STATUS OF REFORESTED MINE SITES IN SOUTHWESTERN INDIANA RECLAIMED FROM 1988 TO 1995[1]

R. Rathfon, S. Fillmore, and J. Groninger[2]

Abstract: No attempt has ever been made to track the long term progress of reforested mine sites in Indiana following reclamation bond release. The purpose of this survey was to determine how well reforested mine sites in Indiana were performing in terms of values and services normally ascribed to native forest and what their future potential might be. Black locust (*Robinia pseudoacacia)* was the most abundant species on 68% of the surveyed sites and accounted for 45% of all tallied trees and shrubs across all sites. Many black locust stands are currently experiencing decline and dieback caused, in part, by the locust borer. Forty percent of stands approached unmined planted tree height growth rates, while only 27% approached stem diameter growth rates of stands on unmined sites. Most reclaimed mine sites had measured site quality indices below the poorer quality sites in the region's native forests. Overall stocking in the establishment phase of stand development appeared adequate for future commercial timber production on many of the study sites. However, the dominance of black locust stocking in many stands limits their future viability for timber production. Tall fescue and serica lespedeza along with naturally occurring goldenrod were the most common ground covers in surveyed tree plantings. With few exceptions the reclaimed mine sites in this study show very low levels of productivity for forest products and carbon sequestration relative to native forests of this region, even though stocking levels appeared to be adequate. This suggests that the current bond performance measurement of 450 trees/acre bears little relevance to long term forest productivity. The results of this survey should serve as a baseline to determine the extent to which recent and future changes in reclamation methods improve reforestation success while meeting the other mandates of Indiana's mining regulatory program.

Additional Key Words: reforestation, forestry, tree stocking, forest productivity, tree growth, carbon sequestration

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[2] R. Rathfon is Extension Forester, Purdue University, Department of Forestry and Natural Resources, Dubois, IN 47527, S. Fillmore is Fuels Management Coordinator, U.S. Bureau of Indian Affairs, Riverside, CA 92507, and J. Groninger is Associate Professor, Southern Illinois University, Department of Forestry, Carbondale, IL 62901
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Introduction

Current Indiana coal mine reclamation regulations require the maintenance of at least 182 living trees and shrubs per hectare (450/ac), as determined in the last year of a five year responsibility period, in order for coal companies to obtain final bond release (IC 14-34-10, IAC 310-12-5-65). However, the minimum stocking requirement for bond release does not necessarily equate to long term reforestation success. No attempt has ever been made to track the long term progress of reforested mine sites following bond release.

In 2002 and 2003 a joint research team from Southern Illinois University, Department of Forestry and Purdue University Department of Forestry and Natural Resources conducted a survey of surface mines reforested from 1988 to 1995. The purpose of the survey was to determine how well reforested mine sites were performing in terms of values and services normally ascribed to native forest and what their future potential might be. The survey results are presented within the context of 1) long term forest health, 2) viability of reforested mine sites as future contributors to local economies, and 3) the viability of reforested mine sites as producers of environmental assets. Specifically this survey:

1. Determined post-bond release tree and shrub composition of the sites
2. Determined post-bond release tree growth and growth potential
3. Quantified post-bond release tree stocking
4. Determined post-bond release ground cover composition
5. Estimated carbon sequestration potential of tree stands on reclaimed mine sites.

Methods

Study Area and Site Selection

Study sites were distributed throughout the Indiana coal basin in the west-central and southwestern portions of the state (Fig. 1). All study sites were located within the Wabash Lowland physiographic province where topography is flat to gently rolling. A total of 22 sites on 16 mines, constituting 323 hectares (798 acres), were inventoried with sites ranging in size from 2.4 ha to 28.4 ha (6 ac to 70 ac).

Sites were selected to represent the range of overburden removal and topsoil replacement techniques, ownership status, and geographic distribution associated with forest cover reclamations planted from 1988 to 1995 (7-14 years prior to the study). Overburden was removed via dragline (n=13), truck/shovel (n=6), or using both techniques (n=3). Topsoil was removed with scrapers on two sites. Topsoil replacement was accomplished via scraper/end dump (n=5), or scraper alone (n=16). End dump-bulldozer was employed on one site. Ownership at the time of the survey included state, company, and private individuals. While the entire Indiana coal producing region is represented, study sites were predominantly within the southern two-thirds of the study area, reflecting the concentration of mining activity there during the early 1990s. This study was not designed to quantify the number of sites originally reforested that still have trees on them. In fact, anecdotal evidence suggests that many reforested mine sites were subsequently converted by landowners to other uses following bond release.

None of these converted sites were included in the study.

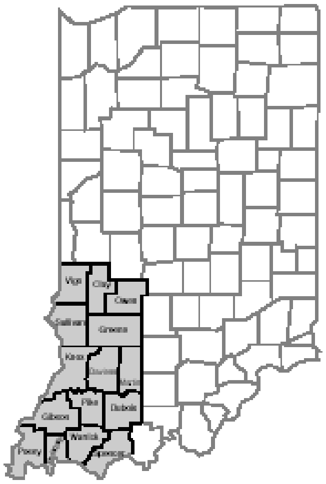

Figure 1. The coal mining region of southwest Indiana.

