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The Revegetation of Abandoned Crop- land in the Cedar Creek Area, Boone and Callaway Counties, Missouri

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The Revegetation of Abandoned Cropland in the Cedar Creek Area, Boone and Callaway Counties, Missouri

WILLIAM B. DREW*

INTRODUCTION

The problems concerned with the management and use of marginal and sub-marginal lands in the United States have been brought into sharp focus during the past decade. Much has already been accomplished by many public and private agencies, in studying the best use to which such areas may be put; yet, perhaps, many of these accomplishments are still in an experimental or tentative stage and numerous fundamental aspects remain to be solved.

Missouri, in common with many highly agriculturalized states, has its share of lands ill-suited for cultivated crops. Thousands of acres of land formerly cultivated have been abandoned, with the result that these areas are now in various stages of natural revegetation. In cooperation with the Soil Conservation Service, which had established a Land Utilization Project in Boone and Callaway Counties, this study was undertaken to determine the basic nature of the revegetation of abandoned cropland in this area. Such information, it was hoped, would be of value in furnishing a "base-level" with which utilization experiments might better be evaluated. Thus, armed with the knowledge of the nature and behavior of the vegetation on such areas under natural conditions, it should be possible to utilize these data as a check on experimental pasture, wildlife, and forestry projects.

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Previous Work on the Revegetation of Abandoned Cropland

Inasmuch as the literature dealing with the revegetation of abandoned cropland in the United States has not hitherto been comprehensively summarized, a brief resume of pertinent papers is here included. Although studies on various aspects of this problem have been made since the early 1900's, perhaps the majority of investigations have been conducted within the past ten to fifteen years. It is certainly no coincidence that these studies have been largely concentrated in so-called sub-marginal lands where the margin between

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successful and unsuccessful growing of cultivated crops has often been a narrow and precarious one.

Considering first that portion of this country originally covered by climax grassland, it may be noted that Shantz (1917) early called attention to stages in the natural revegetation of abandoned land in eastern Colorado. Savage and Runyon (1937), in a comprehensive survey of revegetation in the shortgrass plains from Texas to Colorado, found that some 25 to 40 years were required for the restoration of a full vegetative cover of desirable grasses; yet even after this period, none of the fields investigated had regained a vegetative cover comparable in botanical composition to adjacent virgin areas. Four stages in succession were noted. Nelson (1937), and Nelson and Shepherd (1940), working on grazed, abandoned cropland in Colorado have noted approximately the same situation, although it was found that after 21 to 30 years after abandonment, the coverage of the important blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*) was only one-fourth of that in adjacent virgin areas. Under grazing conditions, it was estimated that between 80 and 100 years would be required for the restoration of blue grama grass to its original density. Judd and Jackson (1939), studying abandoned fields in western Nebraska, have found that after 10 years about 14 per cent of the total number of stems were of the principal climax species, whereas the latter comprised 80 per cent in adjacent grazed grassland. About 30 years were estimated as the length of time necessary for the reestablishment of grassland with a cover of dominant species equivalent to that of grazed unplowed areas. In a companion study in the same area, Judd and Weldon (1939) evaluated some edaphic changes associated with natural plant succession. Judd (1940) has also reported that the length of time necessary for the restoration of a cover of desirable grasses in Montana is less than that for western Nebraska; but the general stages of revegetation between these two states had much in common botanically.

Clarke and Heinrichs (1941), in connection with a study of the regrassing of abandoned farms *et al.* in Saskatchewan, have given a general survey of the natural revegetation process; but time relationships and species lists were not mentioned in detail.

Bruner (1931), in a descriptive ecological survey of the vegetation of Oklahoma, has observed that persimmons frequently invade abandoned cropland in the oak-hickory savannahs; but he makes no mention of sassafras becoming established in similar habitats, although he reports this species as less widely distributed in the state than persimmon. Smith (1940) has made an extensive study of the biotic

and physiographic aspects of succession on abandoned eroded farmland in central Oklahoma. Perhaps most of the work in this study was that done on animal succession; but the data on plant succession indicate the trends clearly, despite the lack of quantitative information for fields abandoned between three, four, and eight years. Time relationships of the stages of plant succession are not brought out clearly, though it is apparent that between 25 and 30 years, or more, are required for the restoration of a cover of prairie grasses.

Booth (1941a) has written of the importance of soil algae in erosion control and as pioneer plants in succession on eroded soils, chiefly of abandoned farmland, in south central Kansas and central Oklahoma. In another study, Booth (1941b) has given a comprehensive account of the revegetation of abandoned fields in east-central Oklahoma and southeastern Kansas. He found three stages in succession which, after 30 years, had not resulted in restoration of the cover characteristic of native prairies. Post oaks and black-jack oaks were found in many fields originally covered by prairie, but few quantitative data regarding the ecological importance of these woody species are given.

Aikman (1930), in a study of the revegetation of abandoned watermelon land of Muscatine Island, Iowa, has found on sandy soils three general stages, culminating in about 30 years, in a prairie dominated by little bluestem (*Andropogon scoparius*) and Indian grass (*Sorghastrum nutans*). This study brings out most clearly the ecological importance of weeds in the successional development of the vegetation. In a later quantitative study of the early weed stage of plant succession on Iowa fields the first year following cessation of cultivation, Aikman and Barr (1939) found green foxtail (*Setaria viridis*), yellow foxtail (*Setaria glauca* = *S. lutescens*), and giant ragweed (*Ambrosia trifida*) were dominant in most plant communities the initial year; but they found little relationship between frequency and constancy of species and previous cultural treatment.

In those parts of the United States originally supporting a forest climax, there are also many acres of abandoned cropland in widely scattered regions. In the northeastern states, Howe (1910), in Vermont, was one of the first to study this problem. On plowed sandy soils near Lake Champlain he found that when a proximate seed source was available either "white" birch (*Betula populifolia*) or pitch pine (*Pinus rigida*) might invade the first year subsequent to abandonment, with certain oaks appearing as early as 12 years later. Since he employed only a single one square-meter quadrat per stage, his quantitative studies of the herbaceous vegetation leave much

to be desired; yet as a qualitative list, it is significant that yellow and green foxtail or common ragweed and tall horseweed (*Erigeron canadensis*) frequently initiated revegetation on former rye fields, while in typical old fields (ca. 20 yrs.) a sedge (*Carex pennsylvanica*), loosestrife (*Lysimachia quadrifolia*) and gray goldenrod (*Solidago nemoralis*) were dominant in order of decreasing rank. He concluded that a pitch pine community was the ultimate dominant forest type.

Without indicating time relationships, Nichols (1914) has outlined the upland succession on former cropland in Connecticut as follows: (1) annual weeds (*Ambrosia artemisiaefolia* "omnipresent"); (2) perennial weeds; (3) gray birch, low juniper, red cedar, followed by post oak (*Quercus stellata*) in sandy areas near the coast, or white pine (*Pinus Strobus*) further inland. Bromley (1935), in writing of the original forest types of southern New England, has referred briefly to the revegetation of old fields as being dependent to a considerable extent on the site and location in regard to light-seeded species of trees. Olmsted (1937), who investigated in central Connecticut the vegetation of certain sand plains which had mostly been cultivated last about 1800, has given a list of the plants making up the inferred stages of revegetation in various habitats. On the ridges of wind-deposited sand chiefly along former fence-rows, an open stand of black oak (*Quercus velutina*) and gray birch (*Betula populifolia*) with various shrubs and herbs (especially *Polygonella articulata*) was developed. In the wind-eroded fields wherein the A horizon had been completely removed, an open grassland community dominated by little bluestem and an herb (*Trichostema dichotomum*) prevailed. Where the A horizon still remained, a complete cover of little bluestem together with numerous lichens and mosses (especially *Polytrichum piliferum*) usually occurred. Such sites apparently were eventually invaded and dominated by forests of black oak and pitch pine. Raup (1940) has summarized some of the pertinent literature concerning plant succession on old fields in southern New England, but, in the majority of these investigations, the early stages of succession have been given only passing attention since most of the efforts have been concentrated on forest communities—and these upon land often merely cleared.

The studies of Blizzard (1931) and Conard (1935) in central Long Island, New York, indicate that on these sandy soils abandoned cropland gradually develops into a little bluestem grassland which is later invaded by red cedar and such shrubs as *Myrica caroliniensis*, which, in turn, may be superseded by an oak or yellow poplar (*Liriodendron Tulipifera*) association. Of further interest is the fact that in old fields dominated by little bluestem are such ubiquitous forbs as *Aster*

ericoides, *Triodia flava*, *Ambrosia artemisiaefolia*, and *Solidago nemoralis*.

In the southeastern region, a number of studies have been carried out, especially in the coastal plain and piedmont areas in North Carolina. Campbell (1927), in a study of wild legumes in relation to soil fertility levels in abandoned fields in Virginia, South Carolina, Georgia, and Indiana, was impressed by the high percentage of legumes. Though probably employing insufficient samples (1 quadrat of 3 yds. square/station), he found that in natural revegetation of cropland in these states the percentage of legumes decreased proportionately to an increase in the total nitrogen of the soil. *Lespedeza*s were observed to be dominant among the legumes, and brief mention was made that sassafras, persimmon, and sumac were common woody species. Wells and Shunk (1931), dealing with the descriptive ecology of the vegetation of the coarser sands of the coastal plain of North Carolina, have given a rather general qualitative treatment to the problem of abandoned cropland. Crab-grass (*Syntherisma* (*Digitaria*) *sanguinale*) was dominant in a initial stage on most sites, followed by various forbs and sometimes by loblolly pine (*Pinus taeda*), in turn superseded by certain oaks and hickories unless repeated burning ensues: Old-field vegetation on drier sands was dominated by tall horseweed associated with such plants (among others) as *Aristida purpurascens*, *Diodia teres*, *Lespedeza capitata*, and *L. hirta*, and panic grass (*Panicum sphaerocarpon*). Hall (1932), in a cursory account of the ecology of upland communities near Greensboro, North Carolina, has made the following enlightening comment: "On account of cultivation and other physical changes the formation is best classified today as being *Syntherisma—Erigeron—Andropogon* formation (Wells) finally ending in *Quercus rubra—Acer saccharum—Fagus grandifolia*. Or if we study this section (sic!) from an association it falls under the *Quercus—Hicoria*, *Quercus—Castanea* and also the *Acer—Fagus* associations. . . ."

In a comprehensive investigation of the ecology of what they erroneously termed "The Old Field Prisere"* near Raleigh, North Carolina, Crafton and Wells (1934) have described the successional stages characteristic of old fields; but, quantitatively, their results appear to be based on too few samples. They have described in detail three stages, which may be summarized briefly as follows: (1) The *Pioneer consocies* (1-2 yrs.) with crab-grass the important dominant on upland fields, and common ragweed, button weed (*Diodia teres*), and wire grass (*Aristida* sp.) abundant on eroded land; (2)

*As McQuilkin (1940) has noted, the best ecological usage of the term "prisere" connotes a primary, not a secondary succession.

The *Tall Weed consociates* (3-? yrs.) dominated by various species of *Aster*, *Solidago*, and other composites; and (3) The *Broomsedge consociates*, the dominants of which were *Andropogon Elliottii* and *A. virginicus*. These investigators concluded that (1) various soil habitats produce no important changes in "priseral" (quotes mine) sequence, and (2) that invasion of broomsedge is made possible by modifications of surface soil moisture brought about by tall weeds.

Through the studies of Billings (1938), Oosting and Humphreys (1940), and Coile (1940) much important ecological evidence has been further adduced regarding various aspects of natural plant successions in the Piedmont region of North Carolina. Billings found a high degree of correlation between the quantitative development of old-field shortleaf pine stands and certain associated edaphic factors. In the old abandoned fields, Billings pointed out that broomsedge (*Andropogon virginicus*) was easily the dominant species; but it, together with its associates, is gradually replaced by other herbs as the shortleaf pines invade and become dominant. Oaks and other deciduous woody species did not appear in numbers in the shortleaf pine stands until the latter had attained an age of 21 years. Thereafter, the deciduous species gradually increased in importance, suggesting their eventual dominance over, or co-dominance with, the pine. Oosting and Humphreys, working in the same area as Billings, have pointed out the importance of buried viable seeds in a successional series of old-field and forest soils. Included in their study is a general statement regarding early stages of succession of abandoned fields. Three stages, represented by as many herbaceous dominants are recognized during the first five years after abandonment. Finally, Coile has correlated certain edaphic changes with loblolly pine succession on abandoned agricultural land in the same general region. He has given a rather detailed list* of the plants in order of their density found in abandoned fields of the early stages. Although the loblolly pine may invade fields the first year subsequent to abandonment, it does not usually become dominant until about 10 years. Following establishment of the loblolly pine, a gradual invasion of hardwoods occurs.

