FOREST PATCH RECLAMATION STUDY ON THE LOWER GREY CLOUD ISLAND[1]

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Abstract: Reclamation specialists are concerned about efficient and effective methods to revegetate landscapes disturbed by surface mining. Traditional reforestation approaches where trees are "lined-out" in plantation fashion, may not always be effective on dry, sandy, upland soils. Therefore, we conducted a study where we created a small forest patch, densely packed with woody plants and observed the expansion of this patch for 10 years (1983 to 1993). In addition, we compared the mortality of plants within the patch with "lined-out" plants. During our investigation, the patch doubled in area and the patch increased its perimeter to area ratio. Mortality for the "lined-out" vegetation was significantly greater ($p<0.01$). However, the development of the forest floor and the introduction to new plants species into the patch was slow. We estimate that the forest patch planting approach would generate woody vegetation cover across the landscape at a rate that was faster than the "lined-out" approach. We suggest that the patch design mitigated the adverse microclimate conditions associated with upland sandy soils, replicating a dry-mesic forest environment.

Additional Key Words: plant ecology, landscape ecology, landscape architecture, planting design, landscape horticulture, urban forestry

Introduction

Revegetating disturbed landscape surfaces in an efficient and effective manner has been a subject of great interest to reclamation specialists. Sand and gravel surface mining operations is one form of landscape disturbance that can generate xeric piles of excess sand that can be a challenge to revegetate. While these surfaces do not typically present toxic environments for plants, they often exhibit environmental stresses associated with droughty soils.

In this paper we present a case study located along the Mississippi River in Minnesota where a sand and gravel surface mine contains extensive hills of excess sand. We initiated a reforestation experiment by planting a xeric clump of densely packed woody vegetation and observed changes to the composition of this xeric clump for ten years. This paper presents our findings.

Numerous authorities have studied the implementation and development of woody plants on reclaimed surface mine landscapes, as illustrated by Ashby (1996), Beckett *et al.* (1995), Larson *et al.* (1994), Zeleznik *et al.* (1993), and Washburn *et al.* (1993). By starting with these studies and following with a literature/citation search, one can explore the fundamental knowledge base associated with establishing woody plants upon reclaimed sites.

In our study, a seminal work by Grime 1979 greatly influenced our initial effort. Grime described various plant survival strategies and influenced our thinking about the establishment of woody plants upon sandy upland soils. Trees planted alone amongst herbaceous vegetation seemed somewhat counter-productive to the survival of the woody plant. This led us to consider xeric clumps, where the vegetation is densely packed together (Sanders *et al.* 1982).

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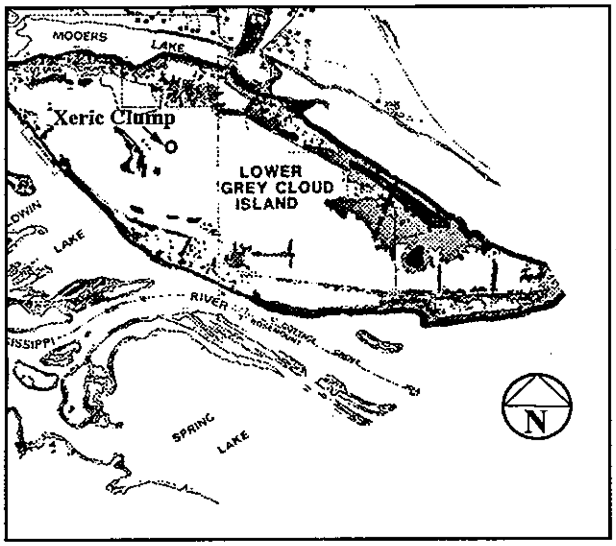

Figure 1. Location of the study area (Sanders *et al.* 1982).

