PLANT SUCCESSION ON ABANDONED CROP LAND

by

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PART I

ALGAE AS PIONEERS IN PLANT SUCCESSION AND THEIR IMPORTANCE IN SOIL EROSION CONTROL

PART II

NATURAL REVEGETATION OF ABANDONED CROP LAND

ALGAE AS PIONEERS IN PLANT SUCCESSION AND THEIR IMPORTANCE IN SOIL EROSION CONTROL

It is generally recognized that plants play a leading role in erosion control and prevention, although research involving the evaluation of their part has been neglected by botanists. Particularly is this true of any correlation of the lower forms with soil erosion. The purpose of this study was to determine some of the soil conservational values of a protective algal crust, which is present over hundreds of acres of badly eroded soil. Such an aim has led to a shifting to this microvegetation of much of the importance heretofore attributed to the higher plants.

Trueb (1888) emphasized the value of blue-green algae on the island of Krakatoa, where they were the first colonists after a volcanic eruption which denuded the island of all visible plant life. Three years after the eruption these algae had formed an almost continuous gelatinous layer over the surface of the cinders and stones constituting the soil, and by their death and decay they rapidly prepared it for the growth of higher plants. The role played by soil algae in plant succession is discussed by Fritch (1907). He concludes that an algal covering on the surface of dry, sandy soil regulates the moisture of the soil, thus forming a shelter for seed plants. Harrison (1913) presents evidence to show that a surface stratum of algae and other organisms play an important role in the production of oxygen necessary for the roots of rice. Piercy (1917) describes the algal crust on the soil and how it thrives during parts of the season when the grasses die off as a result of drought. Petersen (1935) conducted various research problems with algae on the surface and within the soil. He concluded that they are useful, (1) in the addition of organic matter to the soil and (2) they may play a direct or indirect part in nitrogen fixation. Drouet (1937) describes the presence of blue-green algae, mainly Porphyrosiphon Notarisii (Menegh.) Kütz., in Brazil where they grow on dry soil which has been denuded of the macrovegetation. Elwell (1939) noticed a surface crust on abandoned farm land in the Red Plains Region in central Oklahoma, where succession has produced a partial cover of perennial bunch grass. Reference is made to it as a surface accumulation of residue and lichens.

GENERAL DESCRIPTION OF THE AREA INVESTIGATED

Field work and observations necessary to this study were conducted over an area which includes parts of Kansas, Oklahoma, and Texas (Fig. 1.). It extends southward from near Howard, Kansas, to occupy a strip of land through central Oklahoma and terminating in northern Texas. Upon passing into Oklahoma from Kansas, in the vicinity of Sedan, Kansas, there is a rapid decline in the number of fields showing the presence of the algal crust, there apparently having been less destruction of natural vegetation on the Osage Indian Reservation. From Cleveland, Oklahoma, south into Texas the stratum is common except for a break caused by the Red River Valley. The east and west boundaries mapped in this investigation do not establish limits for the usefulness of algae in erosion prevention but rather indicate the extent of a survey which is incomplete at this time. It is very probable that upon further investigation the area will be extended eastward at least to follow the boundaries of the oak savanna, and without doubt will include the entire Red Plains Region to the west and south. The northern boundary of the area investigated may be described as being some 40 miles north of the Kansas-Oklahoma boundary. A copious surface growth of algae, however, has been found on thin soil as far north as Lawrence, Kansas. This northern distribution was unknown at the time the field work was in progress, so has been necessarily omitted in this paper.

Essentially, the general aspect of the native plant cover of this area is that of a savanna on the east and of grassland on the west. The savanna is characterized by varying degrees of dominance of woodland and of climax grasses. The dominant species of the woodland are Quercus marilandica Munchh (blackjack), Q. stellata Wang. (post oak) and the much less abundant Hicoria Buckleyi (Dur.) Sud. (black hickory). The grassed areas are mostly confined to the lowlands and sides of gently sloping hills. In some sections, however, they completely dominate the landscape, while in other places they may appear as alternes or may be completely absent for many miles. The grasses originally most abundant in the savanna were Andropogon furcatus Muhl., Sorghastrum nutans (L.) Nash, Andropogon virginicus L., and Sporobolus cryptandrus (Torr.) A. Gray. The savanna joins on the west in a very abrupt manner with the true prairie, which has Andropogon scoparius Michx. as the dominant species. In its undisturbed condition the following grasses are also very common in the true prairie: Andropogon furcatus, A. hallii, Hack. A. saccharoides, Swartz. Agropyron smithii, Rydb. Sporobolus asper, (Michx.) Kunth. Boutleoua curtipendula (Michx.) Torr., and Elymus canadensis L. Proceeding westward in Oklahoma and Kansas the true prairie blends into the mixed prairie which shows an increasing amount of Agropyron smithii, Bouteloua gracilis, (H.B.K.) Lag., B. hirsuta Lag., and Buchloe dactyloides (Nutt.) Engelm.

The savanna, for the most part, follows closely the sandstone hills. Especially, there is a close correlation on the western margin. Weathering of the Pennsylvanian shales is very noticeable because of recent agricultural practices, which leave the sandstone exposed. The migration of the oaks westward in most sections may be seen to be keeping pace with the uncovering of the sandstone. This sandstone weathers to form a coarse sandy loam soil, which is very susceptible to erosion by wind and water. The trees, however, break the driving force of the wind to the extent that wind erosion is not a general problem throughout the area but may be serious only locally.

The Red Plains Region occupies an extensive belt which formerly included some valuable agricultural land. The red Permian clays and shales have weathered into a gently rolling plain, with a dark residual surface soil from 8 to 12 inches deep, but when once broken for cultivation is very erosible. A reconnaissance survey of Cleveland County, Oklahoma, which is in the central part of the state, brought out the fact that the area of abandoned land is about one-seventh as large as that under cultivation, while 12 per cent of the cultivated land was very seriously damaged by gullying and severe sheet erosion. Cleveland County is partly in the oak savanna and partly in the true prairie. Ninety-one per cent of the abandoned land was found to be in the oak savanna, as was also a large proportion of the serious gullying. Winters (1934) points out that 20 per cent of the Red Plains Region of Oklahoma with a slope of from 2 to 6 per cent is under cultivation, 6 per cent of which is gullied beyond economic repair, and 25 per cent has been abandoned. Of the land broken for cultivation which has a slope of over 6 per cent, practically all has been abandoned because of erosion.

In the portion of the Red Plains Region examined in Kansas, extensive algal crusts were comparatively few in numbers, as is also true to the south in the area traversed by the Salt Fork, Cimarron, and Canadian rivers. In central Oklahoma, however, well established algal crusts, especially on the residual Red Plains soils, are very common. The crust often forms on sandy wind-blown soils during wet seasons and may completely hold the soil against blowing. Often, however, the crust is broken by trampling, and once broken it is easily undermined, which, along with covering by sand, soon leads to its complete destruction.

ALGAL STRATA WITHIN THE AREA

The present vegetation over much of the area studied shows a very contrasting picture as compared with an unabused virgin plant cover. The changes are a result of overgrazing, cultivation of the land for a brief period and then abandoning it, or of frequent burning. Excessive erosion, especially on the cultivated fields, has so profoundly changed the topsoil that the native climax plants are unable to reestablish themselves until the slow process of succession has recreated a suitable environment. It is in these xeric places that soil algae come into prominence, to be accompanied after a short time by moss and by seed plants which are mostly annuals.

The algal crust varies greatly in appearance, but in general may be considered as belonging to the following types:

A. Smooth, soil-covered stratum, composed of *Schizothrix Friesii*, (Ag.) Gom. with *Microcoleus vaginatus* (Vauch.) Gom. nearly always present in lesser quantities.

B. Smooth, dark-colored stratum, composed of *Scytonema ocellatum* Lyngb. as the dominant, accompanied by *Microcoleus vaginatus*, which often is present in nearly equal amounts.

C. Rough, black or reddish-colored stratum, composed of *Porphyrosiphon Notarisii* (Menegh.) Kutz. as the dominant and *Scytonema ocellatum* present in important amounts. *Microcoleus vaginatus* is always present and may even be first in importance.

