Woody Vegetation on Seven Strip Mine Spoil Banks, Spencer County, Indiana

A Thesis
Submitted to the Faculty
Of Saint Meinrad College of Liberal Arts
In Partial Fulfillment of the Requirements
For the Degree of Bachelor of Science

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INTRODUCTION

Coal was first discovered in Indiana along the Wabash River in 1736 and was noted on land surveys and maps as early as 1804.[1] Stripping coal outcrops by pick and shovel was recorded in 1812, and by 1840 roughly 3 tons were mined annually. With the opening of Indiana's first commercial shaft mine in 1850 coal production increased; 100 tons were mined in 1860. Figure 1 shows coal production up to 1971. Over 81,000,000 tons were mined by 1900 and 921,000,000 tons by 1950, with production peaks occurring during the world wars. Coal reserves within Indiana in 1965 were estimated to exceed 33,000,000,000 tons, more than half recoverable. In 1973 it was estimated that these reserves would last 800 years at the then current production rate (Wier 1973).

Only after World War I, with improved equipment and technology did surface mining acquire major significance. In 1915, 4% of the coal produced in Indiana was surface mined; by 1930, 33% of the annual coal production was surface mined; by 1970, 90%. With the petroleum shortages in the 1970's strip mining became increasingly important. By 1975 over 99% of the coal produced was mined at over 60 surface mines within the state.

[1]Some of the historical information presented in this introduction comes from descriptive brochures published by the Indiana Department of Natural Resources and current unpublished documents.

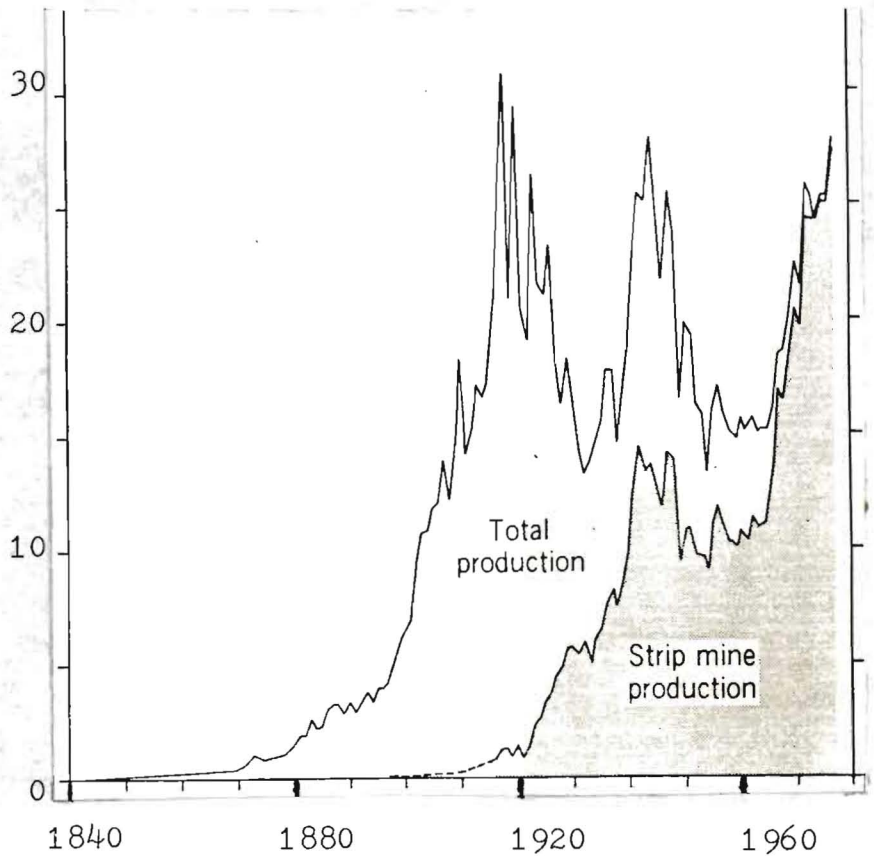


Figure 1. Graph showing the total coal production and total strip mine production in Indiana through 1971 (From Indiana Department of Natural Resources informational brochure).

As of June, 1981 over 135 surface mines existed in Indiana (Wier 1973; DNR 1980-81 Annual Report).

The economic advantages from strip mining are that coal can be more cheaply and quickly produced than by underground methods. Labor and insurance costs are lower, more and larger machinery can be used, and there is less coal wastage. Strip mining also eliminates mine ventilation costs and problems (Loring 1951).

Geographical and geological conditions favor strip mining in southwestern Indiana (Figure 2). Several coal seams lie 10 to 100 feet below gently rolling hills and plains, permitting the use of large machinery; preparation plants with convenient transportation routes can be placed at premium locations. The coal beds lie in strata of the Pennsylvanian Age, overlain by limestone, sandstone, clay and shale having large amounts of carbonaceous matter and a high sulfur content. They are flat deposits of unequal thickness that dip westward 20 to 30 feet per mile from the Illinois Basin's eastern margin where they outcrop, towards its center where they are deepest (Logan et al. 1922; Guernsey 1957; Wier 1973).

Strip mining involves cuts made through the overlying soil and rock to expose the coal seams. The soil and rock is removed and piled in parallel ridges and troughs from 100 to 300 feet wide and 100 to 1000 feet long (Bramble 1952; Guernsey 1957).

The resultant landscape is a hilly, barren terrain with

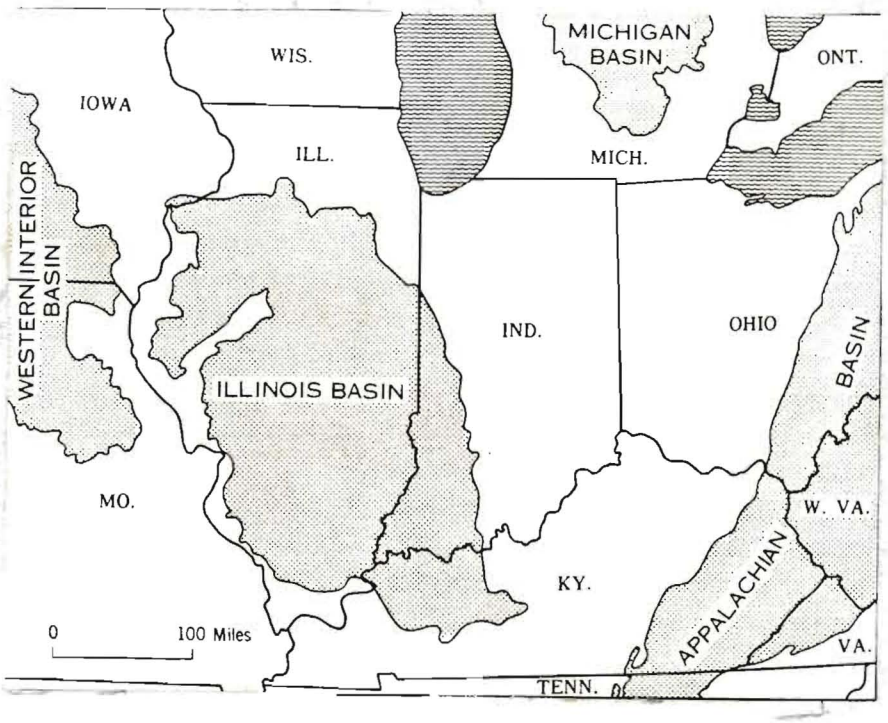


Figure 2. Map showing the Illinois Basin and adjacent basins in relation to Indiana. Strippled pattern shows approximate area underlain by coalbeds (From Coal Resources of Indiana, p. 4).

many lakes and ponds. The spoil banks are susceptible to severe wind and water errosion and suffer high moisture loss by solar evaporation. Soil content of the spoils is only 20% to 50% and acidic. The high acidity of spoils and water results from the production of sulfuric acid from the oxidation of pyrite and marcasite associated with the coal. Other problems at strip mined areas include acid drainage and sedimentation out of the area onto adjacent land or into streams (Bramble 1952; Guernsey 1964).