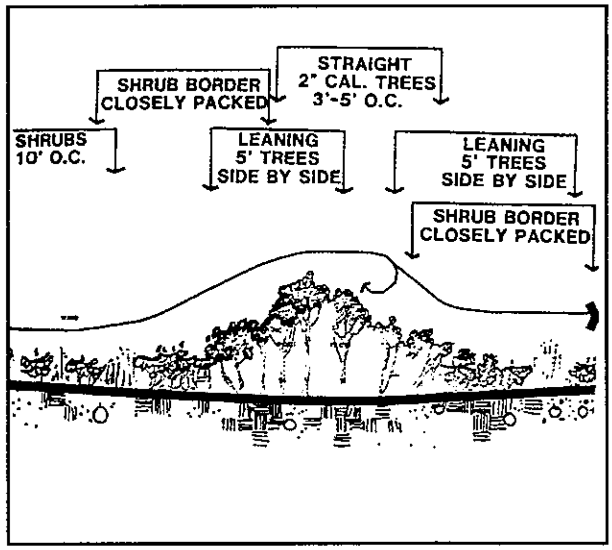

Figure 2. A cross-section of an idealized xeric clump (Sanders *et al.* 1982).

Study Area and Methodology

The study area is located in the south-eastern portion of the Twin Cities metropolitan area (Minneapolis/St. Paul) of Minnesota, along the Mississippi River (Figure 1). The Lower Grey Cloud Island is a deposit comprised of sand and gravel. The processed gravel and some of the sand is shipped by barge, up the Mississippi River to St. Paul, Minnesota for use in construction aggregates. As the island is mined, excess sand is placed to form large rolling hills above the 100 year floodplain to accommodate a post-mining land-use of housing. A series of lakes will be created surrounding the hills and adjacent to the river.

As the large hills are formed, these hills are revegetated with a seed mixture of herbaceous plants suitable to xeric Minnesota landscapes. However, the process of woody plants invading these xeric grasslands is somewhat slow. Woody plants are desirable on these rolling hills to add visual buffers as privacy screens between building sites and to add a woodland character to the landscape setting. On the island, in the undisturbed upland locations residing upon sands and gravels, southern xeric forest vegetation exists, defined by Curtis (1959). The vegetation is a dry southern xeric forest stand comprised predominantly of the oak savanna species bur oak (Quercus macrocarpa Michx.) and northern pin oak (Quercus ellipsoidalis E.J. Hill). Associated with these stands are Eastern red cedar (Juniperus virginiana L.) and sumac (Rhus sp.). In some of the more mesic locations, there are young American basswood (Tilia americana L.), elm (Ulmus sp.), black cherry (Prunus serotina Ehrh.), Manitoba maple (Acer negundo L.), green ash (Fraxinus pennsylvanica Marsh.), and around the forest edges gray dogwood (Cornus racemosa Lam.). These plants have been somewhat slow to colonize the newly formed sandy hills and seem best adapted to invading along the margins of the hills, spreading from existing stands. We believed that we could facilitate this expansion process by creating patches of these xeric woodland stands among the sandy hills (Sanders *et al.* 1982).

We proposed an experiment with several replications of xeric clumps (Figure 2) to assess the suitability of vegetation species, to assess the importance of creating slight depressions for the clumps, to assess the importance of monthly watering, and to assess the importance of mulching as a treatment. We also desired to install environmental monitoring equipment to assess the mitigating micro-climate effects of the xeric clumps. However, only one unreplicated xeric clump was created and environmental monitoring was reduced to gathering some soil temperature data, light intensity data, and measurements of vegetation response one time each year during late August.

The xeric clump and a control plot were installed in the spring of 1983 (Figure 3). They were examined each year in August through 1993, to form a 10 year study. The xeric clump did not precisely replicate a southern xeric forest stand, as many of the species represented in such a stand were not available from commercial growers. In the xeric clump, we installed 38 Manitoba maple, 9 green ash, 8 Eastern red cedar, 15 Siouxland cottonwood, (Populus deltoides Bart. ex Marsh. "Siouxland"), 15 amur chokecherry

