RELATING SOIL PROPERTIES TO NATIVE PLANT ESTABLISHMENT ALONG WEST VIRGINIA HIGHWAYS[1]

Christina Venable and Jeff Skousen[2]

Abstract: The West Virginia Division of Highways is required to develop seeding mixtures comprised of native plants for revegetation of newly constructed highway corridors. The challenges faced when revegetating highway corridors are similar to those of reclaiming minelands. Similar processes such as blasting and backfilling result in a compacted, rocky soil that often contains acidic materials. Non-native species are generally seeded with high fertilizer rates to assure revegetation success. However, these aggressive species prohibit the establishment of desirable native species. When using native species, soil properties are an important aspect of the revegetation process of these disturbed areas. The chemical properties of soils can be manipulated, however the physical properties are more difficult to influence without great expense. This study evaluated the use of native plants for revegetation along roadsides and the soil factors influencing this reclamation. Soil properties of six West Virginia sites (Baker, Hazleton, Parkersburg, Buckhannon, Elkins, and Weston) were evaluated on the basis of bulk density, pH, electrical conductivity, texture, water holding capacity, cation exchange capacity, extractable bases, and various elemental analyses. Younger soils had less profile development as well as higher bulk densities, increased rock fragments, and decreased water holding capacities than older sites. Older sites with more vegetation had higher amounts of organic carbon in the soil, which translated into improved soil conditions and water holding capacity. Soil pH did not significantly influence native species establishment on these sites. The Elkins site had slightly saline soils as determined by electrical conductivity, which related to a decreased amount of vegetation on this site. Sites with higher amounts of vegetation correlated to soils with lower bulk densities, higher CEC and water holding capacities, and ample nutrients.

Additional Key Words: Native plants, soil properties, disturbed soils, revegetation.

---

[1]Paper was presented at the 2005 National Meeting of the American Society of Mining and Reclamation, Breckenridge CO, June 19-23, 2005. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2]Christina Venable, Graduate Research Assistant, and Jeff Skousen, Professor of Soils and Reclamation Specialist, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV 26506.

Proceedings America Society of Mining and Reclamation, 2005 pp 1202-1214
DOI: 10.21000/JASMR05011202
https://doi.org/10.21000/JASMR05011202

Introduction

Due to the mountainous nature of West Virginia, highway construction often involves the blasting and removal of large amounts of geologic material from one area to be used as fill for other areas. These "cut and fill" areas are highly disturbed and easily eroded. Therefore, a fast and effective ground cover is required to control erosion. The current method is to provide a vegetative cover that is fast-growing and easily established. However, owing to their known ability to control erosion, ease of establishment, and cost-effectiveness, nearly all species used for this control are non-native and/or invasive (Skousen and Fortney, 2003). Once established, the non-natives can persist indefinitely and can use vehicular traffic as a vector to expand their range. With the implementation of Executive Orders 13112 and 13148, the use of non-native and potentially invasive species for landscaping and revegetation has come under scrutiny. The goals of these orders are to prevent the introduction of invasive species, control their spread, and implement cost-effective, environmentally sound landscaping practices (Executive Order 13112, 1999 and Executive Order 13148, 2000). As a result, the West Virginia Division of Highways is required to develop seeding mixtures comprised of native plants for revegetation of newly constructed highway corridors.

However, the use of native plants on roadsides has two major problems. First, these are highly disturbed sites with poorly developed soils, which tend to inhibit the successful establishment of the competitively disadvantaged natives. Second, the seeds of native plants are often unavailable in large quantities and/or are too expensive to be cost effective for seeding large areas. Therefore it is important to understand how the physical and chemical properties of the soil can influence the success of the revegetation effort.

Much research has been done on using native plants on roadsides (Ahern et al. 1992, Barton et al. 2002, Corley 1995, Fiedler et al. 1990, Harper 1988, Morrison 1981, Swan et al. 1993) and other studies have examined the properties of disturbed soils (Daniels and Amos 1982, Haering et al. 2004, Johnson and Skousen 1995, and Skousen et al. 1998). However, there has been little research correlating native plant establishment to soil properties. The goal of this study was to correlate the establishment of native plants used for highway revegetation to physical and chemical soil properties.

