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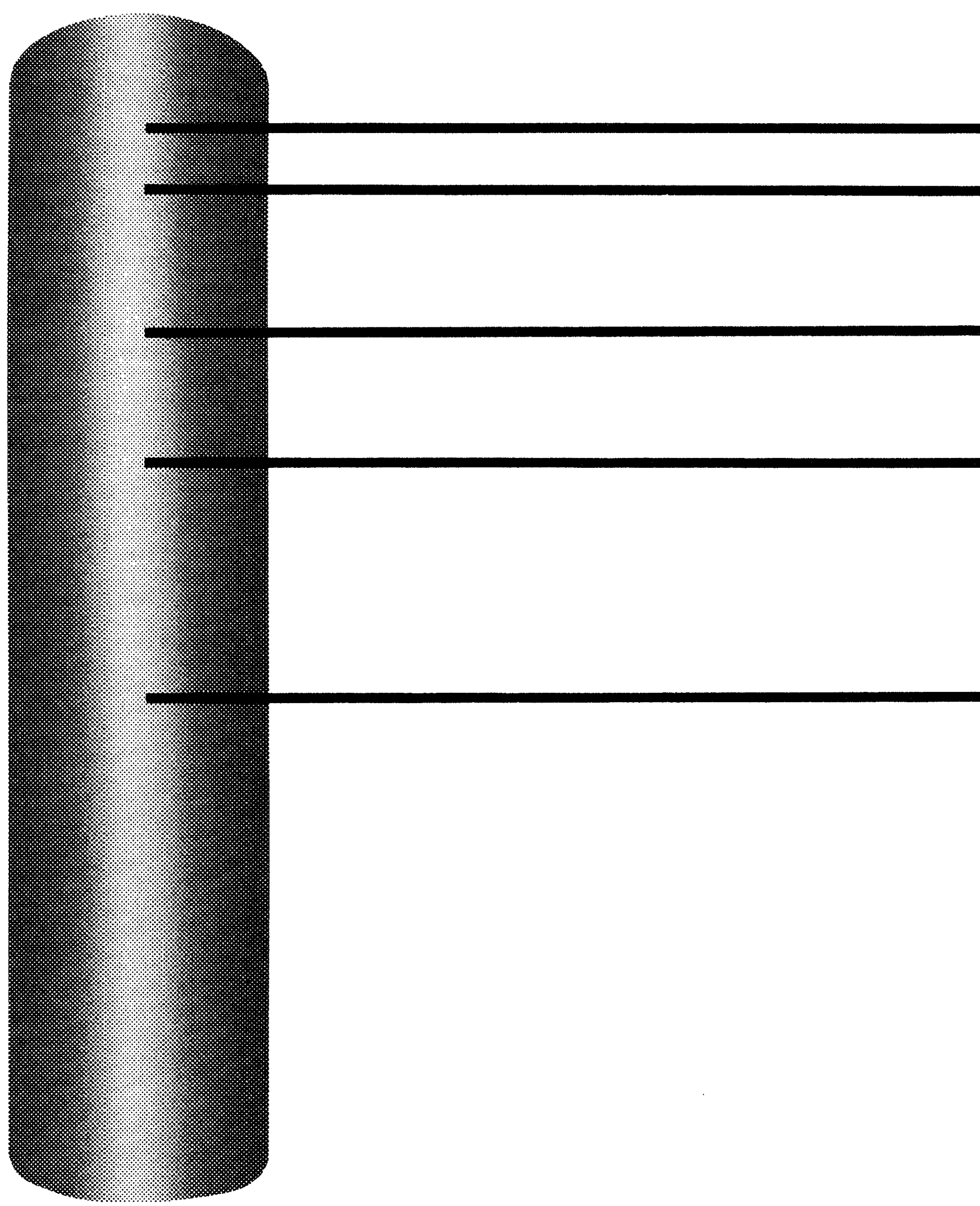
Using Column Lysimetry to Evaluate Acid Precipitation Effects

Alfred Ray Harris and Douglas M. Stone



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USING COLUMN LYSIMETRY TO EVALUATE ACID PRECIPITATION EFFECTS

Alfred Ray Harris and Douglas M. Stone

Acidification of forest soils by precipitation and internally generated acids can accelerate leaching of basic cations (Ca, Mg, K, and Na), resulting in reduced soil fertility. Soil acidification also may result in increased concentrations of aluminum in the soil solution; when this solution moves to open waters, it can have deleterious effects on aquatic ecosystems.

Lakes and streams may be acidified by direct precipitation and from water channeled through surrounding soils. Also, it is hypothesized that water in soils with low base saturation and high anion input can produce highly acidic percolate after prolonged soil contact and subsequent degassing in surface waters.

Theories advanced by Reuss (1983), Reuss and Johnson (1985), and Seip and Rustad (1984) suggest that water in soils with less than 15 percent base saturation is susceptible to pH depression of up to 0.4 units, which is sufficient to cause negative alkalinity in the solution. High concentrations of mobile anions (notably SO_4) are responsible for the negative alkalinity, and these solutions upon CO_2 degassing in surface waters can retain acidities of pH 5.0 or less.

The impact of acid precipitation on nutrient depletion, solubilization of toxic elements, acidification of open waters due to anion loading of the soil, and transport of unbuffered acid precipitation through watersheds is not well known. This research was designed to determine whether these soil processes are important to the acidification of lakes located in the nutrient-deficient, sandy outwash plains of the Superior Uplands.

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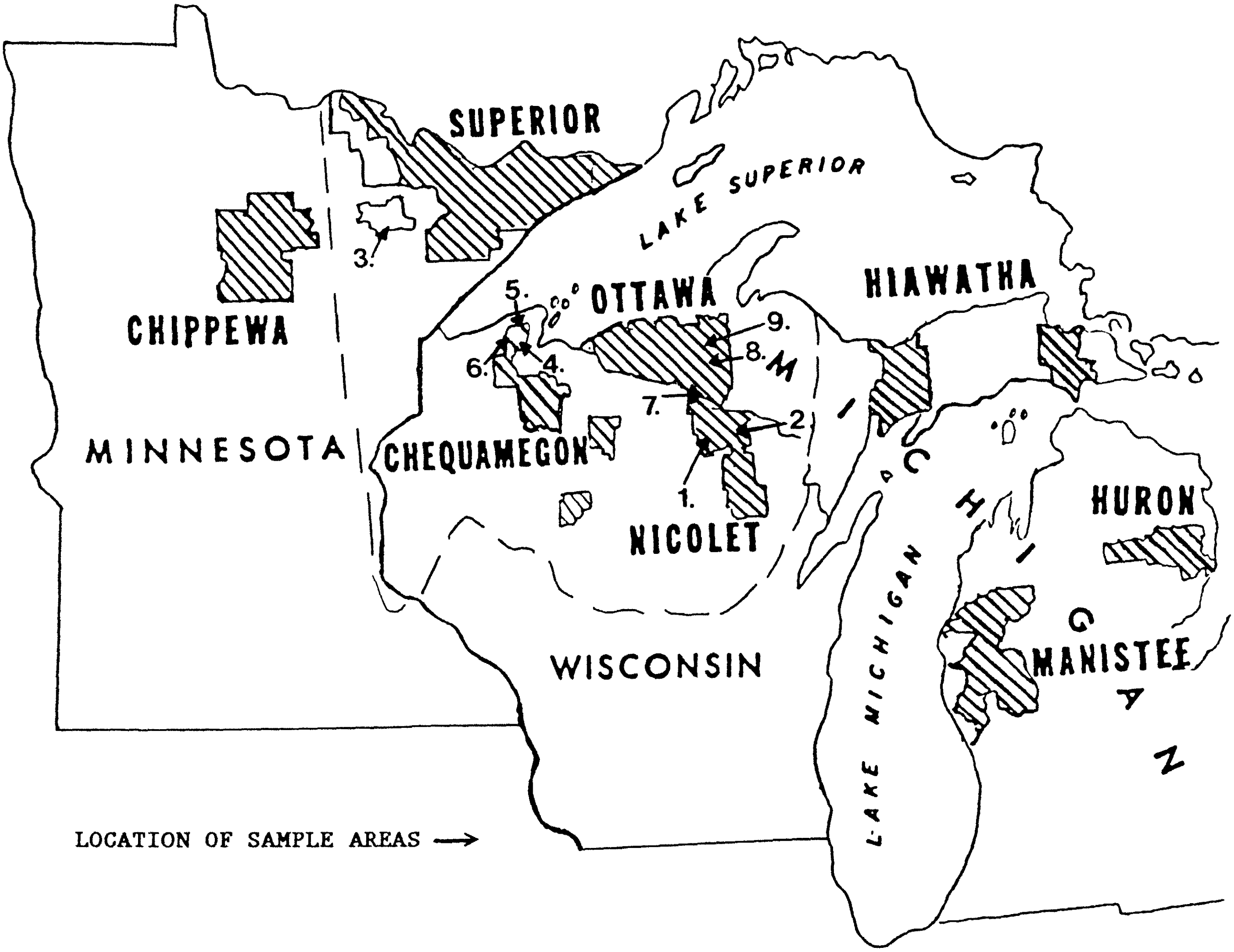
The specific objective of the study was to determine the sensitivity of soils with low base-saturation to increased anion loadings and the susceptibility of these soil solutions to pH depression and negative alkalinities. A secondary objective was to determine whether reduced sulfate deposition will reverse the acidification processes and return soil water alkalinities from negative to positive.

