EFFECTS OF TREE SPECIES ON SOIL DEVELOPMENT AND HUMUS COMPOSITION IN MINESOILS[1]

by

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Abstract. Morris Run, Pennsylvania minesoils were evaluated to determine the effects of tree species on soil development and humus composition. Thirty-six sampling points were established in 50 to 69-year-old white pine (Pinus strobus) and red pine (P. resinosa) plantations and areas where volunteer black cherry (Prunus serotina) was the dominant species. Morphological, physical, and chemical properties were observed in minesoil profiles. There were significant differences in development of litter layers, soil color, horizon development and thickness, organic matter (OM) accumulation and composition, pH, and conductivity. Development of the A1 horizon was the same under all overstory types, but there were three times as many A2 horizons developed under white pine and red pine than under black cherry. More OM accumulated in the A horizon under white pine, and the B horizon of black cherry minesoil had higher OM content than either of the pine soils. More humic acid occurred under white pine but more fulvic acid developed under black cherry. Overall, the A horizon of the minesoil was more acid and contained more soluble salt than the B horizon. These data show the development of the Morris Run minesoils has been influenced by overstory species.

Additional key words: Pennsylvania, organic matter, pH, conductivity, humic acid, fulvic acid.

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Introduction

The immediate and short range goal of surface mine reclamation is to establish a vegetative cover of native and exotic plants that will stabilize the mine spoil, prevent pollution, and create a habitat for native flora and fauna. Often overlooked, but of tremendous importance, are the long-term goals of soil development, soil stability, increases in fertility, and increases in plant growth capacity of the minesoil.

Soil humus is an important source of inorganic nutrients for plant production in natural and managed ecosystems and in soil development. Vegetation is known to influence humus composition of humic and fulvic acids, and soil horizon development. This paper records the effects of three woody species on these processes.

Materials and Methods

The study area is the Morris Run Coal Mining Company surface mine in Tioga County, Pennsylvania. Davidson (1981) reported 22 plantations ranging from 3 to 13 acres, with a total of 180 acres, had been established between 1919 and 1938. Minesoil profiles from these plantations showed distinct soil horizon development. However, sampling points in that study were randomly located within the various plantations. Sampling for the current study was refined to determine the influence of tree species on minesoil horizon development and organic matter composition and concentration.

In July 1988, 36 sampling sites were selected at random in stands which had been planted in white and red pines. Black cherry minesoils were selected from groups of wild black cherry that were present within the pine stands. Criteria for sample sites were that they be located in the center of a group of three or more dominant trees of the desired species without presence of other overstory tree species. Such sample locations should give minesoils whose genesis had been dominantly controlled by the desired tree species.

At each sampling site overstory tree species, time since reclamation (from the mine map), percent herbaceous groundcover, and dominant tree species were recorded. The minesoils on the study site were mapped according to National Cooperative Soil Survey standards (Soil Survey Staff 1975). A soil pit was dug to the depth of the fragipan or about 60 cm. Parent material type was recorded. Thicknesses of the O1, O2, A1, A2, B1, B2, and B3 horizons, if present, were measured at four points down the sides of the pit. The mean of these four measurements was recorded. Depth to fragipan, if present, was recorded in the same manner. Hue, value, and chroma (wet) of the soil matrix were determined using Munsell soil color charts (Soil Survey Staff 1984). Soil texture was determined by the "feel" method in the field. Presence and type of soil structure was recorded and the proportion of rock fragments in the soil profile was estimated. Samples used for organic matter and chemical analysis were collected from the A1 and A2 horizons and the top 15 cm of the B horizon including B1 and B2 horizons as present in that zone.

The minesoil samples were sieved and dried in preparation for organic analysis at Berea College. Humic and fulvic acids were determined by the method of Schnitzer (1982). Conductivity was recorded and pH was determined in 1:1, soil:water ratio (McLean 1982).

The study design was completely random with paired observations at each sample point. Data were analyzed using the SYSTAT statistical package on a Data General Model 7800 computer.

Data were analyzed for skewness, which was found to be not significant. Therefore, the data were not transformed for the analyses. Because samples from A and B horizons were paired, two-way analysis of variance (tree species x horizons) was not appropriate. One-way analysis of variance (ANOVA) was used to determine significance of variance within horizons among treatments. Paired t-tests were used to compare differences among horizons by tree species. One-way ANOVA of differences between A and B horizons was used to check for interaction effects between tree species and soil horizon. The presence or absence of an A2 horizon was noted to be a possible result of an important factor in soil development. T-tests using pooled variances were used to test for significance of A2 presence/absence effects on selected soil variables.

