ESTABLISHMENT OF TREES AND SHRUBS ON LANDS DISTURBED BY MINING IN THE WEST

Ardell J. Bjugstad

Range Scientist, Rocky Mountain Forest & Range Experiment Station, Rapid City, South Dakota

ABSTRACT

Increased research and development of cultural practices and species has assured success of establishment of trees and shrubs on lands disturbed by surface mining. Trickle irrigation and water harvesting techniques have increased survival of planted stock by 250 percent for some species.

INTRODUCTION

Passage and implementation of the Surface Mining Control and Reclamation Act (Public Law 95-87) and attendant regulations have placed a new emphasis on revegetation of spoil materials from coal surface mines in North Dakota, Montana, Wyoming, Colorado, Utah, New Mexico, and Arizona. Although most coal companies in the interior West are applying revegetation practices to surface mines, requirements of the new Federal Reclamation Act, in many cases, will require a reassessment and evaluation of techniques and methodologies employed in present revegetation activities.

Most surface mining is in semiarid to arid regions. These involve surface mining for commodities such as bentonite clay, coal, copper, gypsum, oil from shale, phosphate, uranium, molybdenum, mercury, and sand and gravel. Other activities, such as placer mining and quarrying for limestone, slate and granite, or similar materials, produce waste material which need reclamation. However, problems in reclaiming mined lands are usually similar, even though commodities differ (Thornburg 1982). The major dissimilarity is the configuration of the spoil pile resulting from the mining method. Usually most disturbances all need some landforming to satisfy topographic and surface conditions for planting (Bjugstad et al. 1981; Thomburg 1982; Yamamoto 1982).

Moisture has been reported as the limiting factor in the reclamation of disturbances in northern Great Plains (Packer 1974; USDA, SCS 1971). A report, "Rehabilitation Potential of Western Coal Lands" (Study Committee 1973) stated that areas receiving less than 10 inches of annual precipitation cannot be reclaimed. The report further stated that revegetation can be accomplished under such conditions only with major effort and even then, not with any assurance of enduring success.

This paper discusses efforts to establish trees and shrubs on lands disturbed by mining in the West, with emphasis on the northern Great Plains.

WEST

Efforts to revegetate mined areas in the West impacted by energy-related mining, are fairly recent. Research dealing with range seeding (Valentine 1971), shelterbelt planting (George 1953), roadside stabilization (Environmental Protection Agency 1975), and wildlife habitat restoration (Plummer et al. 1968), provided useful information. Most of these past efforts were to establish plants for specific forage and/or browse production (Brown 1979). Grass species have often been selected because of their availability, information, adaptability, and forage quality for cattle grazing–ultimately the final postmining use (Jasmer, Donart, and Aldon 1982).

Interseeding and interplanting of shrubs and trees in developing grass stands has proven successful in New Mexico, Arizona and Wyoming (Aldon and Springfield 1975; Brock 1982; Bjugstad et al. 1981). Trickle irrigation to increase survival of shrubs and trees in semiarid regions adds to the cost (Aldon and Springfield 1974; Packer and Aldon 1978; Bjugstad et al. 1981). Trickle irrigation for the establishment of shrubs and trees costs between $1,500-$2,000 per acre excluding the sell (Bjugstad In Press; Garcia 1979). The costs providing trickle irrigation often is smaller than the costs of placing spoils. Total costs of $4,000-$5,000 per acre are common (Roybal and Eveleth 1982).

NORTHERN GREAT PLAINS

Coal is a common commodity surface-mined on the northern Great Plains. It is found in two major structural basins. The Powder River Basin of northeast Wyoming extending into southeastern Montana, and the Williston Basin extending northsouth in western North Dakota and eastern Montana. Nearly 240 billion tons of proven reserves of subbituminous coal are in the Powder River Basin (Glass 1972), more than 19 billion tons of which are considered surface minable, and about 440 billion tons of lignite in the Williston Basin (Landis 1973). Coal is most abundant in the Fort Union formation where overburden and interbed materials are mostly weak standstones and shales. Soils range from loam to clay, may be very stony, and vary widely in natural stability (Aandahl 1972).

Although the entire area is classified as semiarid (Thornthwaite 1941), differences in average annual precipitation and evapotranspiration stress are great enough to reflect existing differences in plant species composition and distribution within wooded waterways. For example, annual precipitation averages 12 to 16 inches in northern parts of the Powder River Basin area, compared with about 14 to more than 16 inches in the Williston Basin area. Differences are great enough to have a significant bearing on revegetation potential (Packer 1974).