McQuilkin (1940) has also studied the establishment of loblolly and shortleaf pine in abandoned fields of the piedmont plateau region. He has pointed out that when pines come in during the first year after abandonment on eroded, bare areas, the broomsedge is completely excluded from the succession. He also has mentioned that

*Obtained from Oosting, H. J. 1938. Early Plant Succession on Abandoned Land in the Duke Forest. Unpub. Mss.

gray goldenrod is one of the species most frequently associated with broomsedge where the latter has developed, and that white heath aster usually dominates the second weed stage (2nd yr.) on better soils. However, where all the A_1 horizon was eroded, bracted plantain and buttonweed, together with *Aristida dichotoma* may not only initiate succession but may persist as long as eight years.

In a study of the vegetation of the Okefinokee Swamp, Georgia, Wright and Wright (1932) incidentally refer to former cultivated fields of so-called "hammock" clearings, wherein persimmons and blackberries, among others, are mentioned as occurring; but no serious study of such areas was apparently intended since they made a "feeble effort at collection of weeds."

In the north central states, Bingham (1937) has reported on secondary successions in a gravel pit in Michigan; but, aside from species lists which indicate the occurrence of such widespread plants as green foxtail and common ragweed, the data are not of much relevance to this discussion. Allen (1938) has given a list of the weeds typical of cornfields of Kalamazoo County, Michigan; but no quantitative data were included.

Thompson (1939) has worked out in detail the revegetation in Wisconsin of fields abandoned for from one to 37 years. Following a weed flora which dominates for the first few years, prairie forbs and grasses appear in quantity at from nine to ten years, reaching maximum dominance about 15 years subsequent to abandonment of the fields. The prairie species, in turn, give way and decrease in quantity as the jack pine invades and becomes dominant. Oaks later apparently may replace the jack pine, in part at least.

Stallard (1929), working on secondary successions in the climax forest formations of northern Minnesota, has given qualitative lists of species in subseral stages of the several forest climaxes. Where mixed red (*Pinus resinosa*) and white pine originally formed a climax, Stallard lists various herbs as occurring in former cultivated land without indicating stages or time relationships. In such sites on drained clays and loams, aspens are among the most important arborescent species, capable of ecesis among the annuals covering land abandoned for one year. Sumacs (*Rhus typhina* and *R. glabra*) were found to be important in subseres in floodplains on damper soils. In the maple climax, former cultivated fields supported a weed flora quite comparable in species to that of the former mixed red and white pine lands. A bluegrass or prairie stage generally followed in former cultivated fields if shrubs and trees did not first invade. Then, in the pine climax, on sandy soils, a grass stage was found to follow the old-field herbs sooner than on clays or loams. The old-

field herbs in this type of site were also fairly similar qualitatively to those of the preceding ones. It was noted further that most shrubs, when present, generally spread chiefly by vegetative propagation.

In the central states, Geisler (1926) has mentioned ruderal successions, apparently mostly worked out by Dr. E. Lucy Braun, in the Cincinnati region of Ohio; but detailed lists of species were not given. Broomsedge, triple-awn grass (*Aristida oligantha*), and gray goldenrod were noted, however, as occurring commonly in various types of meadow vegetation. Larsen (1934), also working in Ohio, conducted a survey of natural plant succession on the eroded soils of a single abandoned farm of some 30 acres in the southeastern part of the state. Following a weed stage, dewberry and cinquefoil formed an important community. The latter was followed by sumacs, hazelwood, red root, high blackberries, which, in turn, were superseded by various tall shrubs and low trees, including sassafras, hawthorns, and wild plum. A mixed forest of oaks, elms, hickories, etc. was the ultimate community developed on the farm. A relationship was found between the degree of degradation of the soil profile by erosion and the "density" (basal area) of the vegetation of different plant communities of the successional series; but only one square-meter quadrat was charted for each community, so that these results can hardly be considered reliable. Braun (1936), studying the forests of the Illinoian till plain of southwestern Ohio, has observed that when cultivated land on white clay or Clermont silt loam soils is recently abandoned, it is usually occupied by wire grasses (*Aristida gracilis* or *A. purpurea*). Without entering into the time relationships in detail, Braun has listed many typical old-field herbs, shrubs, and trees which may later develop on such sites.

Cain and Friesner (1929), working with secondary successions in southern Indiana, have called attention to the many acres of wornout abandoned land in the poorer, hilly sections of Kentucky, Ohio, and Indiana. Since these investigators were primarily concerned with evaporation studies in relation to succession, the detailed pattern of revegetation following cultivation was not dealt with. However, from the species-lists given, it is apparent that sassafras and persimmon are important early arborescent species on upland sites, and that various blackberries, cinquefoils, mosses, and lichens are common to old-field vegetation. Duncan (1935), working in the vicinity of Bloomington, Indiana, has made a valuable contribution to the knowledge of root habits of various shrubs and trees, which are important in the revegetation of abandoned cropland. His data indicate that

smooth sumac (*Rhus glabra*) spreads extensively by rhizomatous roots, and that sassafras, unless grazed, may spread by its roots as rapidly as 94 cm./yr.

In Missouri, Arend (1939) has studied the revegetation of woody species on abandoned fields up to 35 years of age on the St. Francis River watershed. He found that 90 per cent of the species of trees occurring in old fields were sassafras (63%) and persimmon (27%). Other species, chiefly in the reproduction class, were hickory (species not given); post, blackjack, white, and black oaks; shortleaf pine; and cedar. Although Arend tentatively concluded that the old fields examined did not restock naturally, he did not distinguish between undisturbed, burned, or grazed areas. His conclusions appear to be largely based on burned or heavily grazed fields. Steyermark (1940) has outlined the theoretical stages of natural succession in the Ozarks in general, although no quantitative data are adduced to support his assumptions. He has pointed out, among other things, that sassafras, persimmon, and red cedar are frequently important in early arborescent stages of natural succession, particularly those of a limestone xerosere which culminates in a sugar maple-white oak community. Sassafras, moreover, was found to be common in arborescent stages of succession on more acid upland areas on which the ultimate woody community is said to be oak-hickory. Detailed lists of species, herbaceous as well as arborescent, add much to this general picture of natural succession.

In the sagebrush climax in Idaho, Piemeisel (1932, 1938) has worked out clearly the changes in plant cover subsequent to abandonment, and has evaluated factors involved in this succession. Russian-thistle (*Salsola pestifer* A. Nels.), mustards [*Sophia parviflora* (Lam.) Standl. and *Norta altissima* (L.) Britt.], and downy chess (*Bromus tectorum* L.) were generally found to be important dominants in successive early stages of revegetation.

OBJECTIVES

The specific objectives of this investigation may briefly be summarized as follows:

1. To determine the botanical nature of the plant cover growing on abandoned croplands in the area;
2. To determine the relationship between specific types of plant communities and time since the last cultivated crop;
3. To determine if a process of natural plant succession actually occurred, and, if so, to obtain information relative to the ultimate type of community likely to develop;

4. To determine, insofar as possible, general relationships between specific plant communities and the relative amount of soil erosion.

METHODS

In planning this investigation, it was found that of the several soil types represented in those parts of Boone and Callaway Counties embraced by the Land Utilization Project, the Lindley series (s. 1.) was perhaps the most important from the standpoint of abandoned farms. Thus the majority of fields selected for intensive study were located on soils of this or closely related series and were mostly concentrated in the Cedar Creek area which supports an oak-hickory forest type. Moreover, most of the fields selected were heavily eroded so that frequently 50 to 75 per cent of the A_1 horizon had been removed.



Map of Missouri to show the geographic location of the Land Utilization Area, Soil Conservation Service, Boone and Callaway Counties.

A preliminary reconnaissance was carried on during July and August of 1940 for the purpose of locating abandoned fields which would provide a successional series of essentially undisturbed natural

vegetation. Fields sown to Korean Lespedeza, grazed, severely burned or recently limed, were eliminated from the study. Some 50 fields were finally selected.

Since the majority of farmers in the Cedar Creek area were short-term tenants, little accurate information could be obtained regarding the last date of cultivation. Consequently, increment borings, chiefly of sassafras and persimmon, had to be relied upon to determine the approximate ages of the fields. Inasmuch, however, as the majority of fields very recently abandoned in the area were found to support a considerable growth of sassafras and persimmon sprouts, it was assumed that the ages of a series of these trees on any one field might give a reasonable approximation of the length of time since the last cultivated crop. From five to 12 increment cores were obtained from trees on each field in order to determine an average age. Some error undoubtedly crept into the results because of the use of this method.

Virtually no information could be obtained on past management practices, although the last crop grown was frequently found to have been corn.

During July and August of 1940 a detailed inventory of herbaceous as well as woody species was made for each field selected for study, and these observations were checked against many other fields in the area as well as with studies carried on in the summer of 1941. Abundance lists of the herbaceous vegetation were made along with censuses, according to the following classes (cf. Cain, 1932):

- Class I—species very rare
- Class II—species rare
- Class III—species common
- Class IV—species abundant
- Class V—species very abundant

Using the same method of estimating abundance of species, a survey was also conducted of the weed flora of crops in the area in 1940 and rechecked in 1941. Twenty fields were censused in detail and the results compared with observations of more than twice as many others.

Count-list quadrat studies of the herbaceous vegetation were carried out on some fields in 1941 in order to determine density values of the species represented and total plant cover. A series of 20 fields in the general vicinity of the University of Missouri Wildlife Area and Arboretum near Ashland was selected for this purpose since it was not possible in the time available to sample all fields otherwise investigated. Moreover, by restricting fields thus studied to one general area, regional fluctuations in precipitation, a most significant factor during the summer months, might be thereby reduced in

importance. An average of 15 one square-meter quadrats per field were employed, the quadrats being laid out with a tape in a line at intervals of 4-6 meters across the topographic relief. Preliminary studies using one-fourth and one-half square-meter quadrats indicated that, while in some fields with exceptionally homogeneous vegetation one-half square-meter quadrats were satisfactory, in other areas an insufficient sample was obtained. Thus, the larger size of quadrat was used throughout.

The arborescent vegetation, including species of trees of all size-classes, shrubs and vines, were also sampled by count-list quadrat methods. Preliminary studies were conducted to determine the method most suitable for the purpose of this investigation. Belt transects 10 meters by 100 meters were compared with scattered plots of one milacre and 10 milacres, and with the latter two laid out with tapes at intervals in a line across the relief. As a result of these studies, it was found that milacre quadrats arranged at intervals of 6-10 meters across the relief gave as adequate a sample as any other method and, moreover, was somewhat more rapidly carried out. An average of 65 quadrats per field were used in this fashion. More fields were sampled for the woody vegetation than for the herbaceous species because of the more sporadic occurrence of forest trees, especially in the older stages of succession.

Observations on the degree of erosion and its relationship to definite plant communities of herbaceous species were made. Attention was also given to soil algae, lichens, and mosses; but, with these plants, nothing of a quantitative nature was attempted.

RESULTS

A. Weed Flora of Cultivated Croplands in the Area

The weed flora of any crop in a given region varies with many factors, not the least of which are management practices of the farmer. Yet despite these many factors the results of this weed survey of more than a score of fields in the area tend to indicate that the most abundant species of weeds are relatively the same per crop. In Table 1 there are given the abundance classes of the important weeds of 10 corn fields investigated in detail. Fall panic grass (*Panicum dichotomiflorum*), large crab-grass (*Digitaria sanguinalis*), and common ragweed (*Ambrosia artemisiaefolia*, var. *elatior*) were found to be the most abundant weeds in corn fields at the time of the study. As may be noted from Table 3, however, many other weeds may occur in corn fields in the area; but these species are usually not as abundant over the area concerned as those noted in the first table.

Weeds of small grain (wheat, oats, barley, etc.) fields, while often similar in species represented, differ quantitatively from those of corn fields in the area.