The species of algae listed for the different types of strata are not conclusive but are the ones most commonly found throughout the area. *Microcoleus lacustris* (Rab.) Farlow and *Schizothrix arenaria* (Berk.) Gom. were the main constituents of the smooth stratum in most collections near Norman, Oklahoma. *Lyngbya* is usually present and may appear as dominant in laboratory samples which have been saturated with water for some time. It cannot, however, be considered as a major constituent of the normal field strata. Other forms of blue-greens were present in all samples but were of little importance.

In the savanna the algal stratum is found on abandoned farm land and in the woods where the topsoil has been removed. Erosion of the oak-covered hillsides does not belong to the natural order but is evident after clearing or extensive burning. Bennett (1934) describes the runoff from a central Oklahoma forested area as being 250 gallons of clear water per acre during a rainy period, as compared with an adjoining burned area which ran 27,600 gallons of muddy water per acre. Burning of woodland destroys the leaf mold, grasses, and low growing plants, which do much to keep the soil open for absorption and break the force of the water. Fires are common throughout the savanna and are partially accidental but often are set with the idea of killing the undergrowth of oaks and ridding the open areas of worthless grasses. The abandoned fields can be detected from a distance by the presence of prairie three-awn grass (Aristida oligantha) Michx., which is clearly a dominant for many years on such impoverished land and may remain as such if normal plant succession is impeded by pasturing or burning.
It is on these abandoned fields that the algal stratum reaches its peak in completeness of ground cover and thus also in the effectiveness of erosion prevention. Throughout the area the stratum has a variation in general appearance and in composition corresponding to the humus content

of the soil and to the degree of macrovegetative cover.

The smooth, soil-colored stratum, type A, is characteristic throughout the area on recently abandoned fields, or in places in older fields which are especially low in humus, and where the grass cover is absent or exceptionally scanty. This stratum may easily go unnoticed since it does not have a distinctive color except during moist rainy seasons, at which time the fingers may be slipped under the stratum and pieces with an area of several square inches pulled up. Although the algal trichomes are microscopically small, the strands may be seen macroscopically by breaking slowly the removed pieces of algal crust. During dry periods the stratum may easily be mistaken for a soil crust formed by the impact of rain drops. The only macrovegetation of any importance where this stratum is found is composed of Aristida oligantha with A. longespica Poir. present often as a minor constituent. During the winter and spring the ground appears almost bare, but later in the season the Aristida makes a growth which may appear luxuriant from the distance. The cover formed by this grass, however, as revealed by the square-foot density method, varies from about 0 to 3 per cent. Basal area quadrats taken of representative areas show a cover of about .8 per cent.

The comparatively smooth but dark-colored stratum, B, is found in places where the soil is a little richer in organic matter. This type is usually found in the same abandoned field with the previously mentioned stratum but is easily distinguished since it is accompanied by a better growth of macrovegetation and by its blackish color. The most characteristic seed plant is Aristida oligantha; however, various species of plants make their appearance during this stage of plant succession. In the savanna of Kansas and northern Oklahoma, Sporobolus cryptandrus and Schedonnardus paniculatus (Nutt.) Trel. are common; Gymnopogon ambiguus (Michx.) B.S.P. and Eragrostis secundiflora Presl. are wide spread but are represented only by scattered bunches. The vegetative cover formed by the higher plants varies from about 1 to 20 per cent, as indicated by square-foot determinations.

Stratum type C may be found in abandoned fields, pastures, and frequently burned over savanna woodlands. In the woodlands the soil is sandy despite the noticeable signs of erosion and ground fires, there is considerable more organic matter than is present on the badly eroded crop land. The algal stratum is somewhat broken and may be patchy in distribution because of irregularities in soil and macrovegetation. The crust is about 6 mm in thickness and is very rough as seen on the upper surface, the roughness being a result of irregularities on the surface of the soil which have been grown over by the algal stratum or by winter thawing and freezing, causing bulges which are held by algal growth. Where type C is present in abandoned fields, it is generally an indication of an advanced stage in succession, or it may be confined to areas in more recently abandoned fields where erosion has not been so severe; thus there is a higher organic content in the soil and a more abundant macrovegetation. In general appearance and composition the stratum most closely resembles that found in oak woodlands, but it is usually more luxuriant and unbroken.

In the vacinity of Sedan, Kansas, several fields were covered by the stratum, type B, which had the additional protection of irregular algal colonies of _Nostoc commune_ Vauch. A quadrat determination was made of the west slope of a twelve-acre hillside in an abandoned field, and it was found that Nostoc formed a 32 per cent cover for the area between the bunches of grass.

The problem of dissemination of blue-green algae to fields when they become abandoned is in no way a limitation, since soil samples taken from cultivated fields show that there are enough of these forms present in the soil to form a crust when conditions become favorable for its growth.

Moss was found throughout the area in both grassland and woodland samples, being most abundant in stratum type C, especially in the woodland, but without exception has been found to be missing from the smooth highly exposed strata. In most cases the moss cover is not sufficient to be of prime importance, although its frequency in many fields may be as high as 30 per cent of the samples taken. The protonema and rhizoids, however, may help in the formation of a tough stratum in many places. In the canyons near the center of the Red Plains Region, as well as on rocky exposures to the east, Selaginella plays an important role in formation and holding the soil on steep ledges and slopes. Selaginella and lichens are highly localized, so are not considered in detail in this study.

EXPERIMENTAL METHODS AND RESULTS

Two plots were selected for intensive study, one being near the center of the oak savanna, on highway 66, about 4 miles south-west of Stroud, Oklahoma; and the other located on highway 99 (11), 12 miles northwest of Sedan, Kansas.

Infiltration

This factor was first studied, because, if the algal layer have proved a decided obstruction to normal percolation, the apparent value of a non-erosible surface would be nullified. Infiltration was also the only entirely unknown factor, since the others were partially apparent upon general field reconnaissance.

All tests were made in the field in order that the soil might be as nearly as possible in an undisturbed condition. For this work thin metal cylinders with a diameter of 12.5 cm. and a depth of 7.5 cm. were used. The cylinders were pushed with a rotating motion into the soil to a depth of about 3 cm., all possible precaution being used to obtain clean cuts without breaking the algal crust. The soil was then sealed to the metal cylinder with shellac. About one-half the soil area within the cylinder was covered with 4 thickenesses of cheese cloth. The purpose of the cloth was to facilitate the pouring of water into the cylinders without stirring up the soil. This precaution was not necessary on the alga-covered soil, but was used regardless of any need. When the cylinders were found to be over small burrows which allowed a very rapid water loss they were changed to a new location. This change was necessary in only 8 per cent of the attempts. Water was added in 250 cc amounts and kept above a three-sixteenths inch depth. The time was calculated to the nearest second for each 250 cc of water which soaked into the soil. The total amount of water used varied, but in all cases was from 3 to 4 liters, which was sufficient to arrive at a constant rate of infiltration. Twelve tests were made in each of the three stratum types, 6 on the undisturbed soil and 6 on small areas from which the algal layer had been removed.

The results of tests on the three stratum types (fig. 2) clearly indicate that the rate of infiltration is not slowed down by the presence of an algal crust, except for stratum type A, where it is only temporarily retarded. The average of 12 tests on this type indicate that infiltration was slowed down until about 3½ liters (about 6½ inches) of water had been taken into the soil. This retardation of infiltration, to the degree that it takes about twice as long for the first 250 cc (about ½ inch) of water to enter the soil, would undoubtedly be serious if this experiment could be completely compared with natural percolation of water from torrential rains. During heavy rains, however, there is a constant pounding and dislodging of soil particles which changes the rate to favor the protected soil. Experiments in which the water was dded in the form of a forced spray, from an atomizer type plant sprayer, may be taken as a better comparison. The results of tests by this method, on stratum type A, showed that it took only 20 seconds longer for the first 250 cc of water to soak through the algal protected soil. For the second 250 cc, it changed over in favor of the protected soil, taking 10 seconds longer to soak into the bare soil. Results similar to these were found in Missouri by Neal (1938) when water was applied gently, as compared with the rate of infiltration during a rain. When the soil is stirred and packed by the downpour of water, there seems to be a puddling of the particles to form a compact layer which retards the infiltration of water into the soil. The soil underlying stratum type C is much more easily stirred than the soil under A and B, and even with the protection of a cheesecloth cover it was impossible to add water with the necessary rapidity, without stirring the soil. This is thought to be partly the reason for the little difference in rate of infiltration for the rough stratum (C) and its corresponding denuded area for the first 250 to 400 cc of water. The presence of small cracks in type C stratum during dry weather also permits a more rapid penetration of water, but allows for very little dislodging of the underlying soil.