This paper describes the experimental design and approach used to solve problems encountered with soil column collection, instrumentation, materials and methods, and maintenance of natural soil temperatures. Some preliminary results are presented. Also, basic data on the soil and vegetation of the sampled sites are included to form a database for use by forest soil scientists and land managers.

SITE CHARACTERISTICS

Study Area

The Superior Uplands physiographic province includes large areas of forest land in the upper Great Lakes region. The province is covered to varying depths by glacial deposits that determine the topography, drainage patterns, and soil parent materials (Fenneman 1938). The region includes extensive areas of outwash plains where numerous lakes occupy basins formed by the burial and subsequent melting of ice blocks. Many of these lakes are sensitive to acidic deposition (Nichols and McRoberts 1986). Nine sites representative of large areas of infertile, sandy soils with base saturations in a range of 1 to 40 percent were sampled (fig. 1). Average annual precipitation ranges from 600 to 850 mm and pH ranges from 5.0 to 4.7 across the region.



SITE NO.	LOCAL NAME	NATIONAL FOREST	RANGER DISTRICT	STATE	COUNTY	-- LEGAL DESCRIPTION -- TOWN	RANGE	SECTION
1	Sevenmile Lake	Nicolet	Eagle River	WI	Forest	39 N	12 E	7
2	Brule Creek	Nicolet	Eagle River	WI	Forest	40 N	13 E	4
3	Dark Lake	Superior	Virginia	MN	St. Louis	60 N	19 W	29
4	Long Lake	Chequamegon	Washburn	WI	Bayfield	48 N	6 W	1
5	Horshoe Lake	Chequamegon	Washburn	WI	Bayfield	48 N	6 W	18
6	Sawdust Lake	Chequamegon	Washburn	WI	Bayfield	48 N	7 W	32
7	Lac Vieux Desert	Nicolet	Eagle River	WI	Vilas	42 N	11 E	7
8	Trout Creek	Ottawa	Kenton	MI	Ontonagon	47 N	38 W	27
9	Baraga Plains	Ottawa	Kenton	MI	Baraga	49 N	35 W	36

Figure 1.—*Location of sample sites in the Superior, Chequamegon, Nicolet, and Ottawa National Forests. Heavy dashed line indicates approximate boundary of the Superior Uplands.*

Vegetation

The predominant species in the overstory, shrub layer, and ground flora of each site are listed in descending order of abundance (table 1). The vegetation on sites 1, 2, and 4 to 7 were classified as Acer-Quercus-Vaccinium using the system of Kotar *et al.* (1988); site 8 was Tsuga-Maianthemum, and site 9 was Pinus-Vaccinium-Deschampsia (Coffman *et al.* 1984). Site 3 on the Superior National Forest was classified using different nomenclature (table 1).

Soils with the lowest base saturation (0 to 10 percent) supported stands with a sparse overstory of jack pine and/or oak. Red maple, paper birch, quaking aspen, and red pine were the most common associated species. A shrub layer frequently was absent on these sites or consisted only of widely scattered pin cherry, juneberry, or oak. The ground flora generally consisted of a sparse cover of reindeer moss, sweet-fern, blueberry, and occasionally bracken fern and mixed grasses.

Relatively open stands of red pine, jack pine, and oak occupied the medium-base (10 to 20 percent) sites, with white pine, paper birch, and aspen as common associates. When present, the shrub layer consisted of scattered pin cherry, oak, and juneberry. Ground flora included sweet-fern, blueberry, bracken fern, raspberry, and woodland strawberry, with reindeer moss and mixed grasses on some sites.

Soils with the highest base saturation (20 to 40 percent) supported stands with closed canopies of white pine, red pine, white spruce, birch, and aspen. These sites generally had a well-developed shrub layer consisting of white pine, red pine, balsam fir, aspen, birch, hazel, and red maple. The ground flora was more abundant and included bracken fern, blueberry, wintergreen, club-mosses, wild strawberry, ground-pine, and seedlings of the overstory species.

Soils

The sites selected for sampling had rapidly permeable sand soils of moderately weathered glacial outwash; these soils ranged in drainage capacity from somewhat excessively to somewhat poorly drained. Sample columns were collected using schedule 35 polyvinyl chloride (PVC) plastic pipe to contain the soil. A column from the center of each site was used for identifying the classification of the soil profile and for characterizing the physical and chemical properties. The litter-humus layer was removed from each column and weights and chemical characteristics were determined on a composite sample from each site (table 2 and Appendix 1).

The ecological land forms for each site are listed as follows:

Site 1 - Hummocky kame-kettle complex. Slopes are complex and range to 50 percent. Local relief is to 100 feet. Glacial materials are sandy outwash sediments.

Site 2 - Nearly level, outwash plain. Slopes are simple and less than 6 percent. Local relief is less than 200 feet. Glacial materials are sandy.

Site 3 - Undulating outwash plain. Local relief is less than 10 feet. Glacial materials consist of outwash sands over grey clay or grey till.

Sites 4,5,6 - Pitted outwash plain. Glacial materials consist of sands and gravel.

Site 7 - Nearly level outwash plain. Slopes are less than 6 percent. Local relief is 20 feet.

Site 8 - Hilly, recessional moraine. Slopes are complex and range from 10 to 25 percent. Local relief is up to 100 feet. Glacial materials are sandy till.

Site 9 - Nearly level, stabilized dune features on lake plain. Slopes are complex and up to 8 percent. Maximum local relief is 20 feet.

The mineral soil from each site was identified as either Haplorthod or Udipsamment. Complete soil profile descriptions are given, in Appendix 2. A soil column from each site was divided into 5-cm depth increments, and standard physical and chemical properties were determined. Table 3 shows mean texture, pH, cation exchange capacity (CEC), and base saturation values. The soils were predominantly sands, grading to almost pure sands at the

150-cm depth. Mean pH measured in water ranged from 3.9 to 5.7 and in 0.02 M $CaCl_2$ from 3.7 to 5.1. In general, pH increased with depth. Cation exchange capacity decreased with depth and with increasing percentage of sand, varying from 23.3 to less than 1 cmole/kg. Base saturation varied with depth, making it impossible to classify an individual soil column in a given base saturation range. However, because leachate was extracted at several depths, the effect of base saturation levels could be tested. Base saturation ranged from 3 to 36 percent. Detailed physical and chemical soil characteristics for each site are listed in Appendix 2-4.

LYSIMETER METHODOLOGY

Soil Column

Intact soil columns were collected in fall of 1984. Schedule 35 PVC collection pipes were cut in 150-cm (60-in.) lengths and beveled on one end with a router (fig. 2). Most of the columns were collected using bevel type A. All four types of bevels were tried to determine which would best penetrate sandy or fine gravelly soils with minimum disturbance.

The columns were collected by setting the pipes upright and pressing them into the soil with a backhoe. At most of the sites, the pipes could only be pressed into the soil about 120 to 140 cm without distorting the penetrating end of the pipe. A trench was dug beside the pipes to the depth of penetration, a plastic Caplug was taped tightly to the top of each, and the pipe was inverted. If the columns had not penetrated to 150 cm, they were backfilled with soil from the appropriate depth. The bottoms of the pipes were then capped and taped, and the columns were transported to the USDA Forest Service's Forestry Sciences Laboratory at Grand Rapids, MN.

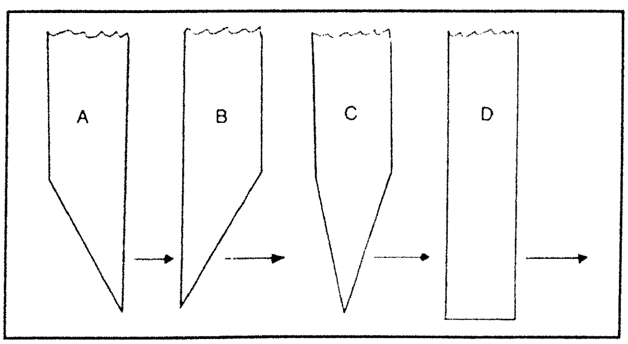


Figure 2.—*Four bevel types of penetrating ends of PVC pipe used to collect soil columns: (A) outside, (B) inside, (C) pointed, and (D) blunt. Arrow points to inside of pipe.*

Instrumentation

Each pipe was drilled at prescribed depths, and soil was extracted from the edge to the center of the column with a cork borer (fig. 3). Porous polyethylene filter candles (70-micron pore size) with polyethylene drainage tubes were inserted into the holes. Both the candle and the drainage tube were sealed to the edge of the pipes with thermal glue. The filter candles were used to collect both gas and water samples. A 0.635-cm-thick, 70-micron porous polyethylene sheet was placed on the bottom of the column above a corrugated plastic mat to facilitate drainage. A support collar and polyethylene plate were then sealed over the end with thermal glue. A collar was glued to the top of each tube, and an extension sealed by a gasket and caulking was placed in the collar. This extension holds the litter-humus layer and treatment precipitation. The columns were reburied to simulate normal soil temperatures.