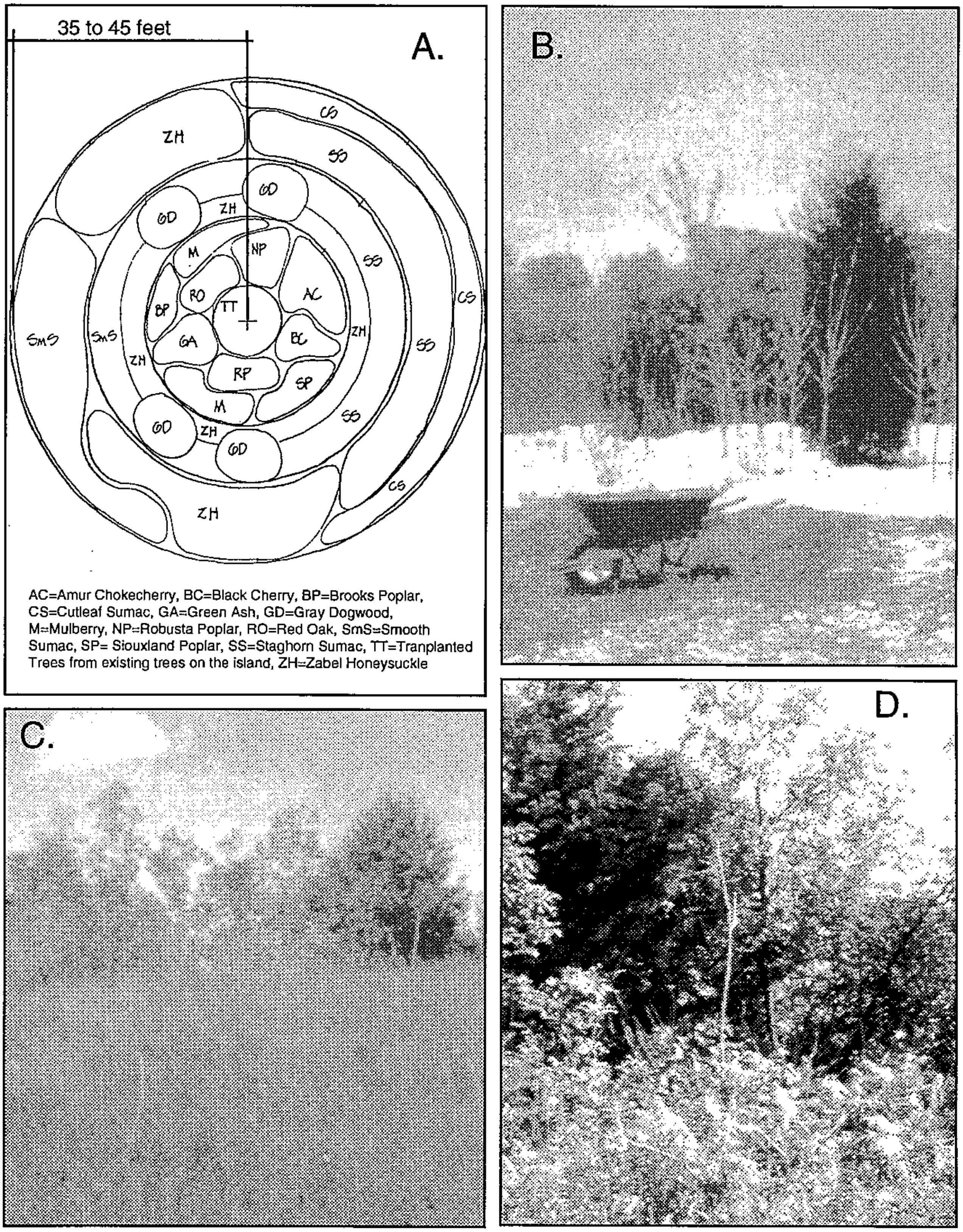

Figure 3. A-Adapted from an original 1982 schematic for a xeric clump (Sanders and Associates, Inc.); B-View of the 1983 freshly planted clump, looking north; C-Distant view of the clump in 1984 looking east;. D-Close-up view of the clump in 1992 looking east.