The natural reforestation of strip mined land is slow and provides an inadequate tree cover during the first twenty years following the mining. In cases where heavy timber stands do develop, trees are generally short boled and limby. Natural tree stands tend to be poorly distributed over the spoil banks (Guernsey 1957).

Tree planting solves many of the problems associated with natural reforestation. Unlike natural reforestation planted trees grow quickly and produce forest products including fence posts, mine props, poles, and Christmas trees (Guernsey 1957).

The Indiana coal industry's revegetation of strip mined land is the oldest continuous program in the country. Fruit trees were planted on spoil banks as early as 1918, and trees such as black locust in 1926. An organized reclamation program was initiated in 1928. Revegetation to commercial forest production and pasture land began about 1945 (Medvick 1970).

Until the late 1960's forestry was generally the preferred land use following surface mining. Studies as late as 1964

indicated that forestry was the most productive use of the largest percentage of Indiana land following surface mining. Trees hide unsightly lands quickly and provide an attractive cover, are often the least costly method of reclamation, and offer some marketable value. Reclamation for row crop remained small up to about 1970, but recently it has proven more economically profitable when the situation allows. During 1980-81 row crops accounted for 31% of land use permits issued for strip mined land; pasture and hay accounted for 44%, water impoundment and wildlife for 11%, and forestry for only 13% (Guernsey 1959, 1964; Medvick 1970; DNR 1980-81 Annual Report).

Determination of the tree species best adapted to strip mine reforestation has resulted from selectively planting species on spoils and observing their success at establishing themselves as permanent residents. Of the 16 conifers and 28 deciduous species originally planted in 1926, only jack pine, white pine, red and white oak, tulip poplar and black walnut are still planted. Additional species commonly planted today include sycamore, cottonwood, ash, soft maple, red pine, Virginia pine and pitch pine (Sawyer 1946; Medvick 1970).

In 1941 Indiana passed the first law in the United States requiring the reclamation of all strip mined land. Amendments in 1951 required that all reclamation occur under the administration of the State Forester's Office (Guernsey 1959). Indiana's 1967 Surface Mining Act prohibited the grade of reclaimed land to exceed 33 1/3%. It also provided that prior

to mining operators had to obtain a permit from the state and post a performance bond, as well as revegetate all disturbed areas following mining.

In 1977 Congress passed the Federal Surface Mining Control and Reclamation Act (PL 95-87) regulating surface mining across the country. The act banned surface mining on sites impossible to reclaim. By the act operators must grade disturbed land to its approximate original contour and return the land to equal or higher use. Individual states were required to bring their laws and regulations into alignment with the federal guidelines. Indiana is currently involved in the final stages of that process (Final Rules 1981).

The present study is concerned with the woody vegetation on ungraded spoils in an area strip mined nearly 40 years ago. Five pine species were planted on the spoils, and native hardwoods have invaded the area. The success of the coniferous and deciduous species now inhabiting this strip mined site near St. Meinrad College is examined. Baseline data on all woody vegetation, trees down to herbaceous-sized growth, on a limited number of permanently located spoils is examined.

Previous studies at this site concerned the physical and chemical features of the lakes and spoils (Coe 1972; Gladieux 1975), the phytoplankton and zooplankton of the lakes (Dougal 1975; Ernstberger 1975; Toth 1981), and the growth of certain tree species (Gill 1979).

MATERIALS AND METHODS

The study area, of about 150 acres, is located one and one-half miles east of Mariah Hill in Harrison Township, Dale Quadrangle, Spencer County, Indiana (T45,R4W, SW $\frac{1}{4}$ and NW $\frac{1}{4}$ Sec. 18): Figure 3. Near the eastern margin of the Pennsylvanian Zone, workable coal seams averaged three feet thick overlain by 45 to 70 feet of sandstone, clay and shale.

Surface mined from 1937 through 1942, pine reforestation occurred soon afterward on the spoils. Little modification has occurred at the site since the mining. Several large lakes are found within the study area and access roads to these lakes and to a permanent cabin have been made. Small lakes and ponds are scattered throughout the site. Low areas are flooded during spring and fall rains.

The spoils vary in size and appearance. Because this area was mined and reclaimed prior to the 1967 Surface Mining Act many spoil banks are steep sloped and peaked. The spoils range from approximately 20 to 700 feet long and 10 to 70 feet wide. A variety of native deciduous shrubs and trees is scattered among conifers on a majority of the spoils, along with a sparse cover of annuals and perennials. Some spoils are essentially barren, however, with almost no undergrowth. Sandstone, shale and coal are exposed on many spoils.

The field work was conducted from October, 1981 to March, 1982. Initially the area was surveyed and the major spoils

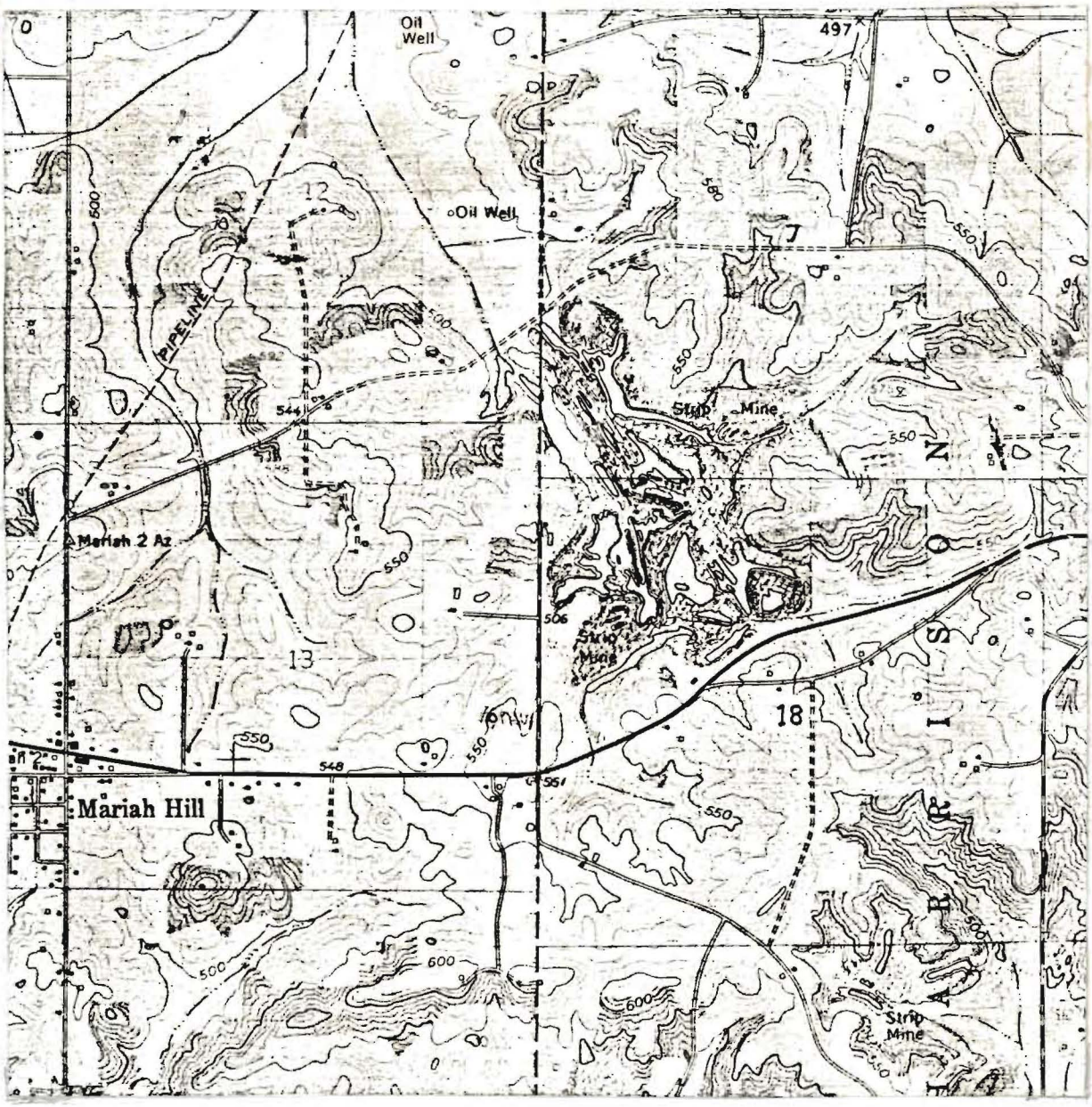


Figure 3. Topographic map of study area (Dale Quadrangle).

mapped. From these, seven spoils were chosen to represent a good cross section of the mined area and a variety of woody vegetation features. It was also necessary to select spoils with reasonably clear margins since they represent randomly shaped mounds of all sizes abutting one another. The irregular shape of the spoils made it impractical to measure their square footage.

