils. Basal cover values for *Sorghastrum nutans* and *Schizachyrium scoparium*, the dominant species in this type, were 54 and 26% on the acid soils. On basic soils their basal cover values were 40 and 23% (Table 2). This was the only type to include more than one soil association. Average precipitation on the Houston Black-Heiden-Ferris soils varied from 86 to 95 cm/yr and from 86 cm/yr to 105 cm/yr on the Wilson-Crockett-Burleson soils. Production on the Houston Black-Heiden-Ferris soils increased from approximately 8,000 kg/ha to near 9,000 kg/ha (Fig. 2). On the acidic Wilson-Crockett-Burleson soils production increased from 3,500 kg/ha to 6,000 kg/ha from south to north (Fig. 2). As might be expected, the forb complement varied with soil. However, the dominant species, in this instance, *Sorghastrum nutans* and *Schizachyrium scoparium* were of approximately equal importance on each soil association (Table 2, 4). The only striking difference between soil associations was that *Sorghastrum nutans* did not occur as restricted clones on the Wilson-Crockett-Burleson soils while this segregated clonal pattern was common on Houston Black-Heiden-Ferris soils.

Castelleja individa, Krigia dandelion, Marshaellia caespitosa and *Oxalis violacea* were vernal forbs characteristic of this community type on the acidic soils.

In the spring *Chaerophyllum tainturri* formed almost a totally white cover on meadows of occurrence and was especially thick in gilgai microdepressions. *Cirsium texanum* was prominent, often attaining an observed height of 125 cm. The biannuals, *Pyrrhopappus carolinianus* and *Hymenopappus artemesiafolius*, were present and had developed a complimentary flowering pattern. One year, *Pyrrhopappus* was evident in a meadow, with few, if any, flowering *Hymenopappus*. The next year the reverse was true. In reality the plants were of equal abundance each year, but the year one species flowered the other was in the rosette stage. *Hedyotis nigricans* and *Lithospermum incissa* often occurred within *Schizachyrium scoparium* clones, particularly on or near gilgai microknolls. *Senecio obovatus* was a common component on the Houston Black-Heiden-Ferris soils and was most abundant in this type. *Krameria secundifolia* and *Sisyrinchium* *varians* occurred throughout the basic soils with no discernible habitat preference.

In the autumn, the combination of *Kuhnia lanceolata* and *Petalostemum purpurea* flowering readily identified this community type on the calcareous soils. *Petalostemum* was found more frequently than *Kuhnia*. Several species such as *Tripsacum dactyloides* and *Helianthus maximilliani* were only observed in gilgai microlows in this type.

Tripsacum-Sporobolus-Panicum type. Dominated by *Tripsacum dactyloides* (38%), *Sporobolus asper* var. *asper* (43%) and *Panicum virgatum* (16%), this type was found on the Houston Black-Heiden-Ferris association north of the Sabine River. Annual average precipitation varied from 100 to 115 cm/yr and production increased from 9,000 kg/ha along the Sabine to over 10,000 kg/ha in the northeasternmost extension along the Red River (Fig. 2). These three dominants were primary components throughout this type and all increased with increasing precipitation. All three dominant species occurred equally throughout the area, showing little preference for microlows or knolls. This was in direct contrast with the distribution pattern of *Tripsacum dactyloides* and *Panicum virgatum* in other communities. The vernal aspect of this community type was marked by *Elymus canadensis* which contributed appreciably to early season production. Also conspicuous were *Delphinium virescens*, *Echinacea pallida*, *Eleocharis acutisquamata* and *Linaria texana*. Here too the flowers of *Chaerophyllum tainturieri* were observed in some meadows. *Astragalus crassicarpus* was abundant. *Oenothera speciosa* and *Castelleja purpurea* were observed scattered throughout most meadows. *Cirsium terraenigra* (Gould 1969), named by the early Spanish explorers "black soil," was endemic to this community type and was observed infrequently.

The *Tripsacum-Sporobolus-Panicum* community type had a much more impressive complement of autumnal-flowering forbs than any other type within the Blackland Prairie. *Helianthus maximilliani* was the largest and highest-producing forb. It usually occurred on gilgai microlows often to the exclusion of other forbs. Other species occurring on microlows were *Aster ericoides* and *Solidago altissima*. *Kuhnia lanceolata* was also abundant, usually preferring microknolls. *Silphium lacinatum* and *Erythonium rostratum* attained an observed height of 2 m or more.

