SENECA SURFACE COAL MINES--A 40 YEAR CASE STUDY IN RECLAMATION TECHNIQUES— TRIUMPHS AND FAILURES: TWO STUDIES OF SHRUB ESTABLISHMENT [1]

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Abstract: Seneca Coal Co. operates the Seneca II, Seneca II-W, and the Yoast Mines in Northwest Colorado, 6,300 ft to 8,500 ft elevation. The reclaimed land was seeded with a diverse mix of native and non-native grasses and forbs. Also, and extensive shrub reestablishment effort was undertaken. Coal production ceased in 2005 leaving 4000 acres of reclaimed land. The success of the reclamation program at Seneca Coal Co. is evident even within a climate of changing regulations, high altitude, and very steep slopes. The Wadge Pasture, a block of reclaimed land approximately 15 years old, was measured for revegetation success in 2004, Study3 #1. Colorado State University, Colorado Division of Minerals and Geology, and Seneca Coal Co. cooperated in a study of shrub establishment techniques and the results are presented in Study #2.more on the results of the studies

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Introduction

Seneca Coal Co. operates the Seneca II, Seneca II-W, and the Yoast Mines in Northwest Colorado. Seneca Coal Company began coal production in 1968 at the Seneca II Mine. The mining progressed to Seneca II-W in 1990 and to Yoast in 1996. Production ceased in 2005 leaving 4000 acres of reclaimed land. The success of the reclamation program at Seneca Coal Co. is evident even within a climate of changing regulations, high altitude, and very steep slopes.

The terrain and climate provide interesting, and intriguing challenges to mining and reclamation technology, equipment operation, post mine contouring and revegetation. The coal lies in a 20-35% pitching grade. The terrain varies in elevation from 6300ft. to 8500 ft. The climate in Northwest Colorado provides an approximate 65-day growing season. The annual precipitation is 17 inches of moisture, mostly in the form of snow.

The post mine land use for Seneca reclamation is wildlife habitat and livestock grazing. Most of this land was overgrazed prior to mining and invasive weeds continue to be a problem. Woody shrubs and trees are difficult to establish. The post mine terrain is steep, up to 33%, resulting in significant erosion potential and the necessity for intensive drainage channel construction. However, successful reclamation is possible.

Methods

Cover Sampling

Cover data were collected along 50 M transects using a point-intercept method in which data were recorded as interceptions of a point with plant species, litter, standing dead plant material, soil, or rock.

The cover sampling points were optically projected using a cover-point optical projection device developed by ESCO Associates. The 50 m transects were randomly located and oriented in the reclaimed area. One hundred points were collected along each transect. A pair of points were collected every meter with points sampled on opposite sides of each transect, 0.5 m from the transect. First hit interceptions were used to calculate absolute top layer foliar cover by dividing the number of interceptions for a particular species or ground cover type by the total number of points taken.

Production Sampling

Herbaceous production sampling was accomplished using on-half square meter (0.5 m^2) circular plots within which all herbaceous growth in a vertical projection was clipped and placed in labeled paper bags. Alfalfa was placed in separate, labeled bags. Lichens, mosses, and woody plant species present in the sample plot were not collected. Clipped material was returned to ESCO laboratory and dried a 105 C for 24 hours, then weighed to the nearest 0.1 gm.

Woody Plant Density Sampling

Woody plant density sampling was undertaken in the Wadge pasture along 50 m transects. All shrubs and sub-shrubs with root crowns located within the boundaries of 2 X 50 m quadrats (belt transects) were tallied according to species and life stage as either seedling, mature, or dead. The presence of dead individuals was recorded but did not contribute to woody plant density calculations.

Results

Study #1--Evaluation of Wadge Pasture Reclaimed Area at Seneca II Mine

Wadge pasture, approximately 350 acres, is a continually monitored reclaimed block at Seneca Mine. The area was reclaimed from 1977 to 1984. From 1988 until present grazing has been allowed on this reclaimed block. Following three years of extended drought conditions the Wadge pasture measurements from 2004 data are as follows.

Total vegetation cover was 54.9 percent. Cover by percentage measured as standing dead, litter, bare soil and rock was 2.4, 35.3, 7.1 and 0.3 respectively. Production average 2493 lb/acre, and the woody plant density was 955 stems/acre in 2004 (see Table 1).

