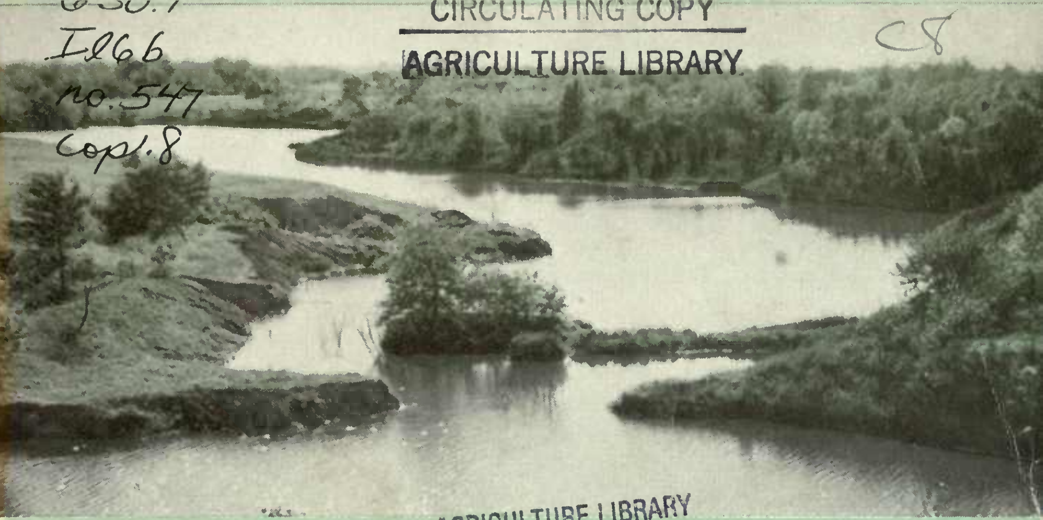

Bulletin 547

RECLAIMING ILLINOIS STRIP COAL LANDS by FOREST PLANTING

By
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UNIVERSITY OF ILLINOIS · AGRICULTURAL EXPERIMENT STATION
In cooperation with Central States Forest Experiment Station,
Forest Service, U. S. Department of Agriculture

FOREWORD

THE OPEN-CUT, or "stripping," method of mining coal destroys the original land surface and produces more or less parallel ridges of earth and rock commonly called spoil banks or spoils. Many people are concerned about the appearance of such areas and the possibilities of putting them to some worth-while use, such as wood production, grazing, recreation, wildlife areas, or even fruit growing.

Most of the areas acquired by coal companies for stripping were formerly farms or parts of farms. Stripped areas remain a part of the land resource of rural areas. For this reason the Illinois Agricultural Experiment Station has from time to time given some attention to the economic and social effects of strip mining and to the possible uses of spoil banks. When the opportunity was presented by the U. S. Forest Service in 1945, the Station was glad to cooperate with the Central States Forest Experiment Station in a study of the tree-growing possibilities of spoil banks and in publishing the results.

The Illinois Agricultural Experiment Station is also engaged in a study of the revegetation of spoils with forage plants and the utilization of such forage. The latter study was undertaken with the support and cooperation of the Illinois Coal Strippers Association.

These investigations, tree-planting possibilities and forage production and utilization, one of which is reported here, broaden our understanding of two of the most promising uses of strip coal lands. They supplement each other in that both of them involve the basic characteristics of spoil banks as they affect plant growth and practical considerations in establishing a valuable cover of vegetation on them. We are concerned here only with the possibilities of using spoil banks once they have been created.

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The Geological Survey of Illinois and the Division of Forestry, Illinois Department of Conservation, have also offered helpful suggestions.

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Urbana, Illinois November, 1951

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

Reclaiming Illinois Strip Coal Lands by Forest Planting

By G. A. Limstrom and G. H. Deitschman[a]

HOW LANDS STRIP-MINED for coal in Illinois can be used most productively has become a subject of increasing public interest. The coal industry, through its conspicuous alterations of the landscape in many rural sections of the state, has brought about new and perplexing problems in land use. Because the area of rich agricultural lands overturned in these operations is frequently overestimated, alarm is often expressed concerning the retirement of these lands from customary uses. Actually, the total potential strippable land in the state is not more than one-half of 1 percent of the total land area, and less than one-fifth of this is high-grade agricultural land. Most strip-mined lands, moreover, need not be retired from productive use nor remain unsightly for long periods of time.

A survey made in 1945 and 1946 disclosed a total area of 39,820 acres of strip-mined lands in the state. From actual field examination, it was estimated that more than 95 percent of this area could be made productive by practicable reclamation methods. More than 9,500 acres of forest plantations classed as initially successful were found, and an additional 2,235 acres had already reverted to forest by natural seeding. Over 15,600 acres were well covered with grasses, legumes, and weeds; much of this area was being used as pasture. The remaining 12,114 acres were classified as barren, and were made up largely of recent stripping.

Producing forest, forage, and other crops on strip-mined lands may rightfully be called "breaking new ground." Much of the knowledge gained through centuries of soil use is not applicable to these lands. Spoils are essentially a new medium for plant growth, and are usually a heterogeneous mixture of all strata overturned in the mining

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Fertile spoils such as these calcareous silty-clay banks in Fulton county can provide good pasture for livestock. This area was seeded to a mixture of legumes and grasses. (Fig. 1)

operation. Despite the lack of long experience and research, the progress to date in developing these lands in Illinois is notable. No doubt errors have been made — and there have been failures — but the lessons already learned and continuing research should result in an even more satisfactory pattern of development.

The purpose of this publication is twofold: (1) to point out and describe site conditions that affect forest plantings on strip-mined lands in Illinois; and (2) to set up planting guides and recommendations for the major types and conditions of spoils in the state. These descriptions and recommendations are based largely on the reconnaissance of strip-mined lands made in 1945 and 1946, on examinations of existing plantations, and on results of a number of forest planting experiments begun in 1947. The recommendations are not final or conclusive; they are being released to aid in reducing plantation failures and to help those who are planning the reforestation of Illinois spoils to evaluate site conditions.

Much of the stripped land in Illinois can be used for pastures (Fig. 1), orchards, recreational areas, and wildlife preserves. The agronomic potentialities are being investigated by the University of

Illinois Agricultural Experiment Station in cooperation with the Illinois Coal Strippers Association. Although the recommendations included in this report are confined to forest planting, there is no intention to imply that these lands should be used exclusively for forestry purposes.

REVIEW OF LITERATURE

This brief review of some of the previous literature relating to the reclamation of strip-mined lands in Illinois aims to present a picture of the over-all problems involved and to integrate the results of this present investigation with those obtained by other workers in the field.

The social and economic aspects of strip-mining have been the subject of much controversy. Graham[9*] has this to say on this point: ". . . so far as immediate effects are concerned, it would probably be more of a disservice to the area to forbid strip mining than it would be to let it continue. If some 80,000 acres of land in the State of Illinois (less than 1 percent of the state's area) . . . were to be withdrawn from agricultural production, the results would probably be negligible."

Graham concludes that:
". . . if spoil banks in general can be made productive, strip mining may well counteract the disfavor with which it is now regarded by many people. At the same time, society will gain from a more complete utilization of natural resources. Present evidence does not show general, widespread success — it shows, rather, that much has been done and much more can be done, and that, over a long period of time, the interests of the coal strippers and the agriculturists may not be incompatible."

Walter[18*] states that:
". . . it is of importance . . . that stripped lands be returned to an economically sound and productive use after mining operations cease. . . . efforts should be made, however, to avoid discriminatory or penalty legislation that is not in the interest of either the strip-coal companies or the public as a whole. In order to best serve all interested parties considerable additional information and analyses must be obtained relative to the effects of coal-stripping operations and the practicable uses for stripped lands."

One prerequisite to the understanding of problems encountered in the rehabilitation of strip coal lands is a knowledge of coal seams mined and, particularly, a knowledge of the character of material overturned in the stripping operation. Shortly after the First World War, when extensive strip mining for coal in the United States was just beginning, Culver[8*] prepared a preliminary report on coal-stripping possibilities in Illinois. Weller and Wanless[19*] have contributed

* All superior figures with asterisks refer to literature citations on page 240.

much data on the correlation of coal seams mined in Illinois, Indiana, and western Kentucky, and have made substantial improvements in the nomenclature of coal seams in Illinois. Cady's[2, 3, 4*] work on the stratigraphy, location and character of coal deposits, and on other important phases of the coal geology of Illinois has been monumental in scope.

The succession of natural vegetation on spoil banks in Illinois has been studied by Croxton,[7*] who has found a rather definite correlation between the density of vegetation and the hydrogen-ion concentration of the spoils. Natural vegetation was lacking or sparse on highly acid spoils; it was well established on banks with a pH of 5.0; and was dense on banks that were neutral or alkaline in reaction. On slightly acid to alkaline spoils he noted the following successional changes: within one or two years after stripping, the spoils become rather densely covered with a smartweed (*Polygonum pennsylvanicum*); on calcareous spoils the smartweed is soon replaced by sweet clover (*Melilotus alba*); on slightly acid spoils the succession is to wild lettuce (*Lactuca canadensis* and *L. scariola*) instead of to sweet clover. On acid banks, those with a pH of 5.0 or less, smartweed is again one of the first invaders and is gradually replaced by annual and perennial weeds, cottonwood (*Populus deltoides*), and sycamore (*Platanus occidentalis*).

A brief historical sketch of forest planting on stripped lands in Illinois has been made by Schavilje.[16*] He reports that the first attempt to plant trees on strip-mined lands in Illinois was made in 1920, in Vermilion county. Six acres were planted, mainly to black locust; to red, jack, and Scotch pines; yellow poplar; black walnut; white ash, and black ash. Large-scale plantings were begun in 1939, using a wide variety of species for experimental purposes. Of the species tested, black locust and shortleaf pine were reported superior to others in early survival and growth.

The beneficial effects of black locust on the growth and development of hardwoods has been demonstrated by Chapman.[5*] Although considerable progress has been made during recent years, Chapman[6*] has also pointed out that:

"much remains to be learned about the requirements of trees and the characteristics of spoils. To date, research has only scratched the surface of the over-all problem. Nevertheless, application of present information has prevented many costly plantation failures during the last few years. As additional information becomes available, forestation of spoil banks will become more precise and efficient."

That "successful forestation . . . has not as yet been achieved in all strip-mine areas" is the conclusion of Holmes,[11*] who points out that:

"One of the most difficult districts lies south of Wilmington in northern Illinois. In this location the glacial debris and shale immediately above the coal form a hard, compact mass so nearly impervious to water that it will not support tree growth, except in localized places. Near Morris and Ottawa, also in northern Illinois, successful forestation has thus far been impossible because of the large amount of acid in the spoil banks."

Holmes concludes, however, that:

". . . by turning the spoil banks into forest, pasture, recreational areas, and game preserves, all of them may be used to advantage, and many will return a yearly profit to the owner equally as great as that produced by the land prior to mining. Certainly with a minimum of time and labor the great majority of strip-mine dumps in Illinois can become 'cover hills.' "

Much information of use in the reforestation of strip-mine lands in the state is contained in a tree-planting manual prepared by the Division of Forestry of the Illinois Department of Conservation.[13*] Among other recommendations is one limiting the planting of yellow poplar, cypress, and shortleaf and loblolly pine to the southern portion of the state.