So that this study could be repeated with reasonable accuracy some years from now, by definition, the edge of a spoil was taken to be the line at which the slope approached zero. Vegetation in the swale between adjacent spoils was not recorded.

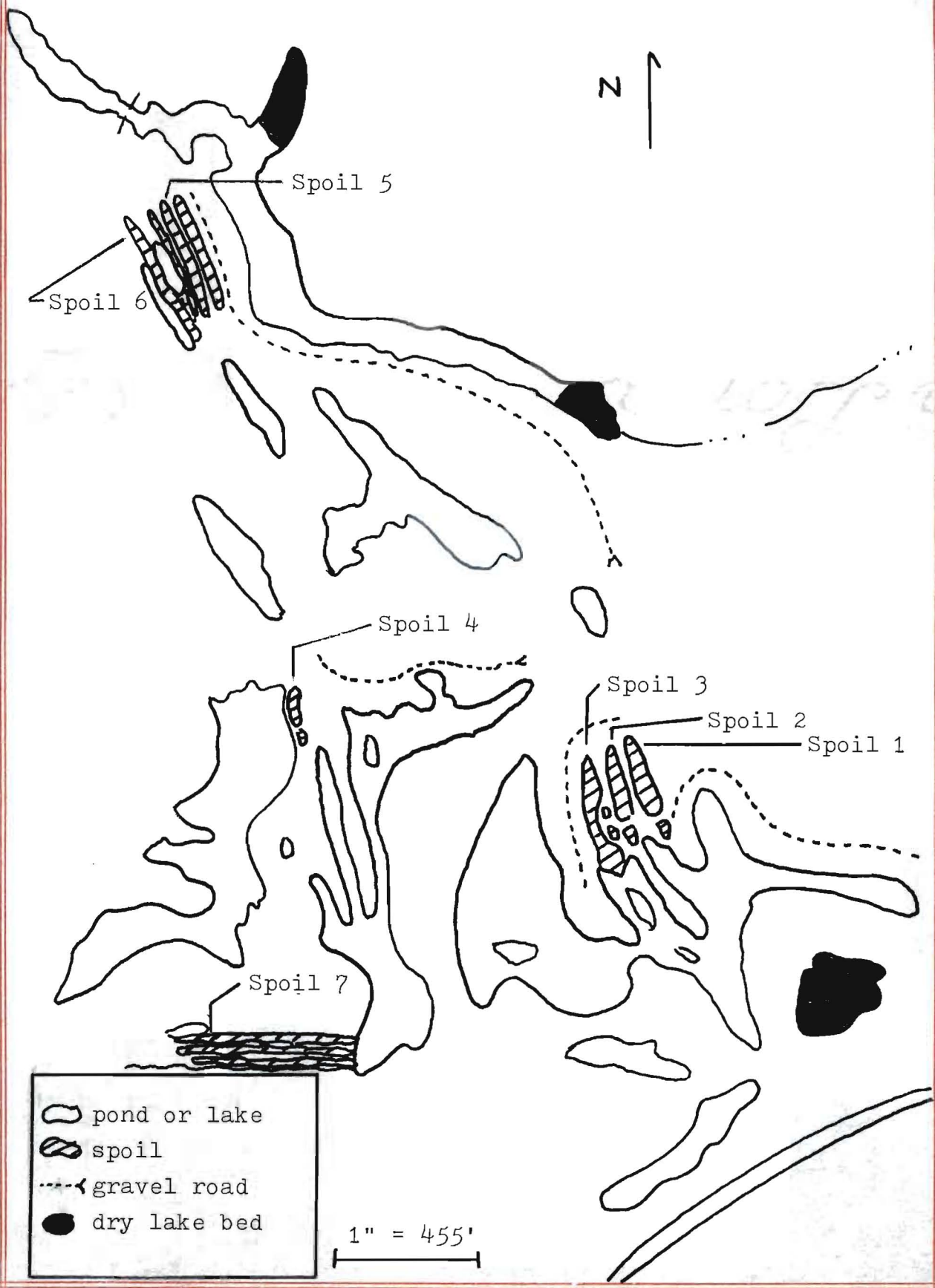
Figure 4 locates the spoil banks studied. Spoils 1,2 and 3 were steep sloped, 250-350 feet long and 30-75 feet wide. These three slopes were bounded by a grass clearing east of spoil 1 and a gravel road west of spoil 3. They were mostly covered with trees and reproductive growth, along with numerous annuals and perennials. The southern end of spoil 3, however, had little undergrowth and juts out into a lake.

Spoil 7 was similar in size and shape to spoils 1,2 and 3 but had little undergrowth. It was the third spoil north of a drainage ditch leading into a large lake.

Spoil 4 was 250-350 feet long and 10-30 feet wide; it was located along another lake's northeastern corner. On the east it sloped steeply to the lake; it was more rounded than the other spoils.

Spoils 5 and 6 were 450-600 feet long and 10-40 feet wide.

Figure 4. Detailed map of study area and spoils 1-7.


N
Spoil 5
Spoil 6
Spoil 4
Spoil 3
Spoil 2
Spoil 1
Spoil 7
pond or lake
spoil
gravel road
dry lake bed
1" = 455'

East of spoil 5 was a smaller spoil and a gravel road; 6 was the third spoil west of 5 and was bounded between two large ponds. Spoil 5 was covered with a variety of deciduous and coniferous growth along with annuals and perennials and showed the least water influence of any spoil studied. Spoil 6 was mainly barren of undergrowth of any kind, except on its southern third portion.

Pine and hardwood growth on the spoils was recorded in five different sizes:

1. Mature trees- $\geq$4" diameter breast height (dbh)
2. Small trees- 2-4" dbh
3. 15' trees- $<$2" dbh but $\geq$15' tall
4. Shrubs- $>$3' tall but $<$15'
5. Herbs- $\leq$3' tall

Individuals in the first three sizes were identified and recorded according to species on each spoil studied. A diameter tape was used to measure the dbh of every mature tree. Individuals in sizes 4 and 5 were recorded as occurring in rare, common or abundant categories, in the common sense meaning of these words: abundant species dominated growth in a size on the spoil; common species were often observed; and rare species vary sparingly occurred with never over six individuals on any spoil.