Most woody species become established only during years of average to above average precipitation, or during a series of favorable years. This contention is indirectly supported by Thornthwaite (1941) who observed that, except in years of more than normal rainfall, taller growing plants are almost entirely absent. There may be about a 50 percent or less chance of success under natural conditions in any year. The cost of repeat treatments and deadlines imposed by reclamation laws make this high risk of failure often unacceptable (Orr 1977).

The suitability and stability of emplaced spoil as a planting medium must be considered (Dollhopf et al. 1980). Precautions can be taken to avoid placement of potentially toxic materials within the rooting zone. Structure of emplaced spoils may be weak or nonexistent. Surface soils, even though they have been stockpiled and replaced, may be so disturbed structurally that chemical and physical behavior is adversely affected. Higher sodium contents of overburden in most of the Williston Basin area make soil dispersion and surface sealing more of a problem in most of the North Dakota mining area than in Montana or Wyoming (Sandoval 1973).

Because of the rigorous environmental conditions, extra care and precautions must be taken to maximize the quality of effort in all phases of the reclamation process. Careful and close attention is especially critical during early stages (Orr 1977).

Dry Land Tests

Research in the northern Plains involved tests of dryland establishment of shrub and tree species (bare root stock) (Orr 1977; Bjugstad et al. 1981). Species were used that have been reported to be potentially suitable for propagation in particular locations in relation to form and orientation of waterways. The first study was installed at the Belle Ayr Mine of AMAX, Inc., about 18 miles south southeast of Gillette, Wyoming. Species selected for initial trial included:

Green ash (Fraxinus pennsvlvanica lanceolata)
Silver buffaloberry (Shepherdia argentea)
Rocky Mountain juniper (Juniperus scopulorum)
American plum (Prunus americana)
Caragana (Caranana arborescens)
Ponderosa pine (Pinus ponderosa)
Russian olive (Elaeagnus augustifolia)

Efforts of dryland establishment of shrub and tree species (bare root) on coal mine spoil were moderately successful (Table 1). The most striking differences between years of planting were in American plum and Caragana Survival was two to three times greater at the end of the first growing season for the 1974 planting than for the 1973, despite the fact that the 1974 growing season was considerably drier (Orr 1977). A similar procedure was conducted on a bentonite clay mining spoil, and survival was also moderately successful (Bjugstad 1979).

Table 1.--Survival percentages, bare root stock by species, dryland planting at AMAX Belle Ayr Mine, May 1973 and May 1974 (Orr 1977).

Species	Planted May 1973			Planted May 1974
	Date of survey			Date of survey
	Sep 73	Jun 74	Sep 74	Sep 74
Green ash	96 (a)[1]	80	76 (a)	93 (a)
Russian olive	76 (b)	70	51 (b)	54 (b)
Rocky Mtn. Juniper	49 (c)	49	39 (b)	45 (c)
Ponderosa pine	44 (c)	18	11 (c)	32 (c)
Buffaloberry	42 (c)	28	15 (c)	48 (c)
American plum	30 (d)	18	12 (c)	60 (b)
Caragana	16 (d)	12	9 (c)	56 (b)

[1]Species with different letters within survey dates are significantly different at p = .05.

Supplemental water

A second phase of the research involved trickle irrigation on bare root stock. The trickle irrigation system was designed to apply one gallon of water in 1 hour every 4 days to individual plants, starting as early as possible in May and continuing through September for two growing seasons. Water, obtained from a deep well, was of the following quality: Ca-8.1, Na-44.9, K-5.6, Mg-1.6, SO_4-2 in mg/l.

For all but one species, survivals were substantially higher with irrigation than without (Table 2). Buffaloberry responded most to trickle irrigation (257 percent) in contrast to its poor to mediocre showing in the earlier dryland tests. Despite apparent favorable response to supplemental water, the species remained in poor to mediocre overall standing. American plus was second, with a 93 percent response, and also had the highest total survival percentage in the irrigation treatment. Green ash was third in percentage response to irrigation (71 percent), second to plum in survival under irrigation, and equal to plum in survival in the nonirrigation treatment. Caragana and Russian olive followed, also with positive responses to irrigation, but or considerably less magnitude (42 and 32 percent, respectively) (Orr 1977).