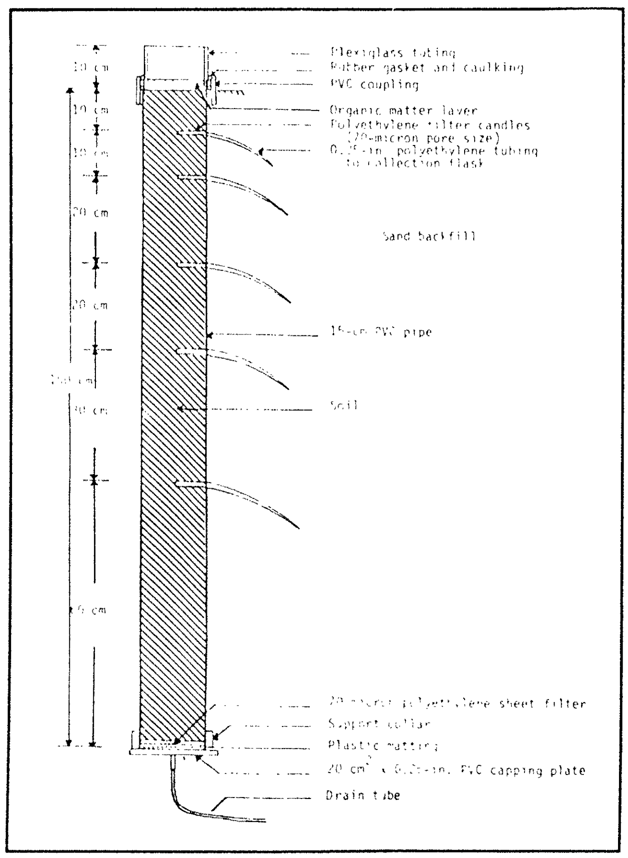


Figure 3.—*Lysimeter with leachate collection system and extension to hold the litter-humus cap and treatment precipitation.*

Caps of the same diameter as the columns were made from ground litter-humus of jack pine, mixed hardwoods, or quartz sand and placed on the columns to provide three surface treatments. Grass was grown in the caps to stabilize the cover and to provide an active root system as a source of CO_2 in the soil columns.

Sample Collection Building

A subterranean building was constructed to collect water and gas samples from the lysimeters (fig. 4). Building construction was similar to wood basement construction in the area. The top and sides of the building were insulated with 5-cm (2-in.) Thermax[1] (R 15) so the inside temperature would not influence the surrounding lysimeters. The roof was 15 cm (6 in.) below the soil surface and covered with sod to maintain a natural surface environment. The soil around the building was excavated, the columns were placed next to the building, the collection tubes were inserted through predrilled holes in the walls, and the holes were caulked to prevent water seepage into the building. Sand was used to backfill around the columns. A sump pump was installed to remove water collecting under the floor. A vacuum system was installed so leachate could be collected using small negative pressures on the sampling ports.

[1]*Mention of trade names does not constitute endorsement by the USDA Forest Service.*

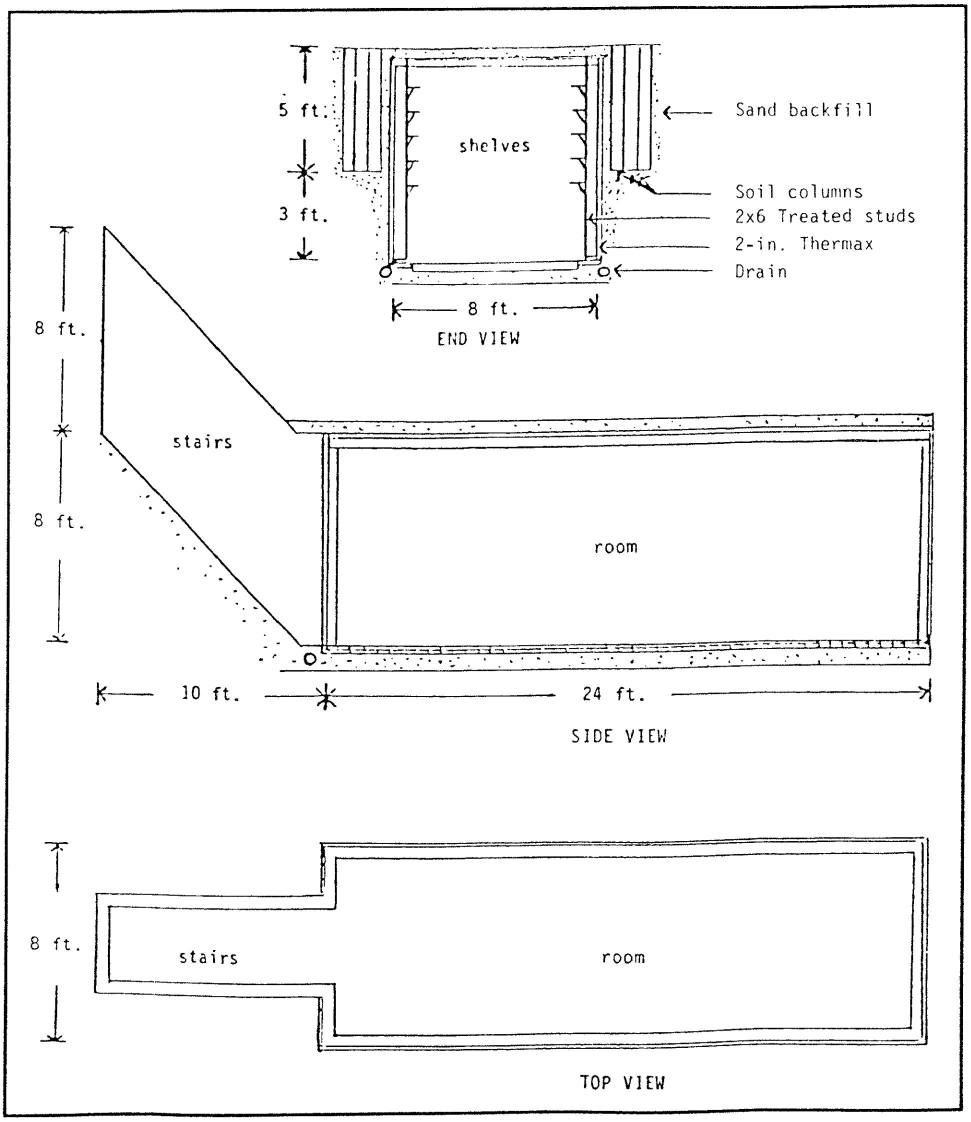


Figure 4.—*Subterranean leachate collection building.*

Pretreatment and Analyses

Before the 1985 treatment season began, the columns were leached with 300 mm of deionized water to stabilize them from disturbance and to equilibrate the initial water content. Plexiglass covers were placed over the columns to exclude ambient precipitation. Covers were opened during nonprecipitation periods during daylight hours over the treatment season.

Alkalinity, pH, Ca, Mg, K, Na, Al, Fe, Mn, Zn, Cd, Pb, Cu, Cr, Ni, B, P, NO_3, SO_4, Cl, and PO_4 in leachate samples were measured. Elemental concentrations were determined on a DC plasma emission spectrometer; total Kjeldahl nitrogen (TKN), total P, and NH_4 by AutoAnalyzer; NO_3, SO_4, Cl, and PO_4 by Ion Chromatography; total alkalinity by Gran plot; and pH by glass electrode.

EXPERIMENTAL APPROACH

Experimental Design

A split plot completely randomized design was used for the study. Three levels of base saturation formed the major plots; for each base saturation level, two precipitation pH levels (4.2 and 5.4) formed the subplots and three surface treatments (quartz sand, hardwood, and jack pine) formed the sub-subplots. Each treatment combination had four replications, for an overall total of 216 columns.

Treatments

Two pH levels were used to investigate effects of acid precipitation on the soil samples: pH 5.4, the level in normal rainfall; and pH 4.2, the level present in high acid rain areas of the United States. Precipitation was collected from a glass greenhouse surface, stored in plastic containers, and adjusted to pH 4.2 or 5.4 with H_2SO_4+HNO_3(1:1 ratio) or NaOH. The adjusted precipitation was applied weekly during the frost-free season in 25- to 50-mm amounts. Approximately 1,500 mm, an amount similar to that falling in high acid rain areas of the eastern United States, were applied each year. Table 4 shows the mean seasonal pH, alkalinity, NO_3, and SO_4 values for rain collected in 1986 before and after adjusting to treatment levels. Two litter-humus types were tested to determine their acidifying or buffering effects on the soil columns. Surface litter-humus samples from jack pine and mixed hardwood sites were collected, air-dried, and coarsely ground. After mixing, 144-gm quantities of each litter-humus type were placed into 15-cm-diameter PVC rings and planted with bluegrass. Also, 300-gm quantities of quartz sand were put into rings and planted with grass. The sand treatment was for purposes of comparison and to simulate sites with little or no organic matter. The litter-humus or sand caps were placed on the soil columns before precipitation treatments began.