Soil Losses from Protected and Unprotected Plots

The value of a protective algal crust on soil was first brought to light by pouring water upon soil from a height of about 5 feet. It was evident that there was little or no cutting, nor was the runoff water muddy. The value of an algal crust in prevention of soil erosion was also evident upon general field survey in central Oklahoma. Many fields had been abandoned because of serious sheet and gully eroision, but after abandonment there was apparently no further erosion, as is shown by the fact that the old furrows and ridges can be seen after a period of from 30 to 50 years. Bluestem bunch grass has established itself in these fields in rows as though it had been planted, and erosion between the rows of grass has been minimized by the presence of a well developed algal layer. In other fields certain bunch grasses have attempted to establish themselves, but because of the absence of a complete algal crust, the soil washed from around them, leaving their bases elevated several inches above the soil level. These observations led to a more extensive study on bare and protected soil.

A field, near Stroud, Oklahoma, which had been out of cultivation for about 10 years was selected for this study. The entire field, with exception of the sides and bottoms of two small active gullies, was covered with a tough algal crust. The macrovegetation consisted mainly of a sparse cover of *Aristida*. The experiment was conducted in a rather simple manner which did not duplicate natural erosion, but which brought about conditions severe enough to yield comparative data for alga-protected and bare soil. Two plots, 2 by 6 feet, with a slope of 5.6 per cent, were staked off and bounded with metal strips. The few scattered stems of grass were clipped from the plots at the soil level, and one plot was watered with about one half inch of water. The smooth algal layer, which is ~~about~~ 3 to 6 mm. in thickness was removed from the unwatered plot. The surface was then packed and sprinkled with an amount of water equalling that of the alga-covered plot, and allowed to dry for 2 days. A soil crust was formed on the surface, much the same in appearance as would naturally be present on a bare area. It was necessary to denude such a plot because a bare area which might be compared with the alga-covered enclosure was not present in the field.

A ten-gallon metal tank with a separating trough, was set in the ground to catch the runoff water from each plot. The separating trough at first consisted of a 10 inch conduit with 9 longitudinal septa. It was found that with small amounts of water there was so much variation in amounts of overflow from the different chambers that it was impractical for use. A two inch repeatedly bifurcate trough was finally used and was found to separate, with sufficient accuracy, one-eighth of the overflow from the ten gallon tank.

Water was applied to the plots by means of a force pump, which was powered by an automobile. The stream of water coming through regular garden hose was broken into drops corresponding quite closely to medium-sized rain drops. The force of the water was sufficient to throw a spray 10 feet into the air when directed upward. The hose was moved back and forth along the plot at a height of five feet.

The soil losses were determined in the usual manner, by siphoning the water from the ten-gallon tank and collecting the silt, which was then dried and weighed. The water which was siphoned off was thoroughly mixed and samples taken, as were also samples taken from a tank which held one-eighth of the overflow from the first tank. The results obtained by the collection of silt and suspended particles in the runoff water from the two plots gave a ratio of 1 to 22. The 100 gallons of water from the protected plot appeared clear but contained .7 pounds of eroded soil. The bare plot did not suffer from channeling by rivulets of water, but the loss of soil by sheet erosion amounted to 15.4 pounds per 100 gallons of runoff water.

A similar experiment was conducted higher up the slope in the same field with the type C stratum. The grass clumps, which formed a 26 per cent vegetative cover, were left standing, but the algal stratum between the clumps was removed and the soil treated as in the previous experiment. The surface soil contained much more humus than did the soil lower on the slope, and was of a loose sandy nature. It appeared to be more erosible than the soil in the previously mentioned test plots, but the amount of eroded material was less. This difference was probably due to the fact that the slope of the plots was less (4.8 per cent), and the presence of vegetation cut down the rate of surface flow over the soil to the extent that miniature alluvial bars were formed around the bunches of grass. Six-tenths of a pound of eroded soil was caught in the 100 gallons of runoff from the alga-protected plot and 9.9 pounds from the plot which was devoid of an algal layer.

Soil Moisture

Soil samples were taken at two different times during the summer (1939) in an attempt to determine any difference in moisture content of soil protected by an algal layer and bare soil. Samples were taken from the upper inch of soil just beneath the algal stratum and similarly just beneath the hardened soil crust on bare areas. Soil moisture content was determined on the basis of vacuum over-dried samples. The results of 24 samples were so variable that no conclusion could be drawn. Such erratic results were probably caused by the fact that the spring and summer had been exceptionally dry, and the percentage of water in both types of samples was extremely low. Difficulty was also experienced in securing samples from bare areas which might be used as a comparison with alga-covered soil.

In the fall two days after a light rain, samples were taken from the upper inch of soil just beneath the algal layer and from just beneath the bare soil crust of plots which had been rid of their macrovegetation and one of which had also had the algal layer removed during the summer. The samples were weighed and dried for three days in a vacuum oven. The average of three samples taken from the algal-protected soil contained 8.9 per cent water, while those from bare soil contained 1.3 per cent. Such limited sampling can not be taken as proof that water is conserved by the presence of an algal stratum, but it does indicated the likelihood, as suggested by Fritsch (1922), that the algal layer acts as a mulch in the conservation of moisture.

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SUMMARY

1. Several species of soil algae, belonging to the Myxophyceae, constitute an initial stage in plant succession by the formation of a complete algal layer over hundreds of acres of badly eroded land in the South-Central United States. The decided prominence of this plant cover may last for many years until higher perennial plants are able to form an abundant ground cover.
2. The rate of infiltration of water into the soil is not slowed down by the algal stratum, with exception of on stratum type, in which there is a slight retardation for about the first 7 mm. of water.
3. Soil losses from plots with the protection afforded by an algal stratum were greatly reduced as compared with the losses from bare areas. The algal resistance to erosion is apparently the result of binding the surface particles of soil into a non-erosible layer which is also very effective in breaking the force of falling water.
4. Somewhat inadequate tests indicate a higher moisture content in the top inch of soil which has had the protection of an algal layer, as compared with bare soil.

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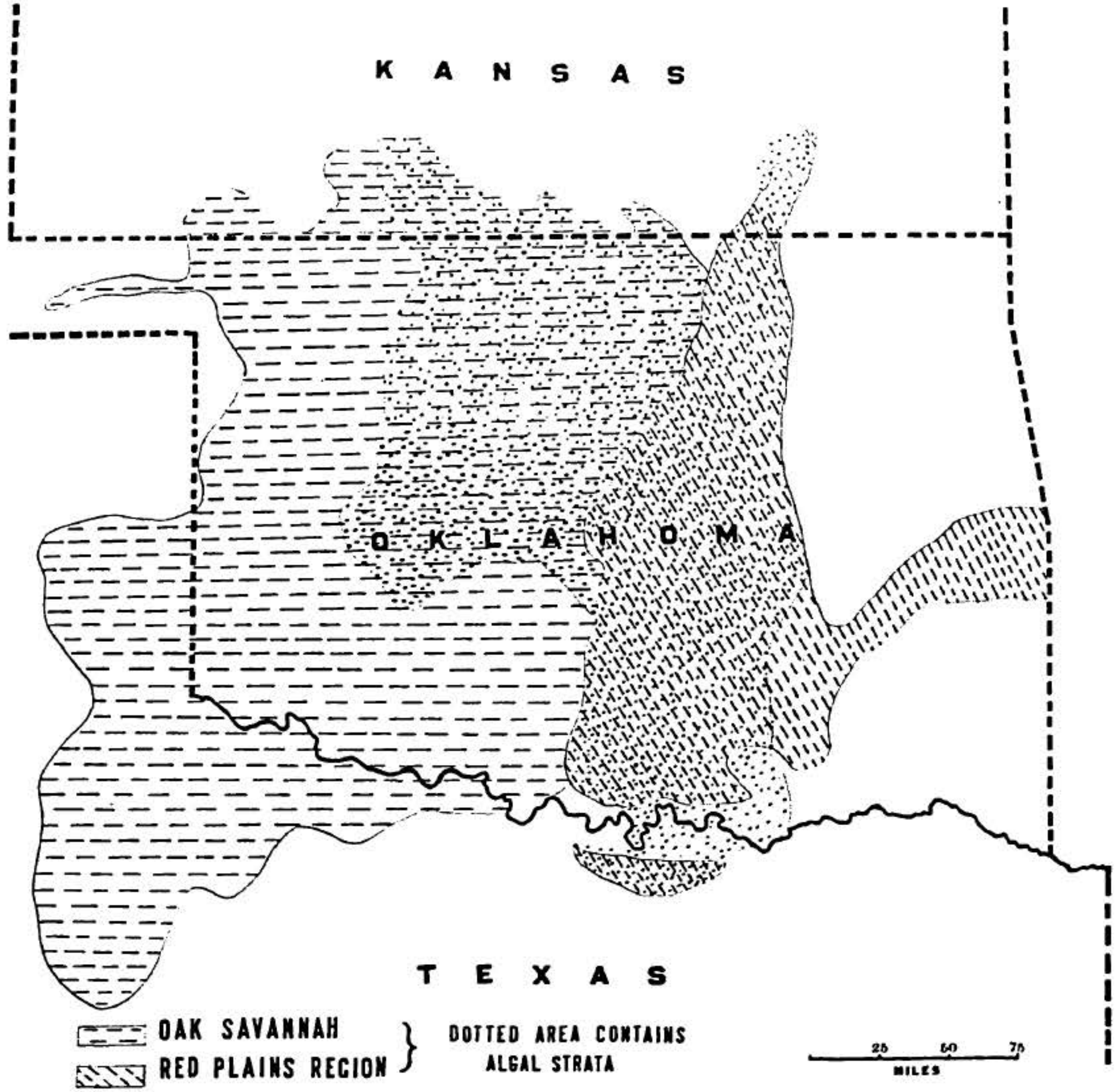