The foregoing review gives perhaps a sufficient idea of the past and current work done on the problem of restoring strip-mined lands of Illinois to some form of use. Despite the complexity of this problem and the general lack of specific knowledge, much progress has been made. Some of the accomplishments are reflected in a progress report prepared by the Illinois Coal Strippers Association.[12*] By December 31, 1949, according to this report, the total estimated mined area was 46,703 acres. Of this area, 11,246 acres was in forest plantations; 15,603 acres in stock range; and 1,300 acres was used as state parks. The report also shows that during the past ten years the area reclaimed has been almost equal to the area strip-mined.

CHARACTER AND EXTENT OF STRIP COAL LANDS

Many of the results obtained from the reconnaissance of strip-mined lands in Illinois have been published in summary form.[14*] The data include the area of stripped lands in the state by county, spoil type, use, plant cover, and coal seam.

For convenience, the tables from that study are reproduced in this bulletin on pages 242 to 244 (Tables 6 to 9).

Basic Classification of Spoil Banks

The basic classification of spoil banks for forest planting used in this report is that proposed in 1948 by Limstrom.[14*] Acidity and texture of spoil materials are the two factors considered in this classification.

Acidity of spoils, expressed in the range of pH values of the surface material, is classified as follows:

Class No. and description		pH *value*	*Extent on area*
1	Toxic	Less than 4.0	More than 75%
2	Marginal	Less than 4.0	50 to 75%
3	Acid	4.0 to 6.9	More than 50%
4	Calcareous	7.0 or more[a]	More than 50%
5	Mixed	(Too varied to be classed as any one of the above)	

([a] For practical purposes any soils testing 7.0 (neutral) are included in the calcareous group.)

On the basis of *texture,* spoils are divided into three broad groups:

Group	*Description of texture*
a	Chiefly sand, sandstone, or sandy shales
b	Chiefly loamy material and silty shales
c	Chiefly clay and clay shales

The acidity class and the texture group are then combined to describe the basic spoil types, as for example:

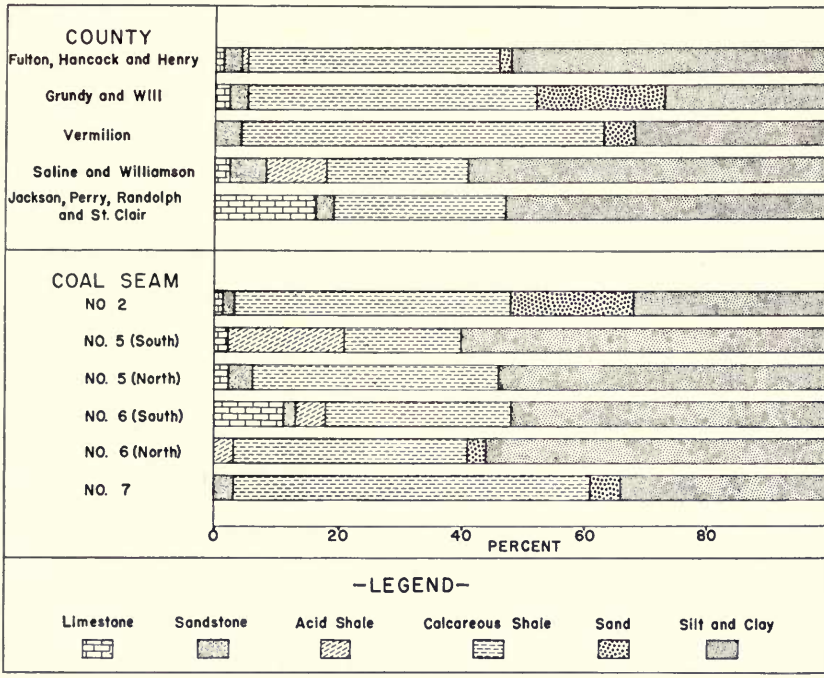
Type designation	*Description*
4a	Calcareous sand
3b	Acid loam
1c	Toxic clay

Variations in Acidity and Texture of Spoils

The general character of any spoils overturned in stripping operations is the result of two things: the character of the overburden and the method of stripping used.

Variations due to character of overburden. Analysis of 36[a] stratigraphic descriptions of high walls adjacent to spoils throughout the strip-mined areas of the state disclosed that more than 80 percent of the overburden of all coal seams consisted of calcareous shales and of soil-sized particles (measuring less than 2 mm.). This

[a] Although this number of descriptions is not enough to represent all the conditions existing in the high walls adjacent to spoil areas, it was considered sufficient to illustrate the effects of various types of overburden on the character of the spoils created by strip-mining in the state.



Relative thickness of different strata above important coal seams strip-mined in Illinois, according to 36 high-wall analyses. Marked variations will be noted from one area to another in the makeup of the overburden. (Fig. 2)

explains why more than 78 percent of the total spoils area in the state is calcareous (Table 6, page 242), and why, in most of these areas, the material is composed of a high proportion of soil-sized particles — an important condition affecting plant growth and the productivity of land.

The principal sources of soil-sized particles are the top soil, glacial till, loess, and residual clay. Although the total thickness of these strata was about the same at all the places examined, the *relative* thickness of the individual strata varied considerably from one part of the state to another. Glacial till, for example, is generally thicker in the northern and eastern parts of the state than in the western and southern parts. The loessal cap is thickest in the valleys of the Mississippi and Illinois rivers, and is thin or even not identifiable in the eastern part of the state. These variations explain some of the marked differences in the spoils in different parts of the state. The spoils of

Will and Grundy counties, for example, are sandy, being derived from sandy glacial till, whereas those of Fulton, Knox, and St. Clair counties are rich in loessal material.

Marked differences in the character and thickness of the residual rocks (shales, limestone, sandstone) were also found in the overburden of the different coal seams examined; and different localities showed differences. The acid, shaly spoils of Saline county, with their massive sandstone blocks, are in marked contrast to the spoils of the counties mentioned above. Fig. 2 shows these facts graphically.

Variations due to method of stripping. Where power shovels or draglines are used singly in stripping operations, a high proportion of the rock strata immediately overlying the coal seam is sometimes placed on the tops of the spoil surfaces; banks so formed are among the least productive in the state. On a few operations the stripping shovel is used to "clean off" the coal surface. Often the material cleaned off is put on the tops of banks, where, because it is so highly acid, it hinders reclamation measures. Dragline stripping also handicaps reclamation measures by creating steep, sharply serrated ridges and conical banks that are hard to work and subject to serious erosion.

Tandem operations—those in which draglines and shovels are used jointly — have resulted in good, plantable spoils. Where a rotary shovel had been used in tandem with other stripping equipment, excellent conditions for plant growth were found. With this method, a high proportion of calcareous material was placed on the tops of spoil banks; and the relief was less pronounced than on banks created by other methods.

Most spoils rich in phosphorus and potash. The materials overturned in strip-mining operations were found to be rich in many mineral elements essential to plant growth. Hundreds of samples of spoils and high-wall strata were collected and sent to the Illinois Agricultural Experiment Station for detailed laboratory analyses. Most of the materials analyzed disclosed high amounts of available potash. A relatively low phosphorus content is shown by the examples given in this report (Tables 10 to 18, pages 245 to 250). But subsequent examinations by the University of Illinois on a more intensive sampling basis have revealed high amounts of available phosphorus to be normally present.

Nitrogen, generally lacking in fresh spoils, is rather quickly added by rainfall and by leguminous plants either naturally or artificially established.

SITE CONDITIONS IN FIVE STRIP-MINING DISTRICTS

In addition to differences in spoil conditions in different parts of Illinois (see preceding section), other environmental factors affect the choice of species for tree planting. The average annual precipitation varies generally from 30 inches per year in the northern extremity of the state to 45 inches per year in the southern portion. The original vegetational cover was largely prairie grass in the central and northern part of the state and oak-hickory forest in the southern part.[17]* The natural range of many commercially important trees includes only the eastern and southern portions of the state.

With due consideration to most of these environmental factors, the areas strip-mined for coal in Illinois have been subdivided into five districts (Fig. 3). Although there are some overlapping characteristics, each district is sufficiently distinctive to warrant separate forest-planting recommendations. A detailed description of site conditions in each district follows.

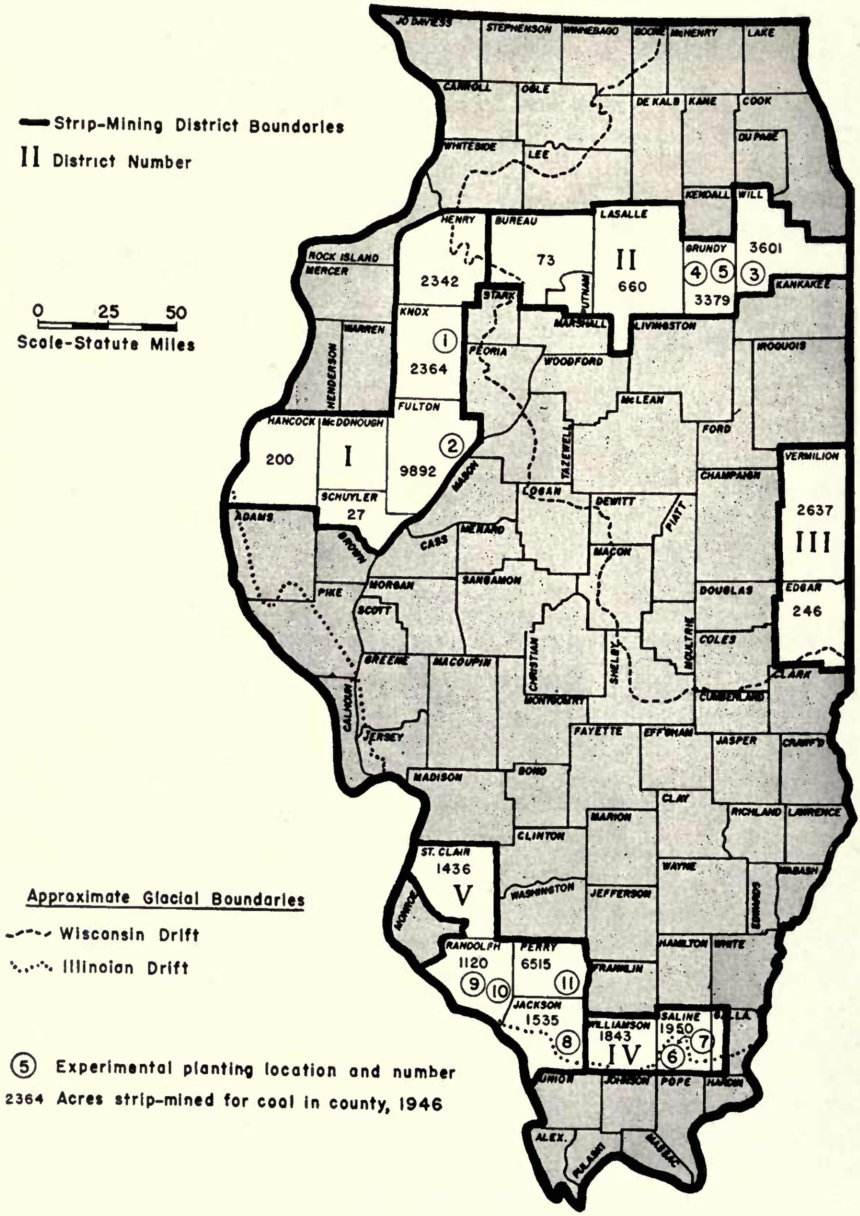
District I

(Fulton, Hancock, Henry, Knox, McDonough, Schuyler Counties)

The spoils in this district are perhaps the most productive in the state (Figs. 4 and 5). This is mainly due to the fact that nearly all of the overburden is composed of thick, fertile mantles of loess, glacial till, and calcareous shale. The resulting mixture is usually a friable, calcareous, shaly loam or clay. The proportion of loess is generally greater in Knox and Fulton counties than in the other counties in the district, and thicker mantles of till occur in Henry county.