RESULTS AND DISCUSSION

This experiment has been in progress for 4 years. Leachate samples have been collected regularly and complete chemical analyses are continuing. Gas samples are now being collected and analyzed. Although collecting, transporting, instrumenting, and maintaining the soil lysimeters worked as outlined, some changes would improve similar experiments in the future. For example, most of the soil columns were collected using an outside bevel on the pipes (fig. 2). We found that bevel types C and D usually did not cause the pipe to collapse while penetrating the soil. Type A tended to collapse inward and type B tended to split outward at greater depths. Schedule 40 pipe would decrease collapse and splitting. Types A and D do not compact the soil columns as the pipe penetrates. Some edge compaction may result with types B and C, but this may be advantageous because the soil must seal against the inner wall of the pipe to prevent water channeling. The blunt end (type D) requires more penetration force, and roots are torn and dragged along the wall of the pipe and not cut as with the beveled types. If this procedure were to be repeated, schedule 40 PVC pipe with bevel C would probably be used.

The 70-micron porous polyethylene candles used to collect soil-water samples worked well where a saturated wetting front was present and a slight negative pressure was used on the collection tubes. However, we generally could not collect water below 40 cm except at the bottom drain. Candles with a smaller pore size probably would be more effective in collecting tension water.

With freezing and thawing, the glued joints on some of the bottom cover plates cracked, allowing soil water to escape the column or percolating soil water to enter. This did not affect sample collection, but we could not determine the water budget for those columns and some samples were contaminated. PVC caps are now available that fit over the end of the pipe, eliminating the problem of joint failure.

Because of the many analyses required and the large number of samples, only acidification results have been completed and analyzed. Soil-water acidity changed significantly between the first- and second-year fall measurements (table 5). This occurred at the 10-, 20-, and 150-cm depths but could not be confirmed for the 40-cm depth due to insufficient data. In 1988, soil-water alkalinity was negative at the 10-, 20-, and 40-cm depths for both pH treatments; the pH 4.2 treatment had the lowest alkalinities. After the first year, pH and alkalinity were not different at the 10-, 20-, and 40-cm depths, but remained different at the 150-cm depth. A new equilibrium was evidently reached in the system because pH and alkalinity values changed little after the first year.

Soil-water pH and alkalinity at 150 cm were much lower after the first year of treatment. Alkalinity in the leachate increased at the 150-cm depth, probably due to accelerated removal of exchangeable cations from upper horizons or adsorption of SO_4 at the lower depths. Alkalinities and pH at the 10-, 20-, and 40-cm depths were significantly lower than those at the 150-cm depth.

Although the soil water became more acidified with both pH treatments, pH and alkalinity were lower under the pH 4.2 treatment. Type of litter-humus also affected acidification; hardwood and to a lesser extent jack pine litter-humus had a buffering effect (table 6). Leachate from soil columns without surface litter-humus was more acid in the upper levels for both pH treatments. Litter-humus treatment effects on pH disappeared with depth.

Leachate alkalinity was also lowest in columns without a litter-humus surface (table 7). Alkalinity and pH were significantly higher at the 150-cm depth than at the lower depths for all treatments. Alkalinity and pH did not differ significantly at the 10-, 20-, and 40-cm depths under the hardwood litter-humus caps for either pH treatment, probably due to acid neutralization by the hardwood humus layer. Jack pine litter-humus did not buffer the soil water as effectively as hardwood litter-humus. There did not appear to be any real seasonal differences for either soil-water pH or alkalinity for any of the treatments.

SUMMARY

Intact soil columns were collected, transported to a central lab, and instrumented as soil water lysimeters. The lysimeters were reburied around an underground collection structure to maintain normal soil temperatures. Hardwood or jack pine litter-humus caps or quartz sand were applied to the columns to test the buffering effect of the organic surface layer. Two pH treaments were applied to the lysimeters: pH 5.4 to represent normal rainfall, and pH 4.2 to represent acid rainfall.

Acidification of the soil water was significant in the first year under both pH treatments. Acidity did not change significantly with three additional years of treatment. The hardwood organic layer had the greatest buffering effect. Treatment effects on pH and alkalinity were greatest near the surface and decreased with depth.

The experimental system succeeded in treating the soils and measuring the desired parameters to determine acidification of soil water under acid precipitation, but some improvements in lysimeter construction and instrumentation are recommended. The lysimeters and treatments were designed to simulate natural conditions so that results would be applicable to field conditions. Basic data have been gathered on the soils sampled to form a database for soil scientists, soil classifiers, and land managers in the Lake States region.

ACKNOWLEDGMENTS

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Table 1. Classification and predominant vegetation on the sample sites in order of decreasing abundance. (Coffman *et al*. 1984; Kotar *et al*. 1988; USDA Forest Service Handbook, 1975 and 1979)

Site	Classification	Overstory	Understory	Ground Flora
1	Acer-Quercus-Vaccinium	Red Pine (*Pinus resinosa*) Jack Pine (*Pinus banksiana*) White Pine (*Pinus strobus*) White Birch (*Betula papyrifera*) Quaking Aspen (*Populus tremuloides*)	Pin Cherry (*Prunus pensylvanica*) Red Oak (*Quercus rubra*) Juneberry (*Amelanchier* spp.)	Bracken Fern (*Pteridium aquilinum*) Sweet-fern (*Comptonia peregrina*) Blueberry (*Vaccinium* spp.) Reindeer Moss (*Cladonia* spp.) Grasses Woodland Strawberry (*Fragaria vesca*)
2	Acer-Quercus-Vaccinium	White Pine Aspen Red Pine White Birch	White Pine Aspen Red Pine White Birch	Bracken Fern Big Leaf Aster (*Aster macrophyllus*) Wintergreen (*Gaultheria* spp.) Blueberry
3	Os-3,* Sh-1, Fo-2	Scattered Residual Red Pine Scattered Jack Pine Underplanted Pole-sized Red Pine	Balsam Fir (*Abies balsamea*) Red Pine White Pine Willow (*Salix* spp.) White Birch Aspen Hazel (*Corylus cornuta*) Alder (*Alnus* spp.)	Blueberry Bracken Fern Club-moss (*Lycopodium* spp.) Reindeer Moss Grasses Sweet-fern Strawberry
4	Acer-Quercus-Vaccinium	Red Oak Jack Pine Scattered White Birch Scattered Red Maple (*Acer rubrum*)		Sweet-fern Bracken Fern Grasses
5	Acer-Quercus-Vaccinium	Scattered Jack Pine Aspen Scrub Oak (*Q. ilicifolia*)		Sweet-fern Mixed Grasses Raspberry (*Rubus* spp.)
6	Acer-Quercus-Vaccinium	Jack Pine Scrub Oak		Sweet-fern Mixed Grasses Reindeer Moss
7	Acer-Quercus-Vaccinium	Red Pine White Pine White Spruce (*Picea glauca*)	Red Maple Sugar Maple (*A. saccharum*) White Birch Hazel Aspen Balsam Fir	Bracken Fern Birch Seedlings Ground-pine (*Lycopodium obscurum*) Club-moss Blueberry Wintergreen
8	Tsuga-Maianthemum	Red Maple Aspen Jack Pine White Birch		Reindeer Moss True Moss Wintergreen Mixed Grasses Raspberry
9	Pinus-Vaccinium-Deschampsia	Mixed Natural Jack Pine Planted Jack Pine		Reindeer Moss Grasses Sweet-fern Blueberry Willow

* Used exclusively by the Superior National Forest and referenced in USDA Forest Service Handbook (1975, 1979).

Table 2. Litter-humus values for Kjeldahl N, total P, total S, exchangeable cations cation exchange capacity, base saturation, pH, and weight for each site and surface treatment

Site-		Total	Total	Exchangeable cations						Base		
trt.	TKN	P	S	Ca	Mg	K	Na	H	CEC	sat.	pH	Weight
	- - - -	- - - -	- - - -	-(mg/kg)-	- - - -	- - - -	- - - -	- -	(cmole/kg)	(%)		(t/ha)
1	14150	750	2260	2780	520	550	180	41	60.8	32	4.5	24
2	5350	655	990	4400	670	900	190	22	52.3	58	5.2	15
3	7250	710	1260	2740	510	700	190	38	58.1	35	4.6	23
4	10000	730	1850	2120	280	430	180	40	54.4	27	4.4	15
5	11100	715	1800	2000	320	910	200	32	48.2	33	4.5	14
6	10100	755	1760	1680	220	650	190	31	44.1	29	4.4	16
7	10050	855	1180	4630	620	810	180	34	64.9	48	5.0	28
8	9350	780	1650	3330	440	370	180	38	59.8	37	4.5	21
9	8200	630	1360	860	80	320	180	48	55.0	12	3.8	13
MH *	11200	1350	1660	9630	1090	850	260	20	80.1	75	5.6	79
JP *	9600	1060	1710	4580	810	700	240	38	70.4	46	4.7	79
QS *	1900	605	200	370	130	200	50	2	5.7	64	6.1	--

* Mixed hardwood (MH), jack pine (JP), and quartz sand (QS) treatment caps with an established grass cover.