Materials and Methods

All sites were located along major highways in West Virginia (Fig. 1). The Baker site (Fig. 2) was located along a newly completed section of Appalachian Corridor H near the town of Baker in Hardy County. The Hazelton site (Fig. 3) was located on I-79 at the West Virginia Welcome Center, near the town of Hazelton in Preston County. The Parkersburg site was near the intersection of I-77 and U.S. Route 50 in Parkersburg, Wood County, another was located along State Route 92 near Elkins, Randolph County, and two were located along U.S. Route 33, near Weston (Fig. 4), Lewis County, and Buckhannon, Barbour County.

The Baker and Elkins sites were 1 and 3 years old at the time of sampling. Both were filled with material that had been blasted from nearby areas during road construction to maintain a moderate grade. Buckhannon and Weston were the oldest sites at 10 and 20 years old at the time of sampling. These sites are located on a cut bench, both with northern aspects, with the Weston site elevated above the road, and the Buckhannon site lower than the road. The Parkersburg and

Hazelton sites, 2 and 3 years old respectively, are on grade. All sites were flat (0-5% slope) with no evidence of erosion.

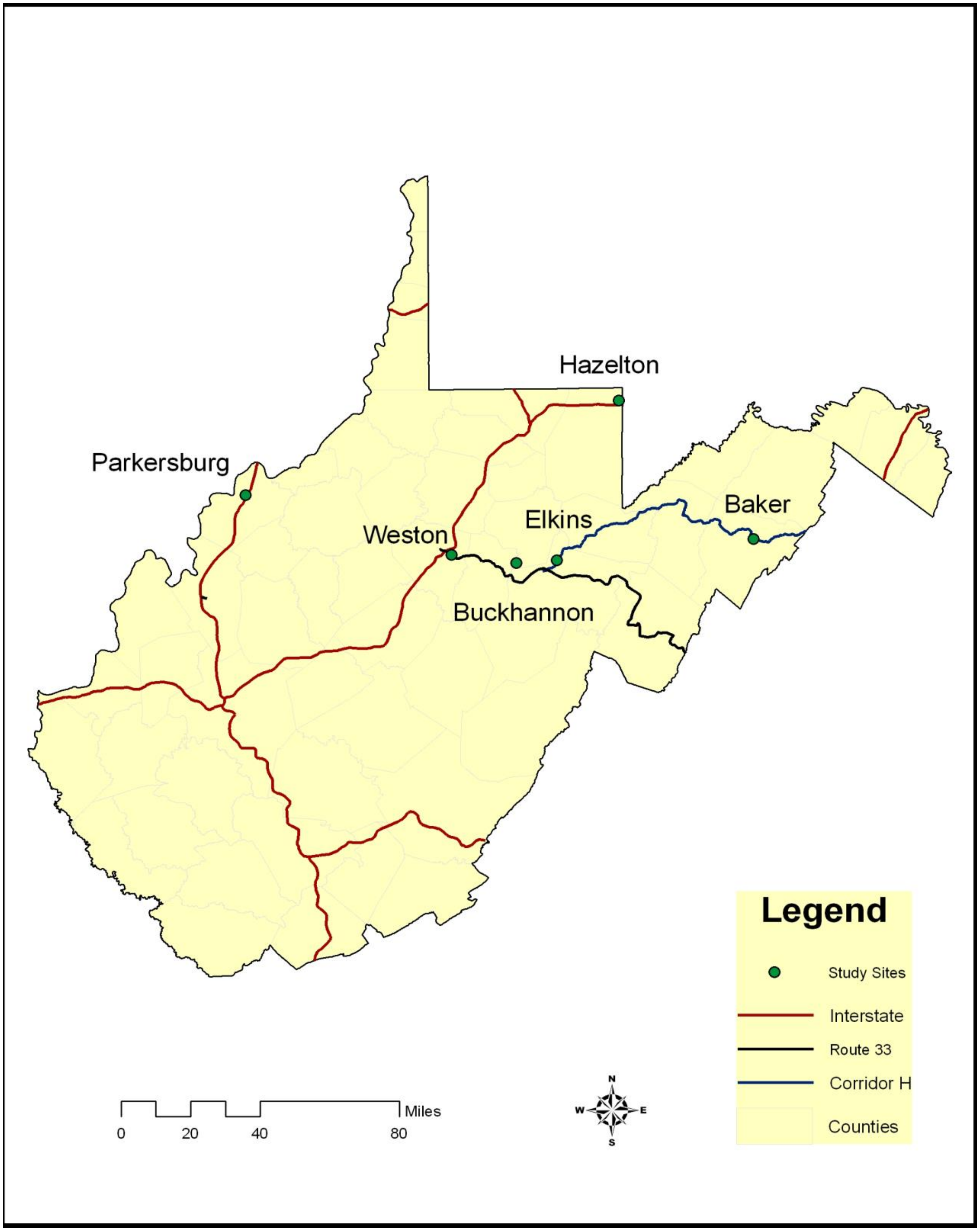

Figure 1. Location of research sites in West Virginia.

Figure 2. Overview of plots located at Baker, WV. This site was approximately 1 year old prior to plot establishment and had little vegetative cover. The soil was very compact and rocky. Plots were arranged in an 11x29 m rectangle (four rows of ten plots).

Figure 3. Overview of plots located at Hazelton, WV. This site was approximately 3 years old prior to plot establishment and is laid out in an 11x29 m arrangement.

Figure 4. Overview of plots located at Weston, WV. It is located approximately 3m above the road. Due to spatial constraints this site was laid out in a linear arrangement. The different surface treatments applied to the plots can be seen. In the foreground is a tilled plot, then an herbicide treated plot, a mowed plot, and another herbicide treated plot.