Three coal seams have been extensively strip-mined in these counties: the No. 2, Colchester, sometimes known as the LaSalle "third vein;" the No. 5, Springfield; and the No. 6, sometimes known in northern and western Illinois as the Streator or LaSalle "second vein."[19]* The thickness of soil, till, and loess over these seams varies more with topography than with the seam itself. Valley bottoms may have little or no glacial and loessal material because of erosion losses, but they often contain more alluvium than the adjoining hills.

A typical high-wall section above the No. 5 coal seam in this district (Fig. 5) includes, from top to bottom, the following strata: 3 feet of acid soil; two distinct ages of calcareous loess totaling 14 feet in thickness; 10 feet of glacial till; 30 feet of gray, calcareous shale; and 2 feet of limestone, with 4 feet of underlying coal. Localized



Illinois is divided into five strip-mining districts. Each is sufficiently distinct in general environment as well as in spoil conditions to call for separate recommendations for forest plantings. (Fig. 3)

Green ash growing on fertile spoils in Fulton county. At nine years of age the trees have grown in height more than 1½ feet a year. Nearly all the overburden in this district includes a thick mantle of loess, glacial till, and calcareous shale. Forest plantings take hold quickly. (Fig. 4)

Overburden of No. 5 coal seam in Fulton county carries a relatively high proportion of soil, till, and loess over the calcareous shale. This condition explains the good growth shown in Fig. 4. (Fig. 5)

variations include thin beds of sandstone and acid shale or clay above and below the calcareous shale.

Except for a small amount of residual rocks, the material over the No. 2 and No. 6 coal seams in this district is generally similar to that found over the No. 5 coal.

District II

(Bureau, Grundy, LaSalle, and Will Counties)

Most of the spoils in Bureau and LaSalle counties are calcareous shaly loams and clays. Except for a slightly greater proportion of glacial till, they are similar to most of the strip-mined lands in Henry, Knox, and Fulton counties.

However, some of the least productive spoils in the state are located in LaSalle county (Fig. 6). In this locality, some of the coal is stripped in conjunction with clay mining. The clays associated with coal seams are generally highly acid, and a small proportion of this material placed on the surfaces of banks is sufficient to make them toxic to plant life. Toxicity of the spoils in the district may also stem from two other sources: (1) sulfurous lenses (pyrite and marcasite) occurring in the coal seams, and (2) roof coal and those fissile shales that occur directly over the coal seams and that contain iron-stone concretions and other sulfurous minerals.[2*]

Extremely acid spoils in LaSalle county and some areas in Bureau county present a problem like this. The site has been planted three times, and all plantings have failed. However, most of the spoils in these two counties are more like the strip-mined lands of Henry, Knox, and Fulton counties, and can be reclaimed with forest plantings, as shown in Fig. 4. (Fig. 6)

Spoil banks composed mainly of loose calcareous sand in Grundy county. Extreme gully and sheet erosion, together with low water-holding capacity, are serious obstacles to the establishment of forest plantings on areas like these. The banks gradually become stabilized, however, by a natural growth of cottonwood trees and various plants. (Fig. 7)

Calcareous, sandy, silty clay spoils like these, with cemented surfaces, predominate in Will and Grundy counties. Of the nontoxic spoils in the state, these are the most difficult to reclaim. Natural vegetation is very sparse for many years after stripping. (Fig. 8)

The character of most of the spoils in District II differ greatly from those found elsewhere in the state. The No. 2 seam is the principal seam strip-mined in this district. The overburden is composed mainly of calcareous sand of glacial origin and a soft, gray, calcareous clay shale. In some localities a small quantity of limestone and sandstone may also occur.

In Will and Grundy counties two spoil types predominate: (1) calcareous sands, and (2) those sandy clays and clay loams that are both calcareous and acid. The newly created sandy spoils are highly erosive (Fig. 7). Trees planted on the slopes suffer severe losses from gully erosion, while those planted in the bottoms are frequently covered by siltation (deposition of eroded material). In three or four years, however, the banks are gradually stabilized by the natural invasion of wild lettuce, ragweed, peppergrass, milkweed, yarrow, sweet clover, sedge, nettles, and cottonwood.

Except for toxic areas, the shaly or sandy clay loam spoils in Will and Grundy counties are perhaps the most difficult to reclaim in the state (Fig. 8). Usually there is enough sand in these spoils to give them a slush-like consistency during wet periods, and mud-flows may occur in times of heavy rainfall. The ridges are high and steep and are subject to severe gullying. Upon drying, the surface becomes compact and cemented. Because of these critical site characteristics, natural vegetation is extremely sparse for many years after stripping.

Seeds falling on the banks during dry weather remain exposed on the hard surface crust until most of them are simply blown away or washed down to the valley bottoms and deeply covered by heavy siltation. Although toxic conditions are spotty, they are common in some areas where roof-coal has been placed on the tops of banks.

District III

(Edgar and Vermilion Counties)

The spoils of Edgar and Vermilion counties result from mining the Grape Creek and the No. 7, Danville, coals. For both seams the overburden consists mainly of sand and boulder clay of glacial origin, and a gray, calcareous shale. The glacial material also is generally calcareous. The usual slate coal, pyritic shale, and concretions which occur in variable thicknesses between coal lenses and just above each seam are responsible for the few scattered areas of toxic spoils.

The spoils in both counties are generally shaly sandy loams or shaly clays. They are calcareous as a whole, but large patches of acid spoils are common, and on some areas the mixed acidity class predominates. Large, wholly toxic areas are rare. Many of the older spoils contain good natural stands of hardwoods where no planting appears necessary; other areas support good stands of grasses and legumes and are being pastured.

Most of the stripping in Vermilion county is along stream bottoms and has resulted in the formation of many ponds and lakes. These, coupled with the rapid conversion of the adjacent spoils to natural forest, offer excellent opportunities for recreational developments and the establishment of game refuges.

District IV

(Saline and Williamson Counties)

The strip-mined lands in Saline and Williamson counties have resulted from mining the Harrisburg, No. 5, and the Herrin, No. 6, coals. The uppermost strata of the overburden for both seams are generally the same and are composed chiefly of soil, loessal silt, and glacial till.[10*] The residual rocks below these strata and directly over the No. 5 coal consist mainly of shale, some limestone, and some sandstone. The thickness of this material varies greatly according to the topography. Analyses of high-wall samples taken at the time of reconnaissance disclosed that the shale over the No. 5 coal in this vicinity is sometimes acid and sometimes calcareous, varying in pH

Overburden of No. 6 coal in Saline county often carries a high proportion of massive stone, mainly sandstone and limestone. (Fig. 9)

from 3.5 to 8.0. The overburden of the No. 6 coal in these counties often consists of a high proportion of sandstone (Fig. 9).

The outside banks of both coals strip-mined in this district often contain a high proportion of glacial and loessal material that is generally calcareous and provides excellent soil conditions for plant growth. Where loessal silt predominates, however, there is apt to be considerable gullying (Fig. 10).

In many locations the interior banks of the No. 5 coal strippings are similar to the outside slopes and make excellent sites for pasturing or for forest planting. Some of the No. 5 spoils in Williamson county are, however, highly acid; reclamation work on these areas should be postponed until conditions for plant growth become more favorable.

Other interior banks, particularly in Saline county, are often composed of yellow or a purplish-gray shale which may lie barren for many years if not planted. Where the yellow shales predominate, the spoils are acid in reaction. The purplish-gray shales are calcareous, but form a smooth pavement-like surface (Fig. 11). Seeds falling on these banks are either blown away by the wind or washed down the slopes before they can germinate. Trees planted on the slope are subject to severe damage by the sliding action of the shale (Fig. 12).

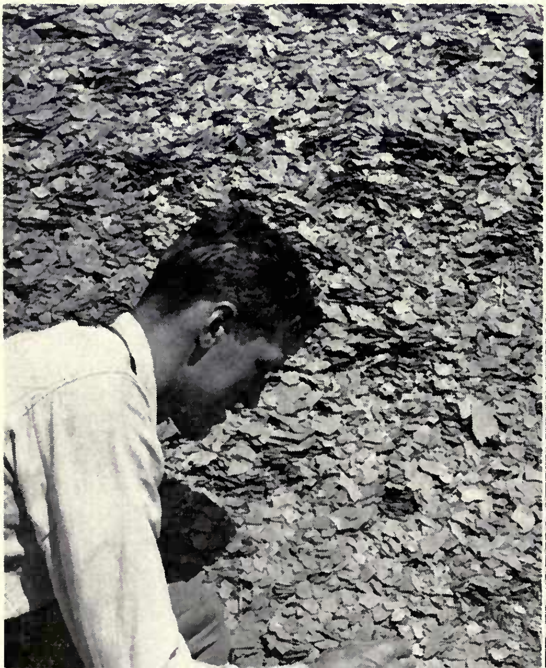
In Williamson county the spoils resulting from the mining of the No. 6 coal are acid to neutral shaly loams and clays; planting conditions are favorable soon after stripping. In Saline county, especially on the interior banks, the No. 6 coal spoils present difficult planting conditions. Wide variations in acidity, ranging from a pH of 3.0 to 8.0, occur within relatively short distances. During the first few years after stripping, acidity is continually changing because of the interaction of acid and basic material in the spoil mass. In addition, there is generally a low proportion of soil-sized particles and a correspondingly high proportion of shale, limestone, and sandstone (Fig. 13). These conditions, unique in Illinois, make planting so difficult that this operation might well be postponed for a number of years after mining. A five-year weathering period, for example, would make planting easier and more successful because of the increased percentage of soil and because of more stabilized acidity conditions.

