

REVEGETATION OF OHIO'S STRIP-MINED LAND

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Revegetation is everywhere recognized as an indispensable means of reclaiming strip-mined land. It must, therefore, be considered in any comprehensive discussion of reclamation. Moreover, forestation is recognized as the most widely applicable type of revegetation.

Foresters rarely, if ever, recommend planting the same tree species on sandy soil as on a mottled clay. The successful farmer usually devotes a good deal of time to deciding what crops to grow on different soil types on his land; he also quite often consults specialists for help in this decision. And yet with strip-mined land, infinitely more variable per unit area than undisturbed land, there is a tendency to plant extensive areas to one species of tree, grass, or legume. There is, admittedly, a practical limit to the number of species that can be used in one reclamation program, but in most operations, the number used is below this limit.

The objectives of this paper are to show what conditions appear to be important in accurate site appraisal for the reclamation of strip-mined land in Ohio and, should a decision be made to revegetate a strip-mined area to trees, what planting plans should be made. Both careful site appraisals and careful planning of the planting are necessary for revegetation to either forage or trees. Spoil banks should be appraised for their texture, aggregation, acidity, topography, and for volunteer vegetation growing on them. Problems to be considered in planting include selection of the most suitable species and seed source, planting practices, specifications for the planting stock, and measures for the control of erosion.

This paper deals only with site conditions and planting problems. Neither should be appraised before mining and grading are completed. Mining and grading can significantly alter the productive capabilities of the land. Therefore, the decision to plant trees, forage, or other crops should be made before these operations begin. The kind of material to be overturned in mining should be considered in making this decision. Once the decision has been made, grading and mining should be carried out, as far as practicable, to favor the chosen use. A decision for forage will require more grading than one for trees. This relation of material overturned, mining, and grading to site appraisal and to planting plans can perhaps be shown more clearly with a diagram (fig. 1).

IMPORTANT SITE CONDITIONS

For site appraisals, we are concerned mostly with those conditions that influence the productivity and plantability of strip-mined land; the relative importance of each condition will vary with the type of land use and the species selected. In some cases a single spoil characteristic may account for good growth, while another may limit both survival and growth. More often, however, the health and vigor of planted trees depend upon the interaction of two or more critical site conditions.

Texture

The relative amounts of stone and soil in the spoil mass will vary, as will the amounts of sand, silt, and clay in the soil fraction. Such differences in the composition of the spoil mass affect drainage problems, soil aeration, and soil moisture. Banks composed largely of sand, sandstone, and hard shales have the advantage

of being better drained, but are apt to be more droughty than those of clay, limestone, and soft shale. An examination of adjacent high walls, though not recommended as a substitute for close examination of the bank surfaces, often indicates the composition of these surfaces and potential site quality. Consider for example experimental plantings described by Finn (1958) from two areas strip mined for No. 8 Pittsburgh coal, one located near Georgetown in Harrison County, the other near Bloomingdale in Jefferson County. In the Georgetown high wall, almost the entire overburden is composed of limestone, whereas at Bloomingdale, only the lower half is composed mainly of limestone, the upper half being mostly sandstone and sandy shale. By the tenth year after planting, borers have completely riddled black locust (*Robinia pseudoacacia* L.) on the banks high in limestone and clay near Georgetown, whereas a merchantable crop of posts and props has been produced on banks high in sandstone and shale near Bloomingdale. This contrast in productivity is unmistakably due to the better drainage and soil aeration on the latter.