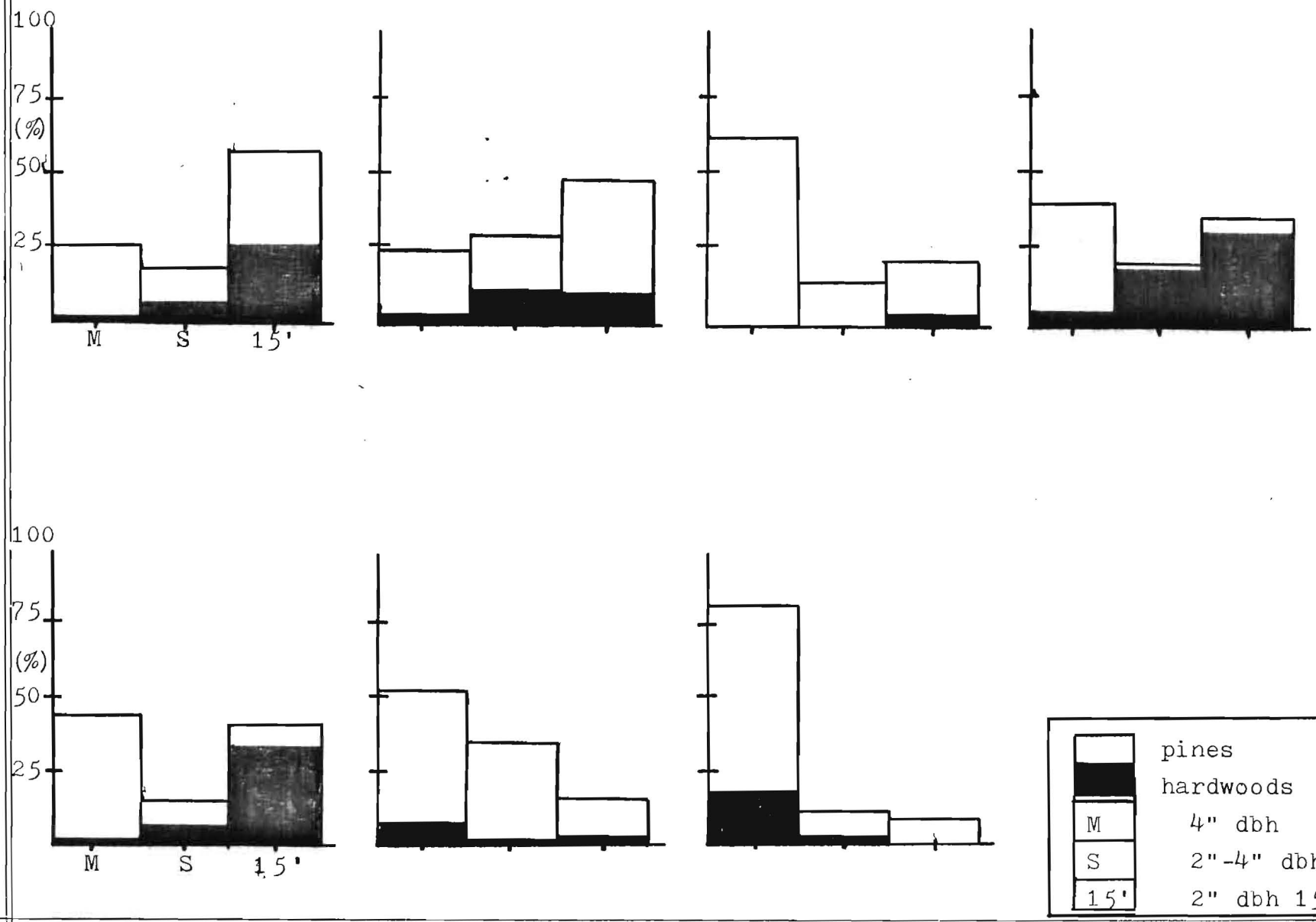
RESULTS AND DISCUSSION

Spencer County lies within the Oak-Hickory Association of the Eastern Deciduous Forest Region. Several oaks and hickories along with a variety of other deciduous species compose the climax stand. Pines are generally pioneer species, which are succeeded by the hardwoods. The expected growth pattern on the spoils studied is replacement of the planted pines by invading hardwoods (Jackson and Petty 1966; Vogel 1981).

Figure 5 presents data on the total number of individual woody trees found on each of the spoils in the three largest size categories. Since the acreage of the spoils was not determined, numerical data has been converted to percentages for purposes of comparing the spoils regarding 1) the distribution patterns among the three sizes, and 2) the differing behavior of pines and hardwoods. These percentage data are easily misleading. Figure 5 suggests that more mature trees were recorded on spoil 6 (51%) than on 5 (44%); actually, 131 trees were recorded on spoil 5 and 100 on spoil 6.

The normal pattern of growth in forests is that the total number of individuals decreases as plant size increases, as on spoil 2. The opposite seems to be occurring on spoil 3,6 and 7; as plant size decreases so do plant numbers. Closely planted pine trees on these three spoils have so effectively shaded the spoils' surfaces that only seedlings tolerant to shade can grow. Also, the pines planted have survived in

Figure 5. Comparison of the percentage of total woody plants represented in each of the tree size classes (mature trees $\leq$ 4" dbh; small trees 2"- 4" dbh; 15' trees $<$ 2"dbh $\geq$ 15' high) on each spoil.


100
75
(%)
50
25
M
S
15'
100
75
(%)
50
25
M
S
15'
pines
hardwoods
M
4" dbh
S
2"-4" dbh
15'
2" dbh 15'

greater numbers to larger sizes than on other spoils. Moreover, the lower portions of the three spoils were subject to periodic flooding and lie proximate to lakes and ponds. And for almost any spoil, the lower pH and deviciency of nutrients exert an influence difficult to assess.

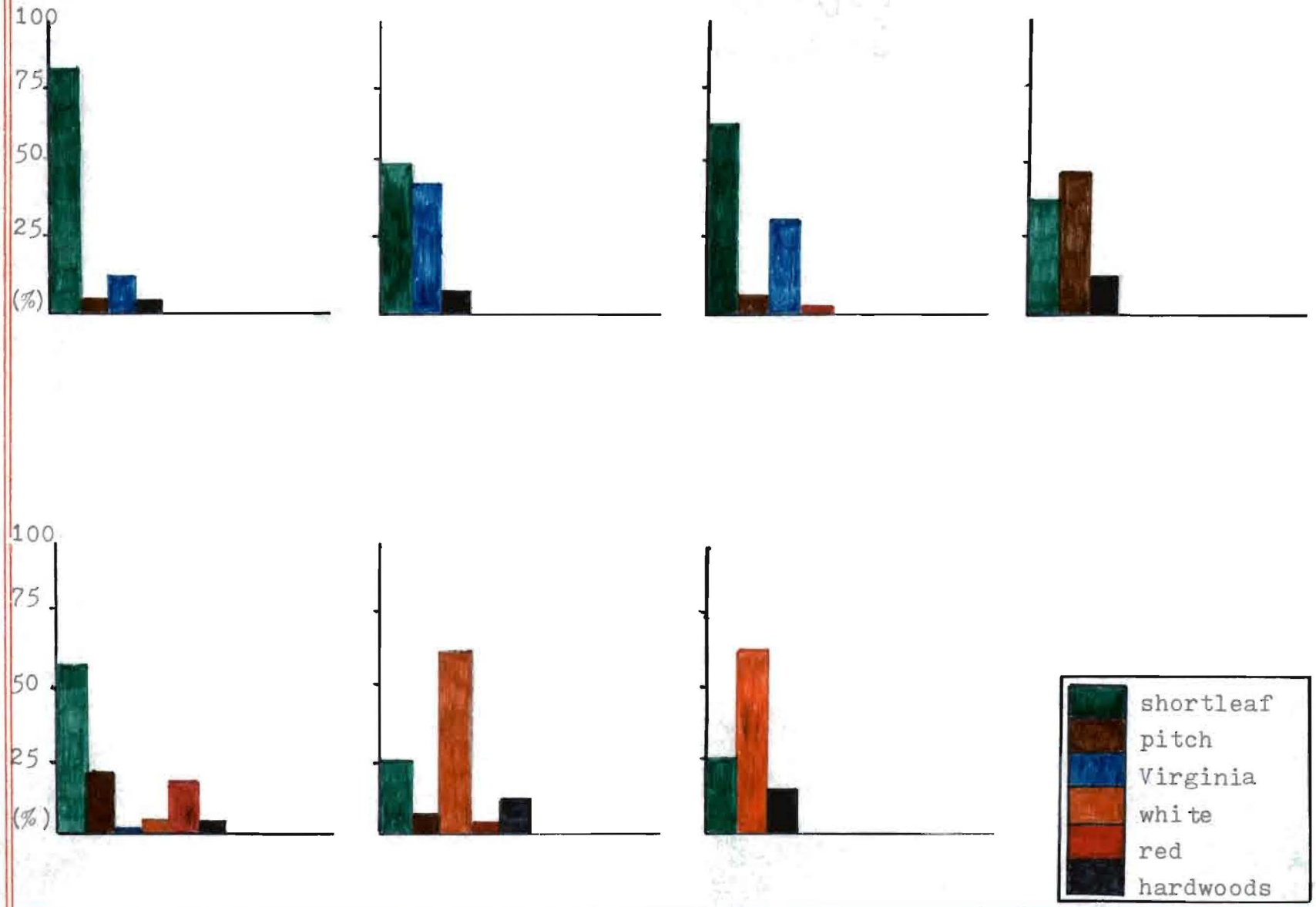
Hardwoods show varying degrees of success in establishing themselves on the spoils studied. The pattern of tree succession on spoils 1,4 and 5 appears to be that expected. Pines remain dominant, the hardwoods increasing in density and dominating spoils 4 and 5 in the smaller sizes.