Native Sagebrush Reference area

Total vegetation cover was 42.2 percent. Cover by percentage measured as standing dead, litter, bare soil and rock was 4.8, 26.2, and 6.5 percents respectively. Production average 1025.1 lb./acre, and the woody plant density was > 3000 stems/acre

Table 1 Long Running Record of Woody Plant Density in the Wadge Pasture – Data from Buckner[1], 2004 Revegetation Monitoring Report SCC

1988—322	1994—271	2000—393
1989—476	1995—182	2001—360
1990—408	1996—239	2002—502
1991—288	1997—210	2003—591
1992—344	1998—547	2004—955
1993—356	1999—227	

Discussion

From this record, it is apparent that during the period 1988 through 2001 there have been fluctuations in density values over the years in the Wadge Pasture that have not constituted consistent trends upward or downward Table 1. There is an apparent uptrend in woody plant density in drought years, 2002, 2003, and 2004. A comparison of these woody plant density data with climate records suggests that there is an inverse relation between favorable growing conditions and the prevalence of shrubs. When the moisture is adequate to allow grasses and other herbaceous species to grow vigorously, the competitive side effects are devastating the shrub numbers. Conversely, when dry times are intense and of sufficiently long duration, the shrub numbers rise.

[1] ESCO Associates Inc, 2005, 2004 Vegetation Monitoring Report, Peabody Seneca II Mine Reclaimed Areas, Routt County, Colorado. Prepared for Seneca Coal Co., Hayden, Colorado. Dr. Dave Buckner; PO Box. 18775 Boulder, CO

It is evident from the cover, production, and shrub density data that the reclaimed land has more cover, more production and less woody stems than the sagebrush reference area. However, the mother plants are in place for succession and re-establishment of the native plant communities.

Study #2--Seneca Mine Shrub Establishment Study Fenced VS Non-Fenced with Both Direct Seeding and Seedling Transplants [2]

The test plots at Seneca are located adjacent to each other in one contiguous block in the Wadge

Pit area at an average elevation of 7600 feet. The selected site for the test plots has an east aspect. Each treatment measures 100 feet by 100 feet. A description of each treatment is presented below.

Plot Treatment Descriptions

1. 6 inches (15 cm) of stockpiled topsoil over spoil and native shrub transplants as tubelings. Surface manipulation incorporated to reduce run off. This treatment is represented by one unfenced 100- x 100-ft plots.
2. 20 inches (50 cm) of stockpiled topsoil over spoil and native shrub transplants as tubelings. Surface manipulation incorporated to reduce run off. This treatment is represented by one fenced and one unfenced 100- x 100-ft plots.
3. 20 inches (50 cm) of stockpiled topsoil over spoil with strip seeding. The strip seeding included a strip of native shrubs and native low-competitive forbs that alternated with a strip of native grasses, forbs, and shrubs. The seed mixtures for this treatment are listed below. This treatment is represented by one fenced 100- x 100-ft plot.
4. Non-topsoiled spoil with native shrub transplants as tubelings. Surface manipulation incorporated to reduce run off. This treatment is represented by one fenced and one unfenced 100- x 100-ft plot.
5. 6 inches (15 cm) of stockpiled topsoil over spoil with strip seeding. The strip seeding included a strip of native shrubs and native low-competitive forbs alternated with a strip of native grasses, forbs, and shrubs. The seed mixtures for this treatment are presented in below. This treatment is represented by one fenced and one unfenced 100- x 100-ft plots.
6. Non-topsoiled spoil with strip seeding. The strip seeding included a strip of native shrubs and native low-competitive forbs alternated with a strip of native grasses, forbs, and shrubs. The seed mixtures for this treatment are presented the following. No transplants. This treatment is represented by one unfenced 100- x 200-ft plot.

Species of transplants used were boxelder maple, Saskatoon serviceberry, black chokecherry, Gambel's oak, Wood's rose, skunkbush sumac and mountain snowberry. All shrub transplants used at the Seneca demonstration plots were grown from local seed sources by Bitterroot

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Restoration, Inc. and were inoculated with a local soil community to facilitate the establishment of appropriate root microsymbionts.

Seeding and transplanting of the test plots was completed in November 2000. Transplants (tubelings) were planted at a rate of one per 20 square ft or a 4 ft by 5 ft pattern. Transplanted species included *Acer negundo, Amelanchier alnifolia, Prunus virginiana, Quercus gambelli, Symphoricarpos oereophilus, and Rosa woodsii*. Not all of these species were planted in each plot and no records were made for species planted or numbers for each plot. Fencing of the study was completed in the spring of 2001. The fence was installed in such a fashion that Treatments 2, 4 and 5 have fenced and unfenced plots. Examples of seeding mixtures of demonstration plots are given in Tables 2, 3

Table 2. Native grass, forb, and shrub seed mixture for demonstration plots at the Seneca Mine.