Sampling Methods and Analysis

Prior to inventorying, sites were evaluated for heterogeneity and size from the ground and using aerial photographs. Transects were established across sites in order to ensure complete coverage of a site and to capture variance in topography and/or species composition. Points were randomly located along transects and 0.00055 ha (1/735th ac) circular plots were established 10 m (33 ft) from points in each of the cardinal eight directions. A total of 1,280 plots were established across all study sites with a minimum of 32 plots at each study site. Sampling intensity increased as a function of site size and heterogeneity.

All trees within each plot were identified to species. No attempt was made to distinguish between planted trees and natural regeneration.

Height was measured to the nearest 0.15 m (0.5 ft). Additionally, diameter at breast height was determined for all trees >1.4 m (>4.5 ft) in height. Stocking of tree species followed standards for even-aged upland hardwood stands (Gingrich, 1967; Roach and Gingrich, 1968). Within each plot, all non-arborescent plant species were identified. Percent cover was recorded for all species constituting >10% of cover.

All site index estimates were based on black oak at a base age of 50 years (Carmean, 1971). Carbon sequestration estimates for bolewood utilized a conoid volume equation (Avery and Burkhart, 2002). Wood volume to carbon sequestered conversions assumed a carbon to dry wood yield ratio of 0.46 (Marland, 1988).

Although outside the scope of this survey, a limited attempt was made to collect soil bulk density and depth to hardpan data and relate this to tree growth and site productivity and overburden removal and reclamation techniques. The data collected was insufficient to develop cause-and-effect relationships, did not yield statistically significant results and thus are not discussed further. All analyses were conducted using the JMP statistical package (SAS Institute, Cary, NC).

Results and Discussion

Species Composition and Long-term Forest Health

Mine sites reclaimed and reforested from 1988 to 1995 and included in this survey were dominated by three woody species. Black locust (*Robinia pseudoacacia)* was the most abundant species on 15 of 22 (68%) sites (Fig. 2). It accounted for at least 25% of tallied stems on over ¾ of the sites, at least 50% of the stem tally on nearly ½ of the sites, and around 75% or more of tallied stems on five of the sites. It accounted for 45% of all tallied trees and shrubs across all sites (Fig. 3).

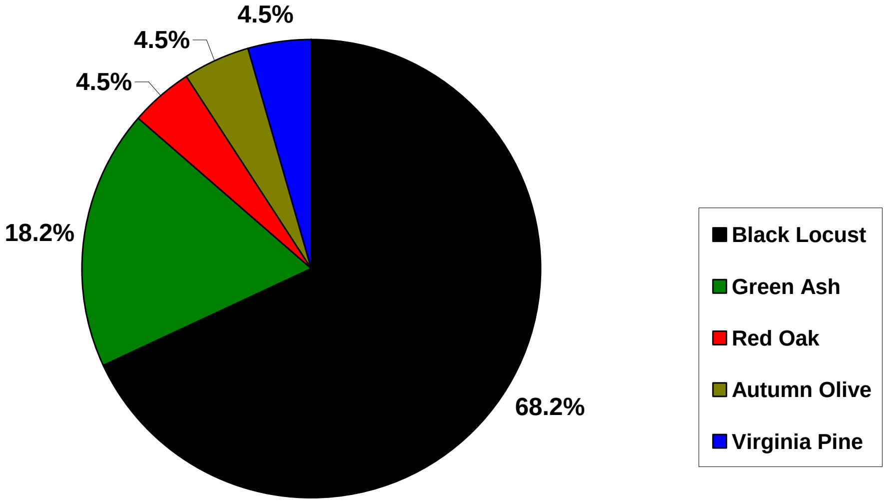

Figure 2. Percentage of sites dominated by tree and shrub species commonly planted on Indiana mines reclaimed from 1988 to 1995.

Green ash (*Fraxinus pennsylvanica*) dominated 4 of 22 sites (18%) and made up 14% of all tallied trees and shrubs. Autumn olive (*Eleagnus umbellatum*), a non-native shrub, was the third most abundant species planted. Forty-five other tree and shrub species comprised the remaining species. Together, three species, black locust, green ash, and autumn olive accounted for 2/3 of all stems tallied across all sites.

Individual sites exhibited different levels of species diversity. Two of the most recently planted sites (1995) contained 22 and 36 different species respectively. On the other extreme, two sites planted in 1991 were each dominated by black locust and contained only four species each. Throughout the surveyed period, with the exception of 1992, black locust dominated stand stocking (Figure 4). Only two sites reclaimed in 1992 and one in 1994 were surveyed.