Maclura pomifera occurred on all community types in high precipitation areas, but was especially abundant in this community type.

Schizachyrium scoparium was observed to increase rapidly with disturbance, responding much like *Bothriochloa saccarroides* in the *Sporobolus-Schizachyrium-Andropogon* type.

Sporobolus-Tridens-Paspalum type. This type was situated on Wilson-Crockett-Burleson soils north of the Sabine River. Average annual precipitation varied from 106 to 115 cm/yr. Species comprising most of the basal cover were *Sporobolus silveanus* (57%), *Tridens strictus* (21%), and *Paspalum floridanum* (17%) (Table 2). Production increased with increasing precipitation from under 6,000 kg/ha along the Sabine to over 10,000 kg/ha at the Red River (Fig. 2). *Sorghastrum nutans* and *Paspalum floridanum* decreased in percent basal cover as precipitation increased (Table 2). Compensating for these decreases was a slight increase in *Tridens strictus* and an increase in *Sporobolus silveanus*. This community type was dominated by species previously reported as subordinate species.

Sporobolus silveanus was reported only as an understory component in East Texas by Hitchcock (1950). General treatments of Texas grasses ommitted it. In this community it often formed monodominant stands. *Tridens strictus* had been reported as restricted to lowland woody areas (Hitchcock 1950), but in this community type often comprised over 25% of the composition. *Paspalum floridanum* was reported only along the Coastal Prairie and in riverbottoms by Hitchcock (1950). Yet it comprised more than 20% of the vegetation in this type (Table 2, 4). While *Tridens strictus* and *Paspalum floridanum* were often codominants with *Sporobolus silveanus* they seldom grew together in abundance. Along ravine banks almost solid stands of *Tripsacum dactyloides* were observed.

Psoralea tenuiflora and *Coreopsis basalis* were evident during the vernal aspect in this community type. In addition, considerable quantities of *Baptisia nuttallii* were encountered. *Rudbeckia maxima* was a prominent early-season species often growing over 2 m tall in lowland areas. *Bifora americana* and *Zygadenus* *leimanthoides* were also abundant on scattered moist sites. *Carex crus-corvi* was abundant throughout this type. *Physalis cinarescens* was found infrequently on upland areas and was usually closely associated with *Tridens strictus*. *Achillea millefolium*, *Erigeron ramosus*, *Linum rigidum* and *Liatris aspera* also added considerable color to the vernal aspect.

There was a distinct strata of low-growing species, dominated by *Panicum linearifolium*, *P. angustifolium*, *P. oligosanthes*, *Plantago lanceolata* and *Aira elegans*. Associated with these species were *Spiranthes longilabris*, *Eragrostis hirsuta* and the rare (in Texas) *E. capillaris*. Although forage production of *Aira elegans* was limited, it was a very conspicuous component of the *Sporobolus-Tridens-Paspalum* community type. It was observed that the abundance of *A. elegans* tended to increase with increased soil sand content.

The autumnal forb complement of this community was larger than all but the *Tripsacum-Sporobolus-Paspalum* type. *Helianthus hirsutus* and *Eryngium yuccifolium* were obvious although *Desmanthus illinoensis*, *Aster euale*, *A. oblongifolius* and *A. praeleus* were frequently observed. In the late autumn, *Gaillardia aestivalis*, a species restricted to this type, was conspicuous.

Mima mounds were abundant in many portions of the areas covered by this community type and vegetation on these mounds differed markedly from the general community. Where the mounds were not mowed an almost zonal 3-part community was observed. Dominating the upper one-third of the mound was *Andropogon gerardii*. This was in contrast since the only other habitat it was observed to frequent in the *Sporobolus-Tridens-Paspalum* type were microlows running perpendicular to the slope. The center section of the mounds was dominated by *Baptisia australis*, *Gaillardia aestivalis* and *Tridens strictus*. The lowest section of the mound did not deviate noticeably from the majority of the meadow.

When the mounds were mowed yearly a different vegetation type occurred probably because it was impossible to control correct cutting height when traversing a mima mound over 2 meters high. Again a 3-part zonal vegetation was observed. The upper section of the mounds was dominated by *Chloris verticillata*, *Aristida oligantha* and *Cenchrus incertus*. The central part of the mound was dominated by *Andropogon ternarius* and *Rudbeckia maxima* while the bottom again differed little from the rest of the meadow.