Scientific name	Common name	Seeding rate in lbs pls/a
Grasses: Grasses		
Agropyron spicatum	Bluebunch wheatgrass	1.0
Bromus marginatus	Mountain brome	1.0
Agropyron trachycaulum	Slender wheatgrass	1.0
Poa ampla	Big bluegrass	1.0
Forbs:		
Balsamorhiza sagittata	Arrowleaf balsamroot	1.0
Lupinus alpestris	Mountain lupine	1.0
Linum lewisii	Lewis flax	1.0
Penstemon palmeri	Palmer penstemon	0.5
Penstemon strictus	Rocky Mtn. penstemon	0.5
Shrubs:		
Purshia tridentata	Antelope bitterbrush	3.0
Amelanchier utahensis	Serviceberry	3.0
Symphoricarpos albus	Snowberry	3.0
Rosa woodsii	Woods rose	2.0
Ribes aureum	Golden currant	2.0
Prunus virginiana	Chokecherry	4.0
		TOTAL 25.0

Table 3. Native shrub and forb seed mixture for demonstration plots at the Seneca Mine.

Scientific name	Common name	Seeding rate in lbs pls/a
Shrubs:		
Purshia tridentate	Antelope bitterbrush	3.0
Amelanchier alnifolia	Serviceberry	3.0
Symphoricarpos oreophilus	Snowberry	3.0
Rosa woodsii	Woods rose	2.0
Ribes aureum	Golden currant	2.0
Prunus virginiana	Chokecherry	4.0
Forbs:		
Balsamorhiza sagittata	Arrowleaf balsamroot	1.0
Lupinus alpestris	Mountain lupine	1.0
Linum lewisii	Lewis flax	1.0
Penstemon palmeri	Palmer penstemon	0.5
Penstemon strictus	Rocky Mountain penstemon	0.5
		TOTAL 21.0

Vegetation Sampling

In July of each year (2000 through 2004) demonstration plots were sampled for vegetative coverby species, bare ground, rock and litter using a point-intercept method. Sampling was stratified in the fenced and non-fenced areas in order to examine the effects of game exclusion. At the Seneca Mine we used three 30-m transects and collected cover data every one meter (90 cover points per plot). Only three plots at the Seneca Mine were divided into subplots by a fence. In addition to cover sampling along these transects, we estimated shrub establishment and shrub height in each demonstration plot within $0.5m^2$ quadrats along each transect. The plots at Seneca Mine quadrats were located every 10 m along each transect for a total sampling area of 4.5 m^2 (9 quadrats) per demonstration plot. Within each of these quadrats all shrubs were identified to species and heights of individuals were recorded. At the Seneca Mine shrub tubelings were planted in September of 2000 in select demonstration plots. To evaluate the success of this operation, survival of transplants was quantified during the vegetation sampling. Shrub survival within each demonstration plot was estimated by following rows of transplants and scoring seedlings as either alive or dead. A minimum of 25% of the transplant rows within each plot was surveyed as such. During the vegetation sampling, voucher specimens of plant taxa were collected for positive identification and for archival in the Restoration Ecology Lab Herbarium. Permanent photo reference points established in 2001 in each demonstration plot were photographed annually to illustrate long-term changes in the vegetation.

Results

The decline or elimination of established shrubs in unfenced plots at Seneca between 2002 and 2004 will need to be followed over time to see if it is a real trend or an artifact of sampling (the low density of shrubs causes variance to be high). While shrub density is relatively low at Seneca, the shrubs are very robust at this site as indicated by height measures (Table 4) due to the fact that transplants were used. Shrub tubelings planted in some of the plots continue to show high survival in 2004 (Table 4) and many flowering and fruiting shrubs were observed at this time. The monitoring results indicate that the fall 2000 seeding at the Seneca mine appears to have been somewhat successful. Many of the seeded species were encountered in some of the plots at Seneca in 2004. Invasive weeds such as yellow sweet clover and Japanese brome continue to dominate most plots at Seneca. Russian thistle, which was a site dominant in 2003, was not found in 2004. It is likely that yellow sweet clover will not be a persistent problem, but Japanese brome and cheatgrass are of concern. Fall application of herbicides should help to reduce the threat from these species if they do become a serious problem in the demonstration plots.

The fence treatment at the mines appears to have generally resulted in increased shrub density, average height, and cover (Table 4). This is especially apparent for preferred browse species such as bitterbrush. Since deer, elk and antelope are known to browse shrub species, this is the expected result. However, many of the unfenced plots have modest numbers of shrubs that could survive in the long-term. Since browsing is an episodic phenomenon in these habitats, it is likely that the fencing treatment will become more significant with increasing time as the chances for destructive browsing events increase with time. Continued monitoring of the plots on a biennial or triennial basis will be needed to gauge the true impact of fencing on shrub establishment over a more ecologically-relevant time frame. [3]

Table 4 . Stems/ acre in Fenced VS Non-Fenced Shrub Plots[3]