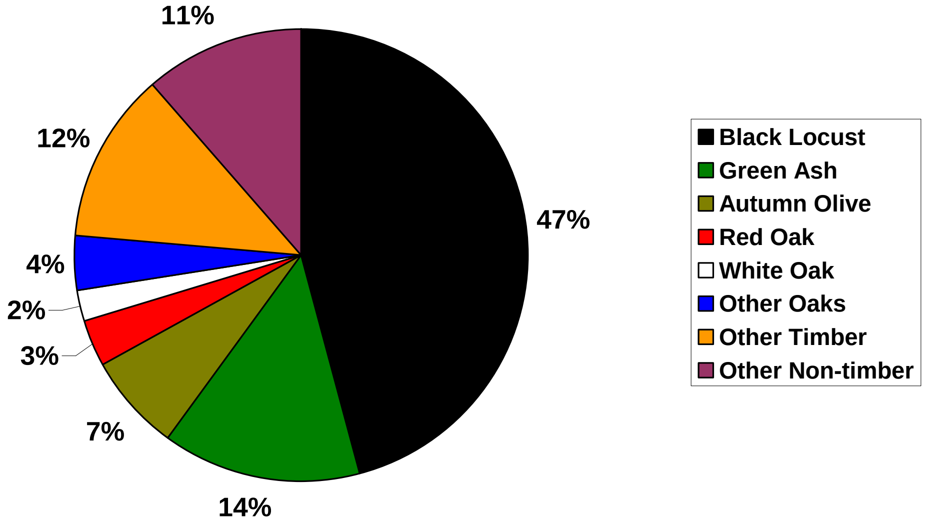

Figure 3. Abundance of trees and shrubs commonly planted on Indiana mines reclaimed from 1988 to 1995 as a percentage of the total number inventoried in the survey.

Although insect pest and disease data were not collected in this survey, observations of tree health conditions were noted. Black locust crowns, particularly on older plantings, were beginning to die back (Fig. 5). Black locust borer (*Megacyllene robinia*) severely damages black locust trees throughout southern Indiana.

Green ash may also prove vulnerable to insect and disease. Ash yellows (a mycoplasma like organism or MLO) (Sinclair and Griffiths, 1994) causes decline and slow death of ash trees. Recent introductions of the exotic emerald ash borer to Michigan and Ohio portend further trouble for ash trees should it spread to southern Indiana.

Many insect and disease outbreaks are merely secondary manifestations of environmental stresses on trees such as drought stress or flooded, saturated soil. Trees not adapted to the soils and inherent environmental stresses of a site more easily succumb to insect predation, disease, and to competition from other vegetation.

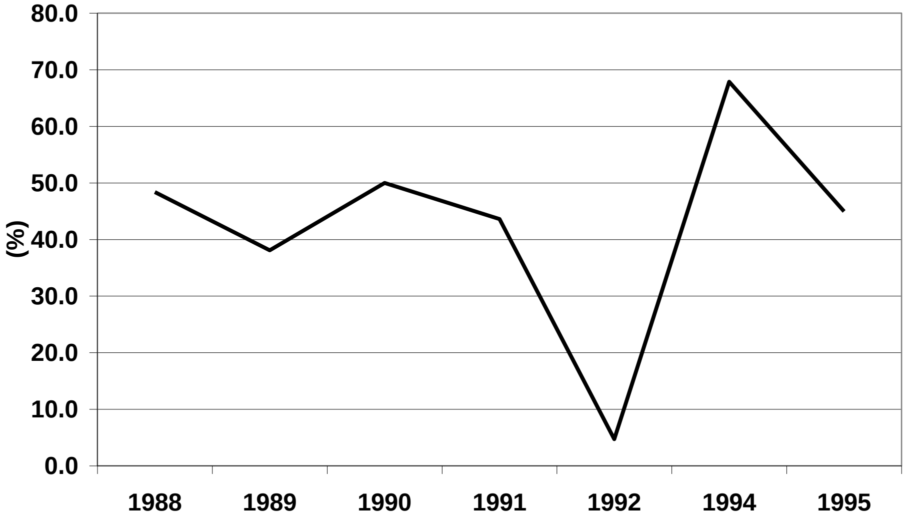

Figure 4. Percentage of total stems that were black locust on surveyed Indiana mines reclaimed from 1988 to 1995.