Plots measuring 2m by 2m with a 1m buffer were seeded in April 2002 at the Baker, Hazelton, and Parkersburg sites, and in April 2003 at the Elkins, Buckhannon, and Weston sites for a related study on the use of native plants for highway revegetation. Due to spatial constraints plots were established in a single row spanning 119m on the Weston and Buckhannon sites, and in four rows of ten plots each covering an 11m by 29m area on the remaining sites. The plots established in 2002 (Baker, Hazelton, and Parkersburg sites) were tilled, fertilized, and hand seeded with varying ratios of a typical mix used to revegetate roadsides by the DOH and a native mix. The species, seeding combinations, and rates used to revegetate the plots are summarized in Table 1.

The plots established in 2003 (Weston, Buckhannon, and Elkins sites) had varying surface treatments applied prior to fertilizing and hand seeding. Surface treatments were as follows: 1) mow and seed, 2) till and seed, 3) herbicide and seed, 4) undisturbed and seed, and 5) undisturbed (control) with no seed. The species, seeding combinations, and rates used to revegetate the plots are summarized in Table 2.

Plots were surveyed (Fig. 5) for total percent ground cover and ground cover percentage by individual species using the Daubenmire cover class system (Daubenmire, 1968). Data presented is the average of two surveys conducted in June and September 2002 for the Baker, Hazelton and Parkersburg sites, and June and September 2003 for the Weston, Buckhannon, and Elkins sites.

In Spring 2004, soil samples were obtained using a shovel from a 0-10 centimeter depth at three different locations on each of the six sites. Soil samples were taken at different locations on the sites due to the differing spatial arrangements of the sites. At Weston and Buckhannon, samples were taken approximately every 60m in a linear transect, while the remaining sites were sampled approximately every 31m on a diagonal transect. The samples were brought back to the laboratory, air-dried, and passed through a 2 millimeter sieve to remove rock fragments prior to analysis.

Table 1. Seeded species and seeding rates (kg/ha) of the four seed mixtures used on the Baker, Hazelton, and Parkersburg sites established in 2002 (DOH, Native, DOH-Native, and DOH½-Native seed mixtures).