Table 3. Soil classification and physical and chemical properties averaged over selected depths

Site	Soil classification	Depth	Texture Clay	Silt	Sand	pH H_2O	$CaCl_2$	CEC	Base sat.
		(cm)	- - - - -(%)- - - -					(cmole/kg)	(%)
1	Sandy, mixed,	0-10	4	11	85	3.9	3.7	10.1	9
	frigid Entic	10-20	3	9	88	4.6	4.4	7.4	3
	Haplorthod	20-40	2	8	90	4.8	4.6	4.0	5
		40-150	1	1	99	5.2	4.8	1.0	23
2	Mixed, frigid,	0-10	3	8	89	5.0	4.5	7.2	25
	Aquic	10-20	4	7	89	5.4	4.6	4.1	32
	Udipsamment	20-40	4	5	91	5.7	5.0	4.8	21
		40-150	3	7	89	5.4	4.6	2.4	20
3	Mixed, frigid	0-10	4	9	87	4.7	4.3	16.1	25
	Aquic	10-20	5	6	89	4.9	4.4	10.4	13
	Udipsamment	20-40	3	4	93	5.6	5.0	5.6	20
		40-150	1	1	98	5.5	4.9	1.3	36
4	Sandy, mixed,	0-10	4	9	88	4.0	3.7	9.9	5
	frigid Entic	10-20	4	9	87	4.4	4.1	6.3	5
	Haplorthod	20-40	2	7	91	4.9	4.6	4.7	4
		40-150	2	4	94	5.4	5.1	0.8	15
5	Mixed, frigid	0-10	4	3	93	4.3	3.9	6.2	10
	Typic	10-20	5	3	93	4.4	3.9	5.7	8
	Udipsamment	20-40	4	1	96	4.9	4.7	3.6	5
		40-150	2	2	96	5.3	4.8	0.6	21
6	Mixed, frigid	0-10	5	5	91	4.7	4.2	7.6	12
	Typic	10-20	5	4	92	4.9	4.4	6.3	9
	Udipsamment	20-40	4	4	92	5.0	4.5	4.3	6
		40-150	2	2	97	5.2	4.8	0.9	15
7	Sandy, mixed,	0-10	6	19	75	4.4	4.1	23.3	29
	frigid Entic	10-20	6	14	80	4.5	4.2	16.9	9
	Haplorthod	20-40	4	12	84	5.1	4.6	8.7	9
		40-150	1	10	88	5.2	4.6	2.8	10
8	Mixed, frigid	0-10	4	5	91	4.3	3.9	8.7	11
	Spodic	10-20	3	2	95	4.6	4.2	9.7	5
	Udipsamment	20-40	2	1	98	4.9	4.5	4.7	4
		40-150	1	0	99	5.2	4.7	1.7	9
9	Mixed, frigid	0-10	4	7	89	4.0	3.8	9.5	4
	Typic	10-20	1	2	97	4.7	4.5	5.4	4
	Udipsamment	20-40	1	0	99	5.0	4.7	1.7	9
		40-150	1	0	99	5.0	4.7	0.8	17

Table 4. Average seasonal pH, alkalinity, and NO_3, and SO_4 concentrations in rainwater collected in 1986 at Grand Rapids, MN

Rainwater	pH	Alkalinity	NO_3	SO_4
		(ueq/l)	----(mg/l)----	
Ambient	5.7	24.6	1.4	1.6
pH Adjusted	5.4	12.0	2.1	2.9
	4.2	-52.0	2.9	4.6

Table 5. Average leachate alkalinity (ueq/l) and pH values by depth (cm) and pH treatment, fall 1985-1988

Soil depth	Year	5.4 pH treatment Alkalinity	5.4 pH treatment pH	4.2 pH treatment Alkalinity	4.2 pH treatment pH
10	1985	9.4 [1/]	5.3	11.4	5.3
	1986	2.6	5.1	- 8.1	4.9
	1987	5.6	5.2	- 4.9	5.0
	1988	- 1.1	5.2	-11.0	5.0
20	1985	55.9	6.3	27.7	6.2
	1986	1.4	5.2	- 3.2	5.0
	1987	5.0	5.2	- 1.7	5.1
	1988	- 2.7	5.2	-10.4	5.0
40	1985	---	---	---	---
	1986	5.1	5.3	- 0.1	5.2
	1987	5.7	5.3	1.1	5.2
	1988	- 6.1	5.3	- 3.2	5.3
150	1985	64.2	6.5	66.8	6.5
	1986	11.1	5.6	14.9	5.6
	1987	15.6	5.7	14.3	5.6
	1988	17.7	5.6	17.6	5.7

1/ Means connected by the same vertical line do not differ significantly at the .05 percent level. Tukey's HSD test.

Table 6. Average pH of leachate by treatment and depth (cm) in spring, summer, and fall of 1988

Season	Soil depth	5.4 pH treatment						4.2 pH treatment					
		Litter-humus surface treatment						Litter-humus surface treatment					
		None		Hardwood		Jack pine		None		Hardwood		Jack pine	
Spring	10	4.9	bc[1]	5.2	a	5.1	ab	4.7	c	5.0	ab	4.8	bc
	20	5.2	abc	5.3	a	5.3	ab	4.9	c	5.1	abc	5.0	bc
	40	5.3	a	5.2	a	5.2	a	5.2	a	5.3	a	5.1	a
	150	5.9	a	5.9	a	5.7	a	5.8	a	5.9	a	5.8	a
Summer	10	4.9	b	5.3	a	5.1	ab	4.9	b	5.2	ab	5.0	b
	20	5.3	a	5.3	a	5.3	a	5.1	a	5.2	a	5.1	a
	40	5.4	a	5.4	a	5.4	a	5.4	a	5.5	a	5.3	a
	150	5.8	a	5.8	a	5.8	a	5.8	a	5.8	a	5.8	a
Fall	10	5.1	abc	5.2	a	5.2	a	4.9	bc	5.1	ab	4.9	c
	20	5.1	ab	5.2	a	5.2	a	4.9	ab	5.1	c	5.1	bc
	40	5.3	a	5.2	a	5.2	a	5.3	a	5.3	a	5.2	a
	150	5.6	a	5.6	a	5.6	a	5.6	a	5.7	a	5.6	a

1/ Means connected by same vertical line do not differ significantly and means with same letter do not differ significantly at the .05 percent level. Tukey's HSD test.

Table 7. Average alkalinity (ueq/l) of leachate by treatment and depth (cm) in spring, summer, and fall of 1988

Season	Soil Depth	5.4 pH treatment						4.2 pH treatment					
		Litter-humus surface treatment						Litter-humus surface treatment					
		None		Hardwood		Jack pine		None		Hardwood		Jack pine	
Spring	10	-13.1	bc[1]	3.0	a	0.0	ab	-29.2	d	- 7.8	abc	-18.9	cd
	20	- 2.9	ab	5.6	a	4.4	a	-15.5	c	- 1.6	ab	- 8.5	b
	40	- 0.6	a	- 0.2	a	- 2.9	a	- 5.3	a	- 3.2	a	- 8.7	a
	150	22.7	a	21.0	a	16.1	a	19.5	a	19.8	a	17.6	a
Summer	10	-14.5	bc	4.9	a	- 0.8	ab	-20.7	c	- 0.6	ab	-12.9	bc
	20	- 2.4	ab	2.2	ab	2.0	a	- 9.7	ab	- 3.4	ab	-11.3	b
	40	- 7.1	a	1.1	a	2.2	a	- 4.9	a	5.6	a	- 1.2	a
	150	20.8	a	27.2	a	20.3	a	16.0	a	23.5	a	18.4	a
Fall	10	-11.6	ab	3.0	a	0.1	a	-16.8	b	- 4.3	ab	-17.0	b
	20	- 7.2	ab	- 1.7	a	0.8	a	-16.0	b	- 6.4	ab	- 8.7	ab
	40	- 7.7	a	- 9.2	a	- 7.4	a	- 2.7	a	- 1.3	a	- 4.1	a
	150	15.2	a	19.2	a	18.8	a	16.8	a	19.4	a	16.6	a

1/ Means connected with same vertical line do not differ significantly and means with same letter do not differ significantly at the .05 percent level. Tukey's HSD test.

Appendix 1. Average total element concentrations for the litter-humus for each site and the three litter-humus surface treatments.

Site-Trt.	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
	(mg/kg)													
1	9600	2400	2800	120	10100	22	4	16	17	13100	3400	33	51	140
2	10600	2500	2800	110	10400	21	4	14	14	14100	1100	17	30	170
3	9700	3200	3300	200	13600	21	4	16	14	19000	1400	24	39	80
4	10200	2600	3200	160	12700	28	5	15	21	20000	4000	40	84	120
5	6200	1900	3400	100	6850	11	4	16	15	15200	600	15	55	120
6	5100	1900	3200	120	11000	14	4	13	16	13500	400	14	81	100
7	13500	2600	3500	120	10900	24	4	18	21	10700	2100	24	91	180
8	10600	2800	3100	140	13200	21	5	22	38	17500	1500	23	62	150
9	2900	1400	2300	110	11100	18	4	14	41	12300	300	14	103	150
MH *	28500	4900	4000	650	18400	43	5	23	25	16800	3600	48	58	280
JP *	17000	4000	4000	670	15400	48	4	23	19	14300	2500	32	52	220
QS *	5800	4600	2900	400	18300	17	4	15	17	21100	300	25	9	40

Site-Trt.	AS	Ba	Be	CO	LI	MO	Sr	Ti	V
	(mg/Kg)								
1	5	132	0.4	5	5	4	51	760	32
2	6	256	0.4	5	6	4	69	780	32
3	5	285	0.4	6	9	5	68	640	26
4	8	152	0.5	6	6	5	62	930	42
5	5	161	0.3	4	4	4	33	730	32
6	6	177	0.4	4	6	5	32	780	30
7	5	430	0.4	5	5	4	82	900	32
8	9	173	0.5	6	6	5	63	1150	46
9	7	165	0.5	4	4	5	20	790	29
MH *	1	161	0.6	11	11	7	132	850	41
JP *	1	313	0.4	7	8	6	109	770	35
QS *	1	105	0.7	10	14	6	54	1050	43

* Mixed hardwood (MH), jack pine (JP), and quartz sand (QS) treatment caps with an established grass cover.

