REVEGETATION SUCCESS AT THE RED HILLS LIGNITE MINE IN MISSISSIPPI[1]

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Abstract: The Red Hills Lignite Mine opened in 1998 with initial production beginning in 2001 and produces 3.3 million tonnes per year. It is located on the eastern edge of the Wilcox geological formation. Soils within the 2350 ha mine area in Choctaw County, MS are generally on eroded hills with an average topsoil depth of 18 cm interspersed with deep, poorly drained alluvial soil along creek bottoms that comprise 29.3% of the permitted mine area. Climate is subtropical with hot summers, mild winters and an annual rainfall of 1200 to 2200 mm/year. The current topsoil substitute permitted is a minimum of 1.2 m of red oxidized overburden that is 10 to 80% sand and 10 to 40% clay with an acid-base accounting level greater than –5 tonnes $CaCO_3$/tonne soil. Forty hectares have been reclaimed per year since 2000. A one-time application of fertilizer as 17-17-17 at 560 to 840 kg/ha is applied to stimulate grass growth. The revegetation sequence consists of planting browntop millet (*Urochloa ramosa, Syn. Panicum ramosum*) along with bermudagrass (*Cynodon dactylon*) to provide soil stabilization followed by planting loblolly pines (*Pinus taeda*). Alternately, wheat (*Triticum aestivum*) is planted to stabilize new soil reclaimed during the cool season. Soil fertility of the red oxidized topsoil substitute is superior to the thin, eroded topsoil in terms of higher extractable P and Ca levels. Establishment of bermudagrass and browntop millet is excellent with ground cover exceeding 80 to 90% within 1-2 months. Survival of loblolly pine is 70 to 90% after three years. Initial tree growth is 0.37 to 0.91 m per year. Species diversity is increasing after three to five years. Native grasses and forbs such as *Andropogon spp*., *Eupatorium spp.*, and *Solidago spp.* are reinvading reclaimed areas from the seedbank present in the topsoil substitute or wind dispersal as bermudagrass declines.

Additional Key Words: early succession, ground cover, topsoil substitute, tree establishment

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[1] Paper was presented at the 2006 Billings Land Reclamation Symposium, June 4-8, 2006, Billings MT and jointly published by BLRS and ASMR, R.I. Barnhisel (ed.) 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2006 pp 421-430
DOI: 10.21000/JASMR06010421

http://dx.doi.org/10.21000/JASMR06010421

Mine Description And History

The Red Hills Mine (RHM) is a surface lignite mine located in Choctaw County near the town of Ackerman, in north central Mississippi. RHM is owned and operated by North American Coal. Mine development began in 1998, with commercial lignite delivery commencing in 2002. Annual coal production of RHM is 3.3 million tonnes per year. Lignite fuels a neighboring 440 megawatt power plant. The mine operates under State of Mississippi Surface Coal Mining and Reclamation Permits MS001 and MS002. The States mining program is administered by the Mississippi Department of Environmental Quality (MDEQ). Red Hills Mine is the first and only surface lignite mine operating in Mississippi.

The 2350-ha mining area is characterized as a wooded rural countryside with occasional pasturelands, ponds, sparse residential development, and very few industrial features[3]. The terrain is gently rolling to moderately sloped with narrow valleys, small streams, and dissected uplands. More than 80% of the area is woodland, consisting of deciduous, evergreen, and mixed timber stands. The predominate pre and post mine land use was and is being returned to a forest land use.

The mining method involves the removal of 6 different lignite seams and the removal of the overburden and inter-burdens separating the seams. Suitable plant growth materials (SPGM) and the overburden material are removed by a combination of truck and shovel operations, dozer push operations and with an 82 cubic yard dragline. In general, the truck and shovel operations remove the upper SPGM and overburden to the first lignite seam. D-11 class dozers sequentially uncover the next 3 seams by pushing overburden into the preceding pit. The last 2 seams are uncovered by a dragline. As lignite seams are exposed, they are recovered using a 17 cubic meter backhoe and an Easi-Miner to load 150-tonne end dump trucks for delivery.