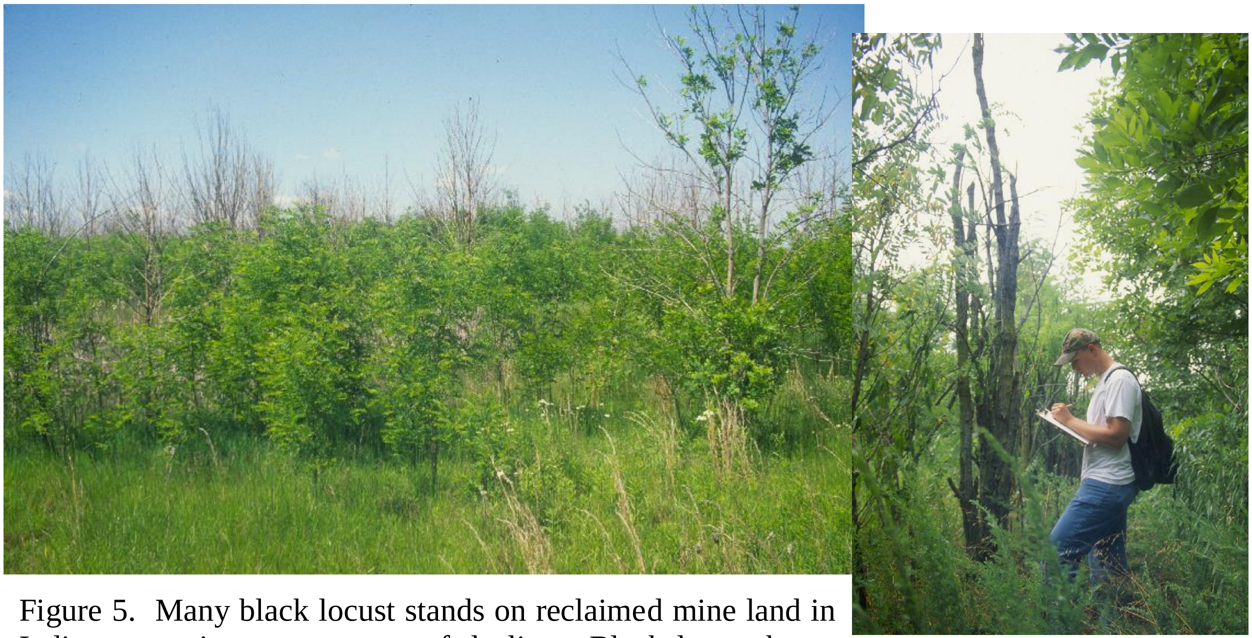

Figure 5. Many black locust stands on reclaimed mine land in Indiana experience symptoms of decline. Black locust borer severely damages its host.

Long term forest health is best achieved when tree species well-adapted to a site and its growing conditions are planted. Foresters in Indiana generally favor planting a variety of tree species that are well-adapted to the site being planted. Monocultures or plantings where a single species dominates are at greater risk of catastrophic loss to insect and disease outbreak and long-term chronic health problems.

In 1999, Indiana Division of Reclamation issued a recommendation that no more than 25% of the stand stocking requirement should be satisfied using black locust. Indiana state nurseries, along with private nurseries have more recently increased both overall seedling production and the number of species available. These two factors have contributed to a reduction in the proportion of black locust planted in more recently established reclamation plantings.

Viability of Reforested Mines as Future Contributors to Local Economies

Wood manufacturing is the fourth largest manufacturing industry in Indiana in terms of employment. It contributes over $3.5 billion value added annually to Indiana's economy and employs over 54,000 workers (Bratkovich et al., 2004). The wood industries are concentrated in the southern half of the state and are vitally important to many local economies. Thus there are strong local markets for timber in the coal producing region of the state. A primary contribution reforested mine sites would potentially make to local economies in the future would be the sale and supply of timber to local mills. In fact mines reforested in the mid 20th century have recently had timber harvested from them.

Foresters attempt to forecast the productive potential of forests for producing timber by observing 1) tree growth rates, 2) site quality, and 3) stand stocking.

Tree Growth Rates. Tree growth is measured directly as height and as diameter of the bole at 1.4m (4.5 feet) above the ground, or "breast height" (Dbh). Growth measurements of stands of different ages can be compared by dividing height or Dbh by the age of the trees to obtain a mean annual growth increment (MAI).

MAI for tree heights (excluding shrubs) ranged from 0.11 m/yr (0.37 ft/yr) to 0.58 m/yr (1.91 ft/yr), with a mean of 0.28 m/yr (0.91 ft/yr) across all sites (Table 1). Average stand heights ranged from 1.46 m (4.8 ft) in a 13 year old stand to 5.33 m (17.5 ft) in a 10 year old stand. The greatest height measured, 10.67 m (35 ft.), was attained by one individual of each of the following species: Black locust, green ash, sawtooth oak (*Quercus acutissima*), and Northern red oak (*Quercus rubra*). Dbh MAI ranged from 0.076 cm/yr (0.03 in/yr) to 1.24 cm/yr (0.49 in/yr) with a mean of 0.28 cm/yr (0.11 in/yr) across all sites. Average Dbh ranged from 1.14 cm (0.45 in) in the same 13-year-old stand to 8.71 cm (3.43 in) in a seven-year-old stand. The largest stem diameter measured in this study was a 21.34 cm (8.4 in) Dbh black locust.

Two 10-year-old white oak stands planted on un-mined old field sites in southern Indiana had MAI for height of 0.29 m/yr (0.95 ft/yr) and 0.70 m/yr (2.29 ft/yr), respectively (O'Connor and Beineke 2004). Stand MAI for Dbh for the same two stands was 0.48 cm/yr (0.19 in/yr) and 1.27 cm/yr (0.50 in/yr), respectively. Approximately 40% of surveyed mine site stands had MAI for height and 27% had MAI for Dbh within their respective ranges of the aforementioned white oak stands growing on un-mined sites. The remaining stands fell below the ranges observed on the un-mined sites. As black locust-dominated stands decline, MAI for height will likely decline relative to stand growth on un-mined sites due to lack of inter-tree competition.

Table 1. Summary of Tree Growth Measurements On Indiana Mines Reclaimed from 1988 to 1995.