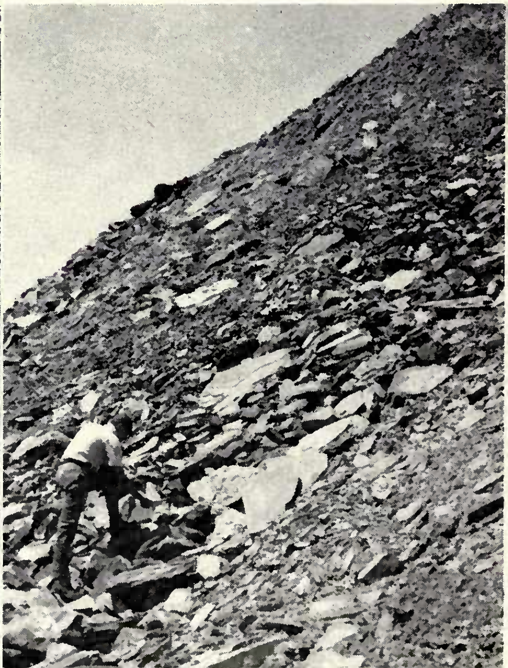
Severe gullying is likely to occur on the outside banks of No. 5 and No. 6 coals in District IV where loessal silt predominates. Exposure of roots has caused high mortality in this shortleaf pine plantation. (Fig. 10)

Purplish-gray, calcareous shale often makes up the inside banks of No. 5 strippings in District IV, especially in Saline county. The hard, bony shales often overlap like slate on a roof. (Fig. 11)

Close-up of above bank. Sliding of the surface fragments often bends, bruises, and even buries the stems in young forest plantations. (Fig. 12)

Planting is difficult for the first five years on the interior spoils of No. 6 strippings, District IV. Note steepness of slope and high proportion of stone. (Fig. 13)





Typical spoils in Randolph county consist of a highly calcareous mixture of loess, silty clay, glacial till, limestone, and shale. Dense patches of sweet clover are detrimental to the pine planted on this area. Banks of this kind are probably best suited for pasture. Material is estimated to be 80 percent soil, 5 percent thin-bedded shale, and 5 percent limestone rocks more than 12 inches in diameter. (Fig. 14)

District V

(St. Clair, Randolph, Perry, and Jackson Counties)

The principal coal seam strip-mined in this district is the Herrin, No. 6, also known as the Belleville seam in St. Clair and Randolph counties. Some spoils also result from the stripping of the Harrisburg, No. 5, coal in Randolph, Perry, and Jackson counties. The overburden of the No. 5 seam is similar to that found over this coal in Williamson county, except that nearly all of the shale is calcareous. Acid shale occurs only within a few feet of the coal.

The overburden of the No. 6 coal in this district differs from the typical sections found in Saline and Williamson counties. Little or no sandstone has been noted in the district, but the thickness of massive limestone is much greater here than over the same coal in Saline and Williamson counties. A generalized section of these strata would include (from top to bottom) 20 to 25 feet of soil, glacial till, and loess; 4 to 10 feet of hard, yellow, massive limestone; 10 to 15 feet of calcareous (sometimes acid) soft, dark gray, thin-bedded shale which in places may be hard and thick-bedded; 2 to 8 feet of hard, gray, massive limestone, and 1 inch to 10 feet of gray, massive shale which locally may be black, slaty, and thin-bedded.

The spoils in the district are generally calcareous shaly loams and clays. A few areas are more acid than calcareous, and there are toxic conditions in localized spots. The latter, however, occupy a very small proportion of the total area. In Perry, Jackson, and Randolph counties large limestone boulders scattered over the spoil surfaces are typical (Fig. 14). However, these banks have a high proportion of soil-sized material, and planting is practicable shortly after stripping.

The St. Clair county spoils have considerably more loessal material and fewer boulders than spoils elsewhere in this district. Here spoil conditions are excellent for plant growth, frequently approaching those of Fulton county in potential productivity.

FOREST PLANTING POSSIBILITIES

A survey of forest plantations on strip-mined lands in Illinois was made in 1946. The plantations were examined critically for the effects of site conditions on the survival and growth of a large number of species. The ages of the plantations generally ranged from 5 to 10 years. The studies were conducted on sample plots, on each of which data were obtained on survival, height growth, evidence of diseases and insect infestations, and general tree development. In addition, such site conditions as the acidity and physical characteristics of the spoils, general relief, and percent of slope were also recorded.

Without detailed historical data proper interpretation of the results from a survey of this kind is difficult to make. Poor survival may be due more to poor planting or to the quality of the stock planted than to site conditions. Nevertheless, the general observations made during the course of this study are useful in evaluating a large number of species for planting on these lands. These results are summarized by species, as follows:

Conifers

1. **Eastern red cedar** (*Juniperus virginiana*). Only one plantation, located in Knox county, was examined. Survival was only 20 percent, but the height growth was fairly good for this species, averaging about 8 inches a year. Some of the trees in the stand were 6 to 8 feet in height at 6 years of age. Erosion was responsible for much of the mortality.

2. **Jack pine** (*Pinus Banksiana*). Only one plantation, 6 years old and located in Knox county, was examined. Survival was 85 percent and height growth was exceptionally good. This is a promising species for sandy and shaly sites in the northern part of the state.

3. **Pitch pine** (*P. rigida*). Six plantations of this species, located in Saline and St. Clair counties, were examined. The survival of 8-year-old plantings ranged from 49 to 98 percent, and height growth was fairly good, averaging about 1½ feet a year.

4. **Ponderosa pine** (*P. ponderosa*). Three plots in Fulton county were measured. The height growth was variable but generally good, even on dry, shaly sites. Survival in the three areas was 71, 37, and 72 percent.

5. **Red pine** (*P. resinosa*). Survivals of two 9-year-old plantings in Perry county were 55 and 81 percent. Average heights of the dominant trees were 16 and 18 feet respectively. The survivals for 2-year-old plantings in Fulton and Knox counties were 50 and 41 percent respectively.

6. **Shortleaf pine** (*P. echinata*). Twenty-four plantings, 5 to 9 years old, were examined. Survival was generally good, in most cases exceeding 60 percent. All plantations examined were heavily infested with the tip-moth, and leaders on many trees had been killed year after year. However, the species seems to recover quickly from this damage, and once past their juvenile period, the trees are not affected by the insect. The canopy of shortleaf pine plantations is usually light and rather open (Fig. 15). Ground cover and volunteer hardwoods are usually denser in plantations of this species than under some other conifers, such as red pine.

Shortleaf pine planting on interior banks of No. 6 coal stripping in District IV. After about ten years of weathering, only a few large limestone boulders are visible, and there is a fairly good ground cover of bluegrass and lespedeza. Bottoms between ridges are rather flat, showing results of siltation from the adjacent slopes. (Fig. 15)

Hardwoods

1. **Black locust** (*Robinia Pseudo-Acacia*). Eight plantations were examined. Survival was usually good and height growth generally exceeded 2 feet a year. All eight plantations were severely damaged by the locust borer. Those located in the northern part of the state were especially susceptible. However, this species has proved to be valuable as a nurse crop for commercially important trees, and by adding nitrogen and organic matter it helps to correct deficiencies that are common to raw spoils and limit good plant growth. A luxuriant undergrowth of herbs and shrubs usually develops under black locust stands within 5 to 10 years.

2. **Black walnut** (*Juglans nigra*). Seven plantings of this species were examined. Survival varied from 18 to 75 percent, and height growth from 0.2 to 1.5 feet a year. The wide range found in seed germination, survival, and growth emphasizes the need for careful selection of sites for this species. The best growth has been obtained on the following sites: (1) in bottoms and on lower slopes, (2) on spoils containing a high proportion of "soil," (3) under black locust stands, and (4) in mixtures with black locust and other hardwoods.

3. **Catalpa** (*Catalpa speciosa*). Two 5-year-old and two 8-year-old plots of this species were measured. Survival ranged from 34 to 96 percent, and height growth was about 1 foot a year. All trees examined had poor form and will be of little or no commercial value. Catalpa is not a very promising species for planting on strip-mined lands in the state.

4. **Green ash** (*Fraxinus pennsylvanica* var. *lanceolata*). This species has grown well on all banks where it was observed. For the nine plots examined, it averaged 1.2 feet of height growth a year, and on some areas the average was nearly 2.0 feet a year. Survival, also, was generally high, ranging from 60 to 95 percent.

5. **Osage orange** (*Toxylon pomiferum*). Only one planting of this species was measured. This 5-year-old plantation had a survival of about 50 percent, and height growth averaged about 1 foot a year. The trees examined were bushy and poorly formed.

6. **Northern red oak** (*Quercus borealis* var. *maxima*). Plantings of this species were examined on spoils composed of loess (Fig. 16), shale, and stony loam. Height growth on the loess and shale spoils, with 90 percent "soil," ranged from 1.0 to 1.9 feet a year; and on the stony loam, with only 50 percent "soil," growth ranged from 0.4 to 0.5 feet a year. Survival averaged more than 75 percent on the loam and shale banks and less than 30 percent on the stony loams.

7. **Sweet gum** (*Liquidambar styraciflua*). This species is definitely a promising hardwood for planting on stripped lands in southern Illinois (Fig. 17). Some of the most rapidly growing plantations in the region are sweet gum. The trees have their usual straight, clean stems and rapid growth. Several of the trees in an 8-year-old plantation were 24 feet in height and 4 inches in diameter at breast height. On a few areas young seedlings were severely injured by rabbits.

An eight-year-old red oak plantation (above) on outside spoil banks composed mainly of loess and glacial till in District IV. The spoil material is neutral to slightly acid and is loose, friable, and absorptive. (Fig. 16)

Sweet gum (right) grows rapidly and is one of the best hardwoods for southern Illinois. This eight-year-old plantation is located on the outer banks of strippings in Saline county, District IV. (Fig. 17)

Low soil content, sliding rock, and severe exposure made a rugged site for this planting of yellow poplar and black walnut. More years of weathering and settling and the inclusion of black locust in the planting mixture would have greatly improved growing conditions. This picture was taken in Saline county, District IV. (Fig. 18)

8. **Silver maple** (*Acer saccharinum*). This species made its most rapid growth on calcareous banks. Survival was generally good. Silver maple produces a heavy litter that often completely covers the spoil surface beneath a plantation.

9. **Sycamore** (*Platanus occidentalis*). The two plantings of this species that were measured were located in Fulton county. The trees were very thrifty and were up to 8 feet in height at 5 years of age.

10. **Yellow poplar** (*Liriodendron tulipifera*). Ten plantings of yellow poplar were measured. Survival and growth were generally poor. Like black walnut, this species has been planted on many sites to which it is not suited (Fig. 18). The best growth was found on spoils having a high proportion of "soil," on bottoms and lower slopes, under black locust stands, or in mixtures of black locust and other hardwoods.

FOREST PLANTING EXPERIMENTS

Thirty experimental plantings were established in the spring of 1947 on eleven strip-mined areas in the state (Fig. 3). All strip-mining districts except No. III were represented.

The major purpose of these experiments was to determine the suitability of a number of tree species for planting on Illinois spoil types. Success as affected by methods of mining, grading operations, differences in spoil types, ground and overhead cover, and aspect and topography was studied. Areas were chosen on the basis of their representative site characteristics and accessibility for demonstration purposes.

Ten experimental areas, briefly described in Table 1, were located on spoils with varying intensities of natural vegetation. On these areas the following 16 species were planted:

Conifers

1-0[a]	Eastern red cedar (*Juniperus virginiana*)
2-0	Jack pine (*Pinus Banksiana*)
1-0	Loblolly pine (*P. Taeda*)
2-0	Pitch pine (*P. rigida*)
2-1	Red pine (*P. resinosa*)
1-0	Shortleaf pine (*P. echinata*)
1-0	Virginia pine (*P. virginiana*)
2-1	White pine (*P. Strobus*)

Hardwoods

1-0	Black locust (*Robinia Pseudo-Acacia*)
1-0	Black walnut (*Juglans nigra*)
	Black walnut seed (*J. nigra*)
1-0	Cottonwood (*Populus deltoides*)
1-0	Green and white ash (*Fraxinus pennsylvanica* var. *lanceolata* and *F. americana*)
1-0	Osage orange (*Toxylon pomiferum*)
1-0	Sweet gum (*Liquidambar styraciflua*)
1-0	Silver maple (*Acer saccharinum*)
1-0	Yellow poplar (*Liriodendron tulipifera*)

With the exception of the cottonwood trees, all planting stock was of good quality. The survival and growth of this species on the experimental areas may therefore not be indicative of its suitability on spoil banks in the state.