Andropogon ternarius was a characteristic indicator of mowing severity or overgrazing and was restricted to this dominance type. Broadleaf plants observed to increase with mowing or grazing severity were *Rudbeckia maxima* and *Marshaellia caespitosa*. *Juniperus americana* was a woody species observed to be associated with communities in the early stages of succession. *Quercus shumardii* and *Maclura pomifera* occurred as scattered motts in native hay meadows within this type.

Schizachyrium type. This community type was found on Wilson-Crockett-Burleson soils between the Trinity and Colorado Rivers. Average annual precipitation varied from 75 cm along the Colorado

River to 95 cm at the Trinity. This was the most easily recognized community type within the Prairie, possibly because of the relatively simple species composition. *Schizachyrium scoparium* was strongly dominant here, composing 81% of the vegetation based on basal cover (Table 2). Production increased with increases in rainfall from 3,000 kg/ha to just under 5,000 kg/ha (Fig. 2). *Andropogon gerardii* was a common codominant. *Sorghastrum nutans*, *Paspalum floridanum* and *Manisuris cylyndrica* were found in all stands, but did not contribute appreciably to production. *Schizachyrium scoparium* production decreased with increasing rainfall and was replaced by increases in *Sorghastrum nutans* production (Fig. 2). *Rudbeckia amplexicaulis*, *Polytaenia nuttallii* and *Lindheimerii pinndifita* were important vernal forbs, although the density of *Oxalis violacea* and *Carex brittonia* was often greater. *Vicia ludoviciana* also was observed abundantly on the sandier sites. *Bouteloua curtipendula*, *Eriochloa sericea* and *Stipa leucotricha* often were found within this type.

DISCUSSION

The grassland formation of North America has been divided into seven associations based on species composition, geologic history, climate and geography. These factors have produced unique kinds of grasslands which can be physiognomically recognized by height relationships. Dodd (1968) in a synthesis of literature discussed the seven grassland associations and classed the dominant vegetation into three groups: short grasses (16-60 cm in height at maturity), mid-grasses (61-120 cm), and tall grasses (> 120 cm).

Based on height classification, dominants of the Blackland Prairie were almost exclusively tall grasses. Only *Eriochloa sericea* was a dominant species that did not commonly reach a flowering height of more than 120 cm in some portion of the Prairie.

Climatically, the True Prairie, in its southern extension, received from approximately 100 cm/yr on its eastern boundary to 75 cm/yr of precipitation on the west. The Coastal Prairie received from 65 to 86 cm/yr average annual precipitation and the Mixed Prairie varied from a high of 69 cm/yr to a low of 25 cm/yr (Dodd 1968). Using only precipitation criteria, the Blacklands could be considered True Prairie or Coastal Prairie.

Studies by Bray (1901), Shantz (1923), Weaver and Albertson (1956) and others recognized the Mixed Prairie as occurring west of the 100th meridian. This alone would exclude the Blackland Prairie. Moreover, the Mixed Prairie was characterized by a combination of mid and short grasses, and production values in the Blackland Prairie far exceeded most reported for the Mixed Prairie. Climatic delineation of the Mixed Prairie also placed its eastern boundary to the west of the Blacklands (Shantz 1923, Dodd 1968).

The True Prairie was indicated to have six major communities; three upland and three lowland (Weaver and Clements 1938, Dodd 1968). For the upland communities *Stipa spartea, Sporobolus heterolepis, Schizachyrium scoparium* were dominant species, while *Andropogon gerardii, Bouteloua curtipendula* and *Koeleria cristata* also were found. Of the three major lowland communities one was dominated by *Andropogon gerardii,* with limited amounts of *Sorghastrum nutans, Panicum virgatum, Stipa spartea* and *Schizachyrium scopatrium,* another by *Spartina pectinata,* while an intermediate community, between *Spartina* and *Andropogon* communities, was dominated by *Panicum virgatum* and *Elymus canadensis*.