Results

Minesoil development under white and red pine had significantly thicker litter layers than under black cherry (Table 1). Only the O1 horizon under white pine was not significantly greater than

Table 1. Thickness (cm) of organic, A and B horizon soils. Standard deviations are in parentheses. Means in a column followed by the same letter are not significantly different due to treatment (Tukey's HSD after ANOVA if significant, P=95%). Number of cases is given below standard deviation.

Tree Species	O1	O2	O Sum	A1	A2[1]	A2[2]	A Sum	B1	B2
White Pine	1.5 ab (0.67) 12	2.8 a (1.6) 12	4.3 a (2.0) 12	4.7 (1.9) 12	5.5 (5.0) 12	7.4 (4.4) 9	10.2 (5.9) 12	3.3 (3.9) 12	17.5 b (10.6) 12
Red Pine	2.2 a (1.08) 12	3.3 a (1.4) 12	5.5 a (2.1) 12	3.6 (1.4) 12	4.3 (3.7) 12	5.7 (3.1) 9	7.8 (2.8) 12	1.8 (4.6) 12	15.9 b (4.6) 12
Black Cherry	0.8 b (0.8) 12	1.0 b (0.7) 12	1.9 b (0.7) 12	4.8 (1.6) 12	1.8 (3.5) 12	7.3 (2.5) 3	6.6 (3.8) 12	2.75 (5.21) 12	31.42 a (14.13) 12

[1] Calculated using 0 for A2 horizon thickness when A2 not present.

[2] Calculated using only cases in which A2 was present.

that under black cherry. The mean A1 horizon thickness was 4.4 cm after 50 to 69 years of soil development and there was no significant difference in thickness among tree species. B1, B2, and sometimes B3 horizons were noted in all soil pits. The B2 horizon was significantly thicker under black cherry than under the pines.

Soil horizons were frequently well defined as indicated by Munsell soil color values and chromas (Table 2). Matrices of A1 horizons were typically 1.9 values grayer than the A2 horizons. Average values for the B1 were 0.9 units grayer than the B2. Chromas were visibly higher in the A2 than the A1. Chroma differences in the B1 and B2 horizons tended to be weakest under white pine. Munsell soil color values and chromas within each horizon and differences between horizons did not vary significantly among tree species.

A1 horizon soils under white pine had significantly more humic acid and a higher humic:fulvic ratio than A1 soils under red pine and black cherry (Table 3). There were no significant differences in A1 fulvic acid concentrations among the three tree species. The humic + fulvic sum in A1 white pine soils was significantly greater than in red pine soils. A1 horizon pH and conductivity did not vary significantly among tree species. The A1 horizon had

Table 2. Wet color value, chroma, and differences in A and B horizon soils. Standard deviations are in parentheses. There were no significant differences due to treatment (ANOVA, P=95%). N is given below standard deviation.

Tree Species	A1 Value	A2 Value	A Value Diff.	B1 Value	B2 Value	B Value Diff.	A1-B2 Value Diff.	A2-B2 Value Diff.
White Pine	2.6	4.8	-2.1	3.8	4.7	-1.0	-2.2	0.4
	(0.5)	(1.0)	(0.9)	(0.8)	(1.2)	(1.7)	(1.3)	(1.1)
	12	9	9	6	11	5	11	8
Red Pine	2.7	4.6	-1.9	3.3	4.3	-0.7	-1.6	0.1
	(0.8)	(0.9)	(1.1)	(0.6)	(0.6)	(0.6)	(1.1)	(1.2)
	12	9	9	3	12	3	12	9
Black Cherry	2.5	4.0	-1.7	3.3	3.9	-1.0	-1.4	0.0
	(0.5)	(0.0)	(0.6)	(0.5)	(0.8)	(0.8)	(1.2)	(1.0)
	12	3	3	4	12	4	12	3