	Seed Mixtures			
Seeded Species	DOH	Native	DOH-Native	DOH½-Native
	---------------------------kg/ha--------------------------			
Tall Fescue (*Festuca arundinacea*)	5		5	2.5
Red Fescue (*F. rubra*)	5		5	2.5
Annual Ryegrass (*Lolium multiflorum*)	1.75		1.75	0.875
Birdsfoot Trefoil (*Lotus corniculatus*)	2.5		2.5	2.5
Indiangrass (*Sorghastrum nutans*)*		1.25	1.25	1.25
Big Bluestem (*Andropogon gerardii*)*		1.25	1.25	1.25
Early Goldenrod (*Solidago juncea*)*		0.5	0.5	0.5
Butterfly weed (*Asclepius tuberosa*)*		0.25	0.25	0.25
Brown-eyed Susan (*Rudbeckia triloba*)*		0.25	0.25	0.25
Gray Beardtongue (*Penstemon canescens*)*		0.25	0.25	0.25
Wild Senna (*Cassia hebecarpa*)*		1.25	1.25	1.25

*Indicates plant is a native species.

Table 2. Seeded species and seeding rates (kg/ha) used on the Weston, Buckhannon, and Elkins sites established in 2003.

Seeded Species	Rate
	kg/ha
Switchgrass (*Panicum virgatum*)	5
Little Bluestem (*Andropogon scoparius*)	5
Partridge Pea (*Chamaecrista fasciculata*)	5
American Vetch (*Vicea americana*)	2
Ox-Eye Sunflower (*Heliopsis helianthoides*)	2
Brown-eyed Susan (*Rudbeckia triloba*)	2

Figure 5. Plots were surveyed using the Daubenmire cover class system to determine total cover and cover by species. For ease, a portable sampling grid was designed with $0.25m^2$ subplots. Four randomly selected subplots were surveyed and results were averaged to determine plot cover.

Soil pH was measured with a Fisher Scientific Accumet pH meter on a 1:1 soil/water paste (Soil Survey Staff, 1996) and electrical conductivity (EC) was measured with a Markson Solution Analyzer on a 1:1 soil/water paste (Gartley, 1995). Organic matter was determined by a loss of weight on ignition (Nelson and Sommers, 1996). Total carbon, nitrogen, and sulfur were determined using a LECO C-N-S 2000 analyzer. A 1M ammonium acetate extraction at pH 7.0 was used to determine cation exchange capacity (CEC) and extractable bases (Ca, Mg, Na, and K) (Soil Survey Staff, 1996). Samples were then analyzed with a Tecator Kjeltec Auto 1030 analyzer to determine CEC, with a Perkin Elmer Plasma 400 ICP Spectrometer for Ca and Mg, and a Perkin Elmer Aanalyst 100 atomic absorption spectrometer for Na and K.

Bulk density was determined using the frame excavation method and was adjusted for rock fragments (Grossman and Reinsch, 2002). Rock fragment percentages were determined from bulk density data, assuming a particle density of 2.65 g/cm^3. Texture was determined on the <2mm fraction by the pipette method (Soil Survey Staff, 1996). Samples were pretreated with hydrogen peroxide to remove organic matter and with sodium acetate to remove carbonates. Water retention difference (WRD) was calculated as the difference in soil moisture percentage between 1/3 and 15 bar as determined on a pressure plate. These moisture differences were adjusted for bulk density and volume of material <2mm (Soil Survey Staff, 1996).

Data was analyzed with SAS using the Spearman Correlation procedure and significance levels set at $P<0.05$ (SAS Institute, 2001). To emphasize native species establishment, all DOH seed mixes (pure or in mixtures) and unseeded control plots were removed from the analysis. Fertilized plots were also removed from analysis because the soil samples were taken from buffer areas between the plots and therefore these unfertilized soil samples were correlated to unfertilized vegetation plots.

Results and Discussion

Parkersburg and Weston had the highest total ground cover (89 and 71%, respectively) and Baker had the lowest at 16% (Table 3). Elkins had more than three times as much ground cover contributed by the seeded natives as the other sites (10% versus ≤3%). It is believed that the lack of previously established cover aided in native plant establishment at this site.