Fig. 1. Map showing region in which soil algae have been found to form extensive surface strata.

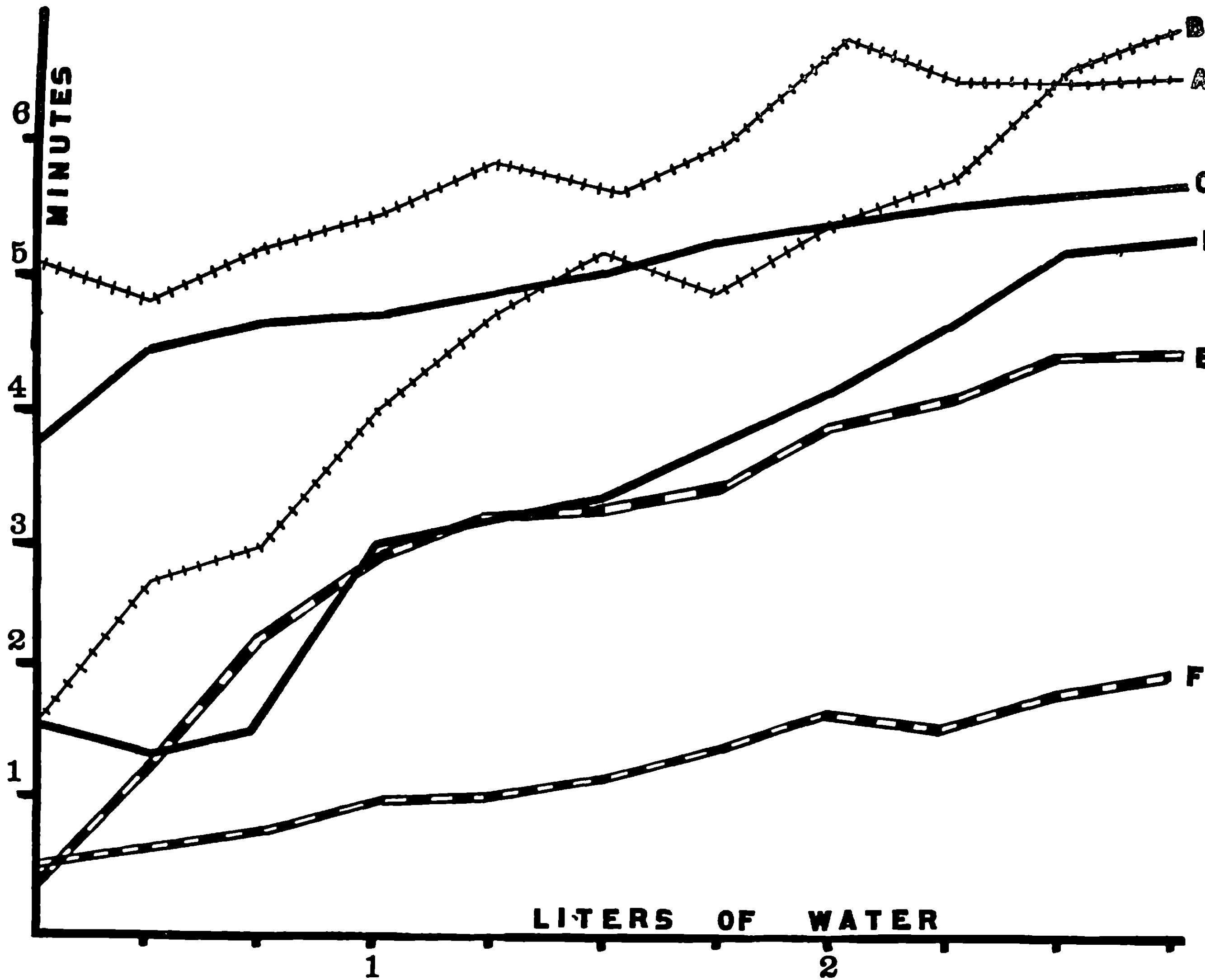

Fig. 2. Rate of infiltration of water into algal-covered and bare soil. Stratum type A, a, algal-protected, b, bare; stratum type B, c, bare, d, protected; stratum type C, e, bare, f, protected.

P A R T II

NATURAL REVEGETATION OF ABANDONED CROP LAND

NATURAL REVEGETATION OF ABANDONED CROP LAND

It is a well known fact that after retirement of fields from cultivation, the first plants to appear are not permanent. Certain plants take hold, flourish for a time, and then decline. In due course they are succeeded by a community of entirely different composition, which in turn may be replaced by still others. Ultimately the plant community reaches its highest development and is composed of species which are characteristic of the undisturbed vegetation of that area.

Although the dynamic aspect of vegetation on abandoned fields is widely recognized, the specific nature of the plant succession and time involved is often left to mere speculation for many localities. It is the purpose of this paper to develop signigicant facts with regard to the natural plant succession on abandoned fields in a portion of Kansas and Oklahoma, and in consequence of that, to develop a substantial basis for soil conservation and grazing practices.

DESCRIPTION OF AREA INVESTIGATED

The region selected for this study includes an area in south-eastern Kansas and one in central Oklahoma, the two being separated by the Osage Indian Reservation (fig. 1). More specifically the Kansas area takes in parts of Chautauqua and Elk counties, and in Oklahoma studies were made in parts of Logan, Oklahoma, Canadian, Cleveland, Pottawatomie and Payne counties. The Osage Indian Reservation was necessarily omitted because of the scarcity of abandoned land.

The Kansas and Oklahoma areas are partially in two distinct vegetative types which include the true prairie and the transitional area between prairie and deciduous forest. Pottawatomie, Lincoln, and parts of Oklahoma, Cleveland and Payne counties in the state of Oklahoma are in the transition. This area is known as the Oak-Hickory Savanna, while most of the area studied in Kansas is in the true prairie.

The topography ranges from gently rolling hills to long gradual slopes. The soils are mostly residual and of a sandy nature, having been derived from underlying sandstone and shale. These soils are highly erosive when under cultivation; and even on the most gradual slope, active sheet erosion and gullying is the rule. The rainfall is about 35 inches per year throughout the area. The spring and summer rains are of the torrential type and of short duration, which under the type of cropping carried on in the past, has been responsible for the removal of much of the topsoil and the dissection of fields by gullies.

The loss of topsoil and the dissection of fields has made it unprofitable and difficult to cultivate many fields in this region. Reports by Blackwell (1930) show that over

1,359,000 acres of land have been abandoned in Oklahoma, which does not include the land retired during the past ten years. Much of this abandoned land is in the form of small hillside fields in central Oklahoma, where devastation is particularly severe. Accelerated erosion is less common in southern Kansas, but abandoned fields and those nearing the abandonment stage are common enough to justify a thorough study.