Of the characteristic dominants only *Schizachyrium scoparium* and *Andropogon gerardii* were found within the Blackland Prairie. In most previous reports of the True Prairie *Andropogon gerardii* was reported to increase in abundance as moisture increased. However, in the Blackland Prairie on two or three soil associations it decreased in both percent composition based on basal cover and production as precipitation increased. This supported observations of Roemer (1849) that *A. gerardii* was more prominent in xeric portion of the Blacklands. *Sorghastrum nutans*, a very important species in the Blackland Prairie, was mentioned as only occurring in limited amounts. *Tripsacum dactyloides* a principal component in higher precipitation zones of the Houston Black-Heiden-Ferris soils was also mentioned as occurring in limited amounts. *Sporobolus asper* var. *asper*, a dominant in two community types in the Blackland Prairie, was only recognized as of "secondary importance," increasing in time of drought. It was worthy of note that *Sporobolus asper* var. *asper* was restricted as a dominant to the xeric *Sporobolus-Schizachyrium-Andropogon* and the mesic *Tripsacum-Sporobolus-Panicum* community types. Such disjunction could indicate genetic viersity. This species was very diverse, having five recognized varieties (Gould 1969). It is possible that further study will reveal plants in these two community types are genetically different.

When ecologically equivalent dominant species were considered only *Eriochloa sericea*, a mid-grass, could be favorably compared with *Stipa spartea*. However, *Eriochloa* was only found as a dominant in one community type within the Blacklands. *Sporobolus silveanus* and *Sporobolus heterolepis* had a very similar seedhead appearance. However, *Sporobolus silveanus* seedheads were observed to reach 2.5 m, far surpassing *Sporobolus heterolepis*. Also *Sporobolus silveanus* produced up to 6,000 kg/ha, more than doubling the *Sporobolus heterolepis* yields. No mention was made of *Paspalum floridanum*, *Tridens strictus* or *Sporobolus silveanus*. On the basis of characteristic graminoid species listed by Dodd (1968) it is uncertain that the Blackland Prairie could be considered True Prairie.

It should be noted that species common to both the True Prairie and the Blacklands were lowland species in the True Prairie. Since minimum rainfall in the Blackland Prairie is 75 cm/yr and most of the Prairie received much more it is possible that biological interaction prevented more xeric species, such as *Sporobolus heterolepis* or its equivalent, from occurring. That is, the taller grasses more efficiently utilized the higher precipitation. Added to the high precipitation values was the high soil moisture retention. Thus, precipitation, soil moisture retention and gilgai microrelief created an environment that enabled lowland species in the True Prairie to occupy upland sites in the Blackland Prairie.

For example, gilgai landform sometimes modified precipitation averages. Gilgai microlows caught and retained water due to the slow permeability of the vertic soils. This added moisture enabled some species to extend their range into more xeric areas. *Helianthus maximiliana* and *Tripsacum dactyloides*, both species encountered in the *Tripsacum-Sporobolus-Panicum* community type, extended their range some 100 km to the south in gilgai microlows. While microlows also limited the cutting height for plants, the additional moisture was probably the primary reason these species extended their range. Moreover, these species were dominants where commonly encountered in high precipitation zones. When found in microlows of more xeric areas they occurred as dominate. Thus, it may be said that microlows extended both their floristic and vegetational range.

The lowland community dominated by *Andropogon gerardii* with limited amounts of *Sorghastrum nutans* and *Schizachyrium scoparium* was somewhat similar to the *Sorghastrum-Andropogon* community type of this study. This community type was the largest in the Prairie and occupied the central portion. If any one community type could be considered typic for the Blackland Prairie, it would be the *Sorghastrum-Andropogon* type. Thus, considering only the community type that best typified the Blacklands, it might be considered True Prairie.

The Blackland and Coastal Prairies have long been considered separate land resource areas (Godfrey, Carter, and McKee 1969). In 1841, an anonymous visitor to Texas recognized the Blackland and Coastal Prairies as separate resource areas noting "The Prairies or levels of Texas may be generally described under two heads: 1st the Southern or those on the coast, and 2nd, the Northern, or interior. . . . The Northern levels or Prairies are of considerable extent in the boundaries of Texas. . . . But they are little known, and as yet scarcely within the view of colonists. . ." (Visit 1841).