Reclamation and re-vegetation involves grading spoil to a gently rolling contour approximate to the original, respreading this landscape with 1.2 m of SPGM to final grade, stabilizing drainage bottoms, seeding of grasses and grains to stabilize the reclaimed landscape and seeding loblolly pines to achieve the desired post-mine forest land use.

Environmental Factors, Stabilization And Revegetation Methods

Rainfall averaging 1400 mm per year, combined with the mine areas rolling topography creates a challenge to mining and reclamation operations and the successful landscape stabilization required to support a newly established forest. In 2002, Red Hills Mine received 2134 mm of rain and discharged over 38 billion liters of run-off from sedimentation ponds. Rainfall over the past three years has been above average. There were 1800 mm in 2003, 2180 mm in 2004 and a normal 1400 mm in 2005.

The sandy clay nature of the SPGM and the gently rolling post mine topographies are subject to rapid erosion damage resulting from minor, major and back-to-back winter rainfall and summer thunderstorm events common to the area. The hot, dry summer months and cool, wet winter months limit the time frames when vegetation can be planted, germinate, and grow to establish an effective soil erosion control barrier that is needed to protect the reclaimed landscape

[3] McMullen, J.W. 1986. Soil Survey of Choctaw County, Mississippi. United States Department of Agriculture, Soil Conversation Service, 128 pp.

for time frames required for pine seedlings to develop into mature commercial forests. To overcome these environmental factors, Red Hills Mine has developed a series of soil stabilization and re-vegetation methods to quickly stabilize reclaimed landscapes to allow for the planting and long term soil stability needed for the growth of reclaimed forests.

SPGM during the initial five-year reclamation plan has included the thin, highly weathered topsoil plus the upper 1.8-3.6 m of the red oxidized subsoil. Soil fertility characteristics of SPGM indicate that its phosphorus, magnesium and calcium levels are higher than the native thin topsoil (Table 1). Its pH is 5 to 6 with acid base accounting values that range from –2 to + 4. Fertilizer, as 17-17-17, is applied at 560 to 840 kg/ha and incorporated into respread soils during seedbed preparation for grass and grain plantings. Little, if any, lime is generally required. Ammonium nitrate (34-0-0) is occasionally applied at 112 kg/ha during mid-summer to stimulate production of the bermudagrass or spot treat areas within a grass stand that appear weak in appearance.

Table 1. Characteristics of native soils and currently used soil substitute within the Red Hills Mine landscape.

Soil	OM	pH	P	K	Ca	Mg	Zn	CEC
	- % -		------ extractable mg/kg -----					cmole/100 g
Red Oxidized Substitute	0.61	4.8	28	80	1125	616	3.2	15.5
Smithdale-Sweatman Native	1.33	5.3	3	104	678	275	0.9	11.0
Oaklimiter-Native	1.83	5.7	12	51	930	78	1.8	9.1

Soil Stabilization and Vegetation Establishment.

The typical revegetation sequence at the RHM, following the respread of SPGM, includes spring plantings of browntop millet (*Urochloa ramose, Syn. Panicum ramosum*) at 22 kg/ha and common bermudagrass (*Cydonon dactylon*) at 34 kg/ha, planted simultaneously using a Brillion seeder. These higher than normal seeding rates are essential for achieving quick and complete ground cover with 30 to 60 days (Fig. 1). Respread of SPGM that occurs late in the summer or early fall are planted to wheat (*Triticum aestivum*) into which bermudagrass and millet are planted the following spring.