TABLE 1
LIST OF MOST ABUNDANT WEEDS OF CORN FIELDS

Species	Abundance Class
<i>Panicum dichotomiflorum</i>	5
<i>Digitaria sanguinalis</i>	4
<i>Ambrosia artemisiaefolia</i> , var. <i>elatior</i>	4
<i>Euphorbia supina</i>	3
<i>Ipomoea hederacea</i>	3
<i>Sida spinosa</i>	3
<i>Solanum carolinense</i>	3

TABLE 2
LIST OF MOST ABUNDANT WEEDS OF SMALL GRAIN FIELDS

Species	Abundance Class
<i>Ambrosia artemisiaefolia</i> , var. <i>elatior</i>	5
<i>Panicum dichotomiflorum</i>	4
<i>Strophostyles helvola</i>	4
<i>Plantago aristata</i>	4
<i>Ambrosia bidentata</i>	4
<i>Erigeron canadensis</i>	4
<i>Aristida oligantha</i>	3
<i>Setaria lutescens</i>	3
<i>Strophostyles pauciflora</i>	3
<i>Euphorbia supina</i>	3
<i>Apocynum cannabinum</i> , var. <i>glaberrimum</i>	3
<i>Solanum carolinense</i>	3

TABLE 3
WEEDS OF LOWER ABUNDANCE CLASSES IN EITHER CORN
OR SMALL GRAIN FIELDS, OR BOTH

	Abundance Class			Abundance Class	
	Corn	Wheat		Corn	Wheat
<i>Aristida dichotoma</i>		1	<i>Euphorbia maculata</i>	2	2
<i>Aristida oligantha</i>	1	3	<i>Abutilon Theophrasti</i>	1	1
<i>Bromus secalinus</i>		2	<i>Sida spinosa</i>	3	2
<i>Digitaria sanguinalis</i>	4	2	<i>Hypericum Drummondii</i>	1	2
<i>Echinochloa pungens</i>	2	1	<i>Hypericum mutilum</i>		1
<i>Eragrostis pilosa</i>	1	2	<i>Oenothera sp.</i>	1	1
<i>Eragrostis spectabilis</i>	1	1	<i>Apocynum cannabinum, vars.</i>	1	3
<i>Panicum capillare</i>	2	1	<i>Acerates hirtella</i>	1	2
<i>Paspalum laeve, var.</i>			<i>Asclepias syriaca, var. kansana</i>		1
<i>circulare</i>		1	<i>Gonolobus laevis</i>	1	1
<i>Setaria lutescens</i>	2	3	<i>Cuscuta Gronovii, var.</i>		1
<i>Setaria viridis</i>	1		<i>Ipomoea pandurata</i>	1	
<i>Triodia flava</i>		1	<i>Ipomoea purpurea</i>		1
<i>Cyperus acuminatus</i>	1		<i>Verbena hastata</i>	1	1
<i>Polygonum pennsylvanicum</i>	2	2	<i>Verbena stricta</i>	1	
<i>Rumex crispus</i>	1		<i>Plantago aristata</i>	1	4
<i>Chenopodium album</i>	1	1	<i>Plantago lanceolata</i>		1
<i>Mollugo verticillata</i>	2	1	<i>Diodia teres</i>	2	2
<i>Rubus flagellaris</i>	1	2	<i>Ambrosia bidentata</i>	1	4
<i>Cassia fasciculata</i>	1	2	<i>Aster ericoides (s. l.)</i>		1
<i>Schrankia Nuttallii</i>		1	<i>Aster pilosus</i>	2	2
<i>Strophostyles helvola</i>	2	4	<i>Bidens sp.</i>	1	2
<i>Strophostyles pauciflora</i>	2	3	<i>Erigeron canadensis</i>	1	4
<i>Oxalis europaea, var.</i>		2	<i>Erigeron ramosus</i>		1
<i>Polygala sanguinea</i>		1	<i>Helianthus annuus</i>		1
<i>Croton capitatus</i>	1	2	<i>Lactuca canadensis</i>		1
<i>Croton monanthogynus</i>	1		<i>Xanthium spp.</i>	1	2
<i>Euphorbia corollata</i>	1	2			

Common ragweed appeared to be the most abundant species, closely followed by several others enumerated in Table 2. Such weeds as bracted plantain (*Plantago aristata*), lance-leaved ragweed (*Ambrosia midentata*), and trailing wild bean (*Strophostyles helvola*) were far more abundant in small grain fields than in corn. In general, also, there were more grasses of importance in small grain fields than in those planted to corn in the area.

Although these results were checked against the floras of many other fields in 1940 and 1941, so many variable factors are concerned that a longer, more intensive study would be required for final definitive inferences. For example, Norris (1939), who has studied the ecology of the weed populations of fields in eastern Nebraska, was able to show very definite quantitative differences in the weed floras of the several crops which she investigated intensively for three years. Nevertheless, this survey does indicate the species, together with their approximate abundance, which may serve to initiate plant succession on abandoned fields in the area.

B. Herbaceous Vegetation of Abandoned Fields

That the vegetation of a field the first year following a cultivated crop is largely determined by the weeds co-existing with that crop is well indicated by the frequency and density data in Table 4. The majority of herbaceous species occurring in fields abandoned one year were doubtless already present as weeds with the last crop. Moreover, the majority of plants of this early stage of revegetation are annuals, a fact borne out by the data in Table 5. Of the perennials present, a few, such as bull nettle (*Solanum carolinense*) occur commonly as weeds with the crops. Typical old-field perennials, such as the gray goldenrod may be present; but the density and frequency of these are very low. Among the species of high density in this stage is yellow foxtail grass which was found by Aikman and Barr (1939) in central Iowa, as well as by other investigators elsewhere, to be of like importance in fields the first season following cultivation.

During the second year following cultivation, the absolute number of perennial species increases somewhat (cf. Table 5); but of more importance is the increase in the densities and frequencies of the two principal old-field dominants: Gray goldenrod and white heath aster (*Aster pilosus*). Yet the high densities and frequencies of the annual dominants of the first year are maintained, chiefly, perhaps, because the old-field composites just mentioned are present mostly as small seedlings.

The annual dominants of the third year after cultivation, however, are much decreased in density, although the frequency of some

TABLE 4 (cont.)
DENSITY (d)* AND FREQUENCY (f) OF HERBACEOUS SPECIES

		1	2	3	5	6	7-8	9-10	11-12	16-20	30-35
Potentilla simplex vars.	d	.....	.....	.....	0.4	.....	.....	1.6	1.1	5.8	7.2
	f	.....	.....	.....	6	x	x	15	9	33	50
Euphorbia maculata	d	.....	.....	.....	0.4	.....	0.9	.....	0.1	.....	.....
	f	.....	.....	.....	18	.....	40	.....	3	.....	.....
Rubus flagellaris	d	.....	.....	.....	0.3	.....	3.0	0.9	0.7	4.4	3.3
	f	x	.....	x	12	x	45	26	40	59	50
Paspalum pubescens	d	.....	.....	.....	0.2	.....	.....	.....	.....	1.0	.....
	f	.....	.....	.....	6	x	x	x	.....	3	x
Hypericum Drum- mondii	d	.....	.....	.....	0.2	0.2	.....	.....	.....	.....	.....
	f	.....	.....	.....	6	10	.....	.....	.....	x	.....
Polygala verticil- lata	d	.....	.....	.....	0.1	.....	.....	.....	.....	0.1-	.....
	f	.....	.....	.....	6	.....	.....	.....	.....	3	.....
Croton monanthog- ynus	d	.....	.....	.....	0.1	.....	.....	0.1	.....	0.4	.....
	f	x	.....	.....	6	.....	.....	4	.....	3	.....
Carex blanda	d	.....	.....	.....	.....	1.8	.....	2.3	.....	1.1	0.2
	f	.....	.....	.....	.....	30	.....	12	.....	18	8
Desmodium mari- landicum	d	.....	.....	.....	.....	0.6	.....	.....	3.8	1.8	6.8
	f	.....	.....	.....	.....	10	x	.....	12.5	18	25
Euphorbia corollata	d	.....	.....	.....	.....	0.6	.....	0.3	0.3	0.8	1.1
	f	.....	.....	x	x	10	x	20	15	51	8
Plantago virginica	d	.....	.....	.....	.....	0.2	.....	.....	0.2	.....	.....
	f	.....	.....	.....	.....	10	.....	.....	3	.....	.....
Lespedeza virginica	d	.....	.....	.....	.....	.....	.....	16.3	0.1	2.0	.....
	f	.....	.....	.....	x	x	x	46	3	8	x
Lespedeza procum- bens	d	.....	.....	.....	.....	.....	.....	11.9	0.7	.....	0.1-
	f	.....	.....	.....	.....	x	x	23	3	x	8
Lespedeza violacea	d	.....	.....	.....	.....	.....	.....	2.8	0.3	1.5	.....
	f	.....	.....	.....	.....	.....	.....	8	3	3	x
Desmodium Dillenii	d	.....	.....	.....	.....	.....	.....	0.4	.....	0.4	1.6
	f	.....	.....	.....	.....	.....	.....	15	.....	3	33
Solidago speciosa	d	.....	.....	.....	.....	.....	.....	0.4	.....	.....	.....
	f	.....	.....	.....	.....	.....	.....	4	.....	x	.....
Hypericum punc- tatum	d	.....	.....	.....	.....	.....	.....	0.3	0.3	0.1	.....
	f	.....	.....	.....	x	x	x	4	3	3	x
Triodia flava	d	.....	.....	.....	.....	.....	.....	0.2	0.5	0.7	.....
	f	.....	.....	.....	.....	x	x	4	6	6	x
Geum canadense, var. d camporum	d	.....	.....	.....	.....	.....	.....	0.1	.....	.....	0.4
	f	.....	.....	.....	.....	.....	.....	4	x	x	12
Carex hirsutella	d	.....	.....	.....	.....	.....	.....	0.1	.....	8.5	1.7
	f	.....	.....	.....	.....	.....	x	4	x	18	6

TABLE 4 (cont.)
 DENSITY (d)* AND FREQUENCY (f) OF HERBACEOUS SPECIES

		1	2	3	5	6	7-8	9-10	11-12	16-20	30-35
<i>Ipomoea pandurata</i>	d	.....	1.8	.....	.....	.....	.....	.....	.....	.....	.....
	f	.....	10	.....	.....	.....	.....	.....	.....	.....	.....
<i>Verbena stricta</i>	d	.....	1.4	.....	.....	.....	.....	.....	.....	.....	.....
	f	.....	20	.....	x	.....	.....	.....	.....	.....	.....
<i>Solidago canadensis,</i> <i>var. gilvocanescens</i>	d	.....	1.4	0.1	.....	.....	0.5	0.6	.....	0.2	.....
	f	.....	60	10	.....	.....	20	8	.....	15	.....
<i>Eupatorium ser-</i> <i>otinum</i>	d	.....	1.2	.....	.....	.....	.....	.....	.....	.....	0.1
	f	.....	10	x	x	x	x	x	x	x	8
<i>Agrostis scabra</i>	d	.....	1.0	22.2	17.5	.....	.....	.....	1.2	0.4	0.4
	f	.....	10	45	41	.....	.....	.....	6	3	8
<i>Erigeron ramosus</i>	d	.....	1.0	8.4	0.2	.....	.....	0.1	.....	0.2	1.1
	f	.....	10	55	12	x	x	4	x	6	25
<i>Eragrostis spect-</i> <i>abilis</i>	d	.....	0.6	.....	1.1	.....	4.6	0.3	0.6	0.5	.....
	f	x	10	.....	6	x	20	4	6	3	x
<i>Acalypha virginica</i>	d	.....	0.6	0.2	.....	13.6	0.7	0.1	1.3	1.8	10.0
	f	.....	10	10	x	70	10	15	15	40	50
<i>Hedeoma pulegeoides</i>	d	.....	0.2	.....	2.2	.....	.....	0.1	.....	.....	0.5
	f	.....	10	.....	24	.....	.....	4	.....	.....	25
<i>Oenothera sp.</i>	d	.....	.....	25.2	.....	.....	.....	0.1	0.2	.....	0.1
	f	.....	.....	65	.....	.....	.....	4	9	x	8
<i>Ambrosia bidentata</i>	d	.....	.....	6.8	.....	.....	1.8	.....	.....	.....	.....
	f	.....	.....	10	.....	.....	10	.....	.....	.....	.....
<i>Andropogon virgini-</i> <i>cus</i>	d	.....	.....	4.2	13.1	0.6	.....	.....	2.1	1.1	0.8
	f	.....	.....	45	24	10	x	x	12.5	3	16
<i>Panicum lanuginosum</i> & var.	d	.....	.....	4.1	4.9	1.2	4.1	12.6	6.2	15.8	18.9
	f	.....	.....	45	41	30	40	57	31	92	83
<i>Poa pratensis</i>	d	.....	.....	0.6	.....	.....	.....	.....	.....	.....	.....
	f	.....	.....	10	.....	.....	.....	.....	.....	.....	.....
<i>Lactuca canadensis</i>	d	.....	.....	0.1	0.1	.....	.....	.....	.....	0.2	0.5
	f	.....	.....	10	6	x	x	x	x	18	25
<i>Panicum lineari-</i> <i>folium</i>	d	.....	.....	.....	8.5	25.6	.....	22.1	.....	92.3	3.0
	f	.....	.....	.....	6	30	.....	4	.....	25	8
<i>Achillea Millefoli-</i> <i>um</i>	d	.....	.....	.....	3.7	.....	.....	0.1	.....	.....	.....
	f	x	.....	x	47	.....	.....	4	x	.....	.....
<i>Lespedeza stipulacea</i>	d	.....	.....	.....	2.9	.....	0.5	1.2	.....	1.3	.....
	f	.....	.....	.....	6	.....	10	8	.....	16	.....
<i>Juncus macer</i>	d	.....	.....	.....	2.7	.....	4.0	0.2	.....	.....	0.3
	f	.....	.....	.....	12	.....	20	4	.....	.....	8
<i>Gnaphalium obtusi-</i> <i>folium</i>	d	.....	.....	.....	0.7	.....	.....	0.1	.....	0.7	.....
	f	.....	.....	.....	35	.....	.....	4	x	14	.....