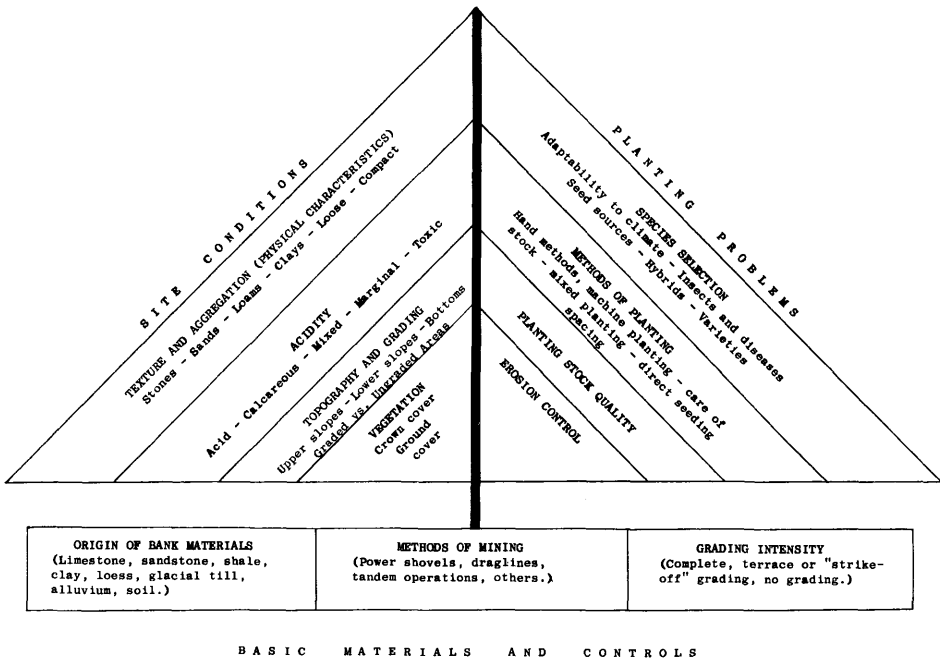


FIGURE 1. A summary of problems in revegetating strip-mined land.

Aggregation

An important characteristic of spoil-bank material is its "aggregation." Other terms that could perhaps be used are "looseness" or "compactness." In strip mining, the material overlying the coal is broken up into fragments of various sizes and shapes. Natural weathering breaks down these materials; with the addition of water, some disperse readily into single grains or small aggregates and thus are easily eroded. At the other extreme are materials that adhere strongly together and remain in large aggregates or clods; dispersion in water is slow, so these adherent and aggregative materials are relatively non-erodible. Bank surfaces range between extreme compactness and looseness. We do not yet have a good quantitative measure of aggregation; until one is found, we should classify banks in terms of these extremes.

"Loose" banks are easily identified. Holes can easily be dug with a spade or an ordinary garden trowel; the material disintegrates into small, single-grained particles or small aggregates; if large stones are present, very little soil adheres to them. Loose banks are sometimes composed only of sandstone or sandy shale, but many in Ohio are composed of silty shales and easily-dispersed silt and clay particles. Footprints are distinct and quite clearly seen, and rapid erosion creates U-shaped valleys in ungraded areas. In areas of loose banks, white ash (*Fraxinus americana* L.) and yellow poplar (*Liriodendron tulipifera* L.) grow much more rapidly in bottoms and on lower slopes than on tops and upper slopes. Some conifers, especially white pine (*Pinus strobus* L.) and pitch pine (*P. rigida* Mill.), are more suited to this type of bank; they grow almost as well on the tops as on lower slopes.

Loose banks, when graded, continue to erode. Those that contain much silt or clay are subject to sheet erosion and tend to form "cemented surfaces" that crack during dry periods.

"Compact" banks are also easily identified. Except when these are very wet, or have been made quite recently, the surface is hard and footprints are seldom recognizable; a pick or mattock is needed to loosen surfaces and dig holes. On ungraded strip-mined land, such compact banks remain V-shaped for many years; erosion is negligible. Ash, yellow poplar, and other species grow almost as well on the tops as on the lower slopes and bottoms.

Acidity

Acidity or alkalinity of the banks is important in reclaiming strip-mined land; it is, in fact, very often the factor limiting plant growth. In site appraisal of strip-mined land in Ohio, pH of 4.0 or less is considered very strongly acid and generally indicates conditions lethal to most plants. A pH of 4.0 to 5.0 is strongly acid; 5.1 to 6.9 is moderately to mildly acid; 7.0 is neutral. A pH higher than 7.0 is alkaline (usually calcareous in Ohio).