(Prunus maackii Thunb.), 5 black cherry, and 10 northern red oak (Quercus rubra L.). In addition several shrubs were installed encircling the trees: gray dogwood, honeysuckle (Lonicera sp.), smooth sumac (Rhus glabra L.), and staghorn sumac (Rhus typhina L.). The control stand was comprised of 15 smooth sumac and 5 green ash trees planted in the open grassland. Soil temperature 5 cm below the surface was recorded in the summer of 1984 and light intensity 5 cm above the soil surface was recorded in 1993. Diameter at breast height for saplings were recorded for each year from 1986 to 1993. The height of seedlings were recorded from 1986 to 1993 and the number of woody plant stems (new, older, fruiting and dead steams) for the sumac were recorded. The number of gray dogwood and honeysuckle plants alive, dead, and fruiting were recorded. New plants invading the site were located and identified and the boundary of the xeric clump was mapped.

We employed the chi-square test for homogeneity (Daniel 1978) to examine the difference in response between the green ash saplings planted in the clump and planted in the control and also for the smooth sumac plants installed in the clump and in the control. To form the contingency tables for this test, we used a 2 by 2 box with one degree of freedom, where the treatment (clump and control) formed one axis and the year (1983 and 1993) formed the second axis. For the year 1983 we recorded the number of stems/trunks for each vegetation type across each treatment and then placed the value of 100, representing 100% of the stems/trunks for each treatment. Then for the year 1993 we took the number of stems/trunks recorded, divided by the number of stems/trunks originally recorded to get a relative number of stems/trunks existing in 1993 for each treatment. We also created a two by two contingency table to examine changes in the patch shape where we tested changes in the area/edge ratio of the 1983 patch and the 1993 patch.

To establish a rate of change in area across the forest patch (xeric clump), we mapped the location of the patch and measured the area of the patch (dependent variable) from 1983 to 1993. Then we employed regression analysis of the dependent variable by using time (year from implementation) as a main effect term and as a squared term to see if the change in the area of the patch was significant over time.

Results

After ten years, there were only 40 percent of the green ash stems left in the control while there were 109 percent in the xeric clump. For the sumac vegetation there were only 93 percent of the stems remaining in the control and 549 percent in the clump. When the chi-square text for homogeneity was applied to the green ash plants and to the smooth sumac plants, the results in both cases were highly significant ($p<0.01$), indicating that the plants' responses to the xeric clump and the control were observably different.

In 1983 the forest patch was 0.115 acres in size, by 1993 the patch had grown to 0.259 acres. In 1991, the edges of the patch were mowed, generating the smallest recorded size for the patch of 0.088 acres. However, in 1992, the patch expanded to 0.218 acres. If the year 1991 were removed form the regression analysis, the predicted expansion for the forest patch would be expressed in Equation 1, (where the adjusted squared multiple R is 0.978, the overall regression is significant at $p<0.001$, and both regressors are significant at $p<0.001$). The derivative of this equation is presented in Equation 2, expressing the predicted rate of change for the patch.

$$\text{Area of Patch in Acres} = 0.121 + 0.001 * (\text{age of stand in years})^2 \quad (1)$$

$$\text{Rate of Change in Area of Patch} = 0.002 * (\text{age of stand in years}) \quad (2)$$

The expected area to edge ratio for the 1993 patch was 30; however the measured actual result was 15.7. In other words, the edge of the patch was almost twice as long as expected for a uniformly radiating patch. The patch approached an undulating "star-shape," with 9 protrusions, two additional new patches, and no holes. When the chi-square test for homogeneity was applied to the area to edge ratio, the results were highly significant ($p<0.01$), indicating that the shape of the patch had significantly changed pattern.