Tree Species	A1 Chroma	A2 Chroma	Chroma Diff.	B1 Chroma	B2 Chroma	B Chroma Diff.	A1-B2 Chroma Diff.	A2-B2 Chroma Diff.
White Pine	1.1	2.2	-1.1	4.0	3.6	0.4	-2.5	-1.9
	(0.3)	(0.8)	(0.8)	(1.3)	(1.6)	(0.5)	(1.6)	(1.7)
	12	9	9	6	11	5	11	8
Red Pine	1.2	2.3	-1.2	3.3	3.8	-1.7	-2.6	-1.4
	(0.4)	(0.7)	(0.7)	(1.2)	(1.5)	(2.5)	(1.6)	(1.7)
	12	9	9	3	12	3	12	9
Black Cherry	1.0	1.7	-0.7	2.5	3.8	-0.8	-2.8	-1.7
	(0.0)	(0.6)	(0.6)	(1.0)	(0.9)	(1.3)	(0.9)	(0.6)
	12	3	3	4	12	4	12	3

significantly higher concentrations of humic and fulvic acids, humic + fulvic sum, and conductivity than the B horizon under all tree species. A1 horizon pH was significantly lower than B horizon pH. The humic:fulvic ratio was not significantly different between the A1 and B horizons except under black cherry.

ANOVA of soil horizon differences in chemical characteristics revealed there were significant interactions between tree species and soil horizon for humic acid concentration and humic:fulvic ratio (Table 4).

The soil profiles under pine exhibited A2 development in 75 percent of the pits, while A2 horizons were discernible only 25 percent of the time under black cherry (Table 5). This observation that A2 horizon development was not uniform within or among soils under different tree species

Table 3. Chemical characteristics of soils. Standard deviations are in parentheses. A horizon means in a column followed be the same letter are not significantly different due to treatment (Tukey's HSD after ANOVA if significant, P=95%). There were no significant differences among B horizon means due to treatment (ANOVA, P=95%). B horizon means followed by "*" are significantly different from the corresponding A horizon means (paired t-tests, P=95%). N = 12 in all cases.

Tree Species	Horizon	Humic Acid %	Fulvic Acid %	Humic-Fulvic Ratio	Humic-Fulvic Sum %	pH	Conductivity umho cm^{-1}
White Pine	A1	1.41 a (0.41)	1.04 (0.11)	1.36 a (0.36)	2.45 a (0.47)	4.55 (0.26)	193 (46)
	B	0.53 * (0.22)	0.65 * (0.19)	0.91 (0.53)	1.18 * (0.24)	4.90 * (0.18)	113 * (23)
Red Pine	A1	0.81 b (0.25)	0.90 (0.26)	0.90 b (0.22)	1.72 b (0.47)	4.60 (0.30)	191 (49)
	B	0.55 * (0.12)	0.62 * (0.17)	0.97 (0.37)	1.17 * (0.26)	5.06 * (0.48)	114 * (28)
Black Cherry	A1	0.95 b (0.35)	1.16 (0.32)	0.80 b (0.12)	2.11 ab (0.67)	4.76 (0.31)	170 (37)
	B	0.64 * (0.20)	0.69 * (0.16)	0.92 * (0.16)	1.33 * (0.34)	5.04 * (0.16)	97 * (18)

Table 4. Mean differences between soil horizons for selected soil variables by tree species. Mean differences followed by the same letter are not significantly different (Tukey's HSD after ANOVA if significant, P=95%). Significant differences indicate significant interaction effects between tree species and soil horizons. Standard deviations are in parentheses. N = 12 in all cases.

Tree Species	A-B Humic Acid	A-B Fulvic Acid	A-B H:F Ratio	A-B H+F Sum	A-B pH	A-B Conductivity
White Pine	0.88 a (0.54)	0.39 (0.20)	0.45 a (0.78)	0.00 (0.00)	-0.35 (0.23)	80 (46)
Red Pine	0.26 b (0.26)	0.28 (0.22)	-0.06 ab (0.48)	0.08 (0.29)	-0.46 (0.52)	77 (56)
Black Cherry	0.31 b (0.36)	0.47 (0.34)	-0.13 b (0.18)	0.00 (0.00)	-0.28 (0.24)	73 (34)

Table 5. Thickness (cm) of organic, A, and B horizons in soils with and without presence of a discernable A2 horizon. Standard deviations are in parentheses. A2-present means followed by "*" are significantly different from A2 absent means for the same tree species (t-test using pooled variances, P=95%). Number of cases is given below standard deviation.