TABLE 4 (cont.)
DENSITY (d)* AND FREQUENCY (f) OF HERBACEOUS SPECIES

		1	2	3	5	6	7-8	9-10	11-12	16-20	30-35
<i>Rumex crispus</i>	d	.....	.....	.....	.....	.....	.....	0.1-	.....	.....	.....
	f	.....	.....	.....	.....	.....	.....	4	.....	.....	.....
<i>Erigeron annuus</i>	d	.....	.....	.....	.....	.....	.....	0.1-	.....	.....	0.3
	f	x	.....	.....	.....	.....	.....	4	.....	.....	6
<i>Solidago ulmifolia</i>	d	.....	.....	.....	.....	.....	.....	0.1-	.....	.....	2.5
	f	.....	.....	.....	x	x	.....	4	.....	x	33
<i>Solidago altissima</i>	d	.....	.....	.....	.....	.....	.....	.....	2.2	4.6	0.1-
	f	.....	.....	.....	x	x	.....	x	9	20	8
<i>Sporobolus vaginiflorus</i>	d	.....	.....	.....	.....	.....	.....	.....	0.6	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	.....	.....
<i>Panicum sphaerocarpon</i>	d	.....	.....	.....	.....	.....	.....	.....	0.3	5.4	7.6
	f	.....	.....	.....	.....	.....	.....	.....	3	33	16
<i>Specularia perfoliata</i>	d	.....	.....	.....	.....	.....	.....	.....	0.2	.....	0.1
	f	.....	.....	.....	.....	.....	.....	.....	6	.....	16
<i>Lespedeza striata</i>	d	.....	.....	.....	.....	.....	.....	.....	0.1	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	.....	.....
<i>Croton capitatus</i>	d	.....	.....	.....	.....	.....	.....	.....	0.1-	.....	.....
	f	x	.....	x	x	.....	.....	.....	3	x	.....
<i>Andropogon scoparius</i>	d	.....	.....	.....	.....	.....	.....	.....	9.8	.....	.....
	f	.....	.....	.....	.....	x	.....	.....	28	x	.....
<i>Danthonia spicata</i>	d	.....	.....	.....	.....	.....	.....	.....	7.4	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	x	x
<i>Andropogon provincialis</i>	d	.....	.....	.....	.....	.....	.....	.....	3.4	.....	.....
	f	.....	.....	.....	.....	x	.....	x	3	x	x
<i>Prunella vulgaris</i>	d	.....	.....	.....	.....	.....	.....	.....	2.7	.....	2.5
	f	.....	.....	.....	.....	x	.....	.....	15	x	8
<i>Rosa sp.</i>	d	.....	.....	.....	.....	.....	.....	.....	1.5	.....	0.1-
	f	.....	.....	.....	.....	.....	.....	x	12	x	8
<i>Helianthus hirsutus</i>	d	.....	.....	.....	.....	.....	.....	.....	1.5	.....	.....
	f	.....	.....	.....	.....	x	.....	x	20	x	.....
<i>Desmodium canadense</i>	d	.....	.....	.....	.....	.....	.....	.....	1.4	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	6	.....	.....
<i>Coreopsis tripteris</i>	d	.....	.....	.....	.....	.....	.....	.....	0.7	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	.....	.....
<i>Bromus commutatus</i>	d	.....	.....	.....	.....	.....	.....	.....	0.2	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	.....	.....
<i>Schrankia Nuttallii</i>	d	.....	.....	.....	.....	.....	.....	.....	0.1	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	.....	x

TABLE 4 (cont.)
 DENSITY (d)* AND FREQUENCY (f) OF HERBACEOUS SPECIES

		1	2	3	5	6	7-8	9-10	11-12	16-20	30-35
<i>Sabatia angularis</i>	d	.....	.....	.....	.....	.....	.....	.....	0.1-	.....	.....
	f	.....	.....	.....	.....	.....	.....	.....	3	x	x
<i>Muhlenbergia sobolifera</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.1
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	25
<i>Eupatorium urticae- folium</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.7
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	16
<i>Carex cephalophora</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.9
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
<i>Polygonum scandens</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.9
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	16
<i>Sanicula canadensis</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.5
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	33
<i>Pycnanthemum flex- uosum</i>	d	.....	.....	.....	x	.....	.....	.....	.....	.....	1.0
	f	.....	.....	.....	.....	.....	.....	.....	x	x	8
<i>Viola papilionacea</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.8
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	16
<i>Aster patens</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.3
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	16
<i>Vernonia altissima</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.3
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
<i>Cirsium altissimum</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.2
	f	.....	.....	.....	.....	.....	.....	.....	x	.....	16
<i>Physalis subglabrata</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.1
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
<i>Penstemon Digitalis</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.1-
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
<i>Galium obtusum</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.1-
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
<i>Solidago serotina</i>	d	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.1-
	f	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
Total species present in fields (including sps. marked "x")		22	24	32	45	41	38	52	58	57	63

* Density = average no. stems / square meter

x = Present in field, but not included in samples based on quadrats.

species remains high. Corresponding increases in the absolute number of species and of perennials also may be noted. Moreover, the densities of the gray goldenrod and white heath aster, considered together, show a further increase. Broomsedge (*Andropogon virginicus*) and panic grass (*Panicum lanuginosum*, var. *fasciculatum*) appear for the first time during this stage; but only scattering traces of trailing dewberry (*Rubus flagellaris*) were observed. The same dewberry (*Rubus* "procumbens") has been reported by Larsen (1934) in southeastern Ohio as being "very active and efficient in covering exposed soil of low fertility;" but this statement apparently does not imply that this plant pioneers on more recently abandoned cropland, for he goes on to write, in part, "They drive out the weeds. . . ."

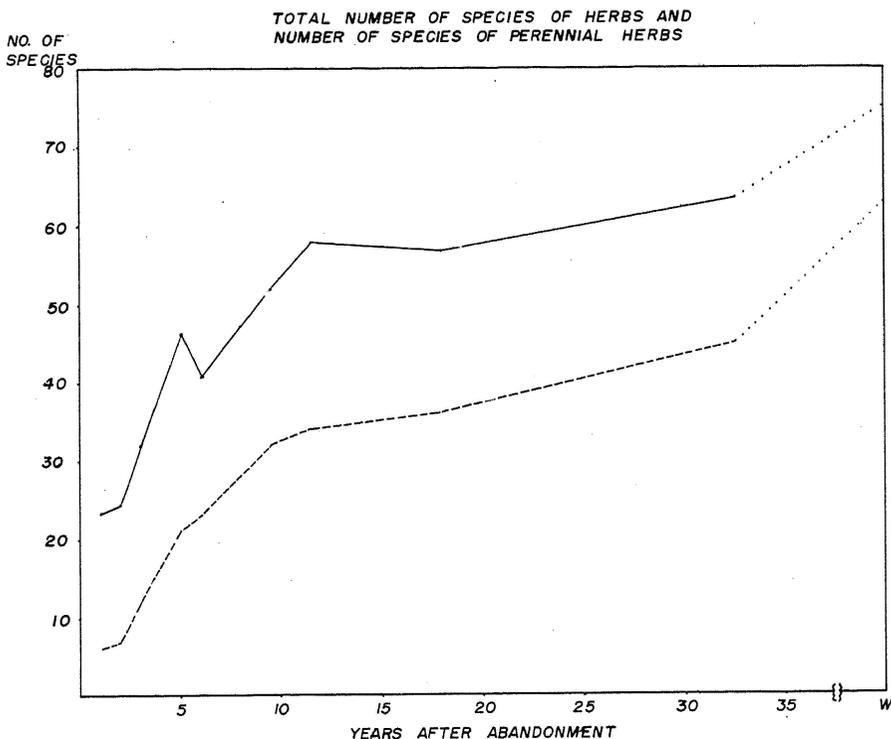
TABLE 5
ABSOLUTE NUMBER OF SPECIES OF PERENNIAL HERBS AND ALL HERBACEOUS SPECIES

	Years after Abandonment										
	1	2	3	5	6	7-8	9-10	11-12	16-20	30-35	*W
Totals of all species of herbs per stage	22	24	32	45	41	38	52	58	57	63	65
Totals of species of perennial herbs per stage	6	7	12	21	23	19	32	34	36	45	62

*W = data from Knight (1941) based on study of second-growth woodlands in vicinity.

Five years after abandonment the absolute number of species and of perennials (Table 5) have considerably increased, and the annual dominants of the first two years have by this stage either disappeared completely or have become reduced to very low densities and frequencies. Usually such plants may persist even for long periods in local areas where certain factors promote disturbance or render the habitat unfavorable to the establishment of perennial old-field herbs. Five years after the last cultivated crop, the gray goldenrod and white heath aster have nearly or completely attained dominance (cf. Table 4). Various wire grasses, especially *Aristida dichotoma* and *A. longespica*, have also become very numerous; but both densities and frequencies of these species fluctuate widely throughout the successional series studied, partly, no doubt, due to erosional variations and associated edaphic changes. That such may be the case is attested by the reports of several writers of the occurrence of various aristidas, including *A. oligantha*, which has been recorded in this study, on eroded soils in different parts of the country. Thus Booth

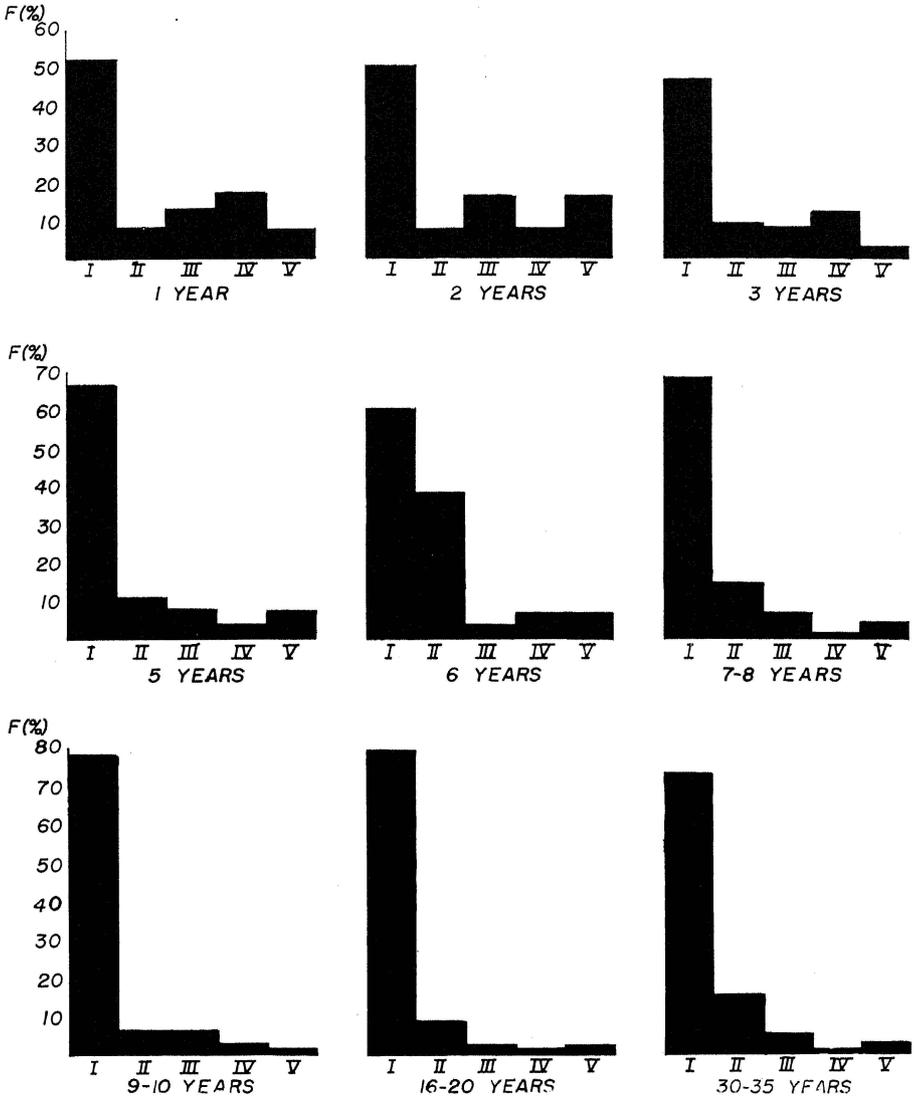
PLATE I



(1941a, b), Nelson (1937), and Smith (1940), among others, have noted the occurrence of various *aristidas* on eroded soils in states where their work has been done. Where a grassland climax prevails, however, certain other species of *Aristida* may occur in later stages of succession where soil conditions have been improved by preceding types of vegetation. (cf. Smith (l. c.), Judd and Jackson (1939), and others.)