Plot Number	*Fence Yes/No*	*Stems/ Acre 2001*	*Stems/Acre 2004*	*Shrub Height (CM)*	*%Shrub cover*
1	No	1619	0	0	0
2	No	809	890	22	0
2	Yes	4452	6232	36	4.5
3	Yes	809	5382	18.4	3.3
4	No	3561	890	40.5	3.0
4	Yes	5666	5342	29.5	5.6
5	No	890	0	0	0
5	Yes	809	1781	11.5	0
6	No	2226	890	8.0	0

Final Comments

Successful reclamation in the mountain shrub community in Northwestern Colorado is possible. The establishment of native shrubs at the levels required by the regulatory agencies is a challenge. Two most effective methods of native shrub reestablishment are tubling transplant and direct seeding. There appears to be a positive correlation between low annual moisture and an increase in stem density. Fencing of the shrub establishment plots prevents grazing by wildlife and livestock and increases survival and vigor. The Seneca Mines have demonstrated a long history of successful reclamation and native shrub establishment.

The following photos show progress of reclamation at Seneca II.

Photo 1. Seneca II-W Pit before reclamation

Photo 2. Seneca II-W Pit after reclamation

Photo 3. Mule deer on the reclamation at Seneca II

Photo 4. Reconstructed drainage channel and freshly replaced topsoil.

Photo 5. Sharptailed grouse have established four leks on reclaimed lands at Seneca II Mine.

Photo 6. Outside the elk proof fence the serviceberry are about 20 cm

Photo 7 Inside the elk proof fence the serviceberry are 75+

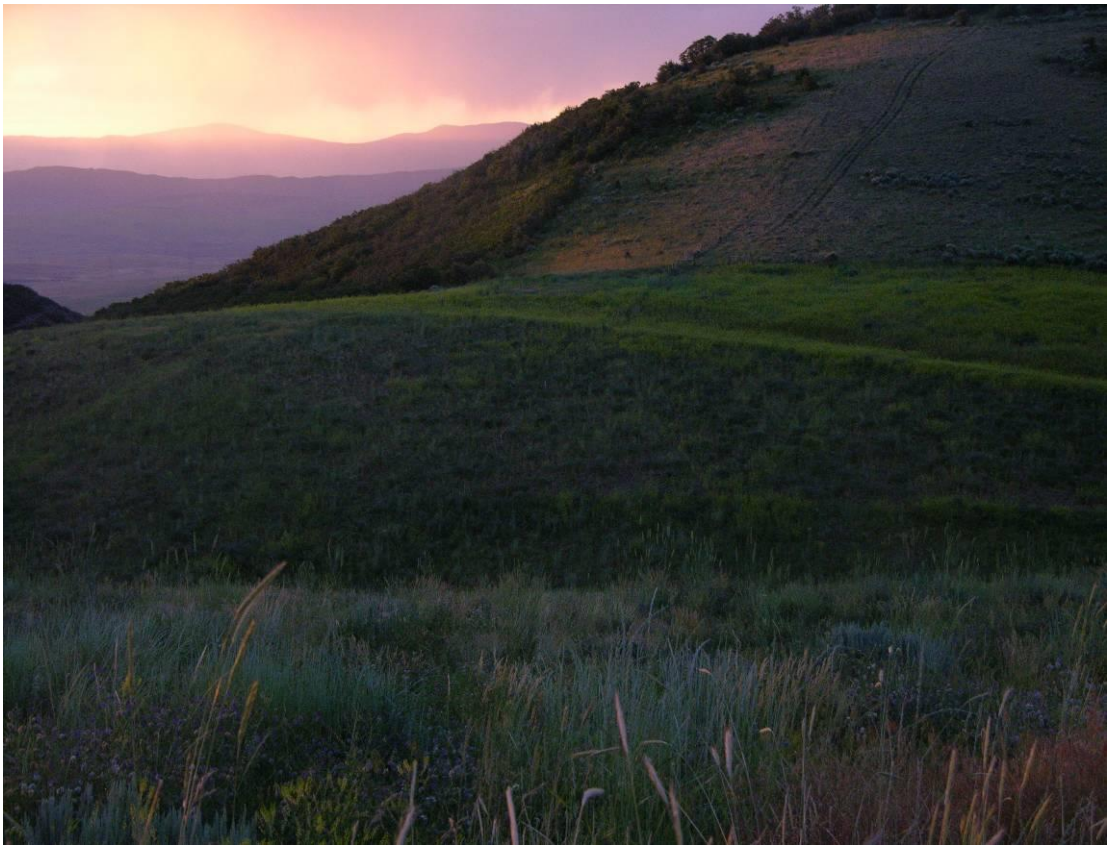

Photo 8. The reclaimed land at Seneca blends well with the surrounding terrain and plant communities.