Soil pH ranged from 5.1 to 7.1 (Table 4). While variable, pH showed no clear trend with plant growth and establishment on these sites (Table 5). Some highly vegetated sites had low soil pH values, and some poorly vegetated sites had high soil pH values.

Electrical conductivity (EC) serves as a measure of soluble salts in the soil and is an important measurement for roadside soils due to the application of de-icing salts in the winter. In West Virginia, bottom ash, which contains many trace elements and salts, from local power plants is used as a major de-icing material on highways. These salts can build up in the soil and negatively affect plant establishment and growth. All sites had low electrical conductivities except the Elkins site, which was almost 10 times higher than the other sites surveyed. The Elkins site is young and on grade with the road. Since the sampling locations at that site are approximately 10 meters from the road it is not believed that the higher salt content is a product of de-icing salts and/or bottom ash applications, but rather from the lack of weathering and leaching that has occurred on the site. The Elkins site contained large amounts of shale rock fragments in the soil. Over the next couple of years, as weathering and subsequent leaching occurs, the salts should be washed from the soil profile resulting in lower electrical conductivities.

Table 3. Total ground cover and ground cover contributed by seeded natives of 6 roadside sites in West Virginia.

Site	Total	Seeded Native
	-----------------%	----------------
Baker	16	1
Elkins	42	10
Hazelton	44	0
Parkersburg	89	1
Buckhannon	51	3
Weston	71	3

Table 4. Chemical properties of the upper 10 cm of soil found on six roadside sites in West Virginia.

Site	pH	EC (dS/m)	OM (%)	CEC (cmol/kg)	Extractable Bases (cmol/kg) Ca	Mg	Na	K	Base Saturation	Total C	Total N	Total S	P	Zn	Cu	Mn
									(---------------------	%	-------------------	)	(-----------	mg/L	------------	)
Baker	6.5	0.15	1.7	7.9	2.4	1.0	0.1	0.5	50	0.6	0.0	0.1	24.3	2.2	2.2	174.4
Elkins	6.5	1.64	2.0	11.9*	18.2*	0.6	0.1	0.4	100*	1.0	0.2	0.1	5.9	3.3	2.2	58.2
Hazelton	6.1	0.16	2.7	8.7	4.0	0.2	0.1	0.5	55	0.9	0.0	0.1	8.4	5.8	1.2	124.2
Parkersburg	5.1	0.14	2.9	19.2	5.3	1.4	0.1	0.7	39	1.0	0.0	0.1	24.5	8.0	2.4	26.0
Buckhannon	5.7	0.15	6.0	12.2	4.6	0.9	0.1	0.6	51	3.0	0.0	0.2	3.9	12.5	3.0	94.5
Weston	7.1	0.30	6.4	19.7	14.1	1.6	0.1	0.6	83	2.9	0.1	0.2	1.2	6.7	8.2	75.5

*Soil contained excess calcium salts

Table 5. Correlation table showing r values.

Correlation Parameters	Total Cover	Seeded Native Cover
pH	-0.41	0.35
EC	-0.26	0.54
OM	0.83*	0.09
CEC	0.89*	0.2
Ca	0.37	0.6
Mg	0.54	0.03
Na	0.66	0.03
K	0.77	-0.2
Base Saturation	-0.26	0.54
Total C	0.71	0.43
Total N	0.09	0.71
Total S	0.09	0.6
P	-0.09	-0.6
Zn	0.83*	0.03
Cu	0.6	0.31
Mn	-0.66	-0.26
WRD	0.83*	0.03
Bulk Density	-0.93*	0.35
Bulk Density <2mm	-0.66	-0.43
Rock Fragments	-0.71	0.71

*Significant at P<0.05.

Table 6. Physical properties of the upper 10 cm of soil found on 6 roadside sites in West Virginia.