After five or six years, the herbaceous vegetation remains relatively homogeneous with only local changes, as in disturbed areas or under heavy shade of arborescent types, until about 20 years after abandonment. The data on the frequency classes of the herbs, given in Table 7, and the diagrams constructed from them (Plate II), further serve to emphasize the relatively homogeneous nature of the herbaceous layer after the old-field perennials have become fully dominant (6-7 years). In contrast, the frequency data and the diagrams for earlier stages of development reflect the more heterogeneous nature of the herb

PLATE II

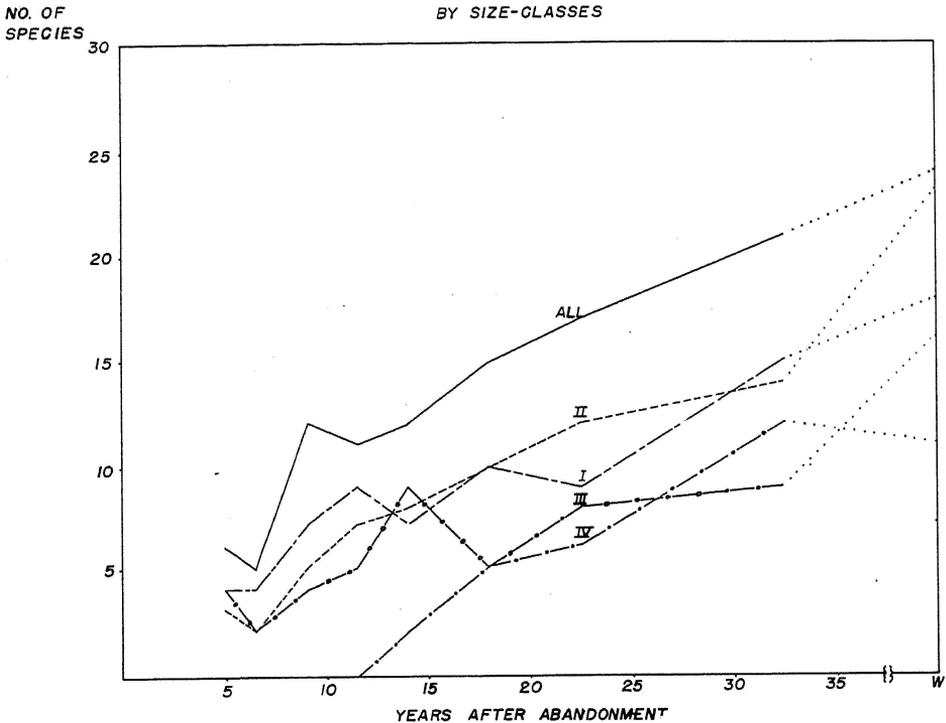
FREQUENCY CLASSES (%) OF HERBACEOUS
VEGETATION

layer, during which period competition between annuals and old-field perennials is most marked. During the period between five or six years and 20 years, the gray goldenrod and white heath aster,

together with other solidagos and asters, are the principal dominants. During this period of old-field development, the gradual increase in importance of trailing dewberry, cinquefoil, several species of perennial legumes and sometimes broomsedge is marked (cf. Table 4). The absolute number of species of herbaceous plants as well as the number of perennials also rises, with some fluctuations, as age of abandonment becomes greater (cf. Plate I).

PLATE III

NUMBERS OF ARBORESCENT SPECIES
BY SIZE-CLASSES



The chief old-field dominants, however, commence to decrease in density as the age of the field after abandonment reaches some 30 years. Many of the fields 20 years or more of age support a considerable arborescent vegetation which tends to shade out those species favored by the open, sunlit habitats of the old fields. Thus the increased number of perennials and species in fields from 20 years through 30 to 35 years of age since the last cultivation are mostly of tolerant types favored by the greater density of an arborescent canopy. For example, these tolerant types include *Solidago ulmifolia*, *Muhlen-*

TABLE 6 (cont.)
 ABUNDANCE VALUES OF ADDITIONAL HERBACEOUS SPECIES
 OBSERVED IN ABANDONED FIELDS*

	1	2	3	5	6-7	8-10	11-12	16-20	30-35
<i>Lepachys pinnata</i>				1					
<i>Lepidium virginicum</i>	2			1		1			
<i>Monarda Bradburiana</i>									1
<i>Monarda fistulosa</i>								2	2
<i>Oxalis europaea</i> , var. <i>Bushii</i> , f.								2	2
<i>Parthenium integrifolium</i>							1	1	
<i>Penstemon pallidus</i>								2	
<i>Physalis heterophylla</i>					1		2		1
<i>Polygala sanguinea</i>						2	1		2
<i>Polygonum pennsylvanicum</i>	1			1					
<i>Pyrrhopappus carolinianus</i>							1		
<i>Rudbeckia hirta</i>					1		2	1	1
<i>Rumex Acetosella</i>						2			
<i>Spiranthes gracilis</i>									1
<i>Teucrium canadensis</i>				2				2	2
<i>Tradescantia canaliculata</i>								1	
<i>Verbascum Thapsus</i>							1		1
<i>Vernonia Baldwini</i>				1	1				1

*Fields in which quadrats were taken.

As brought out by the data in Table 4, the occurrence of valuable native forage grasses, such as the bluestems, is very sporadic. While present in fields abandoned only six years, *Andropogon scoparius* (little bluestem) appears to be more common in later stages of succession; yet the density and frequency of these grasses are so low as to suggest that, in most of this area, except for the Putnam soils, they play a minor role among herbaceous plants in the natural revegetation process. Those fields in which the bluestems occurred almost always were bordered by clumps of these grasses, or were fringed with woods in which they also grew (cf. Plate VIII). The latter condition is fairly common in rather open, dryish, upland woods in the area

(Knight, 1941) as well as in much of the Ozark region to the south (Steyermark, 1940).*

In Table 6, there are listed additional plants found in those abandoned fields where quadrat studies were conducted. A fair number of these species of limited and sporadic occurrence are weeds of rather local occurrence in any one field. Such weeds tend to persist in old fields in areas where the revegetation process has been disturbed by one or more factors. Moreover, as Oosting and Humphreys (1939) have shown, weed seeds may remain buried and viable for rather long periods of time in old fields of the Piedmont region of North Carolina. Thus any factor such as rodent coactions, tending to disturb the old-field vegetation of local areas may result in affording a favorable habitat to the buried, viable seeds which may then germinate.

In summary, it may be said that the herbaceous vegetation of abandoned cropland falls roughly into two well-marked stages, with a third one transitional between them, in relation to time after the last cultivation. The annual stage, dominated by weeds co-existing with the last crop lasts from 2 to 3 years; a transitional, mixed annual-perennial stage, occurs from 2-4 years after abandonment; and a perennial, old-field stage persists for from 5-6 to approximately 30 years.

C. Woody Vegetation

1. **Shrubs and Woody Vines.**—In many parts of the country, particularly the forested sections, shrubs of various kinds have been reported as growing in important numbers in successional series of old fields, usually just preceding an arborescent stage. See Billings (1939), Booth (1941_b), Larsen (1934), Lutz (1928), Olmsted (1937), and others. Among the species of shrubs of importance in the successional development of old fields in much of the entire forested portion of the East and Midwest are *Rhus glabra* (smooth sumac), *Rhus Copallina* (winged sumac), and various tall species of *Rubus* (blackberry). Not only are the foregoing shrubs of significance in the natural revegetation of abandoned cropland in Missouri, but also some of them, especially the sumacs, have been reported to be of even greater importance in the Ozarks in the land which has been logged and cleared, or, in some cases, overgrazed. (Steyermark, 1940).

The observations of the writer in the Cedar Creek Area, as well as in much of the north-central part of the state, are that overgrazed pastures are frequently populated by a heavy shrub growth of *Symphoricarpos orbiculatus* (buckbrush) and various species of

*On Putnam soils, especially on the northern fringe of the L. U. area, bluestems are much more common. Here and there fields may be observed in which these native grasses appear gradually to be invading; but such fields are almost always in pasture and usually are bordered by relic prairie patches.

TABLE 7
FREQUENCY CLASSES OF HERBACEOUS VEGETATION

Years after Abandonment		Frequency Classes					Total No. Sps.
		I	II	III	IV	V	
One year	N*	12	2	3	4	2	23
	%	52	8	13	17	8	
Two years	N	12	2	4	2	4	24
	%	50	8	16	8	16	
Three years	N	15	3	9	4	1	32
	%	46	9	28	12	3	
Five years	N	30	5	4	2	4	45
	%	66	11	8	4	8	
Six years	N	25	8	2	3	3	41
	%	60	38	4	7	7	
Seven - Eight years	N	26	6	3	1	2	38
	%	68	15	7	2	5	
Nine - Ten years	N	41	4	4	2	1	52
	%	78	7	7	3	2	
Eleven - Twelve years	N	47	5	2	2	2	58
	%	81	8	3	3	3	
Sixteen - Twenty years	N	45	5	3	1	3	57
	%	79	9	3	2	3	
Thirty - Thirty-five years	N	46	10	4	1	2	63
	%	73	16	6	2	3	
Second-growth Forest**	N	54	8	2	1	0	65
	%	83	12	3	1	0	

* N = Number of species.

** Data from Knight (1941)

Crataegus (hawthorns), in addition to the sumacs and saplings of sassafras and persimmon. Where the latter have systematically been cut or rooted out, or have failed to become established by natural means, buckbrush and hawthorns appear to be by far the most abundant shrubs of overgrazed upland pastures in the area.

So far as the Cedar Creek Area is concerned, the species of shrubs of most importance in the natural revegetation of abandoned cropland are *Rhus glabra* and *R. Copallina*; but, as indicated by the data in Table 8, the former is usually more frequent and has a greater density. In general, it may be observed that as revegetation proceeds,

TABLE 8
DENSITY (d/mil.) AND FREQUENCY (f) OF SHRUBS AND WOODY VINES

Species		Years after Abandonment							
		5	6-7	8-10	11-12	13-15	16-20	21-25	30-35
Rhus glabra	d	0.08			0.97	0.14	0.38	0.78	0.68
	f	1		x	21	7	15	23	20
Rhus Copallina	d		0.08		0.13	0.10	0.11	0.58	0.29
	f	x	5		1	2	1	7	3
Hypericum prolificum	d						0.32		
	f						8		x
Cornus asperifolia	d							0.31	
	f							1	
Viburnum rufidulum	d							0.28	
	f							3	
Parthenocissus quinquefolia	d							0.01	0.01
	f							1	1
Vitis aestivalis	d							0.01	0.01
	f					x		1	1
Vitis vulpina	d								0.08
	f								1
Symphoricarpos orbiculatus	d								0.08
	f						x		1
Zanthoxylum americanum	d								0.04
	f								1

d = av. number of stems / milacre
x = present in field but not sampled in quadrats.

the density and frequency of shrubs and woody vines increase. It may further be added that for the first five years subsequent to the last cultivation, virtually no shrubs or woody vines occur in old fields. Their invasion of the latter, however, appears to occur after the old-field herbs have established dominance. Almost always seed sources of these shrubs are present along the borders of the fields. In addition, in Table 9, there are listed other species of shrubs observed in old fields but which, because of their uncommon occurrence, were not sampled in milacre quadrats.