METHODS

One of the difficulties, as stated by Hanson and Vorhies (1938) in studies dealing with revegetation of eroded areas, is the insufficient duration of the succession. Because of the comparatively recent ingress of agriculture into this section of the country, most abandoned fields have not been out of cultivation for more than 35 years. Where conditions are not too severe, however, such a period of time is ample for the re-establishment of a good grass cover which is composed of some of the climax grasses.

Fields for study were taken as they appeared along the route selected for travel. If, however, the age of the reversion could not be determined with accuracy, the field was rejected. Such determinations were derived by consulting the tenant or owner of the land. In many fields, especially in the savanna of Oklahoma, a check was made by counting the annual rings of trees which were known by the owner to have appeared a certain number of years after abandonment. In addition to the age of the field, the tenant or owner furnished information as to land use, which included grazing by cattle, horses, and sheep. Information was also obtained as to the frequency of fires which burned over the fields. A total of 106 fields were selected for study. This study, in addition to the information already mentioned, included a botanical analysis for each field, as well as records concerning exposure, per cent slope, and nature of the soil. The botanical study was mainly concerned with density determinations to bring out the percentage area that the different species occupied at one inch above the ground level. In this work a modification of the Density List Method as used by Murray and Glover (1935) was employed and in nearly all fields at least one chart quadrat was made, using the tripod method (Booth, 1940), of what appeared to be the average condition for the field.

PLANT SUCCESSION

No attempt was made to determine how long the various fields had been cultivated before being retired, but it is quite apparent from historical and erosional studies that the time was extremely short. The fertile topsoil at this stage is principally or completely removed, and often the hardpan is exposed or covered by only a few inches of structureless soil.

The early stages in revegetation by seed plants in this region are similar in character to those found by Shantz (1917) in eastern Colorado; namely, (1) an early weed stage, composed of large widly spaced plants, and (2) a late weed stage, which includes essentially the same species of plants as the early stage, but is characterized a dense growth of stunted plants. Shantz found the following stages to succeed the weed stages: short lived grass stage, perennial grass stage, early short grass stage, and finally the typical short grass sod. To complete the succession a period of from 20 to 50 years was necessary.

The species of annual weeds which are the first to populate an abandoned field, in the area examined, are not governed by the locality, but rather by the type of cultivation immediately preceding, or in some cases upon the kind of weed seed present in fertilizers. The variation found in the different fields was great, and since the weed stage lasts for a period of only 2 to 3 years, it was thought not to be of sufficient importance in this study to justify extensive determinations. The percentage of plant cover during this stage, as shown by basal-area determinations, is exceptionally low (fig. 2A). The first year the basal-area cover at mid-season is often about .2 per cent. The second year there are a few more species present and a noticeable increase in numbers of those present the first year. Although the general aspect of the field is quite different the second year, there is but a slight difference in the basal-area. The difference in appearance is caused by the intense competition between thickly spaced individuals, which result in a low-growing, stunted vegetation. This second phase of the weed stage is sometimes not evident for several years in parts of the fields where the soil is more fertile. The better soil is able to support a denser population than is possible on sterile soil before competition results in a stunted growth. These areas of greater fertility are commonly at the upper part of the slope where the gradient is slight and thus erosion has not been so severe. But even in these more favorable spots there is a comparatively rapid change after abandonment from a mesophytic to a xerophytic type. This is a reversion in direction of the change usually to be found in nature, but is common on badly eroded soil after abandonment. The more abuse, such as excessive grazing, trampling, and burning, the more rapid and complete the change will be.

Second stage, the triple-awn grass stage, receives its name from the most characteristic seed plant to be found at this time, Aristida oligantha Michx. This grass, which is commonly referred to by the farmers of this region as wire-grass, is an indicator of extremely poor soil and xeric conditions. It occurs often in pure stands, but other drought resisting and drought evading plants are commonly present. Abandoned fields during this stage are easily detected from a distance and often give the appearance of supporting a luxuriant growth of grass. A more critical examination, however, reveals the fact that the actual basal-area cover of this triple-awn grass stage varies from small patches completely bare up to about .2 per cent cover, the average being about .8 per cent for the fields examined. Even more serious is the fact that this Aristida is slow to start growing in the spring, which leaves the ground essentially bare and open to the impact of rain drops during the spring rainy season. The inferiority of the macrovegetation during this stage, however, is counterpoised by the presence of a copious micro-flora. These lower forms, even though the stage is not named from them, are far more important in conserving the soil than are the seed plants.

The presence of certain of the lower forms as an initial stage in revegetation of eroded land has been reported by Larsen (1934) for south-eastern Ohio. He found that lichens were able, where erosion was not severe, to grow where it was too dry and sterile for weeds and poverty grass. Aikman (1934) found the initial stage in plant succession on sandstone ledges in central Iowa to be composed of crustose lichens, which is followed by foliose lichens and then moss. He found these stages to culminate upon the advent of higher plants which shaded them. Elwell and others (1939) working at Guthrie, Oklahoma, found lichens to be present in the bunch grass stage on abandoned farm land and mentions them as being one of the slow working agencies for the creation of more favorable conditions for plant development. Studies by the present author (1940) bring out the importance of algae in soil erosion prevention, as an aid to water infiltration into the soil, and as a probable factor in soil moisture conservation.

The dominant species to be found in the micro-flora of abandoned fields are certain of the blue-green algae, namely: Schizothrix Friesii (Ag.) Gom., Microcoleus vaginatus (Vauch.) Gom., Scytonema ocellatum Lyngb. and Porphyrosiphon Notarisii (Mengh.) Kutz. Other species are commonly present and may even appear in dominant proportions in local areas. These plants, although too small to be seen with the unaided eye, form a dense reticulum in the surface soil which may easily be recognized by the crusted appearance or color. This crust is about ¼ inch in thickness and tough enough that it can be removed in large pieces when moist. The presence of this crust in the annual grass stage was found in all fields examined. In some fields or parts of fields, however, its development remains incomplete, which usually permits the unhampered removal of soil in the form of sheet erosion. Lichens, liverworts, and mosses are also very common but play a minor role in soil building and conservation in this area.

Invasion of the weed stage by annual grasses quickly ensues after abandonment of badly eroded soil. Fire, excessive grazing, and dry weather expedite and make so complete the change that often the vegetation of the third season is represented by a pure stand of annual grass. The plant succession in fields in which the soil contains a good supply of humus and thus have been abandoned for reasons other than sterility of the soil, is entirely different, and have not been included in this study.

The characteristic grass of the annual grass stage, Aristida oligantha, is often accompanied by A. longespica Poir. Coexisting with the Aristida, the only herbs of wide spread importance are Plantago rhodosperma Decne., P. purshii R. and S., and P. aristata L., which often become the dominant plants for a short period in the spring. Minor communities often result from variations in the amount of humus and physiography within the field. The species of plants present in these isolated spots are varied and seemingly have taken their origin by chance rather than through successional development.

As the annual grass stage progresses for a number of years the flora shows evidence of approaching a mesophytic stage. The extreme uniformity in aspect and in species of the Aristida or Aristida-Plantago communities is no longer so strikingly evident. The Aristida plants are larger and more leafy; there is a decided shift in prominence from Plantago rhodosperma and P. purshii to P. aristata, and numerous other species of forbs appear as a secondary component of the community. Some of these herbs which have appeared consistently throughout the area studied are as follows: Amphiachyris dracunculoides (DC.) Nutt., Specularia leptocarpa (Nutt.) A. Gray, S. perfoliata (L.) A. DC., Croton capitatus Michx., C. monanthogynus Mich., Erigeron ramosus (Walt.) B.S.P., Coreopsis grandiflora Hogg., Rudbeckia hirta L., Achillea lanulosa Nutt., Lechea villosa Ell., L. tenuifolia Michx., Spermolepsis patens (Nutt.) B. L. Robinson, and Leptoglottis Nuttallii DC.