Each of the experimental plots contained 17 rows, with one of the above lots (black walnut making up two) assigned at random to one of the rows. Each row contained about 50 trees planted across the spoil-bank contours, and the trees were spaced at 7-by-7-foot intervals. Plots were replicated two or more times on each study area.

In addition to the foregoing studies, plantings were made the same year under 9-year-old plantations of black locust and shortleaf pine to determine the possibilities of stand conversion (Experimental Area

[a] The dual numbers preceding the names of species refer to the age class of nursery stock used in the planting. For examples, 1-0 Virginia pine means that the stock was grown 1 year in the seedbed and not transplanted; 2-1 white pine means that the trees were grown for 2 years in the seedbed and 1 year in the transplant bed at the nursery.

Table 1. — Description of Experimental Planting Areas Established on Strip-Mined Lands in Illinois, 1947

Area No.	County and district[a]	Coal seam	Stripping method	Spoil type	Toxic area[b]	Proportion of soil-sized material[c]	Cover[d]	Erosion
					perct.	*perct.*		
1	Knox (I)	6	Shovel	Calcareous silty clay	2.6	85	Sparse	Moderate
2	Fulton (I)	5	Tandem	Calcareous silty clay	.2	80	Barren	Slight
3	Will (II)	2	Tandem	Calcareous sandy clay loam, cemented surface	3.0	85	Barren	Severe
4	Grundy (II)	2	Tandem	Calcareous sand	.3	85	Barren	Severe
5	Grundy (II)	2	Tandem	Calcareous sand	.6	85	Medium	Moderate
6	Saline (IV)	6	Shovel	Acid silty clay loam	13.4	50	Sparse	Slight
7	Saline (IV)	6	Tandem	Acid silty clay loam, practically leveled	2.8	55	Sparse	None
8	Jackson (V)	5	Shovel	Acid silty clay	43.2	80	Sparse	Moderate
9	Randolph (V)	6	Shovel	Calcareous silty clay loam	.5	70	Sparse	Slight
10	Randolph (V)	5	Shovel	Calcareous silty clay loam	3.6	70	Dense	Slight
11	Perry (V)	6	Shovel	Calcareous silty clay	.2	90	Dense	None

[a] Roman numerals in parentheses are strip-mine district numbers (see Fig. 3).
[b] Extent of surface toxicity, based on visual examination and approximately 500 field tests on each experimental area.
[c] Proportion of soil-sized particles per unit of volume, based on visual estimates.
[d] Density of vegetation at the time of planting, based on visual estimate according to the following classification: 0-10 percent vegetated = barren; 10-25 percent = sparse; 25-75 percent = medium; 75-100 percent = dense.

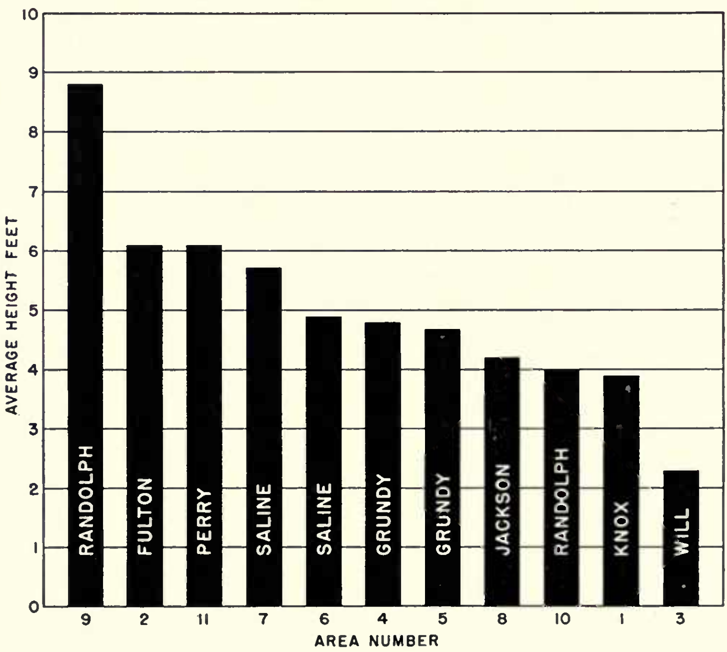
Table 2.—Average Second-Year Survival of Various Species of Trees on Barren and Naturally Vegetated Spoils in Different Locations[a]

Species	Percent survival at locations indicated[b]										Average of all areas
	District I		District II			District IV		District V			
	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	
Eastern red cedar	65	59	7	22	68	75	80	44	63	73	56
Northern conifers											
Jack pine	44	94	7	59	63	70	74	66	65	15	56
Red pine	19	94	12	61	50	69	74	59	34	7	48
White pine	31	81	4	55	56	61	60	65	53	6	47
Southern conifers											
Pitch pine	51	84	3	47	68	76	79	50	70	33	57
Loblolly pine	3	10	0	0	1	73	61	76	48	34	31
Shortleaf pine	2	3	0	0	1	53	52	41	50	11	21
Virginia pine	14	56	0	10	15	82	64	58	63	28	39
Hardwoods											
Ash	91	**97**	**75**	**91**	91	86	91	75	86	**81**	**86**
Black locust	**93**	95	41	85	**96**	**93**	**97**	**85**	**93**	38	82
Black walnut	44	20	16	6	36	30	46	12	67	29	31
Black walnut seed	49	53	7	21	38	42	81	26	66	24	41
Cottonwood	23	70	19	71	24	40	61	54	52	3	42
Osage orange	17	27	11	26	49	30	49	3	67	26	31
Silver maple	83	93	63	80	66	58	31	75	39	17	61
Sweet gum	9	25	2	5	14	78	54	78	73	22	36
Yellow poplar	8	58	2	1	14	43	44	37	40	1	25
Average all species	38	59	16	38	44	62	65	55	61	27	46

[a] Averages are based on two replications at each location except Areas 1 and 3, where they are based on four replications.
[b] Mortality caused by acid-toxicity has been excluded to obtain more accurate comparisons of the suitability of certain species for spoil-bank planting.

11 in Fig. 3 and Table 1). The black locust was in a decadent condition from heavy infestations of locust borer, and the pine had suffered considerably from winterkill and tip-moth injury. The experimental design of the underplantings was similar to that of the other studies. However, these plots contained only 10 rows, with one of the following species assigned at random to each row:

- Black walnut seedlings
- Black walnut seed
- Cottonwood
- Green and white ash
- Osage orange
- Silver maple
- Sweet gum
- Yellow poplar
- Black locust (planted under shortleaf pine only)
- Eastern red cedar (planted under black locust only)



Average height of black locust in experimental plantings on Illinois spoil banks after two growing seasons. The height of this tree in a two-year planting can be taken as a good index to the productivity of spoils and their adaptability to other kinds of planting that might be more desirable. (Fig. 19)

Second-Year Survival and Growth

The severe site conditions encountered on most strip-mined areas of recent origin suggest that plantation mortality will continue to be high over a long period of time. However, comparisons of recent plantings with nearby older plantations indicate that even on the more difficult sites most of the mortality occurs during the first year after planting and that subsequent annual mortality is relatively small. Therefore, a fairly good estimate of stocking in future plantations can often be obtained from second-year examinations.

All plots were examined periodically to determine survival, total height, and causes of mortality or unthriftiness. Differences in survival among species and among areas were obvious two years after planting (Table 2), but at this early age the differences in site quality among areas had no appreciable effect on the height growth of most species. One of the exceptions was black locust, which ranged in height from 2.3 feet on Area 3 to 8.8 feet on Area 9 (Fig. 19). This variation among the experimental areas in rate of early growth suggests the possible use of young black locust plantations as indicators of site quality on strip-mined lands in the state.

Important Site Conditions Affecting Early Success

Because of the typically steep slopes, primitive soil conditions, and lack of protective vegetation, successful plant establishment on recently stripped land is often limited by a complex array of detrimental site factors. These factors are, in turn, influenced by climatic variations, methods of mining, and geologic history. An important purpose in making the experimental plantings was to obtain a basis for evaluating the more outstanding of these conditions in terms of their effect on tree growth and survival.

Latitude. It is well known that the planting of species outside of their natural range is often comparatively unsuccessful. The results obtained in these spoil-bank planting experiments were no exception (Table 2).

The survival of southern and eastern species in northern Illinois (Districts I and II) was much poorer than that obtained in southern Illinois (Districts IV and V). Of the conifers, loblolly, shortleaf, and Virginia pines have been most affected. Sweet gum and yellow poplar were the more noticeably affected hardwoods.

For northern conifers, on the other hand, there is within the bounds of Illinois, little or no relation between survival and latitude.

Method of mining. The method or equipment employed in removing the overburden in strip-mining is important in determining the nature of the resulting spoils and the possibilities of later forestation. Such critical site factors as degree of slope, height of banks, and kind of surface material are partly dependent upon the mining technique.

The surface of spoils thrown up by power shovels in the usual strip-mining operations is composed mainly of mixtures of lower overburden strata which have been placed at random on top of the previously removed topsoil and subsoil materials. Consequently the spoil type of these areas is largely determined by the character and relative thickness of the strata *lying immediately above* the coal seam. In the experimental areas stripped by power shovel, however, there was a general preponderance of calcareous and relatively fine-textured material in the overburden. Excessive acidity and low soil percentage were therefore seldom limiting factors in the survival of plantings on these areas.

Although spoils derived from dragline operations are often composed of a larger number of conical peaks than those derived from power-shovel operations, they are usually similar in composition. However, deeper and wider cuts made possible by the longer reach of the dragline cause banks to be generally higher, and hence subject to more severe erosion. None of the experimental areas were located on land stripped by this method.

Tandem operations, employing a combination of power shovels, draglines, or both, remove the overburden in two steps. In these operations the upper portion of the overburden from a succeeding cut can be placed on top of the lower strata removed from the present cut. Thus the surface spoil material has a higher proportion of soil, and is generally more homogeneous in composition than that from single-unit procedures. Although, normally, this should result in better conditions for plant growth, three of the experimental locations on spoils originating from tandem stripping were very difficult sites because of the unusual nature of the overburden material. The loose calcareous sands of Experimental Areas 4 and 5 were characterized by low water-holding capacity and severe erosion. In Experimental Area 3 the spoils were also subject to excessive drouth and severe erosion because of the low infiltration rate permitted by the peculiar cemented surface material. These severe conditions resulted in high initial mortality for all but a few of the species tested.