Hardwoods are becoming established more slowly on spoil 2 and especially on 3; while spoils 1,4 and 5 each had over thirty-five hardwood 15' trees growing, both on spoils 2 and 3 fewer than eight 15' hardwoods occurred. Portions of spoils 2 and 3 had been heavily planted with Virginia pine; in these areas there was dense canopy coupled with a thick mat of needles. The same effect was apparent on 6 and 7; only four hardwood 15' trees occurred on 6 and none on 7.

Figure 6 and Table 1 illustrate the percentage composition of each of the pine species and all hardwoods lumped together in the mature tree (≥4" dbh) size. Figure 7 combines that percentage with the average basal area to illustrate the current impact of each. Figure 8 presents the maximum, minimum and average dbh.

Shortleaf pine was planted in considerable numbers on all seven spoils. In numbers and total impact it clearly dominated on spoils 1,2 and 3. It has not competed as well with white

Figure 6. A percentage breakdown of the mature trees (≥ 4" dbh) on each of the seven spoils by species.


100
75
50
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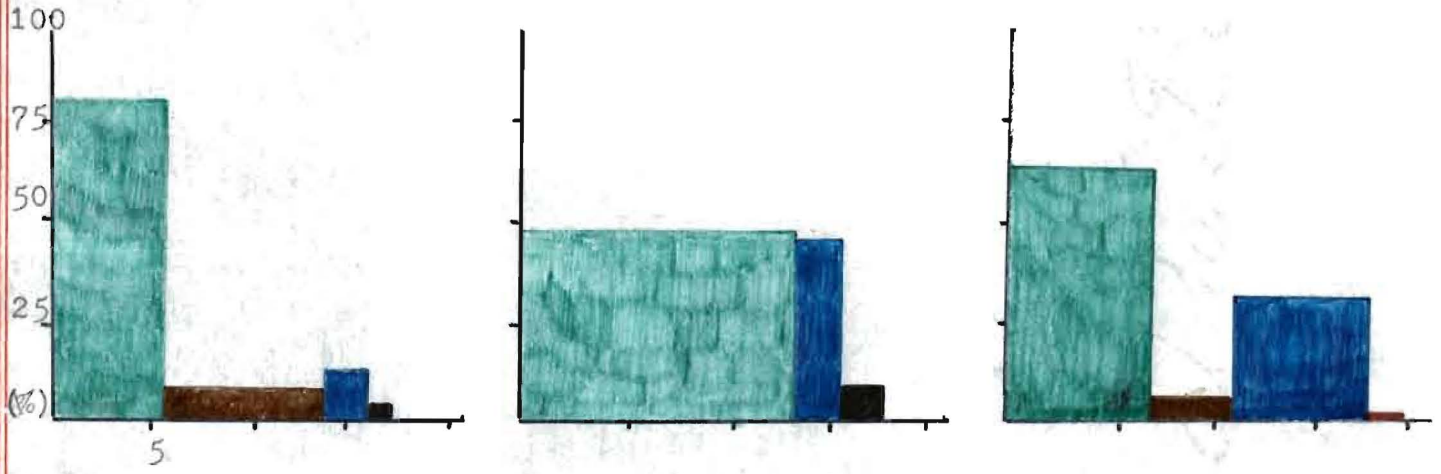
(%)
100
75
50
25
(%)
shortleaf
pitch
Virginia
white
red
hardwoods

Figure 7. Importance or impact of each pine species and the hardwoods together represented by the area of the bar: product of the percentage of the total number of trees (ordinate) and the average basal area (abscissa).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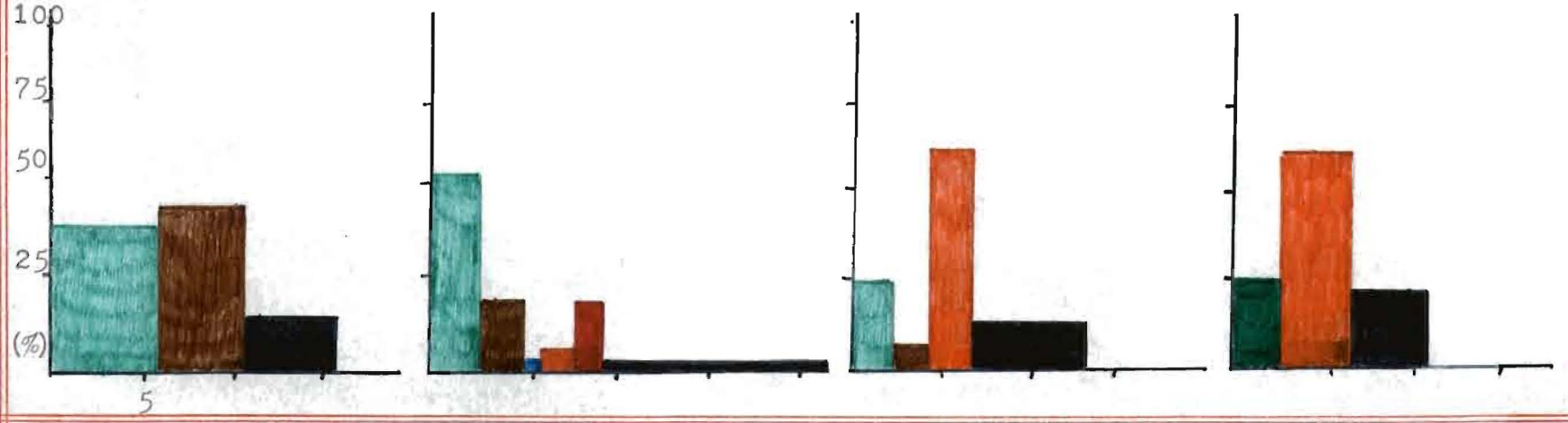
(%)
5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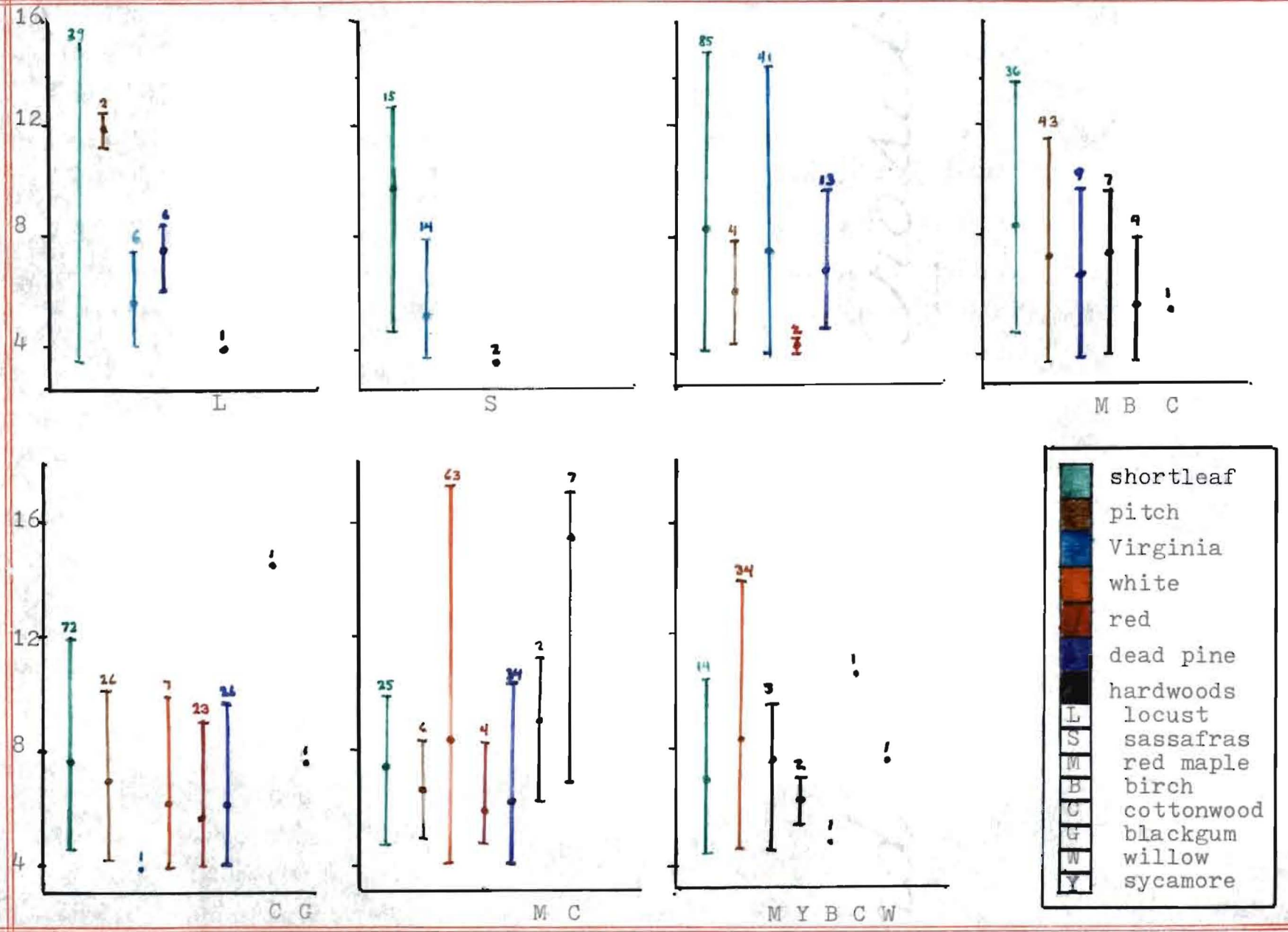
25
(%)
5