Several woody plant species increased in basal area. Green ash increased in basal area (cm squared) from 91.8 cm2 in 1986 to 279.6 cm2. There was no mortality recorded in these saplings and one new seedling was found in 1993. In contrast, amur chockecherry also increased in total basal area, from 105.4 cm2 in 1986 to 313.3 cm2 in 1993; however, four trees died from 1986 to 1993. The boxelder plants were all seedlings when planted and only one tree emerged as a sapling in 1988, yet by 1993, 21 of the boxelder plants had emerged as saplings with a total basal area of 270.4 cm2. Conversely, there were 13 cottonwood saplings in 1986 with a basal area of 1.44 cm2, but in 1993, there was only one plant left of sapling status with a total basal area of 8.0 cm2. All of the other sapling cottonwoods had died or were reduced to suckering stems less than sapling status. Red oak also suffered a decline from 5 live saplings in 1986 with 23.1 cm2 to only two samplings with 10.1 cm2 of basal area. Two seedlings from the red oak group were discovered in the 1990s. Finally, there was no mortality among black cherry saplings and they did not emerge as saplings until 1989. By 1993, their total basal area was 75.2 cm2. Two black cherry seedlings were found growing on the site in the 1990s. In addition, two riverbank grape (Vitis riparia Michx.) seedlings, one Virginia creeper (Parthenocissus quinquefolia (L.) Planch.), a few gray dogwood, and honeysuckle have been identified invading the site. No other woody plants have been observed colonizing the forest patch.

Soil temperature was recorded in August of 1983 and light intensity was recorded in 1993. Soil temperature within 20 feet of the forest patch center range from 70 to 71 degrees Fahrenheit. Soils at the edge of the patch ranged from 79 to 86 degrees Fahrenheit and soils beyond the patch ranged from 84 to 94 degrees Fahrenheit. The dark areas of the forest patch were found beneath Eastern red cedar trees. At these locations the light intensity was about 125 foot candles. Beneath the wood deciduous saplings, the light intensity was about 800 foot candles; while beneath the sumac bushes, the light intensity ranged from 800 to 1200 foot candles. Areas open to full sun, beyond the edge of the forest patch were exposed to 3000 foot candles.

Discussion

At the current rate of expansion, it appears that the forest patch will expand at a rate where the patch will double in size about every 10 years, becoming an acre in size by 2013 AD. In other words, we predict it would take 100 patches 30 years to cover a 100 acre site if the 0.125 acre patches were distributed across a 100 acres upland sandy site in an east-central Minnesota landscape setting. Simultaneously, a planting of the same vegetation per clump planted across a whole acre may result in no noticeable expansion and may even regress in coverage.

In some respects, taking 30 years for a 0.125 acre patch to cover an acre may seem somewhat slow. Nevertheless, we believe that this approach is much quicker than traditional approaches and certainly quicker than invasion by native plant processes. However, we expected greater dynamics within the forest patch. New plants have been slow to colonize the patch. None of the plants have reached tree size in 10 years of growth. The forest patch floor is still relatively uninhabited. Only the sumac are invading the grass and the saplings have yet to expand into the shrub border.

Creating a forest patch may seem counterintuitive to standard nursery practices where plants are arranged according to their anticipated mature size and thus the spacing of the plants typically is much less densely packed. Nevertheless, we believe that this packing structure of the forest patch enables the vegetation to modify the micro-climate of the planting area by providing continuous shade over the soil surface thereby reducing soil moisture loss directly from the soil. In 1989, a drought was recorded in the area. Soil trenches outside the forest patch revealed extremely dry sandy soils several cm into the soil profile while each trench dug within the forest patch exhibited a moist condition immediately below the wood mulch. During the winter and early spring, mine employees have noticed that a snowdrift formed over the forest patch. This snowdrift can slowly release water in the spring through the sandy, well aerated soils and thus increase the available moisture to the patch. In addition, the slight depression that the patch is placed into may also prevent some water from flowing away from the patch. The effects of each of these features to plant growth are unknown because of the one dimensional nature of this experiment. In the long term we believe that the stem density of the patch will be reduced and that only three or four of the saplings will dominate the current location of the patch, illustrating the concern for lost vegetation demonstrated by traditional planting design plans. Nevertheless, we believe that this packing plan affords the opportunity for the potentially dominating trees to obtain that position more quickly.