The effects of grading were studied on one location in southern Illinois (Experimental Area 7) where the spoils were practically

Table 3. — Average Second-Year Height of Species Planted on Graded and Ungraded Acid Silty-Clay-Loam Spoils[a]

Species	Average total height		Species	Average total height	
	Graded	Not graded		Graded	Not graded
	feet	*feet*		*feet*	*feet*
Jack pine........	.6	.9	Black locust.....	5.7	4.8
Eastern red cedar	.6	.8	Black walnut....	.7	.9
Red pine........	.5	.6	Black walnut seed	.5	.6
White pine.......	.4	.5	Cottonwood.....	1.7	2.0
Pitch pine.......	.6	1.2	Osage orange....	.4	.8
Loblolly pine.....	.9	1.5	Sweet gum......	.6	1.1
Shortleaf pine....	.5	.8	Silver maple.....	1.3	1.6
Virginia pine.....	.7	1.4	Yellow poplar....	.6	.8
Ash.............	.9	1.0			

[a] Based on two replications on each area.

leveled by a dragline shovel during tandem stripping operations. Although survival of planted species has been slightly better on these spoils than on the undisturbed spoils of the same type (Experimental Area 8), a slower rate of growth on the graded area was becoming evident in the second year after planting (Table 3). Similar results have been obtained by studies of the effects of grading on strip-mined land in Ohio[14]* and in Kansas.

Acidity. Although only 1 percent of the strip-mined area in Illinois has been classified as too acid for plant growth (Table 6, page 242), patches of acid-toxic spoils occur on almost all stripped land through the chance exposure of sulfurous materials. Where a relatively thick stratum of pyritic material originally lay over the coal seam, the extent of surface toxicity on the spoil banks is largely dependent upon the method of mining. On the experimental plots, numerous field tests disclosed that none of the areas derived from tandem stripping operations had more than 3 percent of toxic surface material, whereas the proportion on the shovel-stripped areas varied from 1 to 43 percent (Table 1).

In making the field acidity tests, consistently higher acidities were noted on southerly slopes than on northerly slopes. Also, some spoil banks that were examined and adjudged largely nontoxic in winter months were found, when reexamined in the summer, to possess considerable toxic material. These phenomena can probably be attributed to the effect of surface temperatures upon the rate of chemical reactions and consequent release of sulfuric acid. It has also been found that dry soil samples give somewhat lower pH readings than moist samples. These shifts in pH readings should be taken into consideration when making field examinations to determine the quality of a site and the suitability of various species for the site. Dry periods during the summer months are perhaps the safest times for obtaining measurements of surface spoil acidity.

Texture. The relative proportions in which spoil materials of various sizes occur in a spoil bank are at least partially responsible for the degree to which many other factors influence the success of a forest. Of these factors, *erosion, available moisture,* and *aeration* are probably of greatest importance on those banks which are composed principally of soil-sized particles.

Spoils with a high proportion of rock fragments are not very prevalent in Illinois, but they do present a problem in certain localities. On such spoils the surface layer down to the normal planting depth is usually characterized by low water-holding capacity and insufficient soil for satisfactory root development. The 1946 survey of existing plantations on a wide variety of spoil types indicated that survival and growth of all species examined were adversely affected when less than half of the spoil material was composed of soil-sized particles. No experimental evidence is yet available to support the preliminary findings obtained from this survey.

Erosion. The severity of erosion on stripped land is chiefly dependent upon three conditions: (1) physical composition of the spoil material, (2) degree of slope and height of spoil banks, and (3) density and character of vegetation.

Seedling mortality is one measure of the severity of erosion on planted areas. This criterion was therefore used to measure the susceptibility to erosion of the four main textural classes of spoil in the areas studied. In order of decreasing susceptibility, these four classes stand as follows:

1. Sandy clay loam, cemented surface (Experimental Area 3)
2. Loose sand (Experimental Area 4)
3. Silty clay (Experimental Areas 1, 2, and 8)
4. Silty clay loam (Experimental Areas 6 and 9)

Plantation losses from erosion were found to vary appreciably with topographic position on the banks. On all study areas, mortality due to erosion on the lower portions of the banks was more than twice that on the upper portions. Much of this additional mortality was caused by siltation in the valleys. On severely eroding banks siltation alone accounted for one-half to three-fourths of the mortality attributable to erosion. The pines were found to be especially susceptible to this form of injury. Seedlings of eastern red cedar and black walnut seed also sustained serious losses. Black locust, ash, and cottonwood were apparently the least affected.

Ground cover. The term "ground cover" is applied only to low-growing herbaceous and shrubby vegetation. On strip-mined land the density and species composition of the natural ground cover varies with the time elapsed since stripping, proximity of seed source, and numerous other site factors such as texture and fertility of the spoil material, erodibility, and moisture availability.

The presence of ground cover on the spoils may be of much importance in determining the early success or failure of forest plantations. The visible benefits derived from the more densely covered areas include reduction of erosion, incorporation of organic matter, and lowering of surface temperature and evaporation. Where legume plants are present, the fertility of the spoils is increased by the fixation of atmospheric nitrogen. However, not all effects of ground cover are beneficial to early tree growth. Depending upon the height, density, and species of the cover, competition for light and moisture may be so severe that planted seedlings of intolerant trees cannot survive. Severe competition of this kind has been observed most frequently on banks where heavy stands of sweet clover had developed prior to planting.

In the experimental plantings, Areas 9 and 10 were essentially similar except that one was sparsely vegetated and the other supported a dense cover of sweet clover. The average over-all survival of the 17 planted species was 61 percent on the sparsely vegetated banks and 27 percent under the sweet clover. Ash and eastern red cedar were the only species tested which had acceptable survival under the clover.

A high rodent population, especially of rabbits, is often associated with the more densely covered spoils. In such areas anticipated rodent damage may become another factor limiting the selection of tree species for planting. On the study areas sweet gum and silver maple were most subject to this type of injury.

Overhead cover. Tree cover established prior to planting operations, either by natural invasion or by planting at some earlier date, is termed "overhead cover." Two of the plantings discussed previously were underplantings of various species in 9-year-old plantations of

Table 4. — Average Survival and Total Height of Several Species Two Years After Planting, Under Three Types of Overhead Cover[a]

Species	Sparse natural cover[b]		Nine-year-old black locust plantation		Nine-year-old shortleaf pine plantation	
	Survival	Total height	Survival	Total height	Survival	Total height
	perct.	*feet*	*perct.*	*feet*	*perct.*	*feet*
Ash	86	1.3	93	1.1	97	1.0
Black locust	93	8.8	([c])	([c])	94	6.1
Black walnut	67	.7	97	1.9	81	1.0
Black walnut seed	66	.6	81	1.8	56	.9
Cottonwood	52	3.1	14	2.3	35	1.5
Osage orange	67	1.0	14	1.5	59	1.0
Eastern red cedar	63	1.1	83	1.1	([c])	([c])
Sweet gum	73	1.3	57	1.8	73	1.1
Silver maple	39	1.4	86	2.5	71	1.4
Yellow poplar	40	.8	75	2.4	65	1.0
Average all species	65	...	67	...	70	...

[a] Based on two replications on each area.

[b] Experimental Area 9. Tree cover consisted of patches of cottonwood, sycamore, and willow averaging approximately 100 to 200 stems per acre, none over three years old.

[c] Not planted.

shortleaf pine and black locust. These older plantations had been opened considerably by locust borer infestation in the black locust stand, and by winterkill in the pine plantation. Early survival and growth of species planted under the older plantations were compared with those of the same species on one of the better planting sites on sparsely vegetated spoils (Table 4). All these studies were located in Strip-Mining District V.

Shading and weed competition, especially severe under the black locust, were responsible for the poor success with the more intolerant species on the underplanted plots. However, the species which are fairly tolerant in their juvenile stage, and which require a good site for successful growth, generally gave better results on the areas with overhead cover than on the relatively open spoils. The site-improving qualities of black locust were particularly evident in the increased survival and growth of black walnut, silver maple, and yellow poplar. The total height of these species averaged about twice as great on areas under locust as on either of the other two areas.

Topographic position and aspect. The typical saw-tooth profile of strip-mined land causes widely varying conditions of exposure, light intensity, and availability of moisture. In order to determine the relative importance of these factors upon early plantation success, the experimental data for each study area and species were grouped according to the location of the trees: (1) on northerly or southerly slopes,[a] and (2) on upper or lower portions of the spoil bank.

Consistent differences in height growth were not as yet discernible either by aspect or by position on the banks. However, for nearly all hardwood species slightly higher survivals were obtained on lower slopes and northern aspects than on upper slopes and southern aspects. Although differences in survival were usually significant statistically, they seldom exceeded 10 percent and were too slight to be of much practical value. The conifers were similarly influenced by aspect, but topographic position had no apparent effect on their survival.

Burning gob. The occurrence of burning mine waste is quite rare, but where it is encountered, planting is not recommended within about ¼ mile. The combination of sulfurous fumes with atmospheric moisture produces sulfuric acid, which causes discoloration and defoliation of nearby trees and eventually kills them. That conifers are apparently more seriously affected by this type of injury than are hardwood species is mentioned by Baxter.[1*] Among the hardwoods that he found least susceptible were: black locust, honey locust, boxelder, catalpa, sycamore, and Ailanthus.

FOREST PLANTING RECOMMENDATIONS

The planting recommendations which follow are based mainly on information obtained from the reconnaissance of strip-mined lands in the state, from the plantation survey, and from experimental plantings begun in 1947. Experimental results and general observations on plantation development elsewhere in the Central States region under somewhat similar conditions were also considered. These recommendations, though tentative, are being released to aid those agencies and companies needing the latest available information relating to the forestation of these lands. *Species not included in these recommendations, especially those not native to the locality, should not be used extensively until small-scale plantings have demonstrated their suitability to local spoil and climatic conditions.*

The choice of species and mixtures to be used are listed separately by the major spoil types occurring in each strip-mining district.

[a] Northerly slopes were considered to be those facing from N.69° W. (clockwise) to S.70° E.; southerly slopes were those facing from S.69° E. to N.70° W.

Table 5. — Survival and Growth Possibilities of Species Planted on Various Spoil-Bank Sites in Illinois

Species	In dense sweet clover	Under black locust	On erosive spoils	On steep northerly aspects and lower slopes	On steep southerly aspects and upper slopes	In bottoms
Conifers						
Eastern red cedar	Good	Good	Poor	Good	Fair	Fair
Jack pine	Poor	Poor	Fair	Good	Good	Poor
Loblolly pine	Poor	Poor	Poor	Good	Good	Poor
Pitch pine	Poor	Poor	Poor	Good	Good	Poor
Red pine	Poor	Poor	Poor	Good	Good	Poor
Shortleaf pine	Poor	Poor	Fair	Good	Good	Poor
Virginia pine	Poor	Poor	Fair	Good	Good	Poor
White pine	Fair	Fair	Poor	Good	Fair	Poor
Hardwoods						
Ash (green and white)	Good	Good	Good	Good	Good	Good
Black locust	Fair	Poor	Good	Good	Good	Good
Black walnut	Good	Good	Poor	Good	Poor	Good
Cottonwood	Fair	Fair	Fair	Good	Good	Good
Osage orange	Fair	Fair	Fair	Fair	Fair	Fair
Red oak	Fair	Fair	Poor	Good	Good	Good
Silver maple	Fair	Good	Fair	Good	Good	Good
Sweet gum	Fair	Good	Fair	Good	Good	Good
Sycamore	Fair	Poor	Fair	Good	Good	Good
Yellow poplar	Very poor	Very good	Very poor	Good	Poor	Good

Readers are also reminded to consult Table 5, which shows the survival and growth possibilities of species planted on various spoil-bank sites in Illinois.