The economic importance of this annual grass stage is exceptionally low. The limited amount of forage of low palatability for all classes of livestock makes this stage almost worthless for grazing. Those who do attempt to pasture such fields find that the triple-awn grass is not eaten, so they often attempt to rid the field of this grass by burning, which apparently does not check it. Burning does, however, prevent the establishment of other grasses and thus the normal plant succession does not take place. The length of time that a field may remain in this inutile stage has not been determined because of the fact that after many years pasturage is necessarily found elsewhere, and attempts to destroy the worthless grass have been found to be futile. The longest time that a field was found to remain in this stage was 23 years (Table I), which should not be taken as the maximum. Under favorable conditions the triple-awn grass may be replaced by perennial bunch grass after about 11 years.

The few attempts which have been made by the farmers in this area to seed at least a part of their Aristida-covered land to some native grass or grass mixture has been unsuccessful. The probable reason for this failure was that the grasses selected were unadapted to such a habitat, or that the expense involved in thoroughly preparing and planting was more than the apparent returns would justify. Elwell and others, working at the Guthrie station, carried out studies by planting several species of native and introduced grass in well-prepared seedbeds on badly eroded soil. Even though the soil in these plots can not be considered as sterile as that in many of the abandoned fields in this area, the grasses, with possible exception of one for which some hope is being held, were unable to establish themselves. Nelson and Shepherd (1940), working in Colorado, find that sites which have a thin soil, a very poor soil, or are otherwise unfavorable are not likely to give sufficient returns to justify reseeding. Those soils which are fairly deep, have good organic matter content, and absorb water readily are desirable for reseeding. Recent plantings in central Oklahoma of buffalo grass (Buchloe dactyloides (Nutt.) Engelm.) and Johnson grass (Sorghum halepense (L.) Pers.) have met with some success in the more favorable locations; however, certain undesirable features associated with the latter, has made it unpopular as a means of forage production.

The few examples of terracing Aristida covered fields in the area examined clearly indicate that it greatly accelerates plant succession, if the terraces remain unbroken for a number of years. Contour furrowing was not being practiced in the region observed, but it seems likely that closely spaced furrows would be the most favorable method of stimulating plant succession without unjustifiable expenditures.

Although some variation may be found in the manner in which the perennial bunch grass becomes established, the resulting composition is very similar. In many fields the first perennial grass of importance is silver beardgrass (Andropogon saccharoides Swartz). ~~Its encroachment into a field may be easily observed as it moves in from the edge of the field or sometimes from spots in the field where plants have accidentally become established~~. This grass, although commonly listed as a forage grass, gives every indication of being only of moderate value in this respect. It is eaten for a short time in the spring but soon is left because of the coarseness of leaves and stems. Since it is not readily eaten by stock, it often comes in as a pioneer perennial under moderate grazing where more palatable species can not survive. Often, however, the dominant grass of this stage, little bluestem (Andropogon scoparius Michx.), is not preceded by other perennial grasses except for scattered plants or clumps of certain species of Eragrostis, Panicum, and Paspalum.

The perennial bunch grass stage is characterized by a paucity of grass species but with a much richer array of widely spaced forbs. The bunches of little bluestem are large, often forming a 20 to 30 per cent ground cover (fig. II, C). This cover is often greater than the total ground cover of the native prairie; however, as viewed from above, large patches of ground are bare in the bunch grass while in the native prairie the vegetation completely hides the ground. The effectiveness of the native prairie grass in preventing soil erosion results from a combination of the following factors: (1) the soil is completely protected from the impact of rain drops, (2) a sponge-like condition is created in the topsoil for the absorption of water, (3) the accumulation of undecayed vegetation on the soil forms a multitude of impediments which serve as dams to slow down or hold the water, and (4) the bases and roots of the grass hold the soil with which they come in contact. These factors, with exception of the last mentioned, are decidedly missing in the bunch grass communities. This deficiency is at least partially equalized by the presence of a surface growth of micro-organisms which are not present in the native prairie (fig. III). The part played by the micro-flora can easily be underestimated by hasty examination of the bunch grass community because of the fact that the bunches are often raised several inches above the general soil level. This, however, is not entirely the result of erosion from around the bunches but is partially a building up by accumulation of organic and inorganic matter within the clump. Examples of erosion where the surface algal layer has not formed are present in parts of many fields. In such places the bunches are often 6 to 8 inches or more above the ground level and undermining of the bunches is actively taking place. The part played by soil algae in holding the soil is further brought out in fields in which the old crop rows are still evident after being abandoned many years. Perennial grass often forms a good cover on the softer ridges, but the furrows remain bare of any seed plants (fig. II, d). In spite of the fact that the furrows are particularly vulnerable to erosion where they are parallel with the slope, there is little cutting. In isolated patches, however, where the soil was unprotected by algae, channels, often a foot or more in depth, are cut down the old furrows.

Expectations as to the thickening of the stand of little bluestem in the bunch grass community are mostly far above the actual occurrence. Grass seedlings both perennial and annual species, are often numerous in the bare areas between the bunches of bluestem, but the mortality rate is exceptionally high and very few ever become established. Most prominent among the herbs of this community are the following: Chaemaecrista fasciculata (Michx.) Greene, Petalostemon purpureus (Vent.) Rydb., Psoralidium tenuiflorum (Pursh.) Rydb., Lespedeza capitata Michx., Leptoglottis Nuttallii, Asclepias tuberosa L., Erigeron ramosus, Polygala incarnata L., Spermolepsis patens, Solanum nigrum L., Oenothera rhombipetala Nutt., Houstonia angustifolia Michx., Lepachys columnifera (Nutt) Rydb. Among the grass or grass-like plants the following were of most frequent occurrence: Panicum perlongum Nash., P. scribnerianum Nash, P. virgatum L., Sporobolus neglectus Nash, Eragrostis capillaris (L.) Nees., Andropogon furcatus, Juncus interior Wieg., J. setosus (Coville) Small, and Cyprus ovularis (Michx.) Torr.

During this stage of succession moderate grazing may be practiced to advantage. The bluestem, however, will not stand heavy grazing and extensive trampling will destroy the algal crust. A single field was observed where mowing of the bluestem had been practiced for several years. This observation lends evidence to support the view that where the terrain will permit, mowing and leaving the cuttings on the field is an aid to revegetation of the otherwise bare space between bunches.

The revegetation of active gullies is not properly taken care of by nature and steps should be taken to stop them in order that the land may be in the best possible condition for forage production. Results at the Guthrie, Oklahoma, station

(Elwell and others, 1939) indicate that the most satisfactory results were obtained from setting clumps of native grass and seeding perennial sweetclover and lespedeza in gullies after temporary check dams were prepared and the banks plowed down to a 1:1 slope. For the best growth of sweetclover in these experiments the soil was also fertilized with lime and superphosphate. This may appear to be too extensive a program, in which case merely seeding the gullies with innoculated yellow sweetclover seed will be found worth while. Experiments conducted by the author, now in their ninth year in central Oklahoma, show that innoculated sweetclover will make a fair growth in most gullies. Although it was grazed closely, it was able to reseed itself and spread to adjoining gullies. The sides of the gullies at the time of seeding had a slope of about 80 per cent, while now it is only 63 per cent. The movement of cattle up and down the sides while grazing is apparently responsible for this change. Water may be diverted from the gullies, but with the establishment of plants in them the deposition of silt on the floor of the gully and the wearing down of the steep sides is a decided benefit.

In many abandoned fields of the oak-hickory savanna, shrubs and trees have become well established. In most cases the trees are widely spaced, there being only 3 or 4 trees per acre, but a few fields which were originally prairie now show a decided dominance of trees or shrubs. The trees occupying these fields are mainly blackjack oaks (*Quercus* marilandica Munchh,) or post oak (Q. stellata Wang.). The shrubs are commonly Quercus prinoides Willd., accompanied with stunted specimens of Q. marilandica, Q. stellata margaretta Sarg., and Q. stellata rufescens Sarg., or Rhus glabra L. and R. copallina L.

The soils resulting from exposure of the sandstone in this section are well suited for the growth of scrub oaks, which follow the sandstone so closely that they can be used in determining the border line between the sandstone and shale to the west. The two types of vegetation, woodland and grassland, are so nearly alike in the completeness with which they dominate the habitat when they are once established that the one to first gain entrance in sufficient numbers is the one that persists. Once established, the woodlands and grasslands are in a state of equilibrium which is for the most part apparently static. This balance, however, is often upset by man--the grassland converted into woodland or the woodland into grassland. Upon abandonment of cultivated fields it would seem that the chances would be about equal for the establishment of the two types. The oaks, however, are decidedly more mesic than the annual grasses and so must wait until a favorable environment is created. The oaks and bunch grass usually come in at about the same time, but since the means of dispersal of the oaks is less effective they are usually secondary to the grass. If continual abuse of the grass is practiced, the oaks may become dominant after time has allowed for the slow invasion.

