

SUCCESSION AND SPECIES DISTRIBUTION IN RELATION TO EROSION IN SOUTHERN ILLINOIS

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ABSTRACT.—Fields abandoned for 30-35 years are common in southern Illinois. Abandonment is related both to the inherently poor quality of the soil and to erosion. This study compares the vegetation of two fields abandoned for the same time yet different in the degree of erosion. In the severely eroded field, large gullies were present, the tree layer was poorly developed and individual trees and shrubs were generally small; the herbaceous cover was high and the number of species was high; the reverse was true for the moderately eroded field. Severe erosion has led to the formation of many microhabitats in which different plant species are present. These species were distributed according to the degree of erosion, and some of them appear to be good indicators of erosion.

Large areas of abandoned agricultural land occur in the eastern part of the Shawnee Hills of southern Illinois. Most of this area was covered by oak-hickory forests before settlement by European immigrants. The loess soils, on Mississippian bedrock, are usually shallow, highly weathered and leached, rather acid, and low in nutrients. The upper parts of the profile are well drained, and water moves readily downward until it reaches the firm fragipan which is typical of these soils (Fehrenbacher and Odell, 1959).

The major soil type in the area is Grantsburg silt loam (301), a light colored soil developed from 80 in. of loess over sandstone residuum or sandstone bedrock. Much of this area is under forest vegetation with

2-18 percent slopes (Fehrenbacher and Walker, 1964). This soil is highly weathered and leached, has bisecting profile and the most developed fragipan in the area (Grossman, Fehrenbacher, and Beavers, 1959). Its noneroded phase has an A_p layer (0-6 in.) of dark brown friable silt loam; an A_2 (6-12 in.) of yellowish brown friable silt loam; a B_1 (12-16 in.) of firm heavy silt loam; a B_2 (16-23 in.) of yellowish brown silty clay loam. Below this is a A'_2 (gray layer) which is about 4 in. thick and consisting of firm silty clay loam with light gray coatings; the B'_2 (27-34 in.) is mottled very firm silty clay loam with coarse prismatic structure. Below this is the B'_3 "fragipan", A layer of high bulk density, low clay content and massiveness. The layer is very hard and brittle when dry and greatly restricts water movement and root penetration. Erosion is extensive in the area because of the restriction of water movement into the soil, the relatively high rainfall (120 cm) and the rugged topography. As a result, the effective part of the soil profile is very shallow and the plants are frequently subjected to drought.

Erosion and poor soils have led to reduction in crop yields and to abandonment of fields. When compared with other areas of similar vegetational trends, secondary suc-

sion is much slower on these fields (Bazzaz, 1968). Different degrees of erosion have created many microhabitats in which different plant species predominate. This study was conducted to determine if correlations between degree of erosion, plant cover and succession, and the distributions of various plant species could be made. Also of interest was possible use of these species as indicators of severity of erosion.

METHODS

Two fields located in Pope County and abandoned for thirty years were studied. Both were located on Grantsburg silt loam soil type. One field was located on a 4-7% slope and was moderately eroded, with some of the A horizon remaining, whereas the other field was located on a 7-12% slope and was severely eroded. The soil type of the first is therefore designated as (301 C) and that of the second as (301 D) (Fehrenbacher and Walker, 1964). The sampling plots were laid out as follows: for trees, 10-by 10 m; for shrubs, 4-by 4 m; and for herbs, 2-by 1 m. Twenty-five plots of each size located on both sides of an east-west compass base line were used in each field. Species and dbh values for trees (above 2.5 cm) were recorded; species and cover values for herbs and shrubs were estimated. Basal area and density were calculated for trees; density and cover were obtained for shrubs; and cover was estimated for herbs (Table 1). Nomenclature is that of Jones (1963).