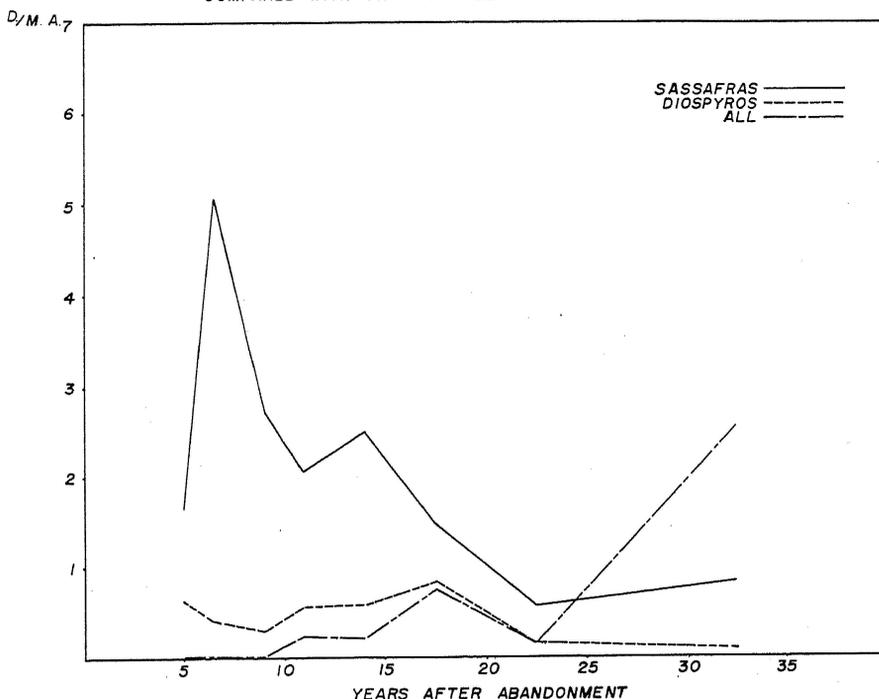
A comparison of the shrub layer of second-growth oak-hickory woodland on upland sites in the vicinity (Knight, 1941), indicates that many species persist in this type of forest. Old-field species which thus were found in second-growth forest included *Rhus glabra*, *Rubus occidentalis*, and *Symphoricarpos orbiculatus*; yet the density of these plants in a wooded habitat was, at least in the case of *Rhus glabra*, much less than that of the old fields.

TABLE 9
 ABUNDANCE OF OTHER OBSERVED SPECIES OF SHRUBS AND WOODY VINES

Species	Abundance Classes							
	5	6-7	8-10	11-12	13-15	16-20	21-25	30-35
<i>Ceanothus americanus</i>					1			1
<i>Celastrus scandens</i>								1
<i>Rhus aromatica</i>						1		1
<i>Toxicodendron radicans</i>						1	1	1
<i>Rubus</i> spp.		1		1	1		1	2

PLATE IV

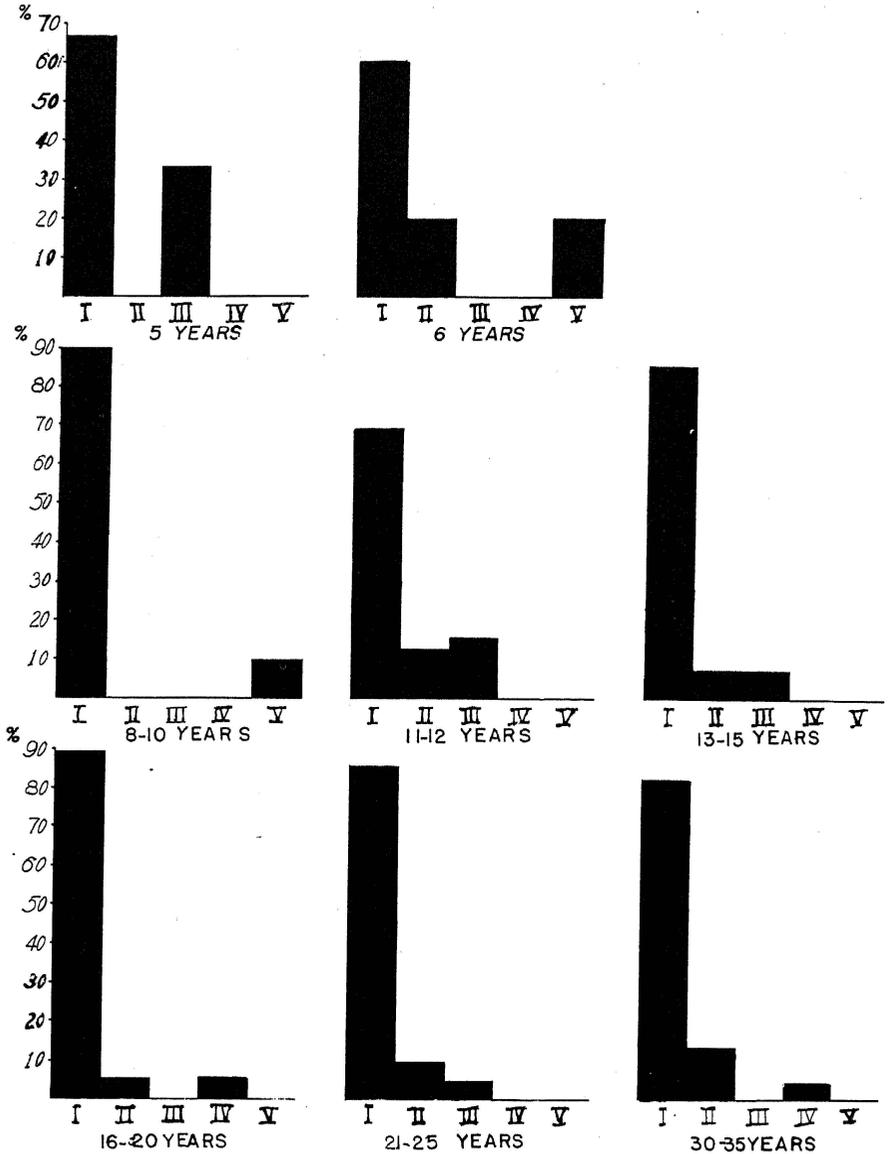
DENSITY (SIZE-CLASS I) OF SASSAFRAS AND DIOSPYROS
 COMPARED WITH THAT OF ALL OTHER ARBORESCENT SPECIES



Finally, it seems worthwhile to point out that in the abandoned fields of the area, various species of wild grapes (cf. Table 8) do not usually appear to become established prior to about 20 years after the last cultivated crop.

PLATE V

FREQUENCY DIAGRAMS OF ARBORESCENT VEGETATION



2. **Arborescent Vegetation.**—It has already been pointed out in a foregoing section of this paper that the majority of cultivated fields

PLATE VI



Figure 1



Figure 2



Figure 3



Figure 4

Explanation of Figures

Fig. 1.—Annual weeds and persimmon sprouts in corn field one year after the last cultivation. July 1941. R11W T46N Sec. 29, SE $\frac{1}{4}$.

Fig. 2.—Sassafras and gray goldenrod (*Solidago nemoralis*) in old corn field, about six years after the last crop. July 1941. R11W T46N Sec. 19, NE $\frac{1}{4}$. (University Arboretum and Wildlife Area, near Ashland).

Fig. 3.—Gray goldenrod in corn field abandoned about ten years, showing exceptionally homogeneous stand from which woody sprouts had been thoroughly eliminated. July 1941. R11W T46N Sec. 20, NE $\frac{1}{4}$. (University Arboretum and Wildlife Area, near Ashland).

Fig. 4.—Eroded corn field, 10-12 years after abandonment, showing stand of broomsedge (*Andropogon virginicus*) at terminus of a wash, with smooth sumac in the foreground, sassafras and persimmon in the background. August 1941. R11W T46N Sec. 28, NE $\frac{1}{4}$.

in the Cedar Creek Area support, at the time of abandonment, an often considerable growth of sassafras and persimmon sprouts, as well as those of an occasional oak or hickory. Moreover, the borders of most of the abandoned fields in the general vicinity of Cedar Creek are contiguous to patches or larger areas of forest. Indeed, in the narrow borders themselves are numbers of oaks, hickories, elms, white ash, red cedar, and other species in addition to the ubiquitous sassafras and persimmon. There is, therefore, a source of seed of

PLATE VII

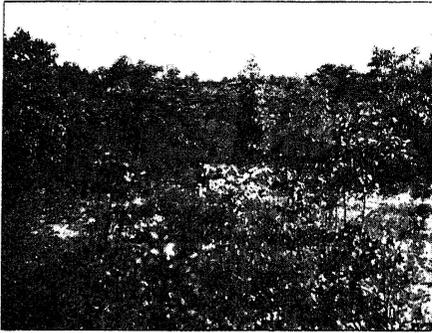


Figure 5

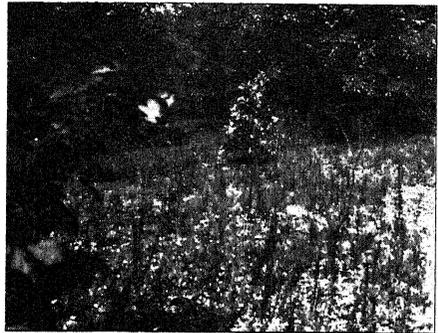


Figure 6



Figure 7

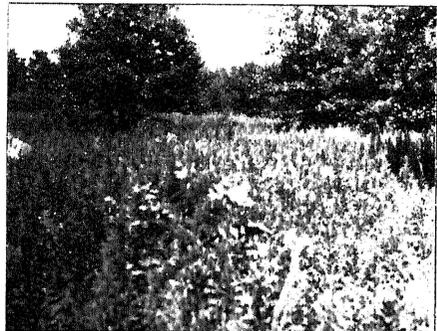


Figure 8

Explanation of Figures

Fig. 5.—Eroded field, about fifteen years after the last cultivation, with dense cover of sassafras and a little persimmon; Ozark pignut hickory in center foreground. August 1941. R11W T46N Sec. 18, SW $\frac{1}{4}$. (University Arboretum and Wildlife Area, Ashland).

Fig. 6.—Eroded western edge of corn field, 20-25 years after abandonment, showing stand of *Lespedeza virginica* and panic grass (*Panicum linearifolium*); dense stand of sassafras in background; oak saplings at left and center. August 1941. R12W T45N Sec. 2, NW $\frac{1}{4}$.

Fig. 7.—Dense stand of panic grass (*Panicum linearifolium*), with some *Lespedeza virginica*, on eroded, western edge of old field, about thirty years after the last cultivation. August 1941. R11W T46N Sec. 15, SW $\frac{1}{4}$.

Fig. 8.—Margin of old field, abandoned about 30-35 years, showing mixed stand of gray and tall goldenrods (*Solidago nemoralis* and *S. altissima* respectively), with acorn-producing post and shingle oaks. July 1941. R11W T47N Sec. 17, NW $\frac{1}{4}$.

numerous species of trees comparatively near to the abandoned fields. This is without question an important factor in the early reestablishment of forest species on abandoned cropland for, obviously, a field not thus favored by a nearby source of seed of different trees will not become invaded by such vegetation, other factors being equal, for a much longer interval of time. Furthermore, the presence of occasional sprouts of various oaks, hickories, *et al.* in recently aban-

PLATE VIII

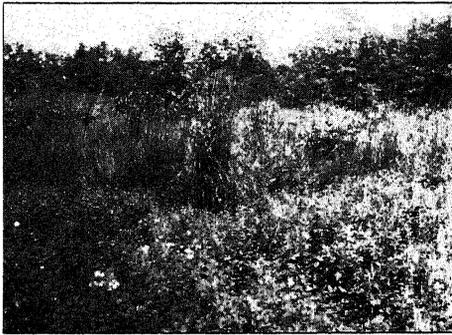


Figure 9

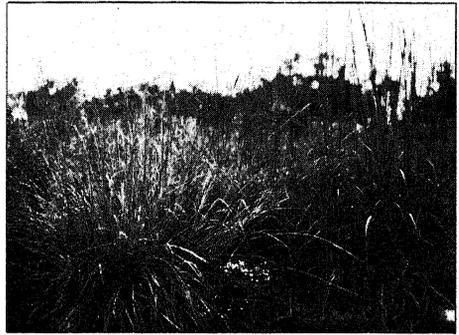


Figure 10



Figure 11



Figure 12

Explanation of Figures

Fig. 9.—Border of field out of cultivation for nearly ten years, showing big bluestem (*Andropogon provincialis*) extending from woodland margin (right) into former cropland. Sensitive brier (*Schrankia Nuttallii*) in foreground. August 1941. R11W T46N Sec. 19, NW $\frac{1}{4}$. (University Arboretum and Wildlife Area, Ashland).