District I

(Fulton, Hancock, Henry, Knox, McDonough, Schuyler Counties)

Acid and calcareous banks. Use mixtures consisting of 50 percent black locust and 50 percent of one or more of the following species: white and green ash, black walnut, sycamore, silver maple, red oak, red elm, and red cedar. In pure plantings or group-wise mixtures use sycamore, cottonwood, red elm, red cedar, jack, red, white, pitch and Virginia pines.

Consult Table 5 to check survival and growth possibilities of all species when planted under various site conditions.

District II

(Bureau, Grundy, LaSalle, and Will Counties)

Acid and calcareous banks in Bureau and LaSalle counties. Use mixtures consisting of 50 percent black locust and 50 percent of one or more of the following species: white and green ash, black walnut, sycamore, silver maple, red oak, red elm, and red cedar. In pure plantings or group-wise mixtures use sycamore, cottonwood, red elm, red cedar, jack, red, white, pitch and Virigina pines.

Toxic spoils. Do not plant until toxic conditions have been ameliorated to the extent that tests show more than 50 percent of the area with pH values greater than 4.0.

Calcareous, sandy spoils in Will and Grundy counties. For barren or sparsely covered areas, use a mixture consisting of 50 percent black locust and 50 percent of one or more of the following species: green ash, sycamore, red oak, and silver maple. Or use pure plantings or group-wise mixtures of cottonwood, sycamore, and jack, red, white, and pitch pines.

Where the ground cover is of medium density, the same species and mixtures are recommended as listed above but red cedar may be added.

If planting of conifers is desired, the use of large stock in the bottoms between steep ridges is recommended to reduce losses from siltation.

Calcareous spoils with compact, cemented surfaces. Use a mixture consisting of 50 percent black locust and 50 percent green ash and silver maple.

All spoil types. Consult Table 5 to check survival and growth possibilities of all species when planted under various site conditions.

District III

(Edgar and Vermilion Counties)

Acid and calcareous banks. Use a mixture consisting of 50 percent black locust and 50 percent of one or more of the following species: white ash, green ash, yellow poplar, black walnut, silver maple, sycamore, red cedar, red elm, chestnut oak, and red oak. Or use pure plantings or group-wise mixtures of cottonwood, sycamore, silver maple, red elm, and red, jack, white, pitch, and Viriginia pines.

Consult Table 5 to check survival and growth possibilities of all species when planted under various site conditions.

District IV

(Saline and Williamson Counties)

Acid and calcareous banks containing a high proportion of soil. Use a mixture consisting of 50 percent black locust and 50 percent of one or more of the following species: yellow poplar, sweet gum, black walnut, white ash, green ash, silver maple, sycamore, red oak, chestnut oak, red elm, and red cedar. On outside slopes where gullying is likely to be severe, increase the proportion of black locust to 75 percent of the mixture. Where losses from erosion will not be high, recommended species for pure plantings or group-wise mixtures are sycamore, cottonwood, silver maple, sweet gum, red elm, and shortleaf, jack, loblolly, red, pitch and Virginia pines.

Acid and calcareous banks consisting of a high proportion of shale, sandstone, or limestone. If practicable, planting should be postponed for 3 to 5 years after stripping; species recommendations are the same as for the preceding site.

Both spoil types. Consult Table 5 to check survival and growth possibilities of all species when planted under various site conditions.

District V

(Jackson, Perry, Randolph, and St. Clair Counties)

Use mixed plantings composed of 50 percent black locust and 50 percent of one or more of the following species: white ash, green ash, black walnut, yellow poplar, sweet gum, silver maple, sycamore, red oak, red elm, and red cedar. Or use pure plantings or group-wise mixtures of sycamore, cottonwood, silver maple, sweet gum, red elm, red cedar, and shortleaf, jack, loblolly, red, white, pitch and Virginia pines.

Consult Table 5 to check survival and growth possibilities of all species when planted under various site conditions.

LITERATURE CITED

1. BAXTER, D. V. Pathology in forest practice. John Wiley & Sons, Inc. 1943.
2. CADY, G. H. Geology and mineral resources of the Hennepin and LaSalle quadrangles. Ill. State Geol. Surv., Bul. 37, 136p. 1919.
3. ————. Coal-stripping possibilities in southern and southwestern Illinois. Ill. State Geol. Surv., Coop. Mining Ser., Bul. 31, 59p. 1927.
4. ————. The Illinois coal field. Analyses of Illinois coals. U. S. Dept. Int., Tech. Paper 641, 1-23. 1942.
5. CHAPMAN, A. G. The effects of black locust on associated species with special reference to forest trees. Ecol. Monog. 5, 37-60. 1935.
6. ————. Rehabilitation of areas stripped for coal. Cent. States Forest Exp. Sta., Tech. Paper 108, 13p. 1947. (Processed)
7. CROXTON, W. C. Revegetation of Illinois coal-stripped lands. Ecology **9**, 155-175. 1928.
8. CULVER, H. E. Preliminary report on coal-stripping possibilities in Illinois. Ill. State Geol. Surv., Coop. Mining Ser., Bul. 28, 61p. 1925.
9. GRAHAM, H. D. The economics of strip coal mining. Univ. of Ill., Bur. of Econ. and Bus. Res. Bul. 66, 77p. 1948.
10. HENBEST, L. G. Coal-stripping possibilities in Saline and Gallatin counties near Equality. Ill. State Geol. Surv., Coop. Mining Ser., Bul. 32, 28p. 1929.
11. HOLMES, L. A. Reclaiming stripped lands in Illinois. Sci. Monthly **59**, 414-420. 1944.
12. ILLINOIS COAL STRIPPERS ASSOCIATION. Acreage of land mined by Illinois coal strippers and land reclamation programs carried out, 1939-1950 inclusive. 1950. (Processed)
13. ILLINOIS DEPARTMENT OF CONSERVATION. Forest tree planting manual for Illinois. 23p. [n. d.]
14. LIMSTROM, G. A. Extent, character, and forestation possibilities of land stripped for coal in the central states. Cent. States Forest Exp. Sta. Tech. Paper 109, 79p. 1948. (Processed)
15. MERZ, R. W. Forest seeding and planting tests in Ohio. Cent. States Forest Exp. Sta. 1949. (Unpublished rpt.)
16. SCHAVILJE, J. P. Reclaiming Illinois strip-mined coal lands with trees. Jour. Forestry **39**, 714-719. 1941.
17. VESTAL, A. G. A preliminary vegetation map for Illinois. Ill. State Acad. Sci. Trans. **23** (3), 204-217. 1931.
18. WALTER, G. H. Agriculture and strip coal mining. U. S. Bur. Agr. Econ. Agr. Econ. Res. **1** (1), 24-29. 1949.
19. WELLER, J. M., and WANLESS, H. R. Correlation of minable coals of Illinois, Indiana, and western Kentucky. Ill. State Geol. Surv. Cir. 48, 18p. 1939.

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Table 6. — Area of Strip-Mined Land in Illinois by Acidity and Texture Classes, 1946

Acidity class	SANDS		LOAMS AND SILTY SHALES		CLAY		Total	
	acres	*perct.*	*acres*	*perct.*	*acres*	*perct.*	*acres*	*perct.*
1 **Toxic.** More than 75 percent of area with pH less than 4.0	0	0	253	.6	163	0.4	416	1.0
2 **Marginal.** 50-75 percent of area toxic, less than 51 percent with pH 4.0-6.9, and less than 51 percent with pH 7.0+	0	0	362	.9	173	.4	535	1.3
3 **Acid.** More than 50 percent of area with pH of 4.0−6.9	0	0	2 717	6.8	1 323	3.3	4 040	10.1
4 **Calcareous.** More than 50 percent of area with pH of 7.0 or higher	878	2.2	21 754	54.7	8 662	21.8	31 294	78.8
5 **Mixed.** Approximately the same proportion of toxic, acid, and calcareous areas	1 984	5.0	178	.4	1 373	3.4	3 535	8.8
Total	2 862	7.2	25 264	63.4	11 694	29.4	39 820	100.0

Table 7. — Area of Strip-Mined Land in Illinois by County, Soil Texture, and Acidity Class, 1946

County	SANDS: acres in acidity classes—					LOAMS AND SILTY SHALES: acres in acidity classes—					CLAY: acres in acidity classes—					Total
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Bureau	0	0	0	0	0	0	0	0	73	0	0	0	0	0	0	73
Edgar	0	0	0	0	0	0	0	0	246	0	0	0	0	0	0	246
Fulton	0	0	0	0	0	0	0	0	5 928	0	0	173	0	3 752	39	9 892
Grundy	0	0	0	785	0	19	251	0	2 024	0	0	0	300	0	0	3 379
Hancock	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	200
Henry	0	0	0	0	0	0	0	0	2 198	144	0	0	0	0	0	2 342
Jackson	0	0	0	0	0	0	37	0	298	0	0	0	236	111	853	1 535
Knox	0	0	0	0	0	0	0	0	1 605	0	0	0	0	759	0	2 364
LaSalle	0	0	0	0	0	0	0	0	0	0	163	0	0	497	0	660
Perry	0	0	0	0	0	0	0	30	4 958	0	0	0	0	1 527	0	6 515
Randolph	0	0	0	0	0	0	0	0	0	0	0	0	0	1 120	0	1 120
St. Clair	0	0	0	0	0	0	0	0	1 436	0	0	0	0	0	0	1 436
Saline	0	0	0	0	0	24	0	1 926	0	0	0	0	0	0	0	1 950
Schuyler	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	27
Vermilion	0	0	0	0	0	0	0	4	1 538	34	0	0	143	641	277	2 637
Will	0	0	0	93	1 984	0	74	0	1 450	0	0	0	0	0	0	3 601
Williamson	0	0	0	0	0	210	0	757	0	0	0	0	444	228	204	1 843
Total	0	0	0	878	1 984	253	362	2 717	21 754	178	163	173	1 323	8 662	1 373	39 820

See Table 6 for description of acidity classes.

Table 8. — Area of Strip-Mined Land in Illinois by County and Character of Vegetation

County	Barren	Weeds, grasses, shrubs and legumes	Forested		Total	Date of estimate
			Natural	Planted		
	acres	*acres*	*acres*	*acres*	*acres*	
Bureau	5	1	1	66	73	7/46
Edgar	0	230	16	0	246	8/46
Fulton	3 007	4 167	151	2 567	9 892	7/46
Grundy	1 378	1 764	73	164	3 379	9/46
Hancock	20	150	30	0	200	7/46
Henry	370	1 103	196	673	2 342	7/46
Jackson	470	385	56	624	1 535	5/46
Knox	1 339	291	28	706	2 364	7/46
LaSalle	255	380	25	0	660	7/46
Perry	1 548	1 598	317	3 052	6 515	6/46
Randolph	270	253	89	508	1 120	5/46
St. Clair	280	768	101	287	1 436	6/46
Saline	811	876	50	213	1 950	7/46
Schuyler	24	2	1	0	27	7/46
Vermilion	501	1 293	814	29	2 637	9/46
Will	676	2 049	249	627	3 601	7/46
Williamson	1 160	374	38	271	1 843	6/46
Total	12 114	15 684	2 235	9 787	39 820	....