Tree Species	A2 Present	O1	O2	O Sum	A1	A Sum	B1	B2
White Pine	yes	1.22* (0.51) 9	2.72 (1.86) 9	3.94 (2.14) 9	4.89 (2.12) 9	12.29* (5.34) 9	3.28 (4.21) 9	16.44 (11.71) 9
	no	2.17 (0.76) 3	3.00 (1.00) 3	5.17 (1.44) 3	4.00 (1.00) 3	4.00 (1.00) 3	3.50 (3.28) 3	20.67 (7.10) 3
Red Pine	yes	2.11 (0.78) 9	3.11 (0.61) 9	5.22 (1.20) 9	3.11* (1.02) 9	8.78* (2.58) 9	2.33 (5.24) 9	16.83 (3.91) 9
	no	2.50 (1.32) 3	3.83 (2.84) 3	6.33 (4.16) 3	5.00 (1.32) 3	5.00 (1.32) 3	0.00 (0.00) 3	13.00 (7.55) 3
Black Cherry	yes	0.50 (0.00) 3	1.00 (0.00) 3	1.50 (0.00) 3	4.67 (0.58) 3	12.00* (2.65) 3	8.83* (7.52) 3	20.00 (8.19) 3
	no	0.92 (0.85) 9	1.06 (0.85) 9	2.00 (0.83) 9	4.83 (1.84) 9	4.83 (1.84) 9	0.72 (2.17) 9	35.22 (13.88) 9

prompted an examination of pedons with and without A2 horizon development. Under white pine, soils with developed A2 horizons had significantly thinner O1 horizons, but this was not true for soils under red pine or black cherry. A1 horizons were significantly thinner under red pine if an A2 had developed, but this was not true under white pine or black cherry. Development of an A2 led to a significantly greater total A1 + A2 under all three tree species, so the A2 was not merely a development from or at the expense of the A1. B1 horizons were significantly thicker when an A2 horizon developed under black cherry, but this did not hold true under other species. No discernible B1 horizon was observed under red pine where an A2 had not developed.

Soil color values in A and B horizons and A horizon chromas were not significantly related to A2 development (Table 6). B1 chromas were significantly lower under black cherry when an A2 had formed. B2 chromas were significantly higher under white pine when an A2 had formed.

Development of A2 horizons seemed to be unrelated to the organic matter fractions in the soils (Table 7). The only significant difference found was that the mean B horizon fulvic acid concentration was lower under white pine when A2 horizons had developed.

Herbaceous cover did not vary significantly with A2 horizon development under the pines. However, herbaceous cover was significantly lower

Table 6. Wet color value and chroma differences in A and B horizons of soils with and without presence of a discernable A2 horizon. Standard deviations are in parentheses. A2-present means followed by "*" are significantly different from A2-absent means for the same tree species (t-test using pooled variances, p=95%). Number of cases is given below standard deviation.

Tree Species	A2 Present	A1 Value	A2 Value	A Diff. Value	B1 Value	B2 Value	B Diff. Value	A1-B2 Diff. Value	A2-B2 Diff. Value
White Pine	yes	2.7 (0.5) 9	4.8 (1.0) 9	-2.1 (0.9) 9	4.0 (0.8) 4	4.4 (1.1) 8	0.0 0.0 3	-1.8 (1.0) 8	0.4 (1.1) 8
	no	2.3 (0.6) 3	- - -	- - -	3.5 (0.7) 2	5.7 (1.2) 3	-2.5 (2.1) 2	-3.3 (1.5) 3	- - -
Red Pine	yes	2.7 (0.7) 9	4.6 (0.9) 9	-1.9 (1.1) 9	3.3 (0.6) 3	4.4 (0.5) 9	-0.7 (0.6) 3	-1.8 (1.0) 9	0.1 (1.2) 9
	no	2.6 (0.5) 9	- - -	- - -	4.0 - 1	3.9 (0.8) 9	-1.0 - 1	-1.0 (1.0) 3	- - -
Black Cherry	yes	2.3 (0.6) 3	4.0 (0.0) 3	-1.7 (0.6) 3	3.0 (0.0) 3	4.0 (1.0) 3	-1.0 (1.0) 3	-1.7 (1.5) 3	0.0 (1.0) 3
	no	2.6 (0.5) 9	- - -	- - -	4.0 - 1	3.9 (0.8) 9	-1.0 - 1	-1.3 (1.1) 9	- - -