APPENDIX 2. Soil profile descriptions.

Site 1
Taxonomy: Sandy, mixed, frigid Entic Haplorthod
Drainage: Somewhat excessive
Parent Materials: Glacial outwash

Oe	1-0 cm	slightly decomposed leaves, twigs, and grass blades.
E	0-3 cm	very dark gray (10YR 3/1) loamy sand; light brownish gray (10YR 6/2) dry: weak medium subangular blocky structure; pH 3.8; abrupt smooth boundary.
EB	3-7 cm	very dark grayish brown (10YR 3/2) loamy sand; weak medium subangular blocky structure; very friable; pH 4.0; abrupt smooth boundary.
Bs	7-23 cm	dark brown (7.5YR 4/4) sand with silt coatings; weak medium subangular blocky structure; very friable; pH 4.5; clear smooth boundary.
BC	23-57 cm	dark yellowish brown (10YR 4/4) sand; single grain; loose; pH 4.8; clear smooth boundary.
C1	57-84 cm	yellowish brown (10YR 5/4) sand; single grain; loose; pH 5.3; clear smooth boundary.
C2	84-150 cm	brown (10YR 5/3) gravelly sand; single grain; loose; 15 percent pebbles; pH 5.2.

Site 2
Taxonomy: Mixed, frigid Aquic Udipsamment
Drainage: Somewhat poor
Parent Material: Glacial outwash over lacustrine

A	0-8 cm	black (10YR 2/1) sand; weak fine subangular blocky structure; very friable; pH 5.0; clear boundary.
E	8-20 cm	very dark grayish brown (10YR 3/2) sand; light brownish gray (10YR 6/2) dry; weak fine subangular blocky structure; very friable; pH 5.4; clear boundary.
Bw1	20-30 cm	dark brown (7.5YR 4/4) sand; weak medium subangular blocky structure; very friable; pH 5.6; clear boundary.
Bw2	30-62 cm	strong brown (7.5YR 4/6) sand; single grain; loose; pH 5.8; clear boundary.
C	62-82 cm	dark yellowish brown (10YR 4/4) sand; single grain, loose; pH 5.8; clear boundary.
Cg	82-150 cm	brown (10YR 5/3) and dark grayish brown (10YR 4/2) stratified sand, loamy sand and sandy loam; common medium distinct strong - brown (7.5YR 5/6, 4/6) mottles; single grain and loose in sandy material and massive and very friable in sandy loam; pH 5.2.

Site 3
Taxonomy: Mixed, frigid Aquic Udipsamment
Drainage: Moderately well
Parent Material: Glacial outwash

Oi	1-0 cm	undecomposed roots from Lycopodium and leaves.
Ap	0-6 cm	brown (10YR 4/3) sand; single grain; loose; this horizon appears disturbed; abrupt boundary; pH 4.9.
A	6-12 cm	black (10YR 2/1) loamy sand; weak medium subangular blocky structure; very friable; pH 4.6; clear boundary.
Bw	12-36 cm	brown (10YR 4/3) sand; single grain; very friable; pH 5.2; gradual boundary.
Bc	36-53 cm	yellowish brown (10YR 5/4) sand; single grain; loose; Ph 5.8; gradual boundary.
C	53-150 cm	light brownish gray (2.5YR 6/2) sand; few medium distinct light olive brown (2.5 Y 5/4); mottles beginning at 104 cm; single grain; loose; pH 5.6.

Site 4
Taxonomy: Sandy, mixed, frigid Entic Haplorthod
Drainage: Somewhat excessive
Parent Material: Glacial outwash

A	0-10 cm	very dark gray (10YR 3/1) sand; weak fine subangular blocky structure; very friable; pH 4.1; clear smooth boundary.
Bs	10-40 cm	dark yellowish brown (10YR 3/4) sand with silt coatings; weak medium subangular blocky structure; very friable; pH 4.8; clear smooth boundary.
BC	40-70 cm	dark brown (7.5YR 4/4) sand; single grain; loose; pH 5.3; gradual boundary.
C	70-150 cm	dark brown (7.5YR 4/4) sand; single grain; loose; pH 5.4.

Site 5
Taxonomy: Mixed, frigid Typic Udipsamment
Drainage: Moderately well
Parent Material: Glacial outwash

A	0-15 cm	dark brown (7.5YR 3/2) sand; single grain; loose; pH 4.3; abrupt smooth boundary.
Bs	15-27 cm	dark brown (7.5YR 4/4) sand; single grain; loose; pH 4.8.
BC	27-60 cm	dark brown (7.5YR 4/4) sand; single grain; loose; pH 5.2.
C1	60-110 cm	brown (7.5YR 5/4) sand; loose; pH 5.3.
C2	110-150 cm	dark brown (7.5YR 4/4); few fine distinct strong brown (7.5YR 5/6) mottles above a band of higher silt content sand; single grain; loose; pH 5.4.

Site 6
Taxonomy: Mixed, frigid Typic Udipsamment
Drainage: Somewhat excessive
Parent Material: Glacial outwash

Ap	0-15 cm	dark brown (7.5YR 3/2) sand; single grain; loose; pH 4.8; abrupt boundary.
B1	15-40 cm	dark brown (7.5YR 4/4) sand; single grain; pH 5.0; gradual boundary.
Bs2	40-60 cm	brown (7.5YR 4/4) sand; single grain; loose; pH 5.1; clear boundary.
BC	60-84 cm	brown (7.5YR 5/4) sand; single grain; loose; pH 5.2.
C	84-150 cm	brown (7.5YR 5/4) sand; single grain; loose; pH 5.3

Site 7
Taxonomy: Sandy, mixed, frigid Entic Haplorthod
Drainage: Moderately well
Parent Material: Glacial outwash

Oe	5-4 cm	slightly decomposed organic matter; abrupt smooth boundary.
Oa	4-0 cm	decomposed organic matter; abrupt smooth boundary.
E	0-5 cm	very dark grayish brown (10YR 3/2) loamy fine sand; pinkish gray (7.5YR 6/2) dry; weak fine subangular blocky; very friable; pH 4.6; abrupt smooth boundary.
B1	5-15 cm	dark brown (7.5YR 3/4) loamy fine sand with cracked silt coatings; weak medium subangular blocky; very friable; pH 4.3; smooth boundary.
Bs2	15-37 cm	dark brown (7.5YR 4/4) loamy fine sand; weak medium subangular blocky; very friable; pH 5.0.
BC	37-58 cm	brown (7.5YR 4/4) fine sand; single grain; loose; pH 5.2.
C1	58-87 cm	brown (7.5YR 5/4) loamy fine sand; massive; very friable; pH 5.3.
C2	87-150 cm	brown (7.5YR 5/4) loamy fine sand; massive; very friable; pH 5.1.

Site 8
Taxonomy: Mixed, frigid Spodic Udipsamment
Drainage: Somewhat excessive
Parent Material: Glacial outwash

Oi	1-0 cm	undecomposed leaves and roots; abrupt smooth boundary.
E	0-12 cm	dark brown (7.5YR 4/2) sand; single grain; loose; pH 4.3; clear smooth boundary.
Bs	12-37 cm	dark brown (7.5YR 4/4, 3/4) sand; single grain; loose; pH 4.8; clear smooth boundary.
BC	37-90 cm	brown (7.5YR 4/4) sand; single grain; loose; pH 5.0; abrupt smooth boundary.
C	90-150 cm	brown (7.5YR 5/4) sand; single grain; loose; pH 5.3.

Site 9
Taxonomy: Mixed, frigid Typic Udipsamment
Drainage: Somewhat excessive
Parent Material: Glacial outwash

Oe	1-0 cm	slightly decomposed organic matter of roots and leaves; abrupt smooth boundary.
A	0-2 cm	dark brown (7.5YR 3/2) loamy sand; weak fine subangular blocky structure; loose; pH 3.8; clear wavy boundary.
Bw	2-17 cm	dark yellowish brown (10YR 4/4) sand; single grain; loose; pH 4.4; clear wavy boundary.
BC1	17-38 cm	yellowish brown (10YR 5/4) sand; single grain; loose; pH 4.9; clear wavy boundary.
BC2	38-54 cm	brown (7.5YR 5/4) sand; single grain; loose; pH 5.1.
C	54-150 cm	pinkish gray (7.5YR 6/2) sand; loose; pH 5.1.