Figure 8. Maximum, minimum and average dbh values of each mature tree species.


16
12
8
4
L
S
M B C
C G
M C
M Y B C W
shortleaf
pitch
Virginia
white
red
dead pine
hardwoods
L locust
S sassafras
M red maple
B birch
C cottonwood
G blackgum
W willow
Y sycamore

pine on #6 and #7. It has grown well, to have the largest stems on most of the spoils. Some shortleaf has reproduced since the initial planting (note the small stems, 4" dbh). At the same time it had a high mortality rate on most spoils. Over 13% of the shortleaf on five of the spoils was dead. Age is not the factor for shortleaf's high mortality rate, for many dead trees were young. Flooding on spoil 6, disease and competition from other trees contributed to shortleaf's high death rate.

Table 1. Comparison of the percentage composition of the mature trees on each spoil by species

	Spoil number						
	1	2	3	4	5	6	7
Shortleaf	82	48	64	40	55	25	25
Pitch	4	----	3	47	20	6	----
Virginia	12	45	31	----	1	----	----
White	----	----	----	----	5	63	61
Red	----	----	1	----	18	4	----
Hardwoods	2	6	----	13	2	11	14

Pitch pine was planted on five spoils but most heavily on spoils 4 and 5. Fewer than six pitch pine remained on #1,#3 and #6, and only two old pitch remained on #1. Some reproduction occurred since the original planting on spoils 4,5 and 6 where there were some small trees.

White pine was planted on three spoils and dominated #6 and #7. White pine successfully reproduced itself in closely planted stands and outcompeted other pines where close stands of white occurred. White pine tolerated flooding better than

shortleaf on spoil 6.

Virginia pine had its greatest impact on spoil 3, where it must have been planted. It also had considerable influence on spoil 2. It was represented in the smallest tree sizes on these and two other spoils but was absent from the others entirely.

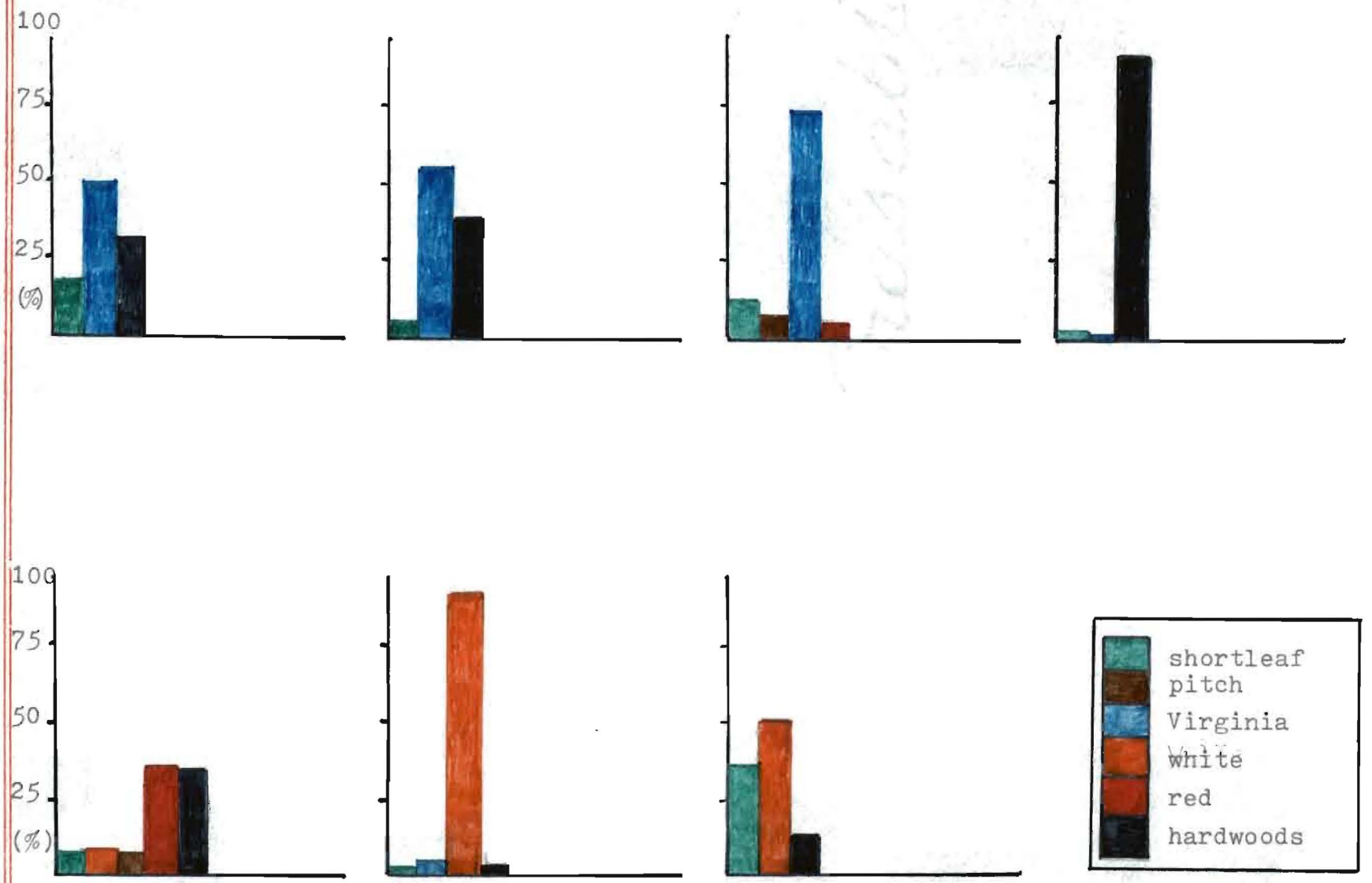
Red pine must have been planted along with several other species on spoils 5 and 6 and seems to have invaded #3 since the planting.

Few mature hardwood trees existed on the spoils studied. Only on spoils 4,6 and 7 was more than 10% of the tree population hardwood. Moisture appeared to be one deciding factor; the hardwoods on 4 and 7 and most on 6 all occurred on slopes proximate to bodies of water where birch and red maple were common species. Few hardwoods were found elsewhere, except for seven eastern cottonwoods on spoil 6.