Examination of several gullies in the area suggested a possible correlation between the distribution of some

plant species and degree of erosion. To test this possibility the vegetation of a part of a large but shallow gully was mapped in a transect 4.5 m long and 0.5 m wide, extending from the bottom to the stable, upland herbaceous community dominated by *Andropogon virginicus* and *Solidago nemoralis*. The transect was divided into 10-by 10 cm units and each mapped on coordinate paper, indicating species, numbers, and positions of individuals, and their relative cover. Frequency and density values were calculated for species present. The degree of erosion along the transect was estimated, using as a reference the "gray layer" of the soil.

Correlation coefficients (DeVries, 1954) were calculated for the three important species in the gully using the formula:

$$r = \text{Sin } (T-90^\circ) \text{ and}$$

$$T = \frac{AD - 3C}{P+Q+R+S} \text{ where}$$

A = No. of times species X and Y occur together; D = No. of times neither is present; C = No. of times Y occurs without X; P = No. of times Y is found in sampling; Q = Total No. of samples minus R; R = No. of times X occurs without Y; S = Total No. of samples minus P.

RESULTS AND DISCUSSION

The tree layer was dominated in both fields by persimmon (*Diospyros virginiana*), sassafras (*Sassafras albidum*), red cedar (*Juniperus virginiana*), and winged elm (*Ulmus alata*). *Crataegus mollis*, *Carya tomentosa*, *Ulmus rubra*, *Nyssa sylvatica*, and *Gleditsia triacanthos*

were also present. These were found mainly on the stable, less eroded parts of the fields. The first two dominant species, which form clonal populations by root proliferation, were mostly in clumps. The same woody species plus *Rhus copallina* were found in the shrub layer. The herbaceous layer consisted mainly of *Andropogon virginicus*, *Smilax glauca*, *Aristida dichotoma*, *Potentilla simplex*, *Rubus occidentalis*, *Panicum dichotomum*, *Solidago nemoralis*, *Andropogon elliotii* and *Solidago altissima*.

Erosion greatly affects plant growth. In addition to loss of soil profile and change in pore space relationships erosion increases runoff and organic matter losses from the soil (Bazzaz, 1963) and lowers the infiltration rates. The degradation in soil characteristics leads to slower establishment and growth of plants. Comparisons of the basal area, the density values, and the plant cover in the two fields (Table 1) clearly show that the moderately eroded field has a better developed tree layer. Slow growth of plants on the severely eroded field is also indicated by the low stature of individual trees. For instance, although persimmon

had a higher density on the severely eroded field (224 vs 144/hectare), its basal area was lower (0.047 vs 0.058 m²) reflecting smaller individuals. The herb layer was better developed in the severely eroded fields, as is indicated by its higher total cover (Table 1).

The number of species (Table 1) in the tree and the shrub layers was higher in the moderately eroded field, indicating that only erosion tolerant species are capable of becoming established in the more severe habitats. In the herb layer, however, there was a larger number of species in the severely eroded field. This was correlated not only with the lower tree and shrub cover of the field, but was also related to the diversity of microhabitats created by erosion.

Aristida, which dominated the gullies (Fig. 1, Table 2), was more important in the severely eroded field, having a cover value of 8.5 percent/m² and a frequency of 56%. In the other field its cover and frequency were 3.9 percent/m² and 44%, respectively. In the severely eroded field there was also a higher lichen cover (2.1 vs 0.05 percent/m²) and more rosettes of *Solidago nemoralis*

TABLE 1. — Vegetation of two abandoned fields with different degrees of erosion.