Measurement	Maximum	Minimum	Mean	Median
Individual Heights (ft.)	35.0	0.5	10.0	17.8
Mean Stand Height (ft.)	17.5	4.8	10.6	11.2
MAI Height (ft./yr.)	1.91	0.37	0.91	1.14
Individual Dbh (in.)	8.40	0.10	1.26	4.25
Mean Stand Dbh (in.)	3.43	0.45	1.26	1.94
MAI Dbh (in./yr.)	0.49	0.03	0.11	0.26

Site Quality. Site quality refers to the influence of soils and other site factors on long term tree growth rates. Perhaps one of the best measures of site quality is the quantity of wood a site can produce over a given amount of time. This measure of site productivity is not possible for young stands growing on sites that do not have a timber harvest record.

Site index (SI) is the most common measurement of site quality used in forestry. The SI of a site is commonly measured as the height of the dominant, best growing trees when they are age 50. Equations have been developed allowing foresters to determine SI when trees are much younger and much older than 50 years old by simply aging the tree and measuring its height.

Tree height growth is sensitive to site quality and less sensitive to inter-tree competition than stem diameter growth. Thus SI becomes an easily-measured surrogate for all the site factors that influence tree growth. SI is commonly used in developing stand yield prediction equations and models.

Using black oak (*Quercus velutina)*, one of the most commonly occurring species in southern Indiana, as the standard, SI on surveyed sites ranged from less than 6 m (20 ft) to 20 m (65 ft) and averaged 12 m (40 ft) at the base age of 50 (Table 2) (Carmean, 1971). The median and the mode were both 9 m (30 ft). Within site variability occurred with one site averaging SI = 12 m (40 ft) but having small pockets of SI = 24 m (80 ft). Black oak site indices for un-mined upland sites in southern Indiana range from 12 m (40 ft) to 24+ m (80+ ft), with the average SI = 20 m (65 ft) to 21 m (70 ft) (Hannah, 1968). Low site indices (12 to 20 m) are usually associated with dry sites, shallow soil depth, slow growing trees, lower rates of stocking, and lower quality timber. Higher site indices (21 to 24 m) are associated with deep soils, good soil moisture, faster tree growth, higher stocking rates, and better timber quality. At the current stage of stand development, most sites fell well below the lowest site quality of local native forests.

Table 2. Summary of Site Quality and Stand Stocking Data of Indiana Mines Reclaimed from 1988 to 1995.

Site/Stand Characteristics	Maximum	Minimum	Mean	Median
Site Index (ft. white oak, base age 50 years)	65	<20	40	30
% Stocking	93	13	69.5	72.7
Density (trees/acre)	3,859	575	1,551	2,217
Basal Area (ft^2/acre)	78.3	1.4	25.6	39.9

<u>Stand Stocking</u>. Stocking of trees refers to the number of trees competing for a limited amount of space and resources (soil moisture, nutrients, and sunlight) in a stand. Forest stands can be understocked, fully stocked, or overstocked. Understocking occurs when the trees growing in a stand do not fully utilize the site's space and resources. Future profit potential is lost due to unutilized space and resources. Additionally, trees growing with too much space do not experience the competitive pressure they need to grow tall, straight, limb-free trunks that are most highly-valued in timber markets. Understocked stands result in trees with poor timber form and quality (Fig. 6).

Overstocked stands are overcrowded. There are not enough site resources to meet the growing demands of all trees present. The growth of large numbers of trees may be stunted, tree health may decline, and mortality occurs. Self-thinning will naturally occur in overstocked stands. Foresters usually prescribe timely thinning for well-stocked and overstocked stands to increase the growth potential and vigor of remaining trees.

Stocking guidelines have been established for the Central Hardwood Region forests (Roach and Gingrich, 1968). These guidelines are based on the average diameter of tree stems in a stand and the total number of trees per hectare. Foresters often measure stocking as a percentage of full stocking.

Surveyed stands ranged in stocking from 13% of full stocking to 93% of full stocking (Table 2). Four of the stands were considered understocked. None of the stands were overstocked while 18 out of the 22 stands were considered fully stocked (Fig. 7).

All stands still met or far exceeded the 182 stems/ha (450 stems/ac) bond release requirement. Tree and shrub densities ranged from 233 stems/ha (575 stems/ac) in an understocked stand reforested in 1992 to 1,563 stems/ha (3,859 stems /ac) in a 93% fully stocked stand reforested in 1990 (¾ of the stems were black locust, however). The mean number of trees and shrubs per hectare was 628 (1,551/ac).

Figure 6. In understocked stands, trees lack sufficient inter-tree competition needed to grow tall, straight, limb-free trunks that are most highly-valued in timber markets.

Figure 7. Understocked stands (left) may have well stocked pockets interspersed with understocked or un-stocked areas. The photo on the right represents good hardwood stocking on a reclaimed mine.