Fig. 10.—Cumps of big bluestem on roadside and field border, serving as potential sources of seed for establishment of this grass in adjacent abandoned land. August 1941. R11W T46N Sec. 8, NE $\frac{1}{4}$.

Fig. 11.—Big and little bluestem at margin of corn field abandoned about fifteen years. August 1941. R11W T46N Sec. 18, SW $\frac{1}{4}$. (University Arboretum and Wildlife Area, Ashland).

Fig. 12.—Persimmon sprouts developing in field limed and sown to Korean lespedeza. August 1941. R11W T46N Sec. 15, SW $\frac{1}{4}$.

doned fields implies a proximate source of seed of most of these trees, since after 15 to 20 years they have far overtopped the sassafras and persimmon and may then, or soon thereafter, have attained seed-producing age. Such trees as post and shingle oaks, commonly occurring as occasional sprouts in recently abandoned fields, thus are represented in later stages of revegetation by numerous seedlings. (cf. Plates VI, VII.)

In Table 10, a list of numbers of species by size-classes* is given, beginning with the stage five years after abandonment. These data are represented graphically in Plate III. In general, the data indicate a substantial and gradual increase in total number of species of all size-classes for all the periods of abandonment studied. The second-growth woodland sampled in the vicinity (Knight, 1941) of several of the abandoned fields included more species than recorded for the oldest stage (30-35 years), but a wider-ranging survey of more stands of such forests no doubt would have yielded several additional ones.

TABLE 10
NUMBERS OF ARBORESCENT SPECIES BY SIZE-CLASSES

Size-Classes	Years after Abandonment								W*
	5	6-7	8-10	11-12	13-15	16-20	21-25	30-35	
Size-class I	4	4	7	9	7	10	9	14	18
" " II	3	2	5	7	8	11	12	14	23
" " III	4	2	4	5	9	5	8	9	16
" " IV	0	0	0	0	2	5	6	12	11
" " V	0	0	0	0	0	0	0	0	7
Total all size-classes	6	5	12	11	12	16	17	20	24

*W = Data from Knight's (1941) study of second-growth woodland in the vicinity of old fields.

Though the gradual increase in numbers of species of trees in relation to time may in itself be taken as suggestive of natural plant succession, the corresponding rise in the reproduction classes (I, II) is that much more convincing. The first occurrence of species in size-class IV marks the point at which growth of sprouts of oaks or hickories, which were present at the time of abandonment, have attained this size. Sassafras and persimmon in the average upland old-field sites were not found to have reached this size-class (IV) until about 16 to 20 years subsequent to the last crop grown. In the oldest fields included in this study (30-35 years), a much larger proportion of the total number of sassafras and persimmon were found to be of this size.

*The size-classes employed here consist of the following (cf. Weaver and Clements, 1938):

- I 0—0.9 ft. tall
- II 0.9 ft. tall—0.9" d.b.h.
- III 1.0" d.b.h.—3.5" d.b.h.
- IV 3.6" d.b.h.—9.5" d.b.h.
- V 9.6" d.b.h. and over

Density data, expressed in average number of stems per milacre, from Table 11, are presented in order to bring out more clearly the dominance of sassafras and persimmon in the stages of old-field development studied. Sassafras, as a rule, has a greater density than any other species including the persimmon. Despite sampling errors and other variables not possible to control, the total densities per stage of abandonment are quite constant. No well marked trend of decreasing density of sassafras may be noted, although such a tendency may be represented by persimmon. Nevertheless an irregular but fairly marked rise in the density of all other species appears to be indicated.

TABLE 11
DENSITY OF ALL SIZE-CLASSES OF SASSAFRAS AND DIOSPYROS
COMPARED WITH ALL OTHER ARBORESCENT SPECIES

Species	Average Density /Milacre							
	Years after Abandonment							
	5	6-7	8-10	11-12	13-15	16-20	21-25	30-35
Sassafras albidum	5.30	12.28	9.65	5.14	6.00	5.16	2.10	5.06
Diospyros virginiana	4.03	1.50	0.76	2.55	2.10	2.29	1.07	0.60
All others	0.18	0.08	0.21	1.19	0.73	1.53	0.66	3.25
Total Average Density	9.51	13.86	10.62	8.88	8.83	8.98	3.83	8.91

An inspection of the density data of the reproduction classes of arborescent vegetation, given in Table 12, indicates fairly clearly a decrease in the production by sassafras of plants of the seedling class (I), at least after 16-20 years following abandonment. The data also suggest a more vigorous reproduction, probably mostly vegetative, of the sassafras in the earlier stages of old-field development. As Duncan (1937) has found in Indiana, sassafras in Missouri also appears to have a marked capacity for comparatively rapid vegetative propagation by elongating roots. Along with a decreasing trend in the density of the seedling class of sassafras after 16-20 years, there appears to be a similar reduction in persimmon and an irregular but nonetheless definite rise in the density of seedlings of other species of trees. Among the latter, post oak, shingle oak, American elm, sugar maple, and black oak appear to be important. (cf. Plate IV.)

Frequency data for the reproduction classes of arborescent vegetation are given in Table 13. Although saplings (Class II) of sassafras do not appear to have been greatly reduced in number by 30-35 years after abandonment, there is a slight decrease in the seedling class (I). In the case of the persimmon, however, there appear to be more definite indications of decreasing frequencies in both seedling (I) and sapling (II) classes, with increasing periods subsequent to abandonment. Concerning other species of trees, there is, as in the case of their densities, an irregular but definite indication of a gradual increase in frequency of the seedling (I) and sapling (II) classes. Due to the sporadic appearance of sprouts of certain oaks, hickories, *et al.* in recently abandoned fields, such an irregularity in frequency of their reproduction classes is certainly to be expected.

Regarding the species-time relationship, it has already been shown (Table 10 and Plate III) that the total number of woody species tends to increase as age of abandonment becomes greater. It remains to note the occurrence of different species in relation to the time factor. Post oak, shingle oak, and shagbark hickory (*Carya ovata*) were the species found as sporadic sprouts, as well as seedlings, in cropland at the time of abandonment. Thereafter, up to 30-35 years after abandonment, these three species tend to increase, though irregularly so, in density and frequency of seedlings, and saplings (Tables 12, 13). Seedlings developed from the windborne fruits of American elm, sugar maple, and white ash appear in cropland six to eight years after the last cultivation. Except for the ash, the other two species tend to manifest irregular increases in density and frequency of seedlings and, except perhaps in the case of the maple, in saplings also. Red cedar (*Juniperus virginiana*) and black oak (*Quercus velutina*, and var. *missouriensis*) were not found as seedlings until at least 10 years after abandonment; thereafter, these trees were usually represented by some seedlings of rather low frequencies and densities. White oak (*Quercus alba*) was not represented by seedlings or saplings until after 12 years following abandonment. The infrequent occurrence of other species as seedlings is more suggestive of the presence or absence of nearby seed sources rather than of any successional tendencies.

In summary, it appears that as the period of time after abandonment of a cultivated field increases up to 30-35 years, there is, first, a definite increase in total number of species regardless of size-class differences; second, a slight decrease in density and frequency of the seedling class of sassafras, and a more definite reduction for the same class in persimmon, at least after 16-20 years; and, third, an

irregular but fairly definite increase in both density and frequency of the reproduction of all other arborescent species.

Density and frequency data for all size-classes of the arborescent vegetation are presented in Table 14. These figures, in general, do not always show the same trends manifested by the data for reproduction classes, largely because of the addition of those individuals

TABLE 14
DENSITY (d) AND FREQUENCY (f) OF ARBORESCENT VEGETATION

Species		Years after Abandonment							
		5	6-7	8-10	11-12	13-15	16-20	21-25	30-35
Sassafras albidum	d	4.35	10.06	9.65	5.14	5.10	5.16	2.10	5.06
	f	48	98	93	48	60	66	47	76
Diospyros virginiana	d	4.03	1.50	0.76	2.55	2.10	2.29	1.07	0.60
	f	60	29	20	47	39	37	29	24
Carya ovata	d	0.11	x	0.03	0.18	0.21	0.04	0.18	0.17
	f	7	x	2	9	14	3	11	11
Quercus stellata	d	0.02	0.02	0.10	0.06	0.03	0.11	0.04	0.30
	f	1	2	3	6	4	8	2	13
Carya Buckleyi, var. arkansana	d	0.02	....	....	0.86	0.12	0.04	0.04	0.03
	f	1	....	....	4	4	2	2	3
Quercus imbricaria	d	0.01	....	....	....	0.17	0.48	0.11	0.52
	f	1	....	....	....	11	13	7	24
Ulmus americana	d	....	0.06	0.01	....	0.03	0.37	0.07	0.82
	f	....	2	2	....	4	15	4	33
Quercus borealis, var. maxima	d	....	....	0.03	....	....	....	0.02	0.06
	f	....	....	1	....	....	....	1	4
Acer saccharum	d	....	....	0.01	0.01	0.01	0.10	0.01	0.84
	f	....	....	2	1	2	10	2	15
Fraxinus americana	d	....	....	0.01	0.01	....	0.17	0.01	....
	f	....	....	2	1	....	13	2	....
Gleditsia triacanthos	d	....	....	0.01	....	....	....	0.02	....
	f	....	....	2	....	....	....	1	....
Juglans nigra	d	....	....	0.01	....	....	....	....	0.01-
	f	....	....	2	....	....	....	....	1
Juniperus virginiana	d	....	....	x	0.03	....	0.04	0.05	0.05
	f	....	....	x	4	....	5	6	6
Quercus velutina & var. missouriensis	d	....	....	x	0.02	0.05	0.04	0.05	0.31
	f	....	....	x	2	3	3	3	17
Carya ovalis	d	....	....	....	0.01	0.07	0.07	0.02	0.02
	f	....	....	....	1	4	5	2	3
Amelanchier canadensis	d	....	....	....	0.01	....	....	....	....
	f	....	....	....	1	....	....	....	....
Quercus alba	d	....	....	....	....	0.05	0.02	0.02	0.06
	f	....	....	....	....	2	2	3	5

TABLE 14 (cont.)
DENSITY (d) AND FREQUENCY (f) OF ARBORESCENT VEGETATION

		5	6-7	8-10	11-12	13-15	16-20	21-25	30-35
<i>Carya cordiformis</i>	d	.....	.....	.....	.....	0.03	.....	.....	.....
	f	.....	.....	.....	.....	2	.....	.....	.....
<i>Ulmus fulva</i>	d	.....	.....	.....	.....	.....	0.02	.....	.....
	f	.....	.....	.....	.....	.....	1	.....	.....
<i>Celtis occidentalis</i>	d	.....	.....	.....	.....	.....	0.01	0.01	0.01-
	f	.....	.....	.....	.....	.....	1	1	1
<i>Prunus americana</i>	d	.....	.....	.....	.....	.....	0.01	.....	.....
	f	.....	.....	x	.....	.....	2	x	.....
<i>Quercus Muhlenbergii</i>	d	.....	.....	.....	.....	.....	.....	0.01	0.01
	f	.....	.....	.....	.....	.....	.....	1	2
<i>Cercis canadensis</i>	d	.....	.....	.....	.....	.....	.....	.....	0.03
	f	.....	.....	.....	.....	.....	.....	.....	2
<i>Prunus serotina</i>	d	.....	.....	.....	.....	.....	.....	.....	0.01
	f	.....	.....	.....	.....	.....	.....	.....	1
<i>Carya tomentosa</i>	d	.....	.....	.....	.....	.....	.....	.....	0.01-
	f	.....	.....	.....	.....	.....	.....	.....	1
<i>Crataegus sp.</i>	d	.....	.....	.....	.....	.....	.....	.....	0.01-
	f	.....	.....	.....	.....	.....	.....	.....	1

d = av. number of stems/milacre

x = Present in field but not sampled in quadrats

sporadically present as sprouts in the cropland at the time of abandonment. Nevertheless, this table does indicate the total density and frequency relationships.

Frequency diagrams, based on the data in Table 14, indicate (Plate V) considerable variation until after 11-12 years subsequent to abandonment. These variations appear due in a large measure to the varying proportions of sassafras and persimmon, and occur at a period when other species are not common. After twelve years, however, the frequency diagram manifests a greater similarity and, therefore, a somewhat greater homogeneity of the arborescent layer.