Appendix 3. Particle size analyses, bulk density, and water content by depth. Site 1

Soil depth	Clay	Silt	Sand						Total > 2mm	Bulk density	Water content
			vfs	fs	ms	cs	vcs	total			
(cm)	- - - - - - - - - - - - - - - -(%)- - - - - - - - - - - - - - - -									gms/cm^3	% vol
0-5	3	12	3	28	51	4	0	86	1	.77	15
5-10	5	10	2	27	48	5	0	85	6	1.13	13
10-15	4	9	4	29	51	5	0	88	2	1.05	13
15-20	3	8	3	31	54	4	0	89	2	1.14	11
20-25	3	8	3	28	51	4	0	89	4	1.25	11
25-30	3	8	3	29	51	4	0	89	5	1.36	11
30-35	2	7	3	28	56	4	0	91	3	1.37	11
35-40	2	7	3	27	55	4	0	91	4	1.41	10
40-45	3	5	4	28	54	5	0	93	1	1.32	10
45-50	2	6	3	59	55	3	0	93	<1	1.40	10
50-55	1	4	4	32	53	4	0	95	<1	1.48	10
55-60	1	3	4	31	54	5	0	96	<1	1.39	8
60-65	1	0	2	17	64	16	0	99	1	1.45	6
65-70	1	1	1	11	64	23	0	99	9	1.67	5
70-75	0	1	1	10	69	19	0	99	7	1.53	7
75-80	0	1	1	10	63	25	0	99	7	1.51	6
80-85	0	0	1	8	49	41	0	99	13	1.64	7
85-90	0	0	1	10	44	44	0	100	19	1.60	6
90-95	0	0	1	15	48	35	0	100	20	1.51	6
95-100	0	0	1	11	44	44	0	100	24	1.61	5
100-105	1	1	1	10	42	46	0	99	27	1.66	6
105-110	1	0	1	13	54	31	0	99	19	1.50	7
110-115	0	1	1	14	45	38	0	99	48	1.63	10
115-120	0	0	1	20	58	19	0	100	10	1.75	11
120-125	0	0	1	11	43	44	1	100	31	1.51	13
125-130	0	0	1	19	53	26	0	100	21	1.70	17
130-135	0	0	1	15	57	27	0	100	22	1.56	14
135-140	0	0	1	19	52	26	0	100	18	1.70	20
140-145	0	0	1	18	54	26	0	100	22	1.70	24

Appendix 3. (Continued). Site 2

Soil depth	Clay	Silt	Sand						Total > 2mm	Bulk density	Water content
			vfs	fs	ms	cs	vcs	total			
(cm)	- - - - - - - - - - - - - - - -(%)- - - - - - - - - - - - - - - -									gms/cm^3	% vol
0-5	3	8	1	21	57	10	0	89	<1	1.17	18
5-10	3	8	1	22	56	10	0	89	<1	1.40	15
10-15	4	7	1	21	54	9	0	89	<1	1.41	14
15-20	4	7	2	22	59	10	0	89	<1	1.38	13
20-25	5	6	1	22	60	11	0	90	<1	1.34	14
25-30	5	5	1	21	55	9	0	90	<1	1.39	14
30-35	4	5	1	21	56	10	0	92	<1	1.33	12
35-40	3	3	1	21	58	11	0	94	<1	1.45	12
40-45	2	4	2	25	56	10	0	94	1	1.51	11
45-50	2	5	2	25	55	10	0	94	1	1.42	9
50-55	2	4	1	25	54	10	0	94	1	1.48	10
55-60	2	3	1	23	58	12	0	95	<1	1.48	9
60-65	2	3	1	24	58	12	0	95	1	1.60	9
65-70	2	2	1	22	60	13	0	97	1	1.54	8
70-75	2	1	1	20	62	14	0	97	1	1.50	7
75-80	2	2	1	22	59	16	0	97	1	1.42	6
80-85	2	2	2	24	55	14	0	96	1	1.51	7
85-90	3	6	4	32	46	10	0	91	1	1.46	12
90-95	7	16	5	25	38	7	0	78	1	1.51	17
95-100	4	10	6	30	40	13	0	87	2	1.40	16
100-105	2	6	4	35	40	9	0	92	1	1.50	16
105-110	3	5	4	30	47	9	0	93	1	1.54	16
110-115	4	9	4	27	43	11	0	87	1	1.50	18
115-120	2	4	3	27	51	12	0	94	2	1.42	17
120-125	4	10	4	26	44	10	0	87	2	1.60	22
125-130	6	15	5	25	41	9	0	79	1	1.58	25
130-135	7	21	6	22	35	8	0	71	<1	1.69	26
135-140	5	13	5	24	41	12	0	82	1	1.70	25
140-145	5	9	3	22	50	15	0	86	1	1.65	25
145-150	5	14	5	27	42	10	0	81	1	1.59	24

Appendix 3. (Continued). Site 3

Soil depth	Clay	Silt	Sand vfs	fs	ms	cs	vcs	total	Total > 2mm	Bulk density	Water content
(cm)	-	-	-	-	-(%)-	-	-	-	-	gms/cm^3	% vol
0-5	4	8	1	36	52	2	0	88	<1	.76	16
5-10	4	9	1	37	48	1	0	87	<1	1.06	18
10-15	5	7	1	34	48	1	0	88	<1	1.14	15
15-20	4	6	2	39	50	1	0	90	<1	1.24	15
20-25	3	4	2	40	52	1	0	92	<1	1.19	12
25-30	3	4	2	36	50	1	0	93	<1	1.37	10
30-35	3	3	2	36	53	1	0	94	1	1.38	8
35-40	2	3	3	42	49	1	0	95	1	1.38	7
40-45	2	2	2	44	48	1	0	96	<1	1.36	6
45-50	2	1	3	43	49	1	0	97	<1	1.38	5
50-55	2	1	3	47	47	1	0	97	<1	1.43	5
55-60	1	1	2	47	48	1	0	98	<1	1.42	5
60-65	1	1	3	45	49	1	0	98	<1	1.35	4
65-70	1	1	3	46	47	1	0	98	<1	1.38	5
70-75	1	1	3	43	50	2	0	98	<1	1.42	6
75-80	1	1	3	42	53	1	0	98	<1	1.39	6
80-85	1	1	2	47	47	1	0	98	<1	1.40	6
85-90	1	0	3	45	49	1	0	99	<1	1.40	8
90-95	1	1	3	43	51	1	0	99	<1	1.36	8
95-100	1	1	3	46	49	1	0	99	<1	1.31	7
100-105	2	0	3	47	47	1	0	98	<1	1.35	9
105-110	2	0	3	46	49	1	0	98	<1	1.37	10
110-115	2	0	2	39	56	1	0	98	<1	1.40	10
115-120	1	0	3	44	50	1	0	99	<1	1.39	10
120-125	2	0	2	44	50	1	0	99	<1	1.42	12
125-130	2	0	3	47	46	1	0	98	<1	1.39	14
130-135	1	0	2	46	49	1	0	99	<1	1.49	14
135-140	2	0	3	45	49	1	0	99	<1	1.46	22
140-145	2	0	2	47	49	0	0	98	<1	1.14	19

Appendix 3. (Continued). Site 4

Soil depth	Clay	Silt	Sand vfs	fs	ms	cs	vcs	total	Total > 2mm	Bulk density	Water content
(cm)	-	-	-	-	-(%)-	-	-	-	-	gms/cm^3	% vol
0-5	4	9	7	38	32	9	0	88	<1	1.05	10
5-10	4	9	8	38	33	9	0	87	<1	1.10	11
10-15	5	9	9	42	31	8	0	87	<1	1.30	13
15-20	4	9	9	40	32	8	0	87	<1	1.33	11
20-25	3	9	11	40	27	7	0	88	<1	1.30	11
25-30	2	7	13	43	25	5	0	91	<1	1.41	10
30-35	2	6	13	43	25	6	0	92	<1	1.40	7
35-40	3	4	13	45	26	6	0	93	<1	1.43	6
40-45	1	6	11	45	27	6	0	93	<1	1.48	5
45-50	1	5	12	44	29	6	0	94	<1	1.50	5
50-55	1	5	12	42	32	7	0	94	<1	1.46	4
55-60	1	5	11	41	33	8	0	94	<1	1.55	6
60-65	1	5	9	40	35	7	0	93	<1	1.49	7
65-70	3	4	9	38	37	8	0	93	<1	1.52	9
70-75	2	4	8	37	38	8	0	94	<1	1.50	12
75-80	2	5	10	37	37	8	0	93	<1	1.57	15
80-85	2	3	10	44	34	5	0	95	<1	1.50	14
85-90	2	4	12	45	32	4	0	95	<1	1.53	16
90-95	2	5	12	42	35	5	0	93	<1	1.49	15
95-100	2	2	11	49	32	4	0	96	<1	1.56	16
100-105	2	4	10	45	35	4	0	94	<1	1.50	18
105-110	1	5	10	43	35	5	0	94	<1	1.54	19
110-115	1	4	10	41	38	6	0	95	<1	1.57	21
115-120	2	2	10	43	37	7	0	96	<1	1.58	21
120-125	1	4	11	43	35	6	0	95	<1	1.72	24
125-130	1	4	10	43	36	5	0	95	<1	1.95	23