SUMMARY

1. An extensive field survey accompanied with a botanical analysis has been extended in an attempt to determine the course of natural plant succession on abandoned crop land.
2. The fields examined were in east-central Oklahoma and south-eastern Kansas. This area includes two distinct vegetative types, savanna and prairie.
3. The sequence of the stages of plant succession are as follows: Weed, annual grass, perennial bunch grass, fully developed prairie. Under favorable conditions the weed stage lasts for 2 years, the annual grass for from 9 to 13 years, and the bunch grass for an undetermined length of time. The oldest abandoned field examined in this stage was 30 years, which did not appear to be nearing the fully developed prairie stage.
4. Heavy pasturing and burning are a hindrance to plant succession and may cause the fields to remain unproductive much longer than would otherwise be necessary.
5. Certain blue-green algae play an important role in soil erosion prevention and thus compensate for the inadequacies of the seed plants.
6. Plant succession can be stimulated by cultural practices such as terracing and contour furrowing.
7. Natural revegetation of gullies should not be relied upon,

but steps should be taken to control them before the injury to future forage production is excessive.

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Years out of cultivation	No. of fields examined		Basal-Area Av. %	Stage of Plant Succession
3-5	Ix	2	.2	Annual Grass
	IIx	2	.1	" "
	IIIx	3	.1	" "
5-7	I	3	.4	" "
	II	5	.5	" "
		1	.4	" "
7-9	I	3	.8	" "
	II	2	.5	" "
	III	2	.7	" "
9-11	I	6	1.2	" "
	II	0	-	
	III	0	-	
11-13	I	4	1.1	" "
	II	0	-	
	III	1	9.2	Bunch Grass
13-15	I	5	2.0	Annual grass
	II	6	14.0	Bunch grass
	III	4	15.0	" "
15-17	I	7	2.1	Annual grass
	II	0	-	
	III	8	20.9	Bunch grass
17-19	I	2	1.5	Annual grass
	II	4	15.2	Bunch grass
	III	0	-	
19021	I	1	2.2	Annual grass
	II	4	18.0	Bunch grass
	III	1	20.2	" "
21-23	I	0	-	
	II	6	20.8	" "
	III	2	20.1	" "
23-25	I	1	2.1	Annual grass
	II	4	19.4	Bunch grass
	III	2	20.5	" "
25-27	I	0	-	
	II	5	22.3	Bunch grass
	III	7	21.6	Bunch grass
27-29	I	0	-	
	II	0	-	
	III	0	-	
29-31	I	0	-	
	II	1	22.2	Bunch grass
	III	2	20.1	Bunch grass

Ix Overgrazed and burned frequently.
IIx Moderate grazing and infrequent burning.
IIIx Ungrazed and burned rarely if at all.

TABLE I. A survey of 106 abandoned fields now in various phases of plant succession.

Figure I

The shaded areas in central Oklahoma and south-eastern Kansas represent an area of approximately 4700 square miles, from which 106 fields were selected for study.

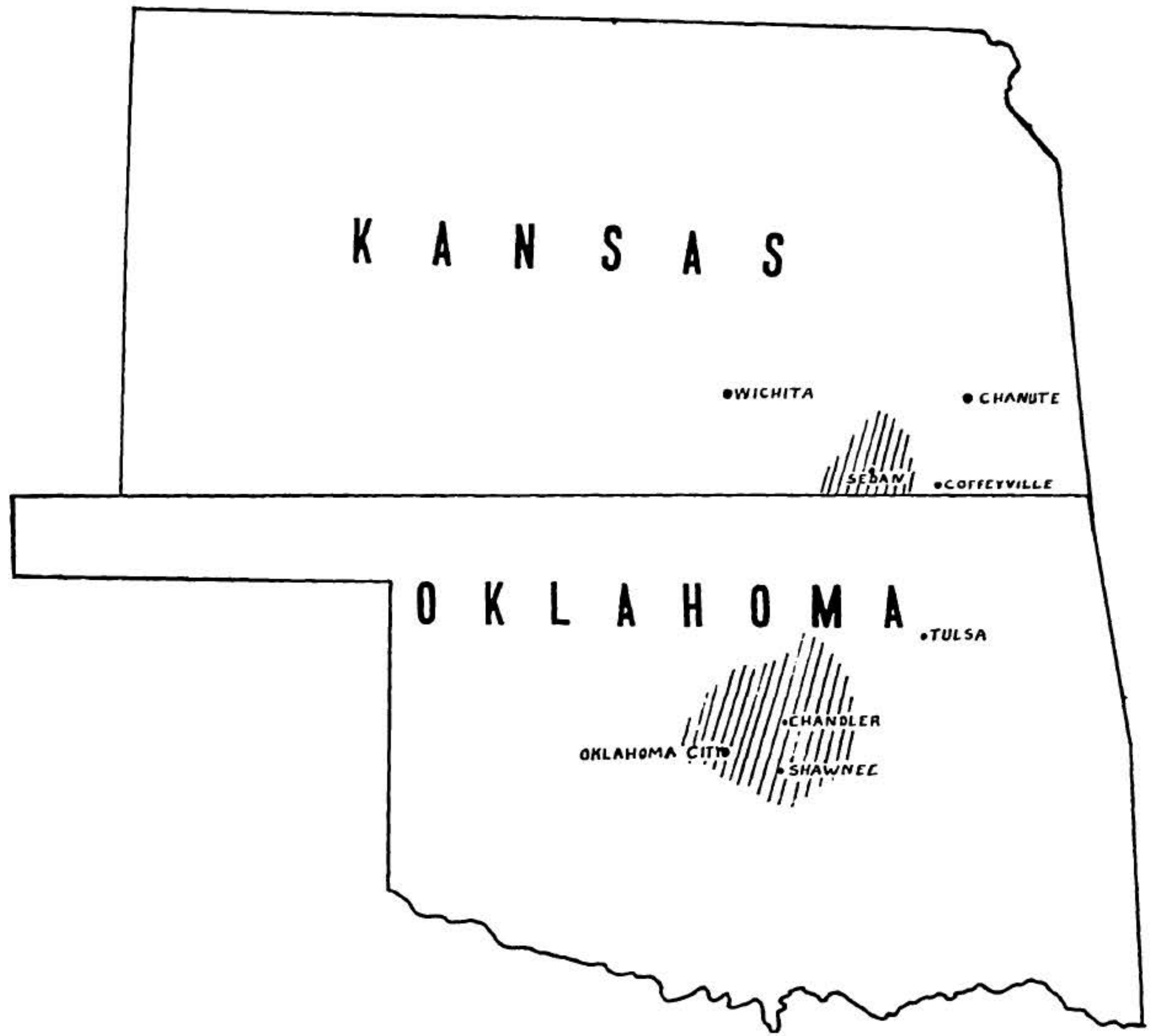

KANSAS
WICHITA
CHANUTE
SEDAN
COFFEYVILLE
OKLAHOMA
TULSA
CHANDLER
OKLAHOMA CITY
SHAWNEE

Figure II

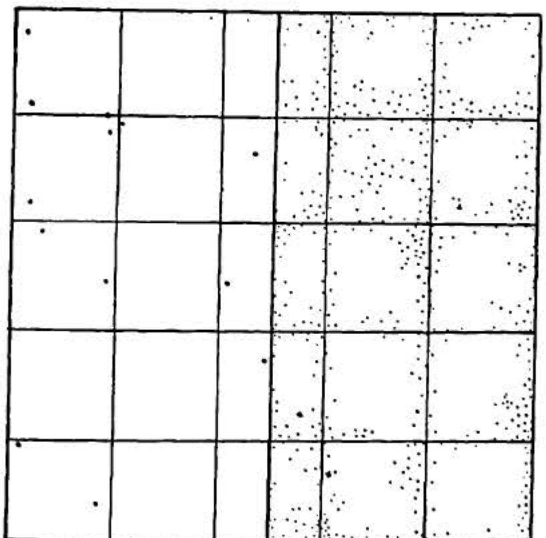
A. Half of a $2\frac{1}{2}$ foot square quadrat showing the basal-area cover of .2 per cent occupied by weeds one year after abandonment.