Table 2.-Percentage survival by species and irrigation treatment after two years at AMAX Belle Ayr Mine (Orr 1977).

Species	Irrigated	Not irrigated	Percent response
Green ash	70	41	71
Russian olive	29	22	32
Rocky Mtn. Juniper	2	0	
Ponderosa pine	10	0	
Buffaloberry	50	14	257
American plum	79	41	93
Caragana	51	36	42
Average	42	22	

In a similar study testing container stock as well as supplemental water, survival 4 years after planting and varied by species, whether planted as container stock or irrigated for 2 years after planting (Table 3). Therefore, a general statement cannot be made that supplemental irrigation water increased the survival of trees and shrubs. Container stock significantly increased the survival percentage only of unirrigated Rocky Mountain juniper.

The data indicate Caragana had the highest survival with nonirrigated container stock (Table 3), but annual growth had high variability with little, if any, benefit from irrigation. For most species, growth appeared to be little affected by cultural treatment. However, this characteristic was difficult to measure because of the relatively slow growth of some species, such as green ash Survival of buffaloberry, ponderosa pine, American plum and Rocky Mountain juniper was significantly higher when irrigated, but the use of container stock was of no benefit. The use of container stock significantly increased the survival rate of Rocky Mountain juniper when not irrigated, but not any other species. Consequently, cultural practices must be carefully evaluated to decide on whether to use container stock or irrigate to have the highest survival of these species at the lowest cost.

Table 3.--Percentage survival of irrigated container and bare root stock on cool spoil four years after planting.[1] (Bjugstad et al. 1981).

Species	Container		Bar Root		Percent Response
	2/I	NI	I	NI	Bare Root
Green ash	55	40	80	67	19
Russian olive	47	40	53	60	-12
Rocky Mt. juniper	93	3/67	93**	27	244
Ponderosa pine	53**	0	40*	7	470
Buffaloberry	60	47	73**	27	170
American plum	60	27	87**	40	118
Caragana	93	100	87	93	-06

1/Percent based on 15 plants per treatment.
2/I = Irrigated; NI = Not irrigated.
3/Significantly different from NI bare root 0.10 level.
*, **Significantly different from NI at 0.01 and 0.05 probability levels, respectively.

A study of effects of a surface mulch (wood chips), supplemental water, and fertilizer on survival and growth of upland shrubs indicated the survival rates were similar to survival rates of the trees and shrubs at the Belle Ayr site (i.e., they showed considerable difference between species (Table 4). Van Epps and McKell (1980) reported similar survival rates for nine shrubs at certain sites in Utah. The survival rate of Rocky Mountain juniper in our study was excellent in most treatments but significantly lower when fertilized. The treatments had no effect on growth of juniper.

Table 4.--Percentage survival of upland shrubs (container grown stock) on coal mine spoil after three growing seasons.[1] (Bjugstadet al. 1981).

Treatments	Fourwing Saltbusb	Big Sage-brush	Rubber Rabbit-brush	Common Winter-fat	Rocky Mountain juniper
Mulched (M)	33	22	19	11	85
Fertilized (F)	37*	30	15	7	48**
Irrigated (I)	2/4	30	26	2/4	70
M + F	22	30	30	2/4	48**
M + I	22	59**	41	0	85
F + I	26	48*	30	0	85
M + F + I	37*	41	15	0	85
Control	11	19	26	0	74

1/Percent based on 27 plants per treatment
2/One plant remaining
*, **Significantly different from control at 0.10 or 0.05 level respectively.

Winterfat establishment was poor in all treatments (Table 4). The other three upland shrubs--fourwing saltbush, big sagebrush, and rubber rabbitbrush--responded to certain cultural treatments. Survival of fourwing saltbush was significantly higher when fertilized and mulched or when fertilized and irrigated; but no treatment increased growth. Big sagebrush had a significantly higher survival when mulched and irrigated or when fertilized and irrigated. However, growth was the same regardless of treatment (Bjugstad et al. 1981).

The survival of rubber rabbitbrush ranged from 15 to 40 percent, with control survival rate at 26 percent. Aldon and Pase (1981) reported a survival rate of 88 percent for this species, regardless of treatment when dry-land planted in New Mexico. Growth in our study was substantially higher when the plants were mulched, irrigated, or mulched and fertilized and irrigated.