Additional soil stabilization is provided by wheat or rice straw mulch applied at 2.24 tonnes/ha and crimped into the soil (Fig. 3). Immediate but short term soil stabilization is provided by the mulch and fast growing millet and wheat cover crops while the slower growing bermudagrass provides long term soil stabilization needed while pine seedling establish and mature to eventually shade out the bermudagrass. Millet is mowed short within a month of spring seeding to prevent shading of the germinating bermudagrass. Basically, mulch provides initial soil protection and millet provides secondary soil protection while bermdagrass is growing and the bermudagrass provides long term protection while the pine trees are growing.

Figure 1. Browntop millet on upland area one month after seeding. Millet stand is ready to mow to allow sunlight to reach under-story bermudagrass seedlings.

Figure 2. Bermudagrass cover 90 days following seeding.

Figure 3. Seeded and mulched upland area with erosion fabric lined water bars.

Generation 2 loblolly pine (*Pinus taeda*) seedlings are planted once bermudagrass is well established or normally the February following the spring seeding of bermudagrass and millet (Fig. 4). Pine seedlings are hand planted using a 1.83 x 2.74 m spacing resulting in a planting density of 1981 trees/ha. Fertilizer is not applied once a healthy bermudagrass stand is established or after pine seedlings have been planted.

Figure 4. Loblolly pine seedlings hand planted on upland area into a winter dormant bermudagrass stand, planted 11 months after initial grass seeding.

The reclamation benefit of these revegetation methods is that erosion and associated erosion repairs of newly reclaimed land and older reclaimed land hosting maturing forest plantings are minimized. This benefit is important considering that erosion repairs following the amount of rain the mine receives can result in very expensive heavy equipment operations to cross and re-disturb reclaimed land to reach and repair erosion damaged land creating travel lanes that must be re-seeded and reforested as well as the erosion damaged site. In maturing forest stands this type of redisturbance will cause uneven aged stands of trees and set back bond release requests.

Reforestation Success Standards And Planting Results

Loblolly pine reforestation of reclaimed land began in 2001 with additional plantings being established each year since. Currently, a total of 100 ha have been reforested with 198,000 trees (Fig. 5). Mississippi Revegetation Success Standards for Commercial Forest require the Mississippi Forestry Commission to establish a stocking rate on a specific permit basis in consultation with MDEQ. For RHM, the Forestry Commission established a pine planting density of between 1480 and 2470 seedlings/ha with a targeted stocking survival rate of 1235 live seedlings/ha at the end of the extended responsibility period. The Commercial Forest Revegetation Success Standards further require tree density at bond release be equal to or greater than ninety percent of the stocking rate approved in the permit or 90% of the minimum recommended stocking rate (1235 trees/ha) of the Forestry Commission or a minimum success standard of 1112 trees/ha. RHM has voluntarily planted 1981 seedlings/ha to avoid inter-planting in future years to meet the 1112 to 1235 trees/ha success standard.

Figure 5. Five years reforested (January 2006).

Vegetation and forest study plots were established within all reforested mine areas. Annual tree density counts were conducted in randomly selected 5.09 m diameter circles. Tree height was measured along permanently placed 100 m transects consisting of two rows of trees on each year's tree plantings since 2001 in 2003 and 2004. These results are summarized in Table 2.

Table 2. Tree Growth and Count of Loblolly Pine Planted in 2001, 2002 or 2003 at the Red Hills Lignite Mine, Ackerman, MS.

Planting Year	Tree Height 2003	Tree Height 2004	Growth 2003 to 2004	Tree Count 2003	Tree Count 2004
	---- meters ----		meters / yr	------------ trees / ha -------------	
2001	1.20	2.11	0.91	1233	1358
2002	0.54	1.13	0.59	1428	1435
2003	0.35	0.72	0.37	1477	1393