The maximum and minimum pH for survival and growth of many tree species are unknown. However, Stiver (1949) observed that Virginia pine (*P. virginiana* Mill.) survived on strip-mined land in Indiana having a pH of 3.5. On three different strip-mined areas in Ohio, two-year-old black locust was almost twice as tall on slightly acid or slightly alkaline surfaces of pH 6.8 to 7.8 as on strongly acid surfaces of pH 3.0 to 5.5 (Finn, 1958). Growth of white pine, white ash, and yellow poplar was stunted in the transition zone between toxic areas having a pH of less than 4.0 and areas of good growth having a pH of 4.5 and higher (Limstrom, 1960).

Within limits, soil acidity in itself does not influence plant growth. Rather, it influences the availability of soil nutrients by its effects on both the solubility of minerals absorbed by plant roots and on the occurrence and abundance of soil microorganisms.

Observations made in current research encourage hopes for discovery or development of trees adapted to highly acid sites. We have found one tree surviving and continuing to grow, in a planting of a hybrid between pitch pine and loblolly pine (*P. taeda* L.) in Perry County on spoil material with a pH of 2.5. As soon as the tree grows larger, and if good techniques for rooting pine cuttings can be developed, we hope to plant cuttings from this tree to verify its apparent adaptation to acid conditions. More plantings of seedlings of this hybrid have recently been made. It appears also that European alder (*Alnus glutinosa* (L.) Gaertn.) tolerates highly acid conditions and it is now being tested widely (Funk and Dale, 1961; Lowry et al., 1962).

Topography and Grading

Topography deals with the shape, relief, and aspect of the land surface. Shape

refers to length, smoothness, and steepness of slopes; relief, to the range in elevation between lowest and highest points; and aspect, to the compass direction that slopes face. Topography influences the success of strip-mine revegetation by its effects on soil properties such as aeration, moisture, depth, and temperature, and on erosion hazards, protection from wind, and light.

The topography of strip-mined land is largely man-made; how man shapes it will have a far-reaching effect on the productivity and use of the land. In appraising sites for tree planting, we should recognize that a given tree species is likely to perform differently on ungraded than on graded strip-mined land. Performance on ungraded land will itself differ with the elevation of the banks. On ungraded banks higher than 15 ft, the upper two-thirds of the slope and the top sometimes present conditions different from those of the lower third of the slope and the bottom. Conditions on these lower slopes of tall banks will be similar to conditions on the low banks (less than 15 ft high). A distinction should be made also between different parts of graded strip-mined land. The slopes on the outside edge of graded areas or near the highwall usually have been compacted very little by grading machinery and can be classified as "ungraded strip-mined land."

Our publications have reported how grading influences the development of forest plantations on strip-mined land and how results vary with species used, character of spoil material, and intensity of grading (Limstrom, 1952, 1960; Limstrom and Merz, 1949). I should like to summarize briefly the 10-year results already reported in our publications and then indicate trends evident 17 years after planting.

Development of three species on graded and ungraded banks has been compared in two areas of Ohio. The two banks differ rather widely in spoil texture and parent material. One is located on land stripped for No. 8 Pittsburgh coal and is a compact, calcareous clay. The spoil material consists mainly of limestone and stiff, plastic clay. The other area was stripped for No. 7 Upper Freeport coal, and is a loose mixture of sandstone and shaly clay, with a pH of 5.0 to 7.3.

The greater height of all species on ungraded banks on both sites was only barely significant 3 years after planting, slightly more prominent at 5 years, and still more prominent at 10 years (fig. 2). If this trend continues, it is obvious that trees will attain merchantable size much earlier on ungraded than on graded banks, even on the coarser textured No. 7 spoil. Observations 17 years after planting appear to confirm this trend.

In earlier publications, I have pointed out the existence of two different conditions in some graded areas (Limstrom and Merz, 1949). "Cut" sections occupy the former position of ridgetops and have been greatly compacted by grading machinery, whereas "fill" sections occupy the former position of troughs between ridges and have not been compacted as much. Three years after planting, black locust on a "fill" section were 3 feet taller than those on a "cut" section. Because borers killed the tops of young black locust, it is not possible to show this contrast 17 years after planting. White ash planted adjacent to the black locust also grew better on the "fill" than on the "cut" section.

White ash, however, grew much better on the ungraded part of the area than on either "cut" or "fill" sections of the graded part. This is true on both the No. 7 and No. 8 study areas, even though growth of white ash on the No. 7 area is slightly poorer than on the No. 8 area.