CONCLUSIONS

Selection of cultural practices to promote survival and growth of trees and shrubs on mine spoils depends on the species. Practices should be selected with care, because some may be detrimental.

Orr's (1977) preliminary conclusions are worth repeating.

"A number of generalizations can be drawn for use in making reclamation decisions, especially those relating to establishment of woody species along waterways for restoration of wildlife and aesthetic benefits. If, for example, a high rish of failure (as much as 50 percent) can be tolerated, bare root planting stock can be used with no cultural treatment. In years of below average growing season precipitation, mortality is likely to be very high."

The greater the potential stress, by planting site or by growing season, the more important it is to obtain the very best possible planting stock, maintain it in the best possible condition throughout production and shipping, and plant in the best and most consistent manner possible. It is important that planters be carefully instructed and closely supervised.

Where it is essential to achieve a high probability and high degree of initial success, there is the option of supplemental watering. Periodic application of relatively small amounts of supplemental water also can help compensate for unknown variations in quality and condition of planting stock and individual planter technique.

For planting in waterways, variable combinations of cultural techniques and species can be used, depending on slope, aspect, and characteristics of the spoil. Low shrubs, such as big sagebrush, rabbitbrush, fourwing saltbush, and winterfat, can be established on south-facing slopes and adjacent uplands; the probability of success can be enhanced by contour furrowing to conserve moisture and minimized erosion. On lower to upper-north facing slopes, taller species, such as green ash, cottonwood, Russian olive, Siberian peashrub, and buffaloberry, appear adaptable. There, also, and in selected locations on other aspects, Rocky Mountain juniper, and some ponderosa pine can be expected to survive and establish, especially if given supplemental water together with application of measures designed to conserve moisture such as contour furrowing and/or mulching.

Shrubs and trees can be established on lands disturbed by mining in the West but high assurance of success of an established stand will require cultural treatments and relatively intensive management compared to established wild stands of shrubs and trees.

LITERATURE CITED

Aandahl, A.R. 1972. Soils of the Great Plains--a detailed map of the soil associations of the Great Plains. P.O. Box 81242, Lincoln, NE 68508.

Aldon, Earl F. and Charles P. Pase. 1981. Plant species adaptability on mine spoils in the southwest: A case study. USDA Forest Service, Research Note RM-398, p 3. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Aldon, E.F., and H.W. Springfield. 1975. Problems and techniques in revegetating coal mine spoils in New Mexico. In: Practices and problems of land reclamation in western North America Mohan Wali (ed.), Univ. North Dakota Press, Grand Forks. p. 122-132.

Bjugstad, Ardell J. In Press. Shrub and tree establishment on coal spoils in northern High Plains-USA. Minerals and the Environment.

Bjugstad, Ardell J. 1979. Bentonite mine spoil and pit reclamation: A major problem. 19 p. In: Proceedings of the Mineral Waste Stabilization Liaison Committee, Eric Mining Company, Eleventh, MN.

Bjugstad, Ardell J., Teruo Yamamoto, and Daniel W. Uresk. 1981. Shrub establishment of coal and bentonite clay mine spoils. p. 104-122. In: Proceedings of symposium on shrub establishment on disturbed arid and semi-arid lands. Wyoming Agricultural Experiment Station, Laramie, WY.

Brock J.H. 1982. Interseeding and interplanting techniques for southwest reclamation. In: Reclamation of mined lands in the southwest. Earl F. Aldon-Wendall R. Oaks (Co-ed). SCSA, PO Box 2142, Albuquerque, NM 87102 p. 192-197.

User guide to vegetation. Mining and reclamation in the West. USDA, Forest Service. GTR INT-64, Intermountain Forest and Range Exp. Sta., Ogden, UT.

Dollhopf, D.J., E.J. Depuit and M.G. Klages. 1980. Chemical amendment and irrigation effects on sodium migration and vegetation characteristics in sodic minesoils in Montana. Reclamation Research Technology Bulletin 736. Montana Agricultural Exp. Sta., Montana State University, Bozeman, MT 59717. p. 110.

Environmental Protection Agency, Office of Water Planning and Standards. 1975. Methods of quickly vegetating soils of low productivity, construction activities. EPA-440/9-75-006. Washington, DC 486 p.