The pines were less numerous in the small tree (2-4" dbh) size (Figure 9 and Table 2). Shortleaf occurred on all seven spoils but did not dominate on any spoil. So few small trees grew on #7 that those percentages are misleading. Pitch and red pine were not reproducing successfully. White pine again dominated spoils 6 and 7; many dead white were on #6. Red pine only grew on #3 and #5. Virginia pine, however, was successfully reproducing, especially on #1,#2 and #3. It apparently had invaded spoils 4 and 6 since the planting.

The hardwoods occurred in greater number in the small tree size, except on #3 where none were found. On five spoils more

Figure 9. Comparison of percentage of the small tree (2-4" dbh) composition represented by each pine species and by all hardwoods.


100
75
50
25
(%)
100
75
50
25
(%)
shortleaf
pitch
Virginia
white
red
hardwoods

than 10% of the small trees were hardwoods. The hardwoods were most numerous (93%) on #4. While the hardwoods on #6 and #7 were still confined mainly to water-facing slopes, elsewhere hardwoods were mixed throughout the spoils.

Table 2. Comparison of the percentage composition of the small trees on each spoil by species

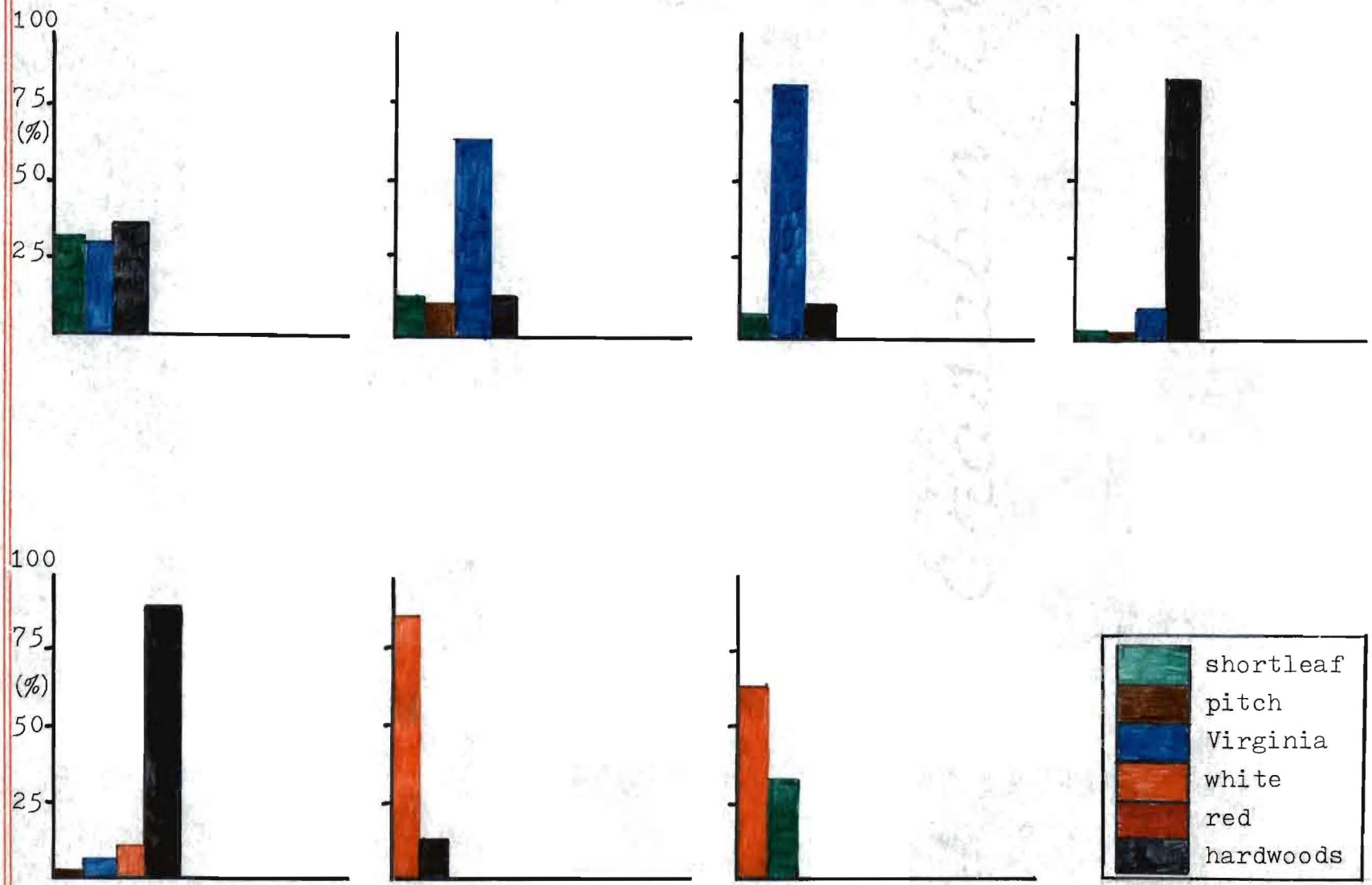
	Spoil number						
	1	2	3	4	5	6	7
Shortleaf	19	5	13	4	9	1	37
Pitch	----	----	6	----	9	----	----
Virginia	50	55	74	2	----	3	----
White	----	----	----	----	9	92	50
Red	----	----	6	----	37	----	----
Hardwoods	31	39	----	93	35	2	12

A greater hardwood variety was found in this small tree size; seven different species occurred in mature size while 17 different species were found in small tree size. Eleven species grew on spoil 4 and seven on #5. Some of the hardwoods found included commercially important red and white oaks.

Though more 15' pine trees (Figure 10 and Table 3) occurred than small trees (2-4" dbh), this number is deceiving. Only Virginia pine was numerous on most of the spoils, but it did not occur on spoils 6, where only two small trees of the species had occurred. It continued to dominate #2 and #3, and grew on #1 and #4. Unlike the other pines Virginia had significantly increased its number compared to the small tree size.

Shortleaf pine was absent on #5 and #6, and few were found except on #1 where many occurred, but hardwoods dominated the

Figure 10. Comparison of percentage of 15' tree (<2"dbh ≥15'high) composition represented by each pine species and all the hardwoods.


100
75
(%)
50
25
100
75
(%)
50
25
shortleaf
pitch
Virginia
white
red
hardwoods

spoil. Pitch and white pines each grew in small numbers on three spoils. No red pine was recorded.

Table 3. Comparison of the percentage composition of the 15' trees on each spoil by species

	Spoil number						
	1	2	3	4	5	6	7
Shortleaf	33	13	7	2	----	----	63
Pitch	----	10	----	1	2	----	----
Virginia	31	64	82	11	7	----	----
White	----	----	----	----	11	86	33
Red	----	----	----	----	----	----	----
Hardwoods	36	13	10	85	89	13	----

Hardwoods continued to increase in number on most spoils. The hardwoods occurred on all spoils except #7 where the dense white pine canopy generally prohibited undergrowth. They dominated #1,#4 and #5. Wetland species were less common in the 15' tree size than the larger tree sizes. The most common hardwoods were oaks (six spoils) and sassafras (five spoils).

White and shortleaf pine dominated shrubs (3'-15' in height) and herbaceous-sized (<3') growth on spoils 6 and 7 (Tables 4 and 5); the tree canopy shaded these spoils to such an extent that little undergrowth of any kind occurred. White and shortleaf occurred on the outer perimeters while hardwoods grew near ponds and lakes.

Elsewhere, Virginia and shortleaf appeared to be the most successful pines. Both were more numerous in the shrub than the herb sizes.

Hardwoods dominated spoils 1 through 5, and of the

hardwoods oaks were dominant. Red and shingle oak occurred on all seven spoils in good numbers. Both species of oak were more numerous in herb growth than in shrub size. Cherry and dogwood were two other common shrubs, though less so than the oaks. Poison ivy and honeysuckle were plentiful on most of the spoils, and in some cases the spoils were hopeless tangles.

Table 4. Comparison of the composition of the shrubs on each spoil by species in abundant (A), common (C), or rare (R) categories.