Table 9. — Area of Strip-Mined Land in Illinois by County and Coal Seam, 1946

County	No. 2, LaSalle	No. 5, Harrisburg (Springfield)	No. 6, Herrin	Not determined	Total
	acres	*acres*	*acres*	*acres*	*acres*
Bureau	0	0	73	0	73
Edgar	0	0	246	0	246
Fulton	579	3 998	3 518	1 797	9 892
Grundy	2 594	785	0	0	3 379
Hancock	0	0	0	200	200
Henry	1 776	0	0	566	2 342
Jackson	0	298	1 237	0	1 535
Knox	0	0	2 104	260	2 364
LaSalle	660	0	0	0	660
Perry	0	758	5 757	0	6 515
Randolph	0	0	1 120	0	1 120
St. Clair	0	0	1 436	0	1 436
Saline	0	1 035	915	0	1 950
Schuyler	0	27	0	0	27
Vermilion	0	0	0	2 637	2 637
Will	3 601	0	0	0	3 601
Williamson	0	1 153	690	0	1 843
Total	9 210	8 054	17 096	5 460	39 820

Table 10. — Descriptions and Chemical Analyses of Strata Over the No. 5 Coal Seam in Illinois: Strip-Mining District I

(Sample was taken from Section 26, T.6N, R.3E, Fulton county)

Description of strata (top to bottom)	Thickness of strata	Acidity[a] of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silt loam, gray	1	5.5	Slight	Medium
Silty clay, mottled	5	5.8	High	Medium
Silt loam, yellow	10	6.7	Medium	Low
Silty clay, mottled, with some alluvial material	4	7.2	Medium	Slight
Silty clay, mottled, becoming increasingly compact	10	7.2	High	High
Shale, hard and thin-bedded	3	...	....	....

[a] Commonly accepted acidity classes are: pH less than 4.0 = toxic range; 4.0-6.9 = acid range; 7.0+ = alkaline range.

Table 10A. — Chemical Analyses of Calcareous Loam Surface Spoils Near Location of Stratigraphic Sample Described in Table 10

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	6.7	Low	High
2	7.3	Medium	Very high
3	6.4	Medium	High
4	7.0	Medium	High
5	7.6	Low	Medium

Table 11. — Descriptions and Chemical Analyses of Strata Over the No. 6 Coal Seam in Illinois: Strip-Mining District I

(Sample was taken from Section 25, T.12N, R.3E, Knox county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silty clay, gray	3	6.9	Low	Very high
Silty clay, mottled	4	7.7	Low	Medium
Silt, light bluish-gray	2	7.8	Low	Medium
Silty clay, mottled	2½	7.5	Low	Medium
Clay, mottled	4	7.3	Low	High
Silty clay, brown	1½	8.0	Low	Medium
Silty clay, yellowish-gray	1	8.2	Low	Medium
Shale, light bluish-gray	15	7.5	Low	High
Limestone, massive[a]	1½	...	....	....

[a] The word "massive" as used here denotes bulkiness and large size.

Table 11A. — Chemical Analyses of Calcareous Clay Surface Spoils Near Location of Stratigraphic Sample Described in Table 11

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	6.9	Low	Very high
2	7.2	Slight	High
3	7.0	Low	Medium
4	7.4	Low	Medium
5	6.3	High	Medium

Table 12. — Descriptions and Chemical Analyses of Strata Over the No. 2 Coal Seam in Illinois: Strip-Mining District I

(Sample was taken from Section 18, T.33N, R.3E, LaSalle county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silty clay loam, gray	1½	5.3	Slight	Very high
Silty clay, mottled, with some alluvial material	1	5.8	High	Very high
Silt, yellow, stratified with alluvial material	1½	6.2	Low	High
Silt, gray to yellow, compact	2	6.7	High	High
Silt, gray, very compact	3½	7.9	High	High
Siltstone, medium to thick-bedded	29½	7.1	High	Very high

Table 12A. — Chemical Analyses of Toxic Clay Surface Spoils Near Location of Stratigraphic Sample Described in Table 12

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	2.3	High	Very high
2	4.8	Low	Very high
3	4.0	High	Very high

Table 13. — Descriptions and Chemical Analyses of Strata Over the No. 2 Coal Seam in Illinois: Strip-Mining District II

(Sample was taken from Section 28, T.32N, R.9E, Will county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Fine sandy loam, dark gray........	1	5.6	Slight	Low
Medium fine sand, grayish-brown...	4	6.8	Slight	Low
Fine to coarse gravel, gray.........	1	6.6	Slight	Low
Compact silt, gray, with some gravel	15	7.5	Low	High
Compact silt, reddish-brown, with gravel.........................	1½	7.9	Low	Very high
Compact silt, gray................	2½	7.8	Low	Very high
Compact silt, gray, with gravel and a few large rocks..................	20	7.6	Low	Very high

Table 13A. — Chemical Analyses of Calcareous Loam Surface Spoils Near Location of Stratigraphic Sample Described in Table 13

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1...............................	7.5	Low	Medium
2...............................	7.0	Low	High
3...............................	7.4	Low	High
4...............................	7.3	Low	Very high
5...............................	5.6	High	Very high

Table 14. — Descriptions and Chemical Analyses of Strata Over the No. 7 Coal Seam in Illinois: Strip-Mining District III

(Sample was taken from Section 30, T.19N, R.12W, Vermilion county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silty clay, gray....................	1½	7.3	Medium	Medium
Fine sandy loam, light gray........	7	7.7	Low	Medium
Fine sandy loam, grayish-brown.....	1½	7.8	Low	Medium
Coarse sand, yellow and gray.......	1	8.0	Low	Low
Coarse sand and gravel.............	2	8.0	Low	Low
Silty shale, bluish-gray, compact....	16	8.7	Low	Very high
Shale, dark gray and thin-bedded...	2	7.2	High	Very high

Table 14A. — Chemical Analyses of Calcareous Loam Surface Spoils Near Location of Stratigraphic Sample Described in Table 14

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	7.0	Low	Very high
2	7.5	Low	Very high

Table 15. — Descriptions and Chemical Analyses of Strata Over the No. 5 Coal Seam in Illinois: Strip-Mining District IV

(Sample was taken from Section 4, T.9S, R.1E, Williamson county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silt loam, grayish-brown	2	5.5	Medium	Medium
Silty clay, mottled and compact	4 }	5.6	High	High
Silty clay, gray and compact	32 }			
Limestone, gray and hard	1	...	....	....
Shale, black, soft, and thin-bedded	2	6.9	High	Very high
Shale, black and hard	7	6.1	High	Very high

Table 15A. — Chemical Analyses of Acid Clay Surface Spoils Near Location of Stratigraphic Sample Described in Table 15

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	6.5	Slight	Medium
2	6.5	High	High
3	5.0	High	Very high
4	5.4	Low	High

Table 16. — Descriptions and Chemical Analyses of Strata Over the No. 6 Coal Seam in Illinois: Strip-Mining District IV

(Sample was taken from Section 22, T.9S, R.5E, Saline county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silt loam, grayish-brown	1	4.6	Low	Medium
Silty clay, mottled	6	6.2	Low	Slight
Sandstone, red and soft	5	6.6	Slight	Slight
Shale, gray and soft	8 }	4.6	Low	Slight
Sandstone and sandy shale, medium-hard, some limestone	10 }			
Impure coal	2	6.5	Low	Very high
Limestone, massive	1–8	...	....	....

Table 16A. — Chemical Analyses of Acid Loam Surface Spoils Near Location of Stratigraphic Sample Described in Table 16

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	3.8	Low	Medium
2	6.3	Slight	Very high
3	5.7	Slight	Medium
4	7.5	High	High
5	4.0	Low	Low

Table 17. — Descriptions and Chemical Analyses of Strata Over the No. 5 Coal Seam in Illinois: Strip-Mining District V

(Sample was taken from Section 7, T.8S, R.1W, Jackson county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silt loam, gray	3 }	6.8	Low	High
Silty clay, gray	3 }			
Clay, mottled gray and brown, calcalcareous	24 }			
Limestone, gray and hard	1½	...	....	....
Shale, soft and hard, thin-bedded, calcareous but with many acid pockets	10	5.9	High	Very high

Table 17A. — Chemical Analyses of Acid Clay Surface Spoils Near Location of Stratigraphic Sample Described in Table 17

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	5.9	Low	Medium
2	6.8	Slight	Medium
3	3.5	Medium	Very high
4	3.8	High	High
5	4.5	Medium	High

Table 18. — Descriptions and Chemical Analyses of Strata Over the No. 6 Coal Seam in Illinois: Strip-Mining District V

(Sample was taken from Section 16, T.6S, R.2W, Perry county)

Description of strata (top to bottom)	Thickness of strata	Acidity of strata	Available phosphorus	Available potassium
	feet	*pH*		
Silty clay, grayish-brown, compact	13	4.7	Medium	Very high
Sandy and silty loam, alluvial	12	7.1	Low	Medium
Shale, gray and soft	9	5.0	High	Very high
Limestone, massive and hard	14	...	.....	....
Shale, black and hard	4½	6.2	High	Very high

Table 18A. — Chemical Analyses of Calcareous Clay Surface Spoils Near Location of Stratigraphic Sample Described in Table 18

Sample No.	Acidity	Available phosphorus	Available potassium
	pH		
1	7.0	Slight	Very high
2	7.7	Medium	Very high
3	6.8	High	High
4	7.1	Medium	High
5	7.1	High	Medium

SUMMARY

Eight conifers and ten hardwood species of trees can be recommended as likely, under specified conditions, to make satisfactory growth on lands strip-mined for coal in Illinois.

Among the conifers observed in a survey of existing plantations, survival ranged from 20 to 98 percent, averaging about 60 percent; height growth was consistently good. Among the hardwoods, the same or slightly lower percentages of survival were indicated. Sweet gum was outstandingly promising for the stripped lands in southern Illinois. Yellow poplar proved more exacting in site requirements than other species tried. A nine-year-old decadent stand of black locust was found to be notably valuable as a nurse crop for black walnut, silver maple, and yellow poplar, but was unfavorable for survival of cottonwood, sweet gum, and osage orange.

Since the greatest mortality in plantings seems to occur the first year, a fairly good estimate of stocking in future plantations can often be obtained from second-year examination. Because of its sensitivity to site conditions, black locust proved a good indicator of site quality. After two growing seasons, trees of this species ranged in height from an average of 2.3 feet in one area to 8.8 feet in another.

The site qualities that largely determine which species are suitable for planting on a particular site are (1) the character of the overburden of the coal seam or area and (2) the method of stripping, as these affect the acidity and texture of the spoils. Tandem operations, which removed the overburden in two steps, generally left the spoils in better condition for tree growth than single-unit procedures did.

Although the recommendations given here are somewhat tentative, the authors believe they will prove useful in reducing failures in tree plantings on Illinois strip-mined lands. The information derived from this study will enable interested agencies — public and private — to evaluate site conditions more accurately than in the past.

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Most strip-mined lands in Illinois can be made productive by practical reclamation methods. Some locations are best used for wood production, some for pasture, and some as recreation areas. This publication describes the various conditions existing on stripped lands in the state and recommends species of trees that can be expected to survive and grow on these areas.