D. Relationship between Plant Communities and Soil Erosion

Since many variable factors other than degree of soil erosion profoundly affect the annual vegetation of the cropland recently abandoned, much further investigation of this complex of environmental forces would be required to determine more precisely the influence of soil removal on these initial plant populations. Observations of

numerous eroded old fields suggested the possibility that degree of soil erosion might be correlated with the occurrence of certain legumes, notably partridge pea (*Cassia fasciculata*), trailing wild beans (*Strophostyles helvola* and *S. pauciflora*), and various lespedezas such as *L. virginica*. An analysis of aspects of this problem is being experimentally investigated and will be reported upon later. So far as the dominant old-field perennials (gray goldenrod and white heath aster) are concerned, the observations made in this study indicate no obvious relationship to degree of soil removal; but, perhaps further study might reveal more subtle relationships between the relative abundance of one of these species and the other and soil loss. In some fields, gray goldenrod was much more abundant than in others, but here again a complex of factors is doubtless involved.

Perhaps the most clearly demonstrable of plant communities related at least in part to degree of soil erosion is that of *Lespedeza virginica*—*Panicum linearifolium*, shown in Plate VII. Over and over again in many fields in the Cedar Creek Area, this natural community, either with both species represented or with only one or the other, appeared on southern or western exposures, often on a slight slope, where 75-100 per cent of the top-soil had been removed. Basal ground coverage was frequently rather high (25 to 50%), especially where the panic grass was abundant. It seems entirely possible that some practical use might be made of these plants, if only to check further soil loss on exposed, eroded sites.

So far as woody vegetation was concerned, no community relationships to soil removal were noted.

E. Role of Lower Plants in Revegetation of Abandoned Cropland

Booth (1941a) has called attention to the part played in soil erosion in Oklahoma and Kansas by soil algae, chiefly of the Myxophyceae. According to this investigator, many of these algae pioneer on eroded, abandoned cropland in the regions studied.

Special attention in this investigation was directed toward the importance in the Cedar Creek Area of soil algae; those species found are given in Table 15.* It is noteworthy that the majority of species of algae described as important by Booth in Kansas and Oklahoma were found to occur on the soil of abandoned fields in this area. In nearly every old field studied, soil algae are common, but no well marked time relationships were noted. However, the reddish *Porphyrosiphon Notarisii*, by far the most common alga in forming

*All identifications of algae were kindly made by Dr. Francis Drouet.

mats on the soil surface, was abundant at any stage, providing the cover of herbs was greatly reduced, and bare, eroded soil was exposed. Although many croplands in early stages of revegetation were observed, no evidence was found that these soil algae act as "pioneer invaders" on abandoned fields. On the contrary, all the data accumulated in this study indicate that these soil algae, especially *Porphyrosiphon Notarisii*, only become prominent, at least in mats, after other plants such as aristedas have become established. Then, with the culms of these grasses and the stems of other plants, mats of the soil algae are formed, often over a considerable area. Sites particularly favorable to the development of mats of the reddish *Porphyrosiphon*, referred to above, are severely eroded areas where from 75-100 per cent of topsoil has been removed and, moreover, where there is a slight slope with rather sparse higher vegetation.

TABLE 15
ALPHABETICAL LIST OF ALGAE OCCURRING
ON THE SOIL OF ABANDONED LAND

<i>Botrydium granulatum</i> (L.) Grev.
<i>Fischerella ambigua</i> (Born. & Flah.) Gom.
<i>Nostoc Muscorum</i> Born. & Flah.*
<i>Porphyrosiphon fuscus</i> Gom.
<i>Porphyrosiphon Notarisii</i> Gom.***
<i>Schizothrix Arenaria</i> Gom.
" <i>Friesii</i> Gom.
" <i>Lamyi</i> Gom.
" <i>purpurascens</i> , var. <i>cruenta</i> Gom.**
<i>Scytonema ocellatum</i> Born. & Flah.
<i>Zygonium ericetorum</i> Kütz.

* Common

** Abundant

*** Very abundant

However, continued observations of marked areas during the winter and spring where mats of soil algae were prominent in the summer, indicated that most of them become severely disrupted by frost-heaving and heavy rains, so that, insofar as the Cedar Creek Area is concerned, the value of these soil algae in preventing soil loss except during the summer and early fall seems negligible. During

the summer and early fall, however, such mats of algae may, perhaps, be of somewhat more importance; but further work is needed on this point.

Lichens were here and there found to be furnishing a soil cover on very dry, sterile sites in fields which had been abandoned at least eight to ten years. Various *Cladonias* occurred in large mats in such sites, but no quantitative studies were made of them.

Various other ecologists have noted that species of *Cladonia* have been common in the stages of succession of abandoned cropland. Among others, Larsen (1932) has recorded their occurrence as pioneers on dry, sterile soils of abandoned fields in Ohio; and Olmsted (1937) has emphasized their importance in plant succession on sandy soils in part of Connecticut.

DISCUSSION

It is apparent from the studies of the revegetation of abandoned cropland that, allowing for some phytogeographic differences in floras of various parts of the country, and for different regional climates and soil types, the initial plants are remarkably uniform as to species, at least within the limits of the principal climaxes. Indeed certain annuals are so ubiquitous as to appear and re-appear in abandoned cropland whether the field be located in Vermont, North Carolina, Missouri, or Minnesota. Yellow and green foxtail grasses, crab-grasses, and common ragweed are among the annual dominants which are almost omnipresent in cropland very recently removed from cultivation within the broad limits of the deciduous forest climax. In those areas where a grassland climax prevails, on the other hand, a somewhat different assemblage of dominant species may initiate revegetation, though even here, annuals from subseries of the deciduous forest zones may also be important, though not abundant, (cf. Aikman, 1930). Various species of *Aristida* are often early dominants in the grassland region, although they may also be common on very poor sites, especially in later stages of revegetation, within the deciduous forest climax. (cf. Crafton & Wells, 1934; Geisler, 1926; Braun, 1936). In the Cedar Creek region of Missouri *aristidas* usually appear in numbers very early in succession, but the dominants of such stages of revegetation are usually other grasses or forbs. Since this portion of Missouri lies in the broad forest-prairie ecotone, considerable numbers of *aristidas* are certainly to be expected.

The old-field herbaceous dominants from one region to another within the deciduous forest climax also show a striking similarity in species, and even more so, in genera. For example, gray goldenrod, white heath aster, cinquefoils, panic grasses, broomsedge, and a

number of different legumes, especially species of *Lespedeza* and *Desmodium* are among those plants nearly omnipresent. Other golden-rods, asters, and several erigerons are also widespread. Broomsedge in much of this region appears to be an important dominant, especially on poorer soils; yet in the Cedar Creek Area of Missouri, its occurrence as a dominant is sporadic. That various edaphic factors are involved in the occurrence of broomsedge in this part of Missouri has been suggested by Terrill (1937) who, in a study conducted on the University of Missouri Wildlife Area and Arboretum, found that this grass grew on eroded soils of a lower content of organic matter and with a somewhat lower lime requirement, as compared to adjacent sites unoccupied by broomsedge. It is likely, therefore, that if a source of seed of broomsedge is adjacent to a recently abandoned, cultivated field on a sterile, eroded site that it may successfully ecicize and compete for dominance with the gray goldenrod and white heath aster; but no evidence was obtained in the present investigation to suggest that this grass may actually initiate revegetation of former cultivated fields.

In the grassland climax, various other grasses appear to be more common than forbs as old-field dominants. (cf. Judd & Jackson, 1939; Booth, 1941b; and Smith, 1940). Several species of *Aristida*, for example, are often important in this latter role.

A number of blackberries and sumacs, among shrubs, parallel the species of the initial weedy flora and the old-field herbs in being of widespread occurrence in subseres on cropland throughout the deciduous forest climax, but, in general, these plants do not appear to be as important in the grassland climax (except for ecotones with the forest). As a matter of fact, in the short-grass plains, shrubs of any kind in the revegetation of former cropland are rare.

Within their natural range in the deciduous forest zone of North America, sassafras and persimmon are of widespread occurrence in former cropland, though their dominance in early arborescent stages of such subseres has not often been noted. In the southeast, other woody species such as shortleaf or loblolly pines may invade recently abandoned cultivated fields and attain overwhelming dominance early in natural succession. In New England, at the northern limits of the range of persimmon, red cedar or gray birch are the common early arborescent invaders of old cropland. Moreover, in more mesic sites within the deciduous forest climax, sassafras and persimmon, where present, compete with many more species of tall shrubs and trees than in the uplands of the Cedar Creek region of Missouri. Except for the broad ecotone between forest and the tall-grass prairie, sassafras and persimmon do not appear to play a prominent part in

the revegetation of abandoned cultivated fields within the grassland climax.

As to the early forest types to develop on former cultivated land, there is as much diversity within the deciduous forest climax, as there is among the associates and the associations of which this formation is comprised. Nevertheless, on poor sites throughout this broad area, various oaks frequently grow, except in the southeast and elsewhere that pines invade first. Post oak and black oak are among the more widespread species. In the Cedar Creek Area of Missouri, post, black, and shingle oaks together with shagbark hickory, Ozark pignut hickory, American elm, and white ash are common early species of trees in later stages of subseres. Blackjack oak, so widespread in much of the upland of the Ozarks, is not common except where thin cherty soils, or those derived from sandstones prevail. It is worth noting further that post and blackjack oaks may also invade former cropland within the grassland climax, or even the grassland itself, but usually only in the ecotone between deciduous forest and tall-grass prairie (Booth, 1941b; Steyermark, 1940).

SUMMARY

1. The initial vegetation supported by abandoned cropland in the Cedar Creek Area is largely composed of the weeds, chiefly annuals that co-existed with the last crop grown. On fields whereon corn was the last crop grown, the chief weeds appear to be fall panic grass (*Panicum dichotomiflorum*), large crab-grass (*Digitaria sanguinalis*), and common ragweed (*Ambrosia artemisiaefolia*, var. *elatior*). For fields whereon small grains were the last crops grown, the important weeds, while including many of those of corn fields, support a number characteristic to them, including bracted plantain (*Plantago aristata*), lance-leaved ragweed (*Ambrosia bidentata*), and trailing wild bean (*Strophostyles helvola*).

2. Following an initial period of 2-3 years, abandoned cropland becomes gradually invaded by perennials among which gray golden-rod (*Solidago nemoralis*), white heath aster (*Aster pilosus*) and sometimes broomsedge (*Andropogon virginicus*) shortly become dominant, persisting in old fields for at least 30 years.

3. Native forage grasses, such as the bluestems, are comparatively unimportant in the natural revegetation process of most of the Cedar Creek region; but they may rarely invade pastures on Putnam soils.

4. Sassafras (*Sassafras albidum*) and persimmon (*Diospyros virginiana*), which are present as sprouts at the time of abandonment of many fields in the area, are dominant among woody plants until 20 to 30 or more years after the last cultivated crop. Of the two species, sassafras is much more abundant, a point in part related to its capacity for production of sprouts, and, to a lesser extent, to its production of fruits and seeds.

5. Smooth sumac (*Rhus glabra*) and winged sumac (*Rhus Copalina*), are the most abundant among shrubs in abandoned, ungrazed cropland in the area. Typical forest shrubs, such as aromatic sumac (*Rhus aromatica*) do not become established naturally in former cropland until an arborescent canopy has developed in the late old-field stages of plant succession.

6. Oaks, hickories, elms, ash, maple, and other forest species appear gradually to invade old fields as seedlings become established in favorable habitats. The occasional presence of some of these trees as sprouts in recently abandoned cropland tends to accelerate the rate of development of forest types. Post and shingle oaks, and shag-bark hickories are commonly present as sprouts and seedlings in early stages of old-field development, whereas white oaks mostly appear as seedlings late in old-field development. In the oldest fields studied, 30-35 years after abandonment, sassafras and persim-

mon are still prominent and typical forest species, though then dominant, are not at all comparable in frequency and density to those of second-growth woodlands in the vicinity, thus suggesting a long interval of time prerequisite for reestablishment of such forest conditions.

7. The presence of a community of a lespedeza (*Lespedeza virginica*) and a panic grass (*Panicum linearifolium*) on dry western or southern sites where 75-100% of the top-soil had been removed is the outstanding relationship observed between a plant community and site factors, including the degree of erosion.

8. Various species of algae, chiefly of the Myxophyceae, are common in the soil of abandoned cropland; but these studies indicate that such cryptogams are not important as pioneering plants on eroded soil, since, on the contrary, these form extensive mats of some slight soil-conserving value only after higher vegetation, such as wire grasses, have become established.

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