	Spoil number						
	1	2	3	4	5	6	7
Shortleaf	A	A	R	A	---	R	C
Pitch	---	---	---	A	C	---	---
Virginia	A	A	A	C	A	---	---
White	---	---	---	C	A	C	C
Red	---	---	---	---	---	---	---
Hardwoods							
Red Oak	C	C	C	A	A	R	R
Shingle Oak	C	C	C	A	A	R	R
Cherry	A	C	---	C	C	R	R
Dogwood	C	C	C	C	C	---	R
Sassafras	R	A	R	---	C	---	R
Red Maple	R	---	---	C	C	R	R
Sumac	R	R	C	C	C	R	---
River Birch	---	---	---	R	---	R	---
Cottonwood	---	---	R	---	---	---	---
Blackgum	---	---	---	---	C	---	---
Mulberry	---	---	---	---	R	---	---
Aralia	C	---	C	---	---	---	---
Pin Oak	---	---	---	---	R	---	---
White Oak	---	---	R	---	R	R	---
Cedar	C	---	---	R	R	R	---
Bittersweet	---	---	---	---	R	---	---
Alder	---	---	---	---	R	---	---
Buttonbush	---	---	---	C	---	---	---

Table 5. Comparison of the composition of the herbs on each spoil by species in abundant (A), common (C), or rare (R) categories.

	Spoil number						
	1	2	3	4	5	6	7
Shortleaf	A	A	---	A	---	R	C
Pitch	---	---	---	---	---	---	---
Virginia	A	A	C	C	A	---	---
White	---	---	---	C	A	C	C
Red	---	---	---	---	---	---	---
Hardwoods							
Red Oak	C	A	A	A	A	R	R
Shingle Oak	C	A	A	A	A	R	R
Cherry	---	---	---	---	C	R	---
Dogwood	---	---	R	C	C	R	---
Sassafras	---	C	---	---	R	---	R
Red Maple	---	---	C	R	R	R	R
Sumac	R	---	---	---	---	---	---
Honeysuckle	C	A	A	C	C	A	---
Poison Ivy	C	C	C	C	C	C	---
Cottonwood	---	---	---	---	R	---	---
Ash	---	---	---	---	R	---	---
Beech	---	---	---	---	R	---	---
Aralia	C	R	R	---	---	---	---
Pin Oak	---	---	---	---	---	R	---
White Oak	---	R	C	C	R	---	R
Cedar	---	---	R	R	R	---	---
Bittersweet	---	---	---	---	C	---	---
Hickory	---	---	---	---	R	---	---
Buttonbush	---	---	---	C	---	---	---
Grape	---	---	---	---	R	---	---

In general the pines were being outcompeted by the hardwoods as size decreased. Pines are successful pioneer species on mine spoils; they tolerate droughty acidic soils with low nutrient content (Vogel 1981). However, on the spoil banks studied in the newer growth pine is less significant.

The success of the different pine species in this study

reflects results of other studies. Of the five species Virginia pine has proven most successful in surviving and reproducing on Indiana spoils; it grows well on very acidic and droughty soils. Virginia is intolerant to shade and eventually gives way to hardwoods (Preston 1961; Vogel 1981).

Eastern white pine also shows some success on Indiana spoils; it is moderately tolerant to shade and a fast grower upon reaching 15' small tree size. However, white pine requires a higher pH than Virginia and moisture laden soil (Vogel 1981).

Red pine is less successful on spoils than virginia or white pine. Red requires a higher pH and more moisture than both Virginia or white pine. It also requires shade during seedling stage and is susceptible to European pine shoot moth (Preston 1961; Vogel 1981).

Past studies have indicated that pitch and shortleaf pine are less successful on Indiana mine spoils. Shortleaf requires a higher pH soil than the other four pines and is intolerant to shade and flooding. Shortleaf competes poorly with hardwoods and is commonly succeeded by them. Pitch is also intolerant to shade and requires a less acidic soil than white or virginia pine. Like shortleaf pine, pitch competes poorly with hardwoods (Preston 1961; Vogel 1981).

The hardwoods show increased success on Indiana mine soils as time passes. Red and shingle oak dominate the hardwoods from the 15' tree through the herbs at the site studied. These oaks often invade older mine spoils where forest

reestablishment is occurring. Both oaks can grow on acidic sites and are moderately tolerant to shade. Red and shingle oak have proven to be two of the better performing hardwoods on mine spoils (Preston 1961; Vogel 1981).

Sassafras is a common hardwood small tree on the spoils. Sassafras is an indicator of poor sites; it is fast growing, very intolerant to shade and short-lived. Sassafras is a common pioneer species in Indiana succeeded by oaks and hickories. Eastern redcedar, another common shrub at the site studied, is similar to sassafras in silvical characteristics (Ammons and Core 1977; Vogel 1981).

Red maple, eastern cottonwood and river birch dominated the hardwood trees. Red maple tolerates wet to droughty conditions and commonly invades lake fronts where other hardwoods are prohibited. Red maple requires a less acidic soil than the oaks and has a low survival rate compared to other hardwoods on Indiana spoil (DenUyl 1955; Vogel 1981).

Likewise, river birch is well suited for poorly drained mine soils and can tolerate a more acid soil than red maple. River birch is outcompeted by other hardwoods on mesic and droughty sites (Preston 1961; Vogel 1981).

Eastern cottonwood is a rapidly growing hardwood and does well on upland spoils. Eastern cottonwood is intolerant to shade, however, and is eventally outcompeted by other hardwoods in an established forest (Preston 1961; Vogel 1981).

SUMMARY

The hardwoods were succeeding the pines on most of the spoils; only where there was a thick bed of needles and a dense canopy did the hardwoods fail to establish themselves. They dominated in the shrub and herb sizes.

Pitch and red pines both have not survived well and have reproduced poorly on the spoils; neither occurred at all in the herb size. Shortleaf pine was the dominant mature tree but had a high mortality rate and limited reproductive success. White pine dominated the woody vegetation in all sizes where it had been heavily planted; it showed limited success in invading other spoils. Virginia pine was successfully reproducing on most spoils; native to this area, it had invaded other spoils since the initial planting and was the dominant pine in the smaller sizes.

Shingle and red oaks dominated the shrub and herb sizes; they occurred in substantial numbers on every spoil studied. White oak was found in the shrub and herb sizes but was less plentiful. Sassafras was a common hardwood shrub. Honeysuckle was common, reducing portions of some spoils to hopeless tangles.

Hardwoods in the small tree and 15' tree sizes included red and shingle oaks, flowering dogwood, cherry and sassafras, along with a variety of other species. Mature hardwood trees were generally wetland species confined to lake or pond banks,

and included red maple and river birch. Some eastern cottonwood occurred on upland sites.

Future studies concerning woody vegetation at the site should focus on the success red and shingle oaks have in becoming the dominant mature trees. Secondly, the success white pine has in dominating and successfully maintaining itself on relatively barren spoils should be studied. Last, whether Virginia pine continues to reproduce on the spoils should be studied.

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APPENDIX

Species Found on Spoils

I. Evergreens

Juniperas virginiana	Northern red cedar
Pinus echinata	Shortleaf pine
P. resinosa	Red pine
P. rigida	Pitch pine
P. strobus	Eastern white pine
P. virginiana	Virginia pine

II. Hardwoods

Acer rubrum	Red maple
Alnus sp.	Alnus
Aralia spinosa	Devil's walking stick
Betula nigra	River birch
Carya glabra	Pignut hickory
Catalpa sp.	Catalpa
Celastrus scandens	Bittersweet
Cephalanthus occidentalis	Buttonbush
Cornus florida	Flowering dogwood
Fagus grandifolia	American beech
Fraxinus sp.	Ash
Lonicera japonica	Japanese honeysuckle
Morus sp.	Mulberry
Nyssa sylvatica	Blackgum

APPENDIX. Continued

Species Found on Spoils

Platanus occidentalis	American sycamore
Populus deltoides	Eastern cottonwood
Prunus serotina	Cherry
Quercus alba	White oak
Q. bicolor	Swamp white oak
Q. palustris	Pin oak
Q. imbricaria	Shingle oak
Q. rubra	Northern red oak
Q. stellata	Post oak
Rhus sp.	Sumac
Robinia pseudoacacia	Black locust
Salix sp.	Willow
Sassafras albidum	Sassafras
Toxicodendron radicans	Poison ivy