White pine behaves much differently than white ash on the study areas. It grows much better on the No. 7 than on the No. 8 study area; the compact calcareous clays on the No. 8 area, especially on the graded part, are unquestionably not suitable for white pine. On the No. 7 area, height of white pine differs little from the graded to the ungraded part.

In 10 years, height of yellow poplar differed significantly from the graded to

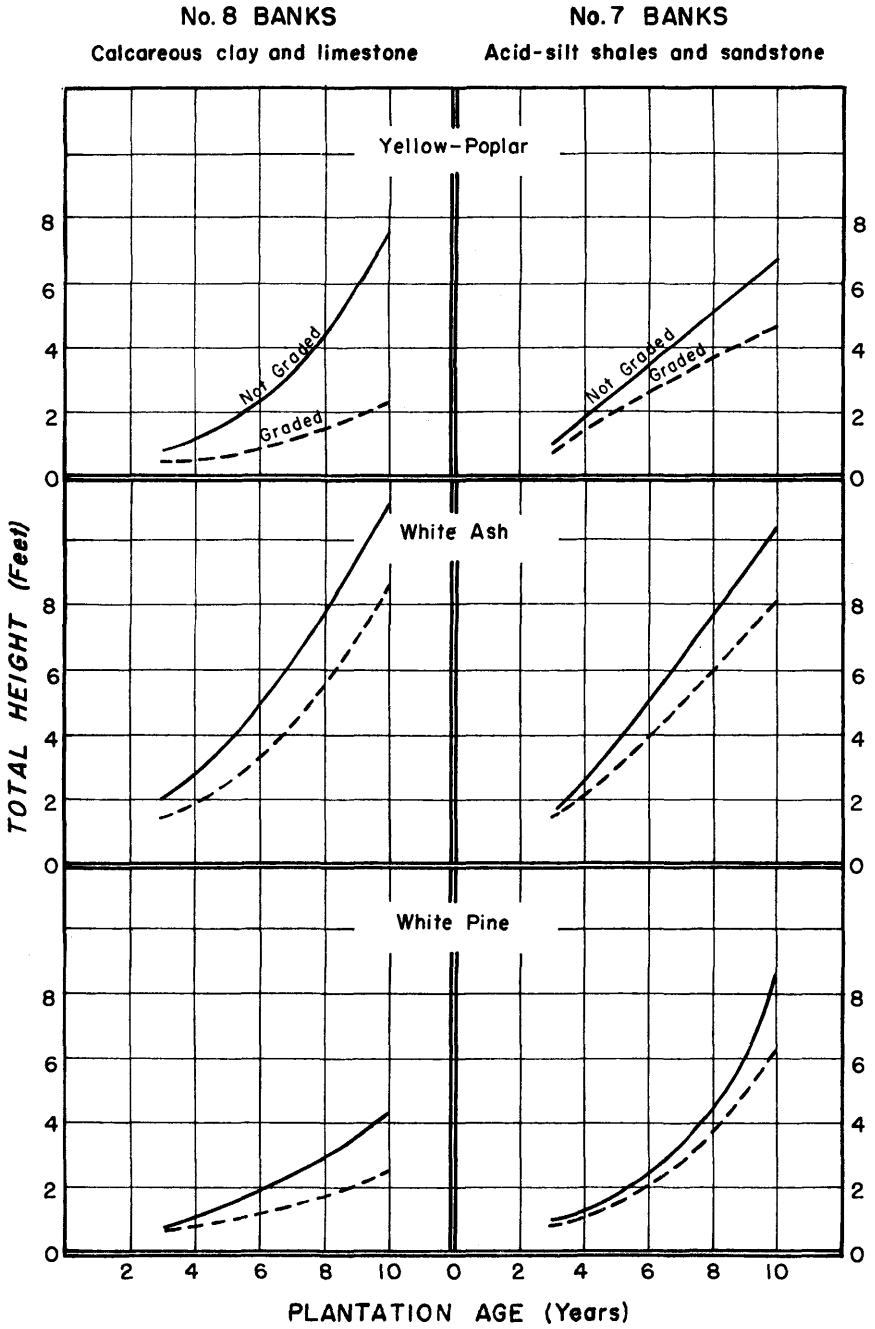


FIGURE 2. Growth on graded and ungraded strip-mine banks (from Raymond F. Finn, 1958).

the ungraded part of both study areas. Survival on the No. 8 study area was only 6 per cent on the graded part and 36 per cent on the ungraded part, whereas on the No. 7 area it was 72 per cent on both graded and ungraded parts. Despite its equally good survival on both parts of the No. 7 area, yellow poplar is much taller on the ungraded than on the graded part.