Site	Texture	WRD (cm/cm)	Bulk Density (g/cm3)	Bulk Density < 2mm (g/cm3)	Rock Fragments (%/Volume)
Baker	Sandy Loam	0.07	1.8	1.3	41
Elkins	Clay Loam	0.08	1.9	1.2	47
Hazelton	Loam	0.14	1.6	1.3	21
Parkersburg	Clay Loam	0.15	1.2	1.2	2
Buckhannon	Loam	0.16	1.5	1.1	22
Weston	Silt Loam	0.15	1.5	1.2	22

Cation exchange capacity (CEC) and base saturation (BS) were moderate across most sites, and higher CECs were found to be correlated with higher total ground covers. Baker and Hazelton had appreciably lower CECs at 7.9 and 8.7 cmol/kg, respectively. Parkersburg and Weston CEC values were more than twice as high, at 19.2 and 19.7 cmol/kg. Base saturation ranged from 39% to 100% and was similar for three of the six sites. While having one of the highest CECs, Parkersburg had the lowest base saturation. Of the extractable bases, Na and K were similar for all sites, while Ca and Mg varied considerably among the different sites. Calcium ranged from 2.4 cmol/kg to 18.2 cmol/kg, and Mg ranged from 0.2 cmol/kg to 1.6 cmol/kg. Elkins and Weston had the highest Ca concentrations and Baker had the lowest. Parkersburg and Weston had the highest Mg concentrations and Hazelton the lowest.

All sites had substantial soil organic matter, and soil organic matter was significantly correlated with total ground cover. The Weston and Buckhannon sites had the highest amount of organic matter (>6%). This most likely reflects the age and productivity of these sites as they are the oldest and therefore have had more time to accumulate organic matter.

Values obtained for total carbon correlate with soil organic matter. The Weston and Buckhannon sites had the highest total carbon concentrations and Baker the lowest. Total carbon showed a trend to increase total ground cover, while total percent nitrogen was significantly correlated to increased seeded native ground cover. The Elkins site had a higher nitrogen concentration (0.22 %) compared to the other sites (three times higher than Weston and seven times higher than Baker, Hazelton, Parkersburg, and Buckhannon) and this correlates to a significantly higher seeded native ground cover (10% versus 0-3%). This indicates that nitrogen is important in the establishment and growth of the seeded natives.

Phosphorus concentrations were low at all sites. The Baker and Parkersburg sites had concentrations three times as high as the other sites. Copper and manganese concentrations were sufficient for plant growth at all sites. Zinc concentrations ranged from 2.2 to 12.5 mg/L and were significantly correlated to total ground cover but not to seeded native cover.

Total bulk density (Table 6) was variable across sites, ranging from 1.2 to 1.9 g/cm3. Higher bulk densities were significantly correlated to decreased total cover but no correlation was found between bulk density and seeded native ground cover. Adjusted bulk density (<2mm) was similar across all sites. A negative trend was seen between rock fragment content and total ground cover, while a positive trend was seen for seeded native cover. A substantial amount of rock fragments occurred at all sites except Parkersburg, which contained only 2% by volume. The Elkins and Baker sites had the highest amount of rock fragments with 47 and 41%, respectively. Water retention difference (WRD) was found to be significantly correlated to total ground cover but not to seeded native cover. At both the Elkins and Baker sites, the WRD was half that of the other four sites. Elkins and Baker are two of the youngest sites and therefore substantial weathering of rock material had not occurred. This would account for the higher rock fragment content as well as the higher bulk densities and lower water retention differences at these sites.

Few of the soil properties measured were significantly correlated to total ground cover (OM, CEC, WRD, zinc and total bulk density only) and none were significantly correlated to the seeded native ground cover. Some of the younger sites tended to have lower total ground covers and soil physical properties that could impede plant establishment and growth (i.e. high bulk densities and high rock fragment content). This trend, however, did not follow with seeded native ground cover. Five of the six sites had similar seeded native ground covers (≤3%), and the highest seeded native ground cover (Elkins, 10%) is on one of the youngest sites.

Further research needs to be done to correlate native plant establishment and soil properties and elucidate their relationships, as there is the potential for correlation to soil properties not measured in this study.

Literature Cited

Ahern, J., C. Niedner, and A. Barker. 1992. Roadside wildflower meadows: summary of benefits and guidelines to successful establishment and management. Transportation Research Record 1334: 46-53.