Garcie, George. A portable irrigation system for remote sites. USDA Forest Service, Research Note RM-374. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

George, E.J. 1953. Tree and shrub species for the Northern Great Plains. USDA Circ. 912. 46 pp.

Glass, G.B. 1972. Midyear review of Wyoming coalfields. Geol. Serv. Wyo. Annu. Rep., 42 pp.

Jasmer, G.E., G.B. Donart, and E.F. Aldon. 1982. Responses of re-established vegetation to simulated grazing. In: Reclamation of mined lands in the southwest. Earl F. Aldon-Wendal R. Oaks (Co-ed). SCSA, PO Box 2142, Albuquerque, NM 87102. p. 188-191.

Landis, E.R. 1973. Coal in mineral and water resources of North Dakota. U.S. Senate Comm. on Inter. and Insular Aff., 93rd Congress, 1st Sess. pp. 45-52.

Orr, H.K. 1977. Reestablishment of wooded waterways and associated upland shrub communities in surface coal mining areas of the northwestern Great Plains. In: Fifth Symp. Surf. Min. and Reclam., NCA/BCR Coal Conf. and Expo IV (Oct. 18-20, 1977. Louisville, KY) p. 235-243.

Packer, Paul E. 1974. Rehabilitation potentials and limitations of surface-mined land in the northern Great Plains. Intermountain For. and Range Exp. Sta., USDA For. Serv. Gen. Tech. Rep. INT-14.

Packer, P.E., C.E. Jensen, E.L. Noble and J.A. Marshall. 1982. Models to estimate revegetation potentials of land surface mined for coal in the West. Gen. Tech. Rep. Int.-123. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT 84401.

Packer, P.E. and E.F. Aldon. 1978. Revegetation techniques for dry regions. In: Reclamation of drastically disturbed lands. A.S.A. - C.S.S.A. - S.S.S.A., Madison, WI. p. 425-450.

Plummer, A.P., D.R. Christensen, and S.D. Monsen. 1968. Restoring big game range 68-3. 184 pp.

Roybal, G. and R.W. Eveleth. 1982. Overview of surface mining in New Mexico and ongoing reclamation projects. In: Reclamation of mined lands in the southwest. Earl F. Aldon-Wendall R. Oaks (Co-ed). SCSA, PO Box 2142, Albuquerque, NM 87102. p. 2-7.

Sandoval, F.M., J.J. Bond, J.F. Power, and W.O. Willis. 1973. Lignite mine spoils in the Northern Great Plains--characteristics and potential for reclamation. Res. and Appl. Technol. Symp. on Mined-Land Reclamation, Pittsburgh, PA. pp. 117-133.

Study committee on the potential for rehabilitating lands surface mined for coal in the western United States. 1973. Rehabilitation potential of western coal lands, a rep. to the Energy Policy Project of the Ford Foundation, Nat. A. of S./Nat. A. of Eng., Washington, D.C. 206 p.

Thornburg, Ashley A. 1982. Plant materials for use on surface-mined lands in arid and semi-arid regions. USDA, Soil Conservation Service SCS-TP-157. 88 pp.

Thornthwaite, C.W. 1941. Atlas of climatic types in the United States 1900-1939. U.S.D. Misc. Publ. No. 421, 5 pp. 95 plates.

U.S. Department of Agriculture, Soil Conservation Service. 1971. Guildlines for reclamation of surface mined aress in Wyoming. Tech. Notes, Environ. No. l., USDA Soil Conserva. Serv., Casper, WY. 10 p.

Vallentine, J.F. 1971. Range developments and improvements. Brigham Young Univ. Press, Provo, UT. 516 pp.

Van Epps, A. Gordon, and Cyrus M. McKell. 1980. Revegetation of disturbed sites in the Salt Desert Range of the Intermountain West. Utah Agric. Exp. Sta. Land Rehabilitation Series No. 5. Coll. Nat. Resour., Utah State Univ., Logan, UT.

Yamamoto, Teruo. 1982. A review of uranium spoil and tailings revegetation in the western United States. Gen. Tech. Rep. RM-92. Fort Collins, CO, USDA Forest Service, Rocky Mountain Forest and Range Exp. Sta. 20 pp.

In: New forests for a changing world: Proceedings of the 1983 SAF national convention; 1983 Oct 16-20; Portland, OR. Washington, DC: Soc. of Am. Foresters: 434-438. 640 p.