Basal area is a measure of stocking based on the collective tree trunk cross-sectional areas of a stand measured at breast height and expressed as m^2/ha (ft^2/acre). It provides a more accurate measure of tree use of space and resources than "trees/hectare". Basal areas in surveyed stands ranged from 0.3 m^2/ha (1.4 ft^2/ac) on the same understocked stand in the preceding paragraph to 17.9 m^2/ha (78 ft^2/ac) on a fully stocked mine reforested in 1995. Stocking of commercially marketable species is also necessary to produce a viable stand of timber. Black locust comprised

46% of the basal area across all sites while green ash comprised 15% (Figure 8). All oak species combined across all sites totaled 14% of the basal area with red oak comprising 5.9% of the total basal area. Other commercially valuable timber species made up another 14¾ % of the basal area.

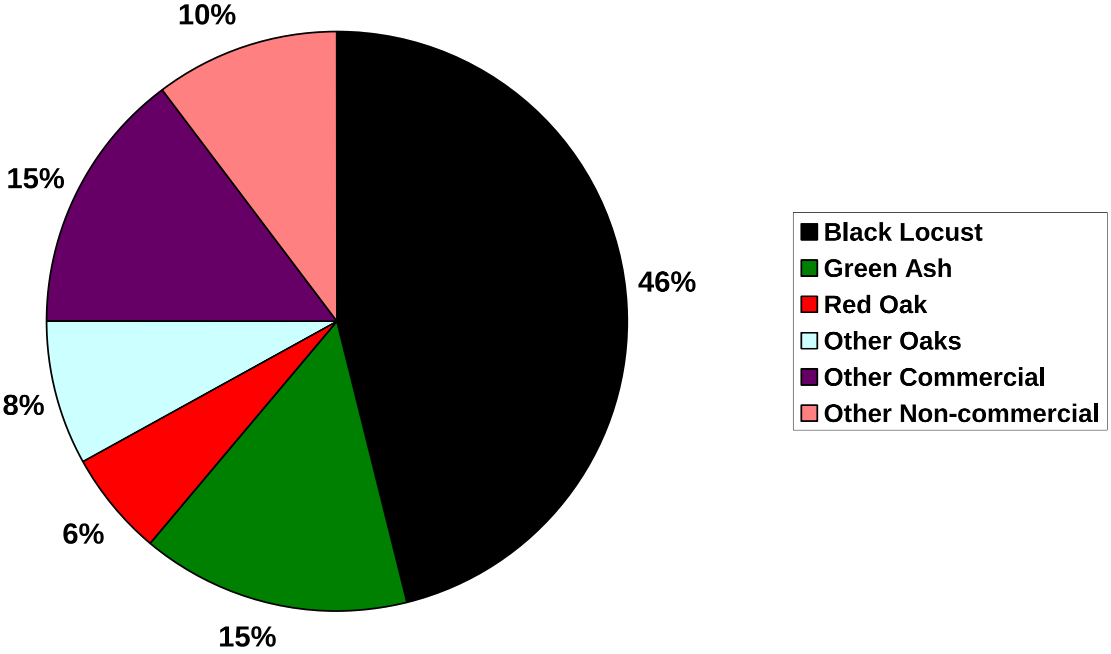

Figure 8. Percentage of basal area by species on surveyed mines in Indiana reclaimed from 1988 to 1995.

Black locust is generally not considered a commercial timber species in conventional timber markets. Its markets are currently limited to firewood, fence posts, railroad ties, and pallet stock. Quality green ash and oak command higher prices in local timber markets.

Viability of Reforested Mine Sites as Producers of Environmental Assets

Forests provide a multitude of environmental benefits. Reforested mines can provide environmental benefits in early stages of stand development with the use of appropriate groundcovers to control soil erosion, enhance water quality, and provide wildlife habitat. Groundcovers on reclaimed mines, if not carefully selected and managed, may adversely affect the growth and development of the newly established forest, thus delaying forest-specific environmental benefits. Reforested mines may also prove beneficial for sequestering atmospheric carbon.

Groundcovers for Watershed Protection and Wildlife Habitat. Forests protect watersheds and thus enhance water quality by preventing soil erosion and filtering polluted runoff. Forests also provide habitat for the majority of wildlife in Indiana. Surface Mining Control and Reclamation Act (SMCRA) regulations require the establishment of groundcovers to control soil erosion on newly reforested mines. Mine reclamation personnel select groundcover species primarily for their ease of initial establishment and their long term success of maintaining a dense covering which meets the requirements for bond release. Cost, availability of seed, and value as wildlife food and cover are also important considerations.

Kentucky-31 fescue or tall fescue (*Festuca arundinacea*) was the most common groundcover surveyed. It was present on 15 of the 22 sites. Where present it ranged from 19% of the groundcover on a site reclaimed in 1990 to 75% of the groundcover on a site reclaimed in 1995. Goldenrod (*Solidago canadensis*) was the second most common groundcover. Although not intentionally planted during the mine reclamation, it seemed to quickly invade and establish on many reclaimed mine sites. It was found on 18 of the 22 sites and where present ranged from 15% to 45% of the groundcover. Serica lespedeza (*Lespedeza cuneata*) was found on 10 of 22 sites ranging from 15% to 41% of the groundcover where present (Fig. 9).