Barton, S., G. Schwetz, and R. Darke. 2002. Enhancing Delaware highways: a roadside vegetation management study. Land and Water May/June 2002: 26-30.

Corley, W.L. 1995. Enhancement of native wildflowers for roadside beautification. Georgia Department of Transportation Report No. FHWA-GA-95-9206. University of Georgia, Athens, GA.

Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, New York, NY.

Daniels, W.L. and D.F. Amos. 1982. Chemical characteristics of some southwest Virginia minesoils. p. 377-380. *In* 1982 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Dec 6-10, 1982, Univ. of Kentucky, Lexington, KY.

Executive Order 13112: Invasive Species. 1999. Federal Register. Vol. 64, No. 25, Presidential Documents. Signed by W. J. Clinton. Washington, DC.

Executive Order 13148: Greening the Government through Leadership in Environmental Management. Federal Register. Vol. 65, No. 81, Presidential Documents. Signed by W. J. Clinton. Washington, DC.

Fiedler, R. R., Schaefer, M. J., and Jaskaniec, M.E. 1990. Roadside Vegetation Management Policy. Division of Highways and Transportation Services, Madison, WI.

Gartley, Karen L. 1995. Recommended soluble salts tests. p. 70-75. *In* Recommended Soil Testing Procedures for the Northeastern US. 2nd Ed. Northeastern Regional Publication #497.

Grossman, R.B. and T.G. Reinsch. 2002. Bulk density and linear extensibility. p. 201-228. *In* J.H. Dane and G.C. Topp (eds.) Methods of Soil Analysis Part 4-Physical Methods. SSSA, Madison, WI.

Haering, K.C., W.L. Daniels, and J.M. Galbraith. 2004. Appalachian Mine Soil Morphology and Properties: Effects of Weathering and Mining Method. Soil Science Society of America Journal, 68(4): 1315-1325. http://dx.doi.org/10.2136/sssaj2004.1315.

Harper, B.L. 1988. Return of the natives to Minnesota roadsides. p. 78-80. *In* 67th Annual Meeting of the Transportation Research Board, Paper No. 870410, January 11-14, 1988, Washington, DC.

Johnson, C.D. and J. Skousen. 1995. Minesoil Properties of 15 Abandoned Mine Land Sites in West Virginia. Journal of Environmental Quality, 24(4): 635-643. http://dx.doi.org/10.2134/jeq1995.00472425002400040014x http://dx.doi.org/10.2134/jeq1995.244635x43.

Morrison, D.G. 1981. Use of Prairie Vegetation on Disturbed Sites. Transportation Research Record, 822: 10-17.

Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 961-1010. *In* D.L. Sparks (ed.) Methods of Soil Analysis Part 3-Chemical Methods. SSSA, Madison, WI.

SAS Institute. 2001. SAS Software v. 8.2. SAS Institute, Cary, N.C.

Skousen, J., and R. Fortney. 2003. Native species establishment on highway corridors in West Virginia. *In* 2003 National Meeting of the American Society of Mining and Reclamation, Billings, MT, June 3-6, 2003. ASMR., Lexington, KY.https://doi.org/10.21000/JASMR03011172

Skousen, J., S. Hoover, K. Owens, and J. Sencindiver. 1998. Physical Properties of Minesoils in West Virginia and Their Influence on Wastewater Treatment. Journal of Environmental Quality, 27(3): 633-639. http://dx.doi.org/10.2134/jeq1998.00472425002700030022x http://dx.doi.org/10.2134/jeq1998.273633x.

Soil Survey Staff. 1996. Soil Survey Laboratory Method Manual. Soil Survey Investigations Report No. 42. Version 3.0. USDA Natural Resources Conservation Service. National Soil Survey center. Lincoln, Nebraska.

Swan, C., R. Cripps, G. Coorts, and B. Byler. 1993. Landscaping with Native Plants and Wildflowers on Tennessee Interstates. Tennessee Department of Transportation Report TN-RES1004, June 1993, Nashville, TN.