Vegetation

Most strip-mined areas to be planted are barren, but vegetation does exist on some of them at the time trees are planted. This can be both beneficial and harmful. If not too dense, natural vegetation helps protect seedlings from drying winds, improves soil conditions, and reduces losses from erosion. On the other hand, it competes with planted trees for moisture and nutrients. Depending upon the species to be planted, natural vegetation may permit the penetration of too little, too much, or just the right amount of light for good survival and growth. Its evaluation and control are therefore important in reclamation planning.

In site appraisals, two broad classes of vegetation are generally distinguished. "Ground cover" includes all weeds, grasses, shrubs, and tree seedlings, whereas "crown cover" includes only the larger trees. Only two classes of ground cover and three classes of crown cover need to be recognized in planting trees on strip-mined land. Ground cover may be either heavy, meaning that it completely shades or overtops 50 per cent or more of the planted seedlings during their first growing season, or light, if it completely shades or overtops less than 50 per cent. Crown cover should be considered "light" when it shades less than 10 per cent of the ground, "moderate" when it shades 10 to 75 per cent, and "heavy" when it shades more than 75 per cent.

Mortality and growth on sites with heavy ground cover will vary with the density and character of the cover, weather conditions, and species planted. Dense cover also encourages high rodent and rabbit populations.

Two near-by experimental areas in Illinois planted in 1947 demonstrate the effect of vegetation on survival (Limstrom and Deitschman, 1951). One area supported a sparse, light ground cover, the other a dense, heavy sweet-clover cover. The average second-year survival of 17 species was 61 per cent in the light, and only 27 per cent in the dense clover. The only species that survived well in the dense clover were white ash and eastern red cedar (*Juniperus virginiana* L.). The other species, all surviving better in light cover, were seedlings of black locust, cottonwood (*Populus deltoides* Bartr.), yellow poplar, loblolly pine, jack pine (*P. banksiana* Lamb.), eastern white pine, Osage orange (*Maclura pomifera* (Raf.) Schneid.), red pine (*P. resinosa* Ait.), shortleaf pine (*P. echinata* Mill.), silver maple (*Acer saccharinum* L.), Virginia pine, pitch pine, sweet gum (*Liquidambar styraciflua* L.), and both seed and seedlings of black walnut (*Juglans nigra* L.).

The character and density of crown cover and the species underplanted also influence the survival and growth of planted trees. Where the crown canopy is composed primarily of leguminous plants, such as black locust, these improve growing conditions by adding nitrogen to the soil. This is brought about by nitrogen-fixing bacteria associated with the root development of these species.

A dense overhead cover of any species, on the other hand, adversely affects the survival and growth of most species underplanted. The response to these environmental conditions varies according to the shade tolerance of the underplanted species and its nutrient requirements, particularly for nitrogen.

PLANTING PROBLEMS

After the site appraisal has been completed, detailed planting plans should be prepared. The most important problems to consider are proper selection of

species, planting methods, planting stock—quality specifications, and where needed, special measures for erosion control.

Selection of Species and Seed Sources

Selection of the proper source of seed as well as the proper species appears to be more and more important as new information becomes available. White pine, for example, may be suitable for several Ohio spoil types. But the performance of planted trees grown from seed whose origin is Quebec may be much different than trees from seed whose origin is West Virginia. Likewise, yellow poplar from a Mississippi seed source probably will be more susceptible to frost damage in Ohio than trees from locally collected seed.