Figure 9. Dense ground covers like tall fescue or the serica lespedeza pictured here control soil erosion but inhibit planted tree growth and prevent establishment of native vegetation.

Tall fescue and serica lespedeza were the groundcovers of choice for mine reclamation until recently. They were relatively easy to establish and provided rapid and reliable cover and erosion control. Tall fescue and serica lespedeza strongly compete with tree seedlings for water and nutrients. Recent research demonstrates that tall fescue releases allelopathic chemicals that further inhibit the growth of neighboring vegetation (Plass, 1968; Anderson et al., 1989). These species also have limited value as wildlife food.

As recently as 1995, tall fescue and sericea lespedeza were being established in tree plantings on reclaimed mines. On older sites the original groundcovers still persisted after 14 years. Tree crown closure was insufficient to shade them out. In the declining black locust stands, dense groundcovers will inhibit the establishment of native trees and shrubs that may seed in naturally (Bramble et al., 1990).

Burger and Torbert (1999) recommend a mixture of grasses and leguminous forbs sown at a rate that provides adequate erosion control throughout the tree establishment phase without severely competing with the trees. Further investigation is needed to develop tree-compatible groundcover recommendations for this region.

Carbon Sequestration. Recent public and scientific interest has focused on the role forests play in capturing and storing carbon dioxide, the chief greenhouse gas implicated in global warming. Within the electric utility and coal production industries interest has arisen over the use of reclaimed mine land and abandoned mine land for the sequestration of atmospheric carbon through reforestation (Kane and Klein, 2002). Before use of mine land for carbon sequestration becomes reality, basic questions of feasibility and profitability must be answered (Konrad et al., 2002).

Carbon sequestration by forests is a function of stand stocking and tree growth rates. These measures are in turn functions of site quality and management practices. Site quality, tree growth rates, and stocking were addressed previously. Additionally, species and timber quality determine the likelihood of stored carbon remaining in long term storage as durable wood products (furniture, buildings, etc.)

Mean annual carbon capture ranged from 0.009 Mton C/ha/yr (0.004 ton C/ac/yr) in a 10-year-old stand growing on a site with SI = <6 m (<20 ft) to 1.23 Mtons C/ha/yr (0.55 ton C/ac/yr) in a seven-year-old stand growing on a site with SI = 14 m (45 ft) (Appendix A). The average carbon capture rate across all sites was 0.29 Mton C/ha/yr (0.13 ton C/ac/yr) (Table 3). Younger stands, less than 11 years old, produced higher carbon capture rates than older stands. This reflects the higher site quality and tree growth rates of more recently reclaimed sites.

Table 3. Summary of Carbon Sequestration Estimate Data from Indiana Mines Reclaimed from 1988 to 1995.

Stand Characteristics	Maximum	Minimum	Mean	Median
Total Carbon, Mtons/ha (tons/ac)	8.71 (3.89)	0.09 (0.04)	3.05 (1.36)	4.48 (2.00)
Carbon Increment Mtons/ha/yr (tons/ac/yr)	1.23 (0.55)	0.009 (0.004)	0.29 (0.13)	0.63 (0.28)

Conclusions

Significant forest health problems currently exist in some forest stands surveyed in this study. Potential forest health threats exist for many other sites dominated by a single species. With few exceptions the reclaimed mine sites in this study show very low levels of productivity for forest products and carbon sequestration relative to native forests of this region, even though stocking levels appeared to be adequate. This suggests that the current bond performance measurement of 182 stems/ha (450 stems/ac) bears little relevance to long term forest productivity. Soil stabilization and erosion control were achieved in the short term through the use of aggressive groundcovers. Forest wildlife habitat development will likely be delayed.

Determining cause-and-effect relationships between specific reclamation practices and tree performance was not possible within the scope of this survey. However, the interpretation and implementation of SMCRA in Indiana has evolved and continues to do so. The improved productivity of some of the younger sites in this study reflects improvements in reclamation practices. Anecdotal evidence suggests that sites reclaimed more recently than those of this study show improved levels of productivity than older reclaimed sites.

Improvements in reforestation may be attributed to the following:

1. Improved soils handling including the mixing of A and B horizons and a shift away from the use of scrapers for topsoil replacement to that of end dumping and grading with dozers (Ashby, 1998).
2. Decreased use of black locust. Since 1999, Indiana Division of Reclamation has recommended that black locust comprise no more than 25% of the planting stock.
3. Decreased reliance on Kentucky-31 tall fescue and sericea lespedeza as groundcovers with a shift to more tree-compatible groundcovers (Burger and Torbert, 1992).
4. Improvement in tree planting methods and weed control. Heavy duty tree planting machinery has replaced hand planting and contractors experienced in mine land tree planting have improved initial seedling survival and establishment resulting in improved long term tree growth.
5. Increased availability of quality tree planting stock.

How much recent changes in reclamation practices may improve long term forest productivity is currently unknown. Stands reclaimed with newer technology are still too young to assess. The results of this survey should serve as a baseline to determine the extent to which recent and future changes in reclamation methods improve reforestation success while meeting the other mandates of the Indiana mining regulatory program.