When describing the Coastal Prairie Dodd (1968) projected, "An abundance of *Stipa leucotricha* distinguished this association from the True Prairie." While the term "abundance," used in this context, is somewhat nebular, *S. leucotricha* never occurred as a dominant in the Blacklands. In addition, it was a characteristic increaser in the more xeric portions. Similar behavior has been documented by Dyksterhuis (1946, 1948) and Launchbaugh (1955). It is questionable that *S. leucotricha* was a dominant in the pristine Coastal Prairie if it invaded in similar edaphic and even more xeric climatic situations. It is doubtful the Blackland Prairie could be considered an extension of the Coastal Prairie. The *Schizachyrium* community type resembled portions of the San Antonio Prairie which had similar soils and precipitation. It was the only community type in the Blackland Prairie resembling the so-called "minor prairies," which have been recognized as True Prairie. If this xeric community type was True Prairie, other more mesic community types must be True Prairie.

Information provided in this study indicates the Blackland Prairie should be considered as a component of the True Prairie. This classification seems to properly classify the Blackland Prairie with regard to all other North American prairies. However, the two most mexic community types, the *Sporobolus-Tripsacum-Panicum* and *Sporobolus-Tridens-Paspalum* differ significantly in both composition and production from the other five. Dominants in the two community types attained observed flowering heights of just under 3 m. In the classification of Weaver and Clements (1938) these two community types would be recognized as Tall-Grass prairie as opposed to True Prairie. No previous accounts of North American grasslands reveal any documented community with an equivalent or even similar composition and thus, it should be recognized as unique among North American communities. The author believes these two community types should

Prairie, when considered as one entity, should be recognized as True Prairie.

Results from the study of the movement of a *Sorghastrum nutans* clone indicated that mowing may have replaced fire as the primary factor in maintaining stability in the *Schizachyrium-Andropogon-Erioochloa* community type. Results of the study of a cemetery located in a native hay meadow supported the hypothesis that mowing may have also replaced burning in the *Sporobolus-Tridens-Paspalum* community type. Moreover, since these two community types represented the most xeric and mesic in the Blackland Prairie, mowing may well have replaced burning as a woody plant control measure throughout the Blacklands.

Sauer (1950) hypothesized that all grasslands would, in the absence of fire, be invaded by woody species. In the Blackland Prairie all community types would probably be invaded by woody plants in the absence of fire or mowing. The rate of invasion would be largely dependent upon soil properties. In a similar isohyet, the Wilson-Crockett-Burleson soils would be invaded by woody species more rapidly than any other soil association. This is because of acidic soil, lower montmorillonitic clay content and readily available seed source. Community types occurring on the Houston Black-Heiden-Ferris soils would have the slowest rate of invasion of any soil association in a given isohyet. This is primarily attributable to the high montmorillonite clay content and resulting vertic properties. The Austin-Stephen-Eddy soils would, with a similar grass cover, be invaded at a rate somewhere between the other two soil associations, primarily because its properties are roughly intermediate with regard to the other two soil associations.

Plant community identity and classification has been the subject of controversy since the inception of ecology. The primary factor governing community identification and classification is the kind of distributional relations between and among species along environmental gradients.

Whittaker (1970) acknowledged four basic hypotheses concerning species behavior along environmental gradients. Since this is not intended to be a comprehensive review of community theory or vegetation classification only the two most dissimilar hypotheses will be considered. These are:

A. Competing species, including dominants, exclude one another along sharp boundaries. Other species evolve toward close association with the dominants and toward adaptation for living with one another. Thus there develops distinct zones along the gradient, each zone having its own assemblage of species adapted to one another, and giving way at a sharp boundary to another assemblage of species adapted to one another.

B. Competition does not usually produce sharp boundaries between species populations and evolution of species in relation to one another does not produce well-defined groups of species with similar distributions. Centers and boundaries of species populations are scattered along the environmental gradient.

For purposes of discussion, "A" will be considered the "community type" hypothesis and "B" the "continuum" hypothesis. These two theories will be examined in relation to species distribution, abundance and production in the Blackland Prairie of Texas.

Daubenmire (1966) questioned classic continuum studies such as Whittaker's (1956) because, ". . . all studies supporting the continuum viewpoint have included many severely disturbed stands, if they were not based on them exclusively." He also indicated that data manipulation and/or presentation determine whether a continuum exists.

The stand selection criteria used in this study were designed to insure that few, if any, disturbed stands were included. It was interesting to note that using undisturbed stands, both dominants and subordinate species exhibited a continuum-type behavioral pattern within a constant soil association along a precipitation gradient. Moreover, these patterns were established using relatively simple methods of presentation. Specifically, no ordinations were used to monitor or present species behavioral patterns.