The choice of species is also important. Resistance to insects and diseases should be considered; the susceptibility of red pine to the European shoot moth makes it a risky species for planting in Ohio. It is important to select species that will yield the desired products or fulfill desired objectives—lumber, pulpwood, Christmas trees, or erosion control. Both seed sources and species should be selected with the following three questions in mind: Is the species suitable to the planting site? Is the seed source or variety adapted to the local climate? Are the species and seed source suitable for the product desired? The planner should be guided by recommendations of research agencies and performance of the species in the same locality on sites similar to the one to be planted.

Planting Practice

Planting methods developed during the past two decades appear satisfactory. The bar and the planting machine should be used where they can be effective; where their use is not practical, the slower, costlier, mattock method must be used. Methods of establishing mixed plantations constitute a more vexing problem than planting methods. Some of the past errors include: using too much black locust in mixtures, mixing faster growing hardwoods with conifers, and mixing intolerant species with faster growing ones. Where mixtures are desired, but the relative tolerance and growth rates of the different species are not known, it is good practice to plant each species in small groups or blocks.

European alder appears promising for mixed planting and for soil improvement (Funk and Dale, 1961; Lowry et al., 1962). Comprehensive trials are now under way to learn the best source of this species, a source that will produce a suitable "nurse tree" as well as a merchantable crop. Many other species of alder are also being tried.

Except for walnuts and acorns, we have not had much success with direct seeding on strip-mined land. On these exposed surfaces, light seed is usually blown away or, especially on loose banks, washed down slopes and buried too deeply by siltation.

Our standard spacing recommendation for planting on strip-mined land is 7 by 7 ft. Where erosion control is a prime objective, a 6- by 6-ft spacing is permissible. In regular forest planting, the recent trends are toward spacings wider than 7 by 7 ft.

Planting Stock

It has long been known that one of the most important phases of the planting operation is the proper care of planting stock. Plans should include definite precautions against tree roots drying out between lifting in the nursery and planting. The quality is also important; specifications for planting stock of species commonly planted on strip-mined land have already been published (Limstrom, 1960).

Erosion Control

The susceptibility of newly strip-mined land to erosion depends chiefly on

topography and physical characteristics of the soil. As slopes increase in length and steepness, erosion also increases. Sandy and silty banks are eroded more easily than banks composed chiefly of clay. Stone on the bank surface reduces erosion from raindrop splash. The importance of texture and aggregation has already been mentioned; single-grain or granular materials erode much more easily than cloddy materials. Flat-bottomed, U-shaped valleys, so common between banks consisting mainly of soft shale, form primarily because of the ease with which soil particles and aggregates are washed down the slope.

Numerous planting experiments conducted on strip-mined land show that the washing away of soil from the roots of seedlings kills many trees on slopes, whereas siltation or smothering kills many trees in bottoms. Erosion, through washing, kills more trees on lower than on upper slopes. Siltation in bottoms is more likely to kill conifers than hardwoods, so planting of conifers there should be avoided. Studies in Illinois showed that siltation caused serious losses among planted trees of several species of pine and eastern red cedar and that it buried black walnut seed too deeply for good germination. Of the species studied, black locust, ash, and cottonwood are least affected by siltation. But to be safe, no species should be direct seeded where much siltation is apt to occur.

Some hardwoods grow poorly on banks flanking silt-covered bottoms. This may result from severe exposure of roots, "soil" being too shallow for root development, limited nutrients, or loss of more soil-sized particles in erosion than are gained in weathering. On areas susceptible to severe gullying, increasing the amount of black locust or alder in mixed plantings may be helpful.

Although trees are a good means for the permanent control of erosion, shrubs, grasses, or legumes may be more effective for quick control on easily eroded slopes. Several species of grasses and legumes are suited to calcareous and mildly acid spoils. Except for trees, however, no suitable species or control measure has yet been found for strongly acid spoils.

SUMMARY

The success of strip-mine revegetation is influenced greatly by the composition of the basic materials, the way these materials are manipulated in mining and grading, site conditions after mining and grading, and planting techniques. Site conditions can be accurately appraised only after mining and grading operations are completed, and include such physical characteristics of spoil materials as texture and aggregation, spoil acidity, bank topography and presence or absence of grading, and cover. Major planting problems to be resolved include the choice of species, planting methods, planting-stock quality, and erosion control.

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