In 1990 the patch experienced a mowing. Edge shrubs were the predominant woody plants disturbed. With the exception of a few Manitoba maple seedlings, none of the seedlings or saplings were mowed. Meanwhile, several of the poorly growing tree saplings placed in the control area were finally eliminated. We believe that the strength of the forest patch idea lies in the fact that the patch, immediately from implementation, has always appeared as a substantial planting and thus is more protected from the landscape management cultural practices employed by individuals.

We also believe that the forest patch concept allows for vegetation diversity and thus some sort of protection against the calamities that may eliminate or hinder selected species. For example, a disease carried by aphids struck the honeysuckle in the Twin Cities area. This disease decimated the honeysuckle to the point of near extinction within the patch. In addition, the site appears too dry for young red oak seedlings and saplings, as these plants are slowly disappearing. Also, white-tailed deer have destroyed all but one of the cottonwood trees. Yet a diverse planting within the forest patch allows vegetation calamities to destroy certain species without destroying the patch.

While we are positive about the results of our one dimensional experiment we believe that reclamation specialists may wish to conduct long-term studies of their own concerning the forest patch idea. We believe that a broader multi-replication forest patch experiment is essential to determine the effects of various design treatments. In addition, we believe that a more committed environmental monitoring project merits investigation.

In closing, we believe that this planting design approach merits consideration in a reclamation plan where a naturalized landscape configuration is desired for an urban post-mining land-use. This approach may reduce initial woody plant mortality and replicate a xeric woodland setting.

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Literature Cited

Ashby, W.C. 1996. Trees chosen for reclamation in southern Illinois, USA. International Journal of Surface Mining, Reclamation and Environment 10:167-168.
https://doi.org/10.1080/09208119608964826

Beckett, P.J., J. Negusanti, T. Peters, J. Vining, J. Miller, and W. Lautenbach. The Sudbury regional land reclamation program - tree and shrub enhancement. Hynes, T.P. and M.C. Blanchette (eds.) In: Proceedings of Sudbury '95 - Mining and the Environment. CANMET, Ottawa, Volume 3:1103-1112

Curtis, J.T. 1959. Vegetation of Wisconsin: an Ordination of Plant Communities. The University of Wisconsin Press.

Daniel, W.W. 1978. Applied Nonparametric Statistics. Houghton Mifflin Company.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley and Sons, NY.

Larson, M.M., D. Kost, and J.P. Vimmerstedt. 1994. Effectiveness of treatments to establish trees on minelands during drought and wet years. International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage: Volume 3 or 4: Reclamation and Revegetation. United States Department of the Interior, Bureau of Mines Special Publication SP 06C-94:257-266.
https://doi.org/10.21000/JASMR94030257

Sanders, W.D., J.B. Burley, and C.A. Churchward. 1982. A study for vegetation and wildlife habitat on the Lower Grey Cloud Island. Svedarsky, W.D. and R.D. Crawford (eds), In: Wildlife Values of Gravel Pits. Miscellaneous Publication 17, Agricultural Experiment Station, University of Minnesota, St. Paul, MN :102-108.

Washburn, B.E., H.G. Hughes, and G.L. Storm. 1993. Establishment of four species of native hardwoods on reclaimed mined lands in Pennsylvania. Zamora, B.A. and R.E. Conally (eds.) In: The Challenge of Integrating Diverse Perspectives in Reclamation: Proceedings of the 10th Annual National Meeting of the American Society for Surface Mining and Reclamation. ASSMR, Spokane, Washington, 724-731.
https://doi.org/10.21000/JASMR93020724

Zeleznik, J.D., J.G. Skousen, and H.V. Wiant, Jr. 1993. Tree survival and growth on two 45-year-old reforestation projects in eastern Ohio. Zamora, B.A. and R.E. Conally (eds.) In: The Challenge of Integrating Diverse Perspectives in Reclamation: Proceedings of the 10th Annual National Meeting of the American Society for Surface Mining and Reclamation. ASSMR, Spokane, Washington, :714-723..
https://doi.org/10.21000/JASMR93020714