Tree Species	A2 Present	A1 Chroma	A2 Chroma	A Diff. Chroma	B1 Chroma	B2 Chroma	B Diff. Chroma	A1-B2 Diff. Chroma	A2-B2 Diff. Chroma
White Pine	yes	1.1 (0.3) 9	2.2 (0.8) 9	4.5 (0.8) 9	4.5 (1.0) 4	4.3* (1.2) 8	0.3 (0.6) 8	-3.1 (1.2) 8	-1.9 (1.7) 8
	no	1.0 (0.0) 3	- - -	- - -	3.0 (1.4) 2	2.0 (1.7) 3	0.5 (0.7) 2	-1.0 (1.7) 3	- - -
Red Pine	yes	1.1 (0.3) 9	2.3 (0.7) 9	-1.2 (0.7) 9	3.3 (1.2) 3	3.8 (1.4) 9	-1.7 (2.5) 3	-2.7 (1.5) 9	-1.4 (1.7) 9
	no	1.3 (0.6) 3	- - -	- - -	- - -	3.7 (2.1) 3	- - -	-2.3 (2.3) 3	- - -
Black Cherry	yes	1.0 (0.0) 3	1.7 (0.6) 3	-0.7 (0.6) 3	2.0* (0.0) 3	3.3 (0.6) 3	-1.3 (0.6) 3	-2.3 (0.6) 3	-1.7 (0.6) 3
	no	1.0 (0.0) 9	- - -	- - -	4.0 - 1	3.9 (0.9) 9	1.0 - 1	-2.9 (0.9) 9	- - -

under black cherry when an A2 horizon was present (Table 8). A1 horizon pH was Significantly lower under black cherry when an A2 was present. A2 horizons developed only in black cherry soils where A1 pH was lower than 4.4. A1 and B soil pH differences were significantly greater when an A2 horizon had formed under black cherry. No clear difference or significant trend in A1 was found to be related to A2 development under the pines. No signif-

Table 7. Organic matter fractions in A and B horizons of soils with and without the presence of a discernable A2 horizon. Standard deviations are in parentheses. A2-present means followed by "*" are significantly different from A2-absent means for the same tree species (t-test using pooled variance, P=95%). Number of cases is given below standard deviation.

Tree Species	A2 Present	% A Humic	% A Fulvic	A H:F Ratio	A H+F Sum %	% B Humic	% B Fulvic	B H:F Ratio	B H+F Sum %
White Pine	yes	1.38 (0.42) 9	1.03 (0.12) 9	1.35 (0.37) 9	2.41 (0.18) 9	0.55 (0.25) 9	0.59* (0.13) 9	1.00 (0.58) 9	1.14 (0.25) 9
	no	1.51 (0.47) 3	1.06 (0.04) 3	1.41 (0.39) 3	2.57 (0.51) 3	0.47 (0.14) 3	0.82 (0.25) 3	0.63 (0.30) 3	1.30 (0.21) 3
Red Pine (0.26)	yes (0.27)	0.85 (0.25) 9	0.92 (0.48) 9	0.93 (0.12) 9	1.77 (0.20) 9	0.55 (0.42) 9	0.60 (0.28) 9	1.01 9	1.15 9
	no	0.71 (0.27) 3	0.85 (0.23) 3	0.82 (0.08) 3	1.57 (0.20) 3	0.57 (0.13) 3	0.67 (0.09) 3	0.84 (0.08) 3	1.24 (0.22) 3
Black Cherry	yes	1.20 (0.36) 3	1.36 (0.40) 3	0.88 (0.06) 3	2.56 (0.76) 3	0.60 (0.29) 3	0.66 (0.23) 3	0.89 (0.22) 3	1.26 (0.51) 3
	no	0.86 (0.32) 9	1.09 (0.29) 9	0.77 (0.13) 9	1.95 (0.62) 9	0.66 (0.18) 9	0.70 (0.15) 9	0.94 (0.15) 9	1.35 (0.30) 9

Table 8. Vegetation cover (%), pH, and conductivity (umho/cm) of A1 and B1 horizons of soils with and without presence of a discernable A2 horizon. Standard deviations are in parentheses. A2-present means followed by "*" are significantly different from A2-absent means for the same tree species (t-test using pooled variances, P=95%). Number of cases is given below standard deviation.