Despite the continuum-type behavior exhibited by many species, both dominant and subordinate, the Blackland Prairie was divided into distinct communities. To some, the acknowledgment of continuum-type behavior of dominants and establishment of community types for the same area would seem mutually exclusive. However, McIntosch (1967) noted, "Continuous transition may occur on the ground but is not necessary to the individualistic or continuum concept that all vegetation change be continuous on the ground or that discontinuities be absent." Greig-Smith (1964) noted that clearly distinguishable units in the field may form a continuum in the abstract.

For some purposes it may be useful to consider the Blackland Prairie as representing precipitation and growing seasons gradients along three relatively constant soil associations. This is a valid observation, for it does occur. On the other hand, the Blacklands may represent several vegetation types sufficiently different to warrant delineation as community types.

Different approaches to the study and classification of vegetation may present two very different projections of the same area and even the same data. The vegetation of the Blackland Prairie, both dominant and subordinate, does exhibit a continuum-type behavioral pattern. But, for practical discussion, it is desirable, expedient and possible to recognize community types, so long as it is understood their boundaries are subject to come variation.

Although a myriad of hypotheses have been projected, no theories of mima mound formation are commonly accepted. Theories of erosion and accumulation are currently the most widely accepted. The erosional theory suggests that removal of the intermound area by running water and wind has left the mounds as essentially residual forms (Featherman 1872, Holland, Hough, and Murray 1952). The accumulational theory (Olmstead 1963) projected the concept that bunch grasses or small shrubs served as centers of accumulation of wind-blown soil and silt. Bailey (1892) discounted most other theories for mima mound formation in the Blackland Prairie: ". . . All are on rolling land and not blood land. . . . They are clay soil so can not be dunes.

"Are too numerous for human work, too large for animal mounds, unless made by Megatherium. Are too circular and even for iceberg or glacier deposits."

The prominence of *Sporobolus silveanus* on the *Sporobolus-Tridens-Paspalum* community type may offer insight to the somewhat nebular origin of the mounds.

The last ice sheet retreated from the northern fringe of the area now recognized as the North American Midcontinental Grasslands about 10,000 years ago (Kupsch 1960). This ice retreat was followed by a warming trend which lasted from about 8,000 B.C. to the beginning of the Christian era (Dix 1964) and is recognized as the Hysithermal period (Deevy and Flint 1957). During the Hypsithermal period the Deciduous Forest retreated eastward and grasslands occupied the vacated area. Some members of the forest flora, especially grasses, withstood the climatic change. These species survived, reproduced and integrated with the grassland flora (Dix 1964). Gleason (1923) noted the three most important grass genera (*Andropogon, Sorghastrum, Panicum*) in the Illinois Tall-Grass Prairie plus *Sporobolus* to the south belonged to this group. While there has been some question concerning the Hypsithermal influence on the vegetation of Texas (Graham and Heimsch 1960), if any area of Texas was affected it would have been the northern portion of the Blackland Prairie.

Dominant species on the *Sporobolus-Tridens-Paspalum* community type have been included with wooded or mesic situations (Hitchcock

1950, Launchbaugh 1955). It is quite possible that these species, or their ancestors, developed as dominants following the forest retreat to the south and east.

A forest-retreat origin of the vegetation would seem to support the accumulational theory of mima mound formation. This theory is founded on the belief that, once the surface horizon(s) had developed, the climate of the area became arid and vegetation became discontinuous. Deflation of the surface soil occurred on the barren areas and accumulated around clumps of remaining vegetation. When humid conditions returned a new profile formed between the mounds. The erosional periods may have been during the arid period which caused the forest to retreat eastward, since wind erosion is prevalent in arid situations (Holland, Hough, and Murray 1952).

SUMMARY

The Blackland Prairie, a major land resource area of Texas, extends from the Red River to the Colorado River. The Prairie varies in width from 70 km along the Red River to 12 km at the Colorado River.

Climatic gradients are distributed from north to south in the Blacklands with virtually all precipitation occurring as rain. Precipitation increases from 75 cm/yr at the Colorado River to 115 cm/yr at the Red River. Because of the vectorial effects produced by geological substrates, the Blackland Prairie has a coastal (toward the Gulf of Mexico) or southeastward orientation. Four major streams dissect the summit slope of the Blacklands. They are the Red, Trinity, Brazos and Colorado Rivers.