Initial survival of pine seedlings was 60 to 80% with tree growth ranging from 0.37 to 0.9+ m per year (Fig. 6, Table 2). Tree growth is accelerating as their root systems become fully established. Measurements made in December 2005 indicate trees planted in 2002 and 2003 are growing at 0.9 to 1.5 m per year. Diameter at ground height is 3.8-6.4 cm and diameter at breast height is 2 to 3 cm four years after planting (data not shown). Ground cover and species composition was estimated visually every 10 m along 100 m permanent transects in 5x10 m plots. Ground vegetation cover ranges from 80 to 100%. Bermudagrass initially planted constitutes 60 to 80 % of the ground cover after 3 years. It is declining and being replaced by early successional species. Overall ground cover is 80 to 100% and easily meets the 70% ground cover success standard. Native species in the soil seedbank or wind dispersal are volunteering and creating a natural early successional substory of vegetation. Early invading species that are native to Mississippi are listed in Table 3 and are illustrated in Fig. 6, 7 and 8.

January 2004 | January 2005

Figure 6. Loblolly Pine Trees Planted in 2001

Table 3. Native early successional species on reclaimed land at the Red Hills Lignite Mine.

Common Name	Scientific name
beach false foxglove	*Agalinis fasciculata*
bushy bluestem	*Andropogon glomeratus*
broomsedge bluestem	*Andropogon virginicus*
rice button aster	*Symphyotridum dumosum, Syn. Aster dumosus*
eastern baccharis	*Baccharis halimifolia*
white doll's daisy	*Boltonia asteroides*
Canadian horseweed	*Conyza canadensis*
small-leaf ticktrefoil	*Desmodium marilandicum*
dogfennel	*Eupatorium capillifolium*
thoroughwort	*Eupatorium serotinum*
rabbittobacco	*Psuedognaphalium obtusifolium, Syn. Gnaphalium obtusifolium*
spoonleaf everlasting	*Gamochaeta purpurea, Syn. Gnaphalium purpureum*
annual marshelder	*Iva annua*
grassleaf rush	*Juncus marginatus*
Canada goldenrod	*Solidago canadensis*
gray goldenrod	*Solidago nemoralis*

Figure 7. Initial tree stand and ground cover, Fall 2003. Establishment of the grass cover was in 2001 and loblolly pine planting was in 2002.

Figure 8. Loblolly pine stand and ground cover of the same area, October 2004.

Conclusions

Successful long-term stabilization of reclaimed drainage ways and the upland under-story is vital to the establishment and long-term development of a forest. Results using the methods described have minimized the need to disturb reclaimed forestlands to repair upland and bottom land erosion problems. Additionally, the stabilization sequence of grass and forest establishment assures the shortest or 2 to 3-year time frame between the respread of SPGM and the final planting of pine seedlings. Both of these results enhance the possibility of achieving bond release within the shortest amount of time.

Native topsoil was thin, eroded and highly weathered due to 1000's of years of heavy rainfall in the Southeast U.S. Several soil limitations such as severe slope, restrictive fragipans and poor internal soil drainage were replaced with superior soil conditions. Utilization of subsoil layers as topsoil replacement has enhanced the native soil fertility by increasing P, K, Ca and Mg levels. Non-native grass species (browntop millet and bermudagrass) planted initially for soil erosion have successfully provided 90 to 100% ground cover and effectively stabilized respread soil in a very high rainfall environment. Browntop millet disappeared from the landscape and was quickly replaced by bermudagrass. Early successional species (*Andropgon*, *Solidago*, *Eupatorium*, etc.) are emerging through the bermudagrass understory from the seedbank present in the respread soil or wind dispersal from off site. This process is aided by the lack of additional nitrogen fertilizer resulting in a comparative disadvantage for the bermudagrass. Overall ground cover remained at 80 to 100% after 5 years even though bermudagrass declined to 60 to 80% due to its replacement by native early successional species. The reclaimed ecosystem is diverse and healthy, capable of supporting commercial forestry and other crop usage. Current landowners have always grown pine trees as long-term land usage. Future land use possibilities will not be limited to pines. Several other crops such as cotton, soybean, corn and fruit trees should also be feasible. Future reclassification of reclaimed soil at RHM will likely result in it being listed as Prime Farmland.