		Moderately Eroded	Severely Eroded
Tree layer	Total Density/hectare	1648	964
	Total Basal Area (m ²)	0.511	0.321
	No. of species	12	7
Shrub layer	Total Density/hectare	6250	2100
	Total percent cover/m ²	0.712	0.700
	No. of species	7	8
Herb layer	Total percent cover/m ²	92.5	118.3
	No. of species	26	34

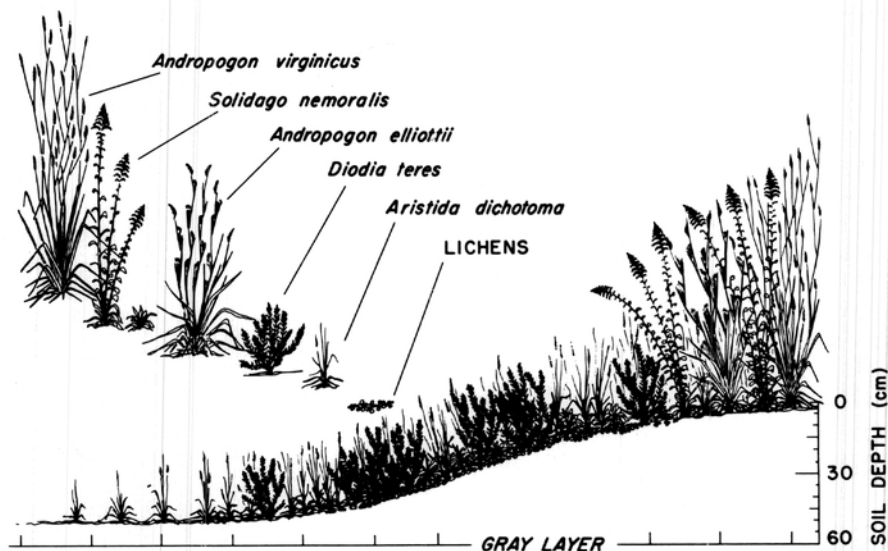


FIGURE 1. Diagrammatic representation of species distribution in a gully.

TABLE 2.—Frequencies and densities of species found in a gully.

Species	Frequency %	Density/m ²
<i>Aristida dichotoma</i>	88.0	645.0
Lichens	40.3	40.0
<i>Diodia teres</i>	31.8	83.0
<i>Crotalaria sagittalis</i>	7.3	16.0
<i>Crotonopsis elliptica</i>	7.1	14.0
<i>Strophostyles umbellata</i>	6.4	12.0
<i>Solidago nemoralis</i> (rosettes)	6.4	9.0
<i>Andropogon elliptii</i>	6.2	2.0
<i>Panicum</i> sp.	1.8	8.0
<i>Smilax glauca</i>	1.2	4.0

that failed to develop flowering stems. Both the lichens and *Solidago* rosettes are found in gullies (Fig. 1).

Table 2 and Fig. 1 show that in the gullies, *Aristida* was the dominant species; it was followed by lichens and *Diodia teres*. At the bottom, where the profile was severely eroded to a depth of 50 cm, *Aristida* was the dominant species, although

individuals were scattered (Fig. 1). A few individuals of *Digitaria sanguinalis*, *Strophostyles umbellata*, and *Crotalaria sagittalis* were found with *Aristida* in the bottom area. Near the side of the gully, where there was less water action, a few lichens and scattered individuals of *Diodia* and *Euphorbia corollata* occurred with *Aristida*. Lichens were more important farther up, and

other species including *Crotonopsis elliptica* and *Cassia fasciculata* occurred. There was also an increase in the importance of *Diodia*.

On the side of the gully, a relatively steep slope, lichens (mainly species of *Cladonia*) were very important and covered almost all the soil surface. The number of plant species also increased but not as much as the number of individuals, especially of *Diodia* and *Aristida*. On the upper half of the gully slope *Smilax glauca* and rosettes of *Solidago nemoralis* occurred. The *Smilax* was very poorly developed and the rosettes of *Solidago* were small. This apparently indicates the severity of microenvironment of these areas with very low nutrient levels and little available water. At the top of the gully slope, lichens and *Aristida* were less important. However, there was an increase in *Crotonopsis*, *Smilax*, and rosettes of *Solidago*. Where the topsoil was completely removed and the B horizon was at the surface, small clumps of *Andropogon elliotii* appeared. In less disturbed sites *A. elliotii* was better developed, lichens decreased greatly and a few individuals of *Panicum* sp. occurred. A stable community association of *Andropogon virginicus* and *Solidago nemoralis* was found on sites where there was some topsoil left. Here there was reduction both in the number of species and the number of individuals present.