Tree Species	A2 Present	% Veg. Cover	A pH	B pH	A-B pH Diff.	A Cond	B Cond	A-B Cond. Diff.
White Pine	yes	59 (39) 9	4.52 (0.26) 9	4.87 (0.15) 9	-0.35 (0.25) 9	189 (53) 9	119 (21) 9	69 (47) 9
	no	100 (0) 3	4.62 (0.28) 3	4.98 (0.28) 3	-0.18 (0.18) 3	208 (12) 3	95 (21) 3	114 (27) 3
Red Pine	yes	41 (34) 9	4.61 (0.30) 9	5.08 (0.55) 9	-0.47 (0.60) 9	186 (53) 9	115 (29) 9	71 (64) 9
	no	17 (12) 3	4.56 (0.36) 3	5.00 (0.23) 3	-0.44 (0.17) 3	205 (35) 3	110 (32) 3	95 (10) 3
Black Cherry	yes	7* (3) 3	4.33* (0.08) 3	4.89 (0.19) 3	-0.56* (0.21) 3	160 (33) 3	108 (13) 3	52 (20) 3
	no	59 (37) 7	4.90 (0.20) 9	5.09 (0.13) 9	-0.18 (0.16) 9	173 (39) 9	93 (19) 9	80 (36) 9

icant differences in A1 or B horizon conductivities were found between soils with or without A2 horizon development.

The Pearson correlation matrix showed a number of interesting correlations between soil chemical and physical characteristics Table (9). Total A horizon thickness was significantly correlated to thickness of A2 horizon, but not to A1 thickness. Greater total A horizon thickness was related also to lower A1 and B horizon pH. Greater differences occurred in conductivity between the A1 and B horizon. Thicker B1 horizons were associated with lower A1 pH. Thinner B2 horizons were associated with thicker O and A2 horizons and higher conductivity in the B horizon. Greater depth to the fragipan was correlated with thinner O and thicker B2 horizons. Higher A1 pH was correlated with higher B horizon pH, greater differences in pH between A1 and B horizons, and lower conductivities in the A1 and B horizons. Greater conductivity of the A1 was correlated with lower differences in pH between horizons and higher differences in conductivity between horizons. This data indicates the A1 horizon is much more variable than the B. Thickness of the B1 horizon was significantly correlated with A1 humic acid concentration, and negatively correlated with B humic acid and the B humic:fulvic acid ratio. Soils with high A1 humic acid also had high fulvic acid concentrations and a higher humic:fulvic ratio. High B fulvic acid also was correlated with high A1 humic acid, but B humic acid was not related.

There were no significant correlations of horizon color values and chromas to soil organic matter fractions. A1 values were significantly correlated with B1 values and A1 chromas. A2 values were positively correlated with thicker O2 and total O. B1 values were significantly higher in soil with greater depths to the fragipan. B2 values were inversely correlated with A1 horizon thickness. B1 chromas were significantly higher with greater depths to the fragipan.

Herbaceous cover was significantly correlated with higher A1 pH and higher B1 values.

Discussion

Forest trees on this site have provided much of the raw materials for organic matter formation, and they control the environments in which this raw material is transformed into the very complex suites of organic compounds which comprise soil organic matter. Hardwoods and conifers differ in the chemical qualities of the litter they produce, and there are also considerable differences within these two guilds. The pines shade and moderate the soil surface temperatures throughout the year, but deciduous hardwoods allow greater heating and cooling of surface layers during the leafless early spring, late fall, and winter. Thus, some variations in

Table 9. Pearson correlation matrix of soil properties. Underlined correlations are significant at P = 0.95.