B. Half of a $2\frac{1}{2}$ foot square quadrat taken from a triple-awn grass field which had been abandoned for 12 years. The triple-awn grass, indicated by dots, forms a .5 per cent basal cover. Forbs are indicated by x.

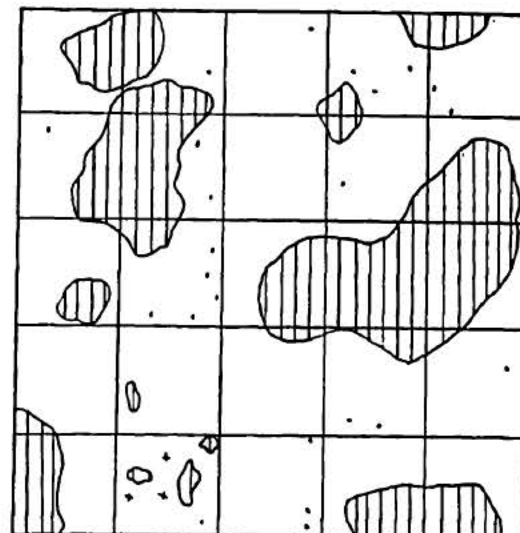
C. Little bluestem(Andropogon furcatus) from a field abandoned for 26 years. Little bluestem is indicated by vertical hatch, seedling grass plants by dots and forbs by x. The total basal-area occupied by seed plants is 21 per cent.

D. Five foot square quadrat showing the old listed rows in a field which has a 6 per cent slope and which has been abandoned for 19 years. The old ridges, now covered with little bluestem, are only $2\frac{1}{2}$ inches above the algal protected furrows. The basal-area cover for a part of the quadrat composed of one "ridge and furrow" is about 11 per cent.

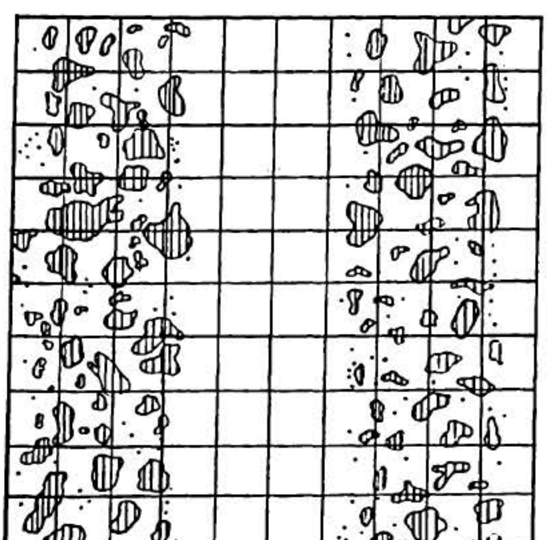
E. Quadrat $2\frac{1}{2}$ feet square showing basal-area occupied by grasses in a typical unused meadow. Vertical hatch is little bluestem, the solid black clumps are big bluestem(Andropogon furcatus) and side-oats grama (Bouteloua curtipendula), and the crosses represent forbs which are chiefly legumes. The total basal-area is 14 per cent.



A B



C



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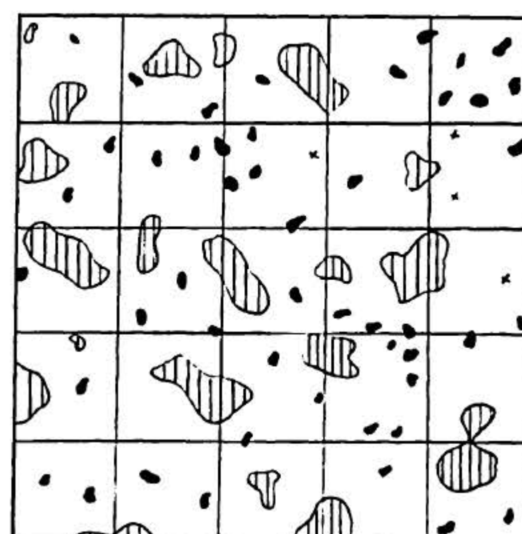

E

Figure III

Diagramatic representation of the stages of plant succession on abandoned land and an approximation of their comparative values in soil erosion control.

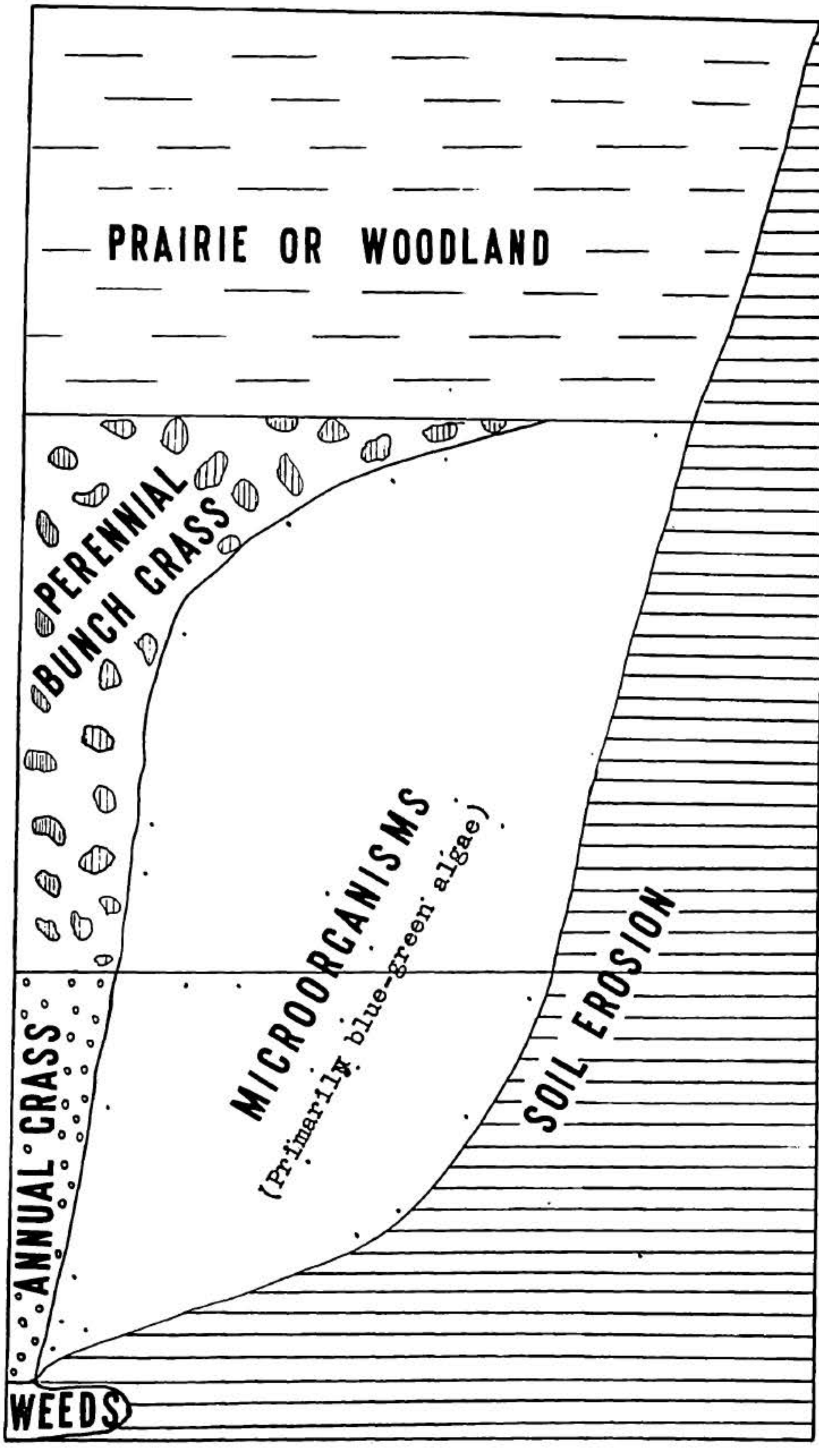
PRAIRIE OR WOODLAND
PERENNIAL BUNCH GRASS
MICROORGANISMS
(Primarily blue-green algae)
SOIL EROSION
ANNUAL GRASS
WEEDS

Figure III