Geologic sediments are more recent from west to east, due to the retreat of a Cretaceous inland sea in that general direction. The Blackland Prairie was geologically subdivided into five parallel, longitudinal north-south units. The divides are the Eagle Ford, Austin, Taylor, Navarro and Midway Groups. This great variety of parent materials within the Prairie results in associated soil diversity.

Three soil associations, named for the three most prevalent series, were established. The Austin-Stephen-Eddy soils association consists of brown silty clays and clay loams that are basic, thermic, carbonatic and shallow. The Houston Black-Heiden-Ferris association is composed of vertisols which share fine, basic, thermic and ustertic properties. The Wilson-Crockett-Burleson soils association consists of acid gray, loany and clayey soils.

In 1971 an extensive study was conducted of the climax vegetation of the Blackland Prairie. Eighty-three stands were selected and sampled using 30 rectangular 0.5 m^2 (100 × 50 cm) quadrats and 300 point quadrats. In November of 1971, 24 stands were sampled for end-of-season production.

Soil samples approximately 10 × 10 × 38 cm were taken of the solum from a representative location in each stand and analyzed for texture, pH, available water and bulk density. Pits were excavated and soil profiles described for typic soils in each association.

One hundred and thenty-three species and varieties were identified in this study. Average basal cover for all stands was 29% and end-of-season foliar production averaged 6,500 kg/ha. A regression of percent composition basal cover for dominants and end-of-season foliar production by dominants showed basal cover and production could be used more or less interchangeably.

Dominant species of the Prairie, those with a basal cover composition of 20% or greater in at least one stand were: *Andropogon gerardii*, *Eriochloa sericea*, *Panicum virgatum*, *Paspalum floridanum*, *Schizachyrium scoparium*, *Sorghastrum nutans*, *Sporobolus asper* var. *asper*, *Sporobolus silveanus*, *Tridens strictus* and *Tripsacum dactyloides*.

In addition to the dominants, some widely distributed species with 50% or greater absolute frequency in three or more stands, include *Carex microndonta, Carex crus-corvi, Coreposis basalis, Centaurea americana, Chaerophyllum tainturieri, Eleocharis acutisquamata, Helianthus hirsuta, Helianthus maximilii, Polytaenia nuttallii* and *Sisyrinchium varians.*

Species that occurred in the highest percentage of stands were: *Sorghastrum nutans, Schizachyrium scoparium, Sisyrinchium varians* and *Bouteloua curtipendula.*

Total foliar end-of-season production on the Austin-Stephen-Eddy soils association increased from 5,500 kg/ha at the Colorado River to over 9,000 kg/ha at the Red River. On the Houston Black-Heiden-Ferris soils association production increased from 5,300 kg/ha at the Colorado River to 10,000 kg/ha at the Red River. Production on the Wilson-Crockett-Burleson soils varied from 3,000 kg/ha at the Colorado River to 10,000 kg/ha at the Red River. Yield components varied continuously along the continuous rainfall gradient from 75 cm/yr to 115 cm/yr from the Colorado to the Red River. Annuals constituted a majority of forb production in xeric areas of the Prairie, while perennials produced a majority of forb yield in mesic areas.

Clonal movement of *Sorghastrum nutans* over 25 years was studied and virtually no movement had occurred. A cemetery located in a native hay meadow was rapidly invaded by woody species when fire and mowing were removed as management practices.

On the basis of data analysis and field observation, seven major community types were recognized. These were the

Sporobolus-Schizachyrium-Andropogon
Sorghastrum-Andropogon
Schizachyrium-Andropogon-Eriochloa
Sorghastrum-Schizachyrium
Tripsacum-Sporobolus-Panicum
Sporobolus-Tridens-Paspalum, and
Schizachyrium.

East-west boundaries were produced by soil differences, while north-south divisions generally coincided with divisions produced by major streams. Only the *Sorghastrum-Schizachyrium* type occurred on more than one soils association.

When compared with the Short-Grass, Mid-Grass, True and Tall-Grass Prairies, the Blackland Prairie as a whole was considered True Prairie. The *Tripsacum-Sporobolus-Panicum* and *Sporobolus-Tridens-Paspalum* community types were identified as Tall-Grass Prairie. When soils were held constant, both dominant and subordinate vegetation tended to follow a normal distribution pattern along a continuous precipitation gradient.

The presence of *Sporobolus silveanus* in the area of the Prairie covered by mima mounds supported the erosional theory of mima mound formation.

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