	COVER	O1	O2	OSUM	A1	A2	ASUM	B1	B2	PAN	AHUMIC	AFULVIC	AHFRAT	BHUMIC	BFULVIC	BHFRAT	A1VAL	A2VAL	B1VAL
COVER	1.000																		
O1	-0.013	1.000																	
O2	0.060	0.566	1.000																
OSUM	0.036	0.815	0.939	1.000															
A1	-0.219	-0.144	-0.149	-0.165	1.000														
A2	-0.270	-0.000	0.292	0.205	-0.073	1.000													
ASUM	-0.342	-0.054	0.224	0.135	0.302	0.929	1.000												
B1	-0.053	-0.221	-0.193	-0.228	0.091	0.215	0.239	1.000											
B2	0.179	-0.376	-0.651	-0.614	-0.007	-0.484	-0.465	-0.138	1.000										
PAN	-0.059	-0.559	-0.617	-0.685	0.250	-0.214	-0.112	0.301	0.710	1.000									
AHUMIC	0.276	0.017	-0.146	-0.096	0.266	0.169	0.261	0.335	-0.024	0.100	1.000								
AFULVIC	0.172	0.012	-0.203	-0.138	0.249	-0.066	0.030	0.169	0.181	0.083	0.538	1.000							
AHFRAT	0.191	0.047	0.009	0.026	0.152	0.277	0.321	0.267	-0.153	0.033	0.867	0.073	1.000						
BHUMIC	-0.017	0.049	0.132	0.113	-0.003	-0.102	-0.098	-0.439	0.027	-0.187	-0.054	0.222	-0.204	1.000					
BFULVIC	0.050	0.107	-0.032	0.022	0.183	-0.283	-0.203	0.002	0.202	0.174	0.376	0.316	0.249	0.312	1.000				
BHFRAT	0.044	0.063	0.218	0.180	-0.244	0.204	0.104	-0.362	-0.187	-0.350	-0.313	-0.151	-0.308	0.581	-0.508	1.000			
A1VAL	-0.041	-0.150	0.152	0.044	-0.037	0.100	0.082	0.012	-0.040	0.132	-0.104	-0.230	0.049	0.200	0.156	0.015	1.000		
A2VAL	0.072	0.378	0.516	0.525	0.326	0.251	0.349	-0.032	-0.380	-0.304	-0.037	-0.023	0.046	0.028	0.268	-0.158	0.251	1.000	
B1VAL	0.576	-0.175	0.487	0.267	-0.210	-0.035	-0.114	0.116	-0.285	0.733	-0.241	-0.272	-0.160	-0.008	-0.222	0.123	0.566	0.447	1.000
B2VAL	0.268	0.227	0.307	0.305	-0.348	0.180	0.040	0.049	-0.289	-0.349	0.042	-0.188	0.164	-0.033	-0.062	0.188	-0.194	0.230	0.055
A1CHR	0.009	0.054	-0.008	0.017	-0.094	-0.027	-0.060	-0.177	0.043	0.019	-0.074	-0.125	-0.019	-0.152	0.038	-0.193	0.380	-0.218	.
A2CHR	0.213	0.000	-0.120	-0.086	-0.168	-0.379	-0.395	-0.145	0.425	0.128	0.196	-0.017	0.231	-0.022	0.045	-0.058	-0.054	-0.329	-0.000
B1CHR	0.280	-0.095	0.475	0.294	0.147	0.114	0.149	-0.057	-0.411	0.842	-0.123	-0.386	0.076	-0.183	-0.277	-0.009	0.487	0.469	0.832
B2CHR	-0.136	-0.299	-0.179	-0.249	-0.039	0.145	0.123	-0.138	-0.021	0.020	-0.043	-0.102	0.082	-0.029	-0.242	0.032	0.136	0.250	-0.172
APHG	0.474	0.146	0.064	0.106	-0.110	-.0304	-0.331	-0.527	0.282	-0.012	-0.065	0.192	-0.205	0.476	-0.018	0.431	-0.250	-0.036	0.428
BPHG	0.023	-0.014	0.031	0.016	-0.061	-0.326	-0.334	-0.287	0.062	-0.161	-0.145	-0.067	-0.146	0.248	0.061	0.114	-0.198	-0.067	0.217
PHDIF	0.390	0.135	0.026	0.075	-0.039	0.032	0.017	-0.189	0.181	0.133	0.076	0.231	-0.046	0.191	-0.072	0.274	-0.035	0.037	0.275
ACONCG	-0.208	-0.040	-0.110	-0.094	0.032	-0.207	-0.186	0.328	-0.008	0.197	-0.100	-0.380	0.060	-0.418	-0.033	-0.338	o.144	-0.251	0.201
BCONDG	-0.267	0.094	0.226	0.198	0.145	0.271	0.313	0.108	-0.354	-0.186	-0.072	-0.145	0.031	-0.307	-0.344	-0.050	0.008	0.075	0.219
CONDDIF	-0.060	-0.090	-0.230	-0.199	-0.045	-0.350	-0.351	0.267	0.182	0.283	-0.060	-0.299	0.043	-0.250	0.155	-0.309	0.138	-0.280	0.099

	B2VAL	A1CHR	A2CHR	B1CHR	B2CHR	APHG	BPHG	PHDIF	ACONDG	BCONDG	CONDDIF
B2VAL	1.000										
A1CHR	-0.208	1.000									
A2CHR	-0.158	0.359	1.000								
B1CHR	-0.219	.	0.202	1.000							
B2CHR	-0.124	-0.090	-0.213	0.172	1.000						
APHG	-0.014	-0.222	0.336	0.253	-0.071	1.000					
BPHG	-0.247	-0.066	0.370	0.290	-0.140	0.386	1.000				
PHDIF	0.207	-0.128	-0.119	0.035	0.065	0.525	-0.583	1.000			
ACONDG	-0.110	0.313	0.105	0.146	-0.182	-0.533	-0.052	-0.422	1.000		
BCONDG	0.047	-0.009	-0.030	0.248	-0.068	-0.350	-0.282	-0.048	0.268	1.000	
CONDDIF	-0.133	0.315	0.117	0.022	-0.144	-0.341	0.102	-0.394	0.851	-0.278	1.000

decomposition products are to be expected.