It is evident from this study that different species were distributed according to the degree of erosion and the stability of the site. *Aristida dichotoma* was found throughout, and was almost the only plant to

tolerate extreme instability caused by erosion. Lichens were excluded from the bottom of the gully, probably because they were not attached firmly to the soil and thus washed away easily.

Andropogon virginicus, the dominant of the stable community, was completely absent where no topsoil was left and was a site indicator in the abandoned fields. In southern Illinois, as well as in other areas (Al-lard, 1942), this species was found only in fields with some topsoil.

Andropogon elliotii indicates more severe erosion. It was found on sites where *A. virginicus* did not grow. *Diodia teres* was quite important in the lichen zone, and only few individuals occurred in the stable community.

Although *Aristida dichotoma* was distributed throughout, it was more prevalent in the area where the lichen cover was thick (Fig. 1). This was indicated by its relatively high correlation coefficient with lichens (Table 3). *Diodia*, however, was more associated with lichens ($r = 70\%$). That *Aristida* was found in larger numbers in the *Diodia* area because of the association of both *Aristida* and *Diodia* with lichens, and not because of direct association of the two, was indicated by the low correlation coefficient between *Aristida* and *Diodia* ($r = 21\%$). Except where the water action is very frequent lichens apparently stabilize the soil surface, reduce erosion, and function as a seed bed where the seeds of *Diodia* and *Aristida* germinate. When lichen mats were brought to the greenhouse, put on sterile soil, and watered adequately,

TABLE 3. — Correlation coefficients of the important species on eroded sites.

	Lichen	<i>Diodia</i>
<i>Diodia</i>	70	
<i>Aristida</i>	43	21

large numbers of *Aristida* and *Diodia* plants developed.

Apparently erosion is a very important factor affecting succession in southern Illinois. It is also evident that the degree of erosion controls the distribution of some plant species in gullies. However, a complete understanding of this distribution must take into account the tolerances of these plants to their different microenvironments, including their possible biochemical interactions. Erosion could be reduced successfully by planting pines in these fields since pine litter protects the soil surface quite well (Bazzaz, 1969).

LITERATURE CITED

- ALLARD, H. A. 1942. Lack of available phosphorus preventing normal succession on small areas on Bull Run Mountain in Virginia. *Ecology* 23: 345-353.
- BAZZAZ, F. A. 1963. Secondary succession on abandoned fields in southern Illinois. Ph.D. thesis, University of Illinois, Urbana. 190 pp.
- . 1968. Succession in abandoned fields in the Shawnee Hills—southern Illinois. *Ecology* 49: 924-936.
- . 1969. Effects of pine on soils and succession in southern Illinois. (Submitted to *Ecology*).
- DEVRIES, D. M. 1954. Constellation of frequent herbage plants based on their correlation in occurrence. *Vegetatio* 5: 105-111.
- FEHRENBACHER, J. B. and R. T. ODELL. 1959. Williamson County soils. Soil Report 79. University of Illinois Agri. Expt. Sta. 72 pp.
- and G. D. WALKER. 1964. Soil Survey: Johnson County, Illinois. Soil report 82. University of Illinois Agri. Expt. Sta. 72 pp.
- GROSSMAN, R. B., J. B. FEHRENBACHER, and A. H. BEAVERS. 1959. Fragipan soils of Illinois I, II, III. *Soil Sci. Soc. Amer. Proc.* 23: 65-75.
- JONES, G. N. 1963. *Flora of Illinois*. 3rd ed. Univ. of Notre Dame Press. Notre Dame. 401 pp.

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