Acknowledgements

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Appendix A. Summary of Site-Specific Data from the 2002 Survey of Mines Reclaimed in Indiana from 1988 to 1995.

Site No.	Year Reclaimed	Tract Size acres	Overburden Removal Method	Topsoil Replacement Method	Most[1] Abundant Tree	No.[2] Species
12	1988	11	Truck/Shovel	Scraper	Black Locust	6
17	1988	60	Dragline/Truck/Shovel	Scraper	Green Ash	6
18	1988	50	Dragline/Truck/Shovel	Scraper	Black Locust	8
11	1989	70	Truck/Shovel	Scraper/End Dump	Black Locust	5
15	1989	15	Dragline	Scraper	Virginia Pine	13
16	1989	59	Dragline	Scraper/End Dump	Black Locust	5
2	1990	40	Dragline/Truck/Shovel	Scraper/End Dump	Green Ash	8
3	1990	60	Truck/Shovel	End Dump/Dozer	Black Locust	5
13	1990	8	Truck/Shovel	Scraper	Black Locust	8
14	1990	9	Truck/Shovel	Scraper	Green Ash	8
1	1991	23	Truck/Shovel	Scraper	Black Locust	8
5	1991	26	Dragline	Scraper/End Dump	Black Locust	4
6	1991	6	Dragline	Scraper/End Dump	Green Ash	5
7	1991	59	Dragline	Scraper/End Dump	Black Locust	10
8	1991	48	Dragline	Scraper/End Dump	Black Locust	9
9	1991	28	Dragline	Scraper/End Dump	Black Locust	4
4	1992	6	Truck/Shovel	Scraper	Red Oak	6
10	1992	26	Dragline	Scraper	Autumn Olive	6
20	1994	23	Dragline	Scraper	Black Locust	6
19	1995	30	Dragline	Scraper	Black Locust	22
21	1995	38	Dragline/Truck/Shovel	Scraper	Black Locust	6
22	1995	104	Dragline/Truck/Shovel	Scraper	Black Locust	19

[1] As a percentage of the total stem count

[2] Comprising at least 1% of the total stem count

Appendix A (cont.). Summary of Site-Specific Data from the 2002 Survey of Mines Reclaimed in Indiana from 1988 to 1995.

Site No.	Year Reclaimed	Tract Size acres	Mean[3] Height -- ft.--	MAI Height ft./yr.	Mean Dbh - in. -	MAI Dbh in./yr.	Site[4] Index ft.	Trees Acre	Stock[5] Rate -- % --	Basal Area ft.^{2}/acre	Fixed Carbon tons/acre	Carbon Capture Rate tons/acre/yr.
12	1988	11	15.0	1.07	1.45	0.10	32	1,746	91	30.8	1.64	0.11
17	1988	60	10.4	0.74	0.97	0.07	30	1,310	81	15.7	0.88	0.06
18	1988	50	9.4	0.67	0.61	0.04	30	1,884	72	6.0	0.21	0.01
11	1989	70	11.4	0.85	1.14	0.09	30	1,333	78	18.7	0.96	0.07
15	1989	15	9.0	0.69	0.79	0.06	30	1,770	72	11.7	0.46	0.03
16	1989	59	4.8	0.37	0.45	0.03	35	758	13	12.6	0.71	0.05
2	1990	40	9.0	0.75	1.33	0.11	30	1,471	73	9.9	0.28	0.02
3	1990	60	11.3	0.94	1.30	0.11	30	1,103	53	11.4	0.55	0.04
13	1990	8	9.3	0.78	0.55	0.05	30	3,859	93	10.1	0.37	0.03
14	1990	9	14.2	1.18	1.54	0.13	32	1,379	81	31.2	1.74	0.10
1	1991	23	7.5	0.68	1.18	0.11	32	2,021	84	16.5	0.85	0.07
5	1991	26	15.1	1.37	2.29	0.21	30	1,080	69	36.0	3.21	0.29
6	1991	6	7.6	0.69	2.44	0.22	30	2,689	81	53.0	1.77	0.16
7	1991	59	8.8	0.80	1.36	0.12	30	919	62	7.7	0.32	0.02
8	1991	48	8.4	0.76	1.32	0.12	30	805	56	8.5	0.36	0.03
9	1991	28	16.3	1.48	2.46	0.22	30	1,287	81	59.5	3.50	0.31
4	1992	6	5.4	0.54	0.76	0.08	<20	575	31	1.4	0.04	0.004
10	1992	26	17.5	1.75	2.31	0.23	30	1,379	62	54.3	3.89	0.38
20	1994	23	7.3	0.91	0.88	0.11	40	1,802	65	21.9	1.01	0.12
19	1995	30	10.6	1.51	3.43	0.49	45	1,470	67	78.3	3.90	0.55
21	1995	38	13.4	1.91	1.66	0.24	45	1,657	84	42.3	2.09	0.29
22	1995	104	10.4	1.49	1.10	0.16	65	1,823	80	26.2	1.21	0.17

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[3] Height data excludes shrubs

[4] Black oak, base age 50 years (Carmean 1971)

[5] Roach and Gingrich 1975