Thicker O1 and O2 under pines are probably a function of lower N content of pines, lower pH, and shaded environments which have lower soil temperatures resulting in lower decomposition rates.

Greater thickness of O1 and O2 horizons, and their sum under pines did not appear to result in significant differences in A1 and A2 horizon thicknesses nor in B1 horizon thickness.

Plant chemistry differences in the pines and black cherry should have caused significant differences in soil pH and conductivity, at least in surface soils. However, this was not the case.

The A1 horizons developed under white pine contained significantly greater concentrations of humic acids and, as a result, had greater humic:fulvic ratios and humic:fulvic sums. Humic acids are the more stable, less reactive, and more maturely developed fraction of soil organic matter. Thus, organic matter developed under white pine in these mined soils might be a little more stable after severe ecosystem disturbance such as clear-cutting or fire. Other soil properties such as anion-cation exchange related to organic matter quality might also differ.

Marked soil horizons and differences between them have developed in the 50 to 69 years since these soil parent materials have been exposed. Soil matrix color value differences between A1 and B2 horizons range up to 1.4 to 2.2 Munsell units; chroma differences range from 2.5 to 2.8 for the same horizons (Table 2). A1 humic and fulvic acids and nutrients (as measured by conductivity) are greater under surface horizons. The A1 horizons were significantly more acid than the B horizon soils.

The most striking differences among vegetation types was the greater number of soil pits showing development of an A2 horizon under the pines (75 percent) compared to 25 percent under black cherry. Conventional soil science theory suggests acidity of tree litter promotes podzolization of soils, but podzolization could also be a residual result of initial acidity differences in surface mine spoils left on the surface. However, B horizon pHs were quite uniform under all three vegetation types with and without A2 development. Therefore, the residual acidity hypothesis was discounted. A2 horizons have developed under black cherry where current A1 pH is below 4.4, but there was not a uniform pH break-point for A2 formation under red or white pines. Some factor other than mere acidity must be involved and it may be related to plant chemistry, but humic/fulvic acid fraction differences do not seem to be the cause.

Under black cherry, development of an A2 horizon may be correlated with development of a thicker B1, but this thickness/depth increase was not accompanied by a significant color value or chroma difference. No B1 was discernible under red pine where an A2 had not developed, and no relationship between A2 development and B1 thickness was apparent under white pine.

A1 horizon thickness was more or less uniform under all three vegetation types and the total A thickness was much greater where A2 horizons had developed. Therefore, A2 development may have been an extension of A horizon illuviation processes into lower levels of the soil parent materials rather than a subdivision of the developing A1 horizon into two horizons with differing rates of A horizon development processes.

Factors which might promote A2 development may be a combination of pH, plant litter organic chemistry and decomposition products, soil texture, initial differences in surface-subsurface soil pH, and activity of herbaceous plants acting as nutrient pumps and supplying quickly-decomposed organic matter to intermediate soil depths.

The breaking-point of A1 pH 4.4 for A2 formation under black cherry supports the pH-podzolization relationship hypothesis, but lack of such correlation for pines does not support this. A2 horizons formed under pines throughout the range of measured pHs.

There was a trend across all three species for A2 development to be associated with thinner O horizons, but there was a significant difference between A2 presence and absence only in white pine O1 (Table 5). Factors which promote litter decomposition are also conducive to podzolization in young soils. Fungi are more important decomposers than bacteria in acid soils. Could fungal extrametabolites or products be more conducive to podzolization than those from bacteria?

Conclusions

Tree species do influence soil horizon development and humus composition on reclaimed minesites. The total O horizon was thicker with pine overstory than with black cherry. Under black cherry, however, there was more OM in the B horizon than under pine. More humic acid developed under white pine while the level of fulvic acid was greater under black cherry. The presence/absence of an A2 horizon influenced several variables. Herbaceous cover was lower under black cherry when A2 was present. Thickness of the O horizon was significantly reduced under white pine in the presence of A2. Development of an A2 horizon was not uniform. It was present in 75 percent of the pine sites and only 25 percent of the black cherry sites. Overall, the A horizons were more acid and contained more soluble salts than the B horizons. There were no significant differences in soil acidity between overstory species.

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