Appendix 3. (Continued). Site 5

Soil depth	Clay	Silt	Sand vfs	fs	ms	cs	vcs	total	Total > 2mm	Bulk density	Water content
(cm)	-	-	-	-	-(%)-	-	-	-	-	gms/cm^3	% vol
0-5	4	3	2	23	55	16	0	93	1	1.23	14
5-10	4	3	2	22	51	15	0	93	1	1.36	13
10-15	5	3	2	22	51	15	0	92	1	1.40	14
15-20	5	2	2	22	49	15	0	93	4	1.46	13
20-25	4	2	2	23	51	16	0	94	5	1.49	12
25-30	4	1	2	21	48	24	0	96	5	1.57	9
30-35	3	0	1	18	49	28	0	97	7	1.59	6
35-40	3	0	1	16	59	24	0	98	5	1.58	5
40-45	3	0	1	18	67	13	0	98	2	1.59	6
45-50	2	0	1	18	69	11	0	98	<1	1.69	6
50-55	2	0	1	17	62	19	0	98	1	1.47	4
55-60	2	0	1	19	62	17	0	99	3	1.57	5
60-65	2	0	2	21	58	18	0	99	4	1.46	4
65-70	1	0	3	27	54	15	0	99	1	1.53	5
70-75	2	0	4	32	51	12	0	99	3	1.47	5
75-80	2	0	4	30	51	15	0	98	5	1.51	5
80-85	2	0	2	28	53	15	0	98	2	1.49	6
85-90	2	0	3	30	53	13	0	97	3	1.52	6
90-95	2	1	5	29	50	14	0	96	2	1.46	8
95-100	3	3	6	29	45	14	0	94	3	1.46	11
100-105	2	2	5	28	51	14	0	97	2	1.54	10
105-110	2	1	3	26	50	20	0	97	5	1.56	11
110-115	2	3	5	24	47	20	0	94	3	1.53	14
115-120	2	5	7	26	45	15	0	93	1	1.55	18
120-125	2	9	8	29	34	14	0	90	1	1.52	22
125-130	2	6	8	27	38	18	0	92	2	1.62	24
130-135	1	7	4	25	47	19	0	92	2	1.66	24

Appendix 3. (Continued). Site 6

Soil depth	Clay	Silt	Sand vfs	fs	ms	cs	vcs	total	Total > 2mm	Bulk density	Water content
(cm)	-	-	-	-	-(%)-	-	-	-	-	gms/cm^3	% vol
0-5	4	5	4	46	40	6	0	92	1	1.12	15
5-10	5	5	3	40	41	8	0	91	<1	1.34	12
10-15	5	3	3	41	43	8	0	92	1	1.33	12
15-20	4	4	3	41	38	7	0	92	1	1.24	12
20-25	5	3	3	42	41	8	0	92	<1	1.36	12
25-30	3	5	3	42	39	7	0	92	1	1.31	10
30-35	4	5	3	42	36	7	0	92	1	1.48	10
35-40	4	3	3	45	38	7	0	93	1	1.33	8
40-45	2	4	3	44	37	6	0	94	1	1.31	7
45-50	2	4	4	45	38	6	0	94	2	1.41	7
50-55	2	5	3	45	38	6	0	93	1	1.41	7
55-60	1	4	2	47	38	6	1	95	3	1.49	7
60-65	2	3	3	50	35	4	0	95	3	1.41	7
65-70	1	5	3	53	35	4	0	95	<1	1.36	7
70-75	2	2	3	56	33	3	0	96	<1	1.36	7
75-80	2	2	3	54	36	2	0	97	3	1.37	8
80-85	2	0	3	50	38	4	0	98	1	1.37	8
85-90	2	0	2	40	41	10	0	98	2	1.33	10
90-95	1	0	4	43	44	11	0	99	3	1.35	11
95-100	1	0	4	48	42	10	0	99	2	1.40	13
100-105	2	0	3	51	39	5	0	99	1	1.32	16
105-110	1	0	3	50	41	3	0	100	<1	1.37	19
110-115	2	0	3	42	45	7	0	99	1	1.38	21
115-120	1	0	4	45	46	7	0	99	2	1.48	27
120-125	1	0	4	45	41	7	0	99	2	1.52	26

Appendix 3. (Continued). Site 7

Soil depth	Clay	Silt	Sand						Total > 2mm	Bulk density	Water content
			vfs	fs	ms	cs	vcs	total			
(cm)					-(%)-					gms/cm^3	% vol
0-5	-	--	--	--	--	-	-	-	3	.55	34
5-10	6	19	11	46	18	3	0	75	<1	1.15	28
10-15	7	16	14	46	17	3	0	77	<1	1.11	30
15-20	4	13	14	49	19	3	0	83	1	1.18	30
20-25	4	13	19	44	16	3	0	84	1	1.31	31
25-30	4	13	19	47	16	3	0	84	<1	1.39	29
30-35	4	12	21	48	14	3	0	84	1	1.39	27
35-40	3	12	25	47	11	2	0	85	<1	1.48	27
40-45	3	9	24	55	9	2	0	89	<1	1.49	25
45-50	2	6	33	52	8	2	0	92	<1	1.48	25
50-55	2	6	30	46	11	2	1	93	<1	1.48	24
55-60	2	5	25	47	17	3	0	93	<1	1.53	22
60-65	2	7	25	42	18	5	1	91	<1	1.59	27
65-70	2	9	27	38	17	7	0	90	1	1.59	29
70-75	2	11	33	38	11	4	0	88	<1	1.65	34
75-80	1	15	37	41	6	1	0	84	<1	1.57	31
80-85	1	15	43	37	5	1	0	84	<1	1.44	36
85-90	0	10	41	44	5	0	0	90	<1	1.45	37
90-95	1	11	44	42	4	0	0	88	<1	1.43	36
95-100	2	13	37	45	3	0	0	86	<1	1.25	21
100-105	2	12	45	43	2	0	0	87	<1	1.27	26
105-110	1	7	42	48	2	0	0	92	<1	1.26	23
110-115	0	14	49	38	2	0	0	86	<1	1.29	26
115-120	2	10	50	38	2	0	0	89	<1	1.31	26
120-125	2	6	39	52	2	0	0	93	<1	1.33	25
125-130	2	12	48	39	2	0	0	86	<1	1.40	28
130-135	1	7	33	55	2	0	0	92	<1	1.36	27
135-140	2	15	42	38	2	0	0	84	<1	1.35	29
140-145	1	15	36	43	2	0	0	84	<1	1.45	33
145-150	1	17	37	34	8	2	0	83	1	1.44	34

Appendix 3. (Continued). Site 8

Soil depth	Clay	Silt	Sand						Total > 2mm	Bulk density	Water content
			vfs	fs	ms	cs	vcs	total			
(cm)					-(%)-					gms/cm^3	% vol
0-5	4	7	5	36	42	6	0	90	2	.88	21
5-10	4	4	5	41	45	5	0	92	5	1.07	15
10-15	4	3	6	41	42	3	0	93	3	1.21	21
15-20	3	1	3	42	48	3	0	97	1	1.23	13
20-25	2	0	3	40	52	2	0	98	<1	1.30	11
25-30	2	1	3	46	47	2	0	97	<1	1.40	10
30-35	2	0	3	43	50	3	0	98	<1	1.36	10
35-40	2	1	1	33	58	5	0	98	1	1.47	10
40-45	2	1	1	34	57	6	0	97	1	1.43	10
45-50	2	1	2	40	54	3	0	97	<1	1.41	10
50-55	2	1	3	40	53	2	0	98	<1	1.50	10
55-60	3	0	2	41	54	2	0	98	<1	1.43	9
60-65	1	0	2	40	55	2	0	99	<1	1.56	10
65-70	1	0	2	40	56	2	0	99	<1	1.54	8
70-75	1	0	2	41	55	2	0	99	<1	1.47	8
75-80	1	1	2	39	56	2	0	98	<1	1.47	9
80-85	1	0	2	43	52	2	0	99	<1	1.55	10
85-90	1	0	3	45	49	2	0	99	<1	1.49	9
90-95	1	0	3	44	50	3	0	99	<1	1.37	9
95-100	1	0	2	38	56	5	0	99	<1	1.45	9
100-105	0	0	2	37	57	4	0	99	<1	1.41	11
105-110	1	0	2	44	50	3	0	99	<1	1.47	14
110-115	1	0	2	41	54	4	0	99	<1	1.45	15
115-120	1	0	1	39	55	4	0	99	<1	1.46	17
120-125	1	0	2	42	51	3	0	99	<1	1.43	17
125-130	1	0	2	43	51	4	0	99	<1	1.42	18
130-135	1	0	2	40	54	3	0	99	1	1.51	21
135-140	1	1	1	38	57	3	0	99	<1	1.58	32
140-145	0	0	3	43	51	3	0	100	<1	.57	15

Appendix 3. (Continued). Site 9

Soil depth	Clay	Silt	Sand vfs	fs	ms	cs	vcs	total	Total > 2mm	Bulk density	Water content
(cm)	- - -	- - -	- - -	- - -	-(%)-	- - -	- - -	- - -	-	gms/cm^3	% vol
0-5	5	11	5	37	41	3	0	85	<1	1.01	17
5-10	3	3	4	37	46	4	0	94	<1	1.31	15
10-15	2	3	3	38	49	5	0	96	<1	1.36	13
15-20	1	1	2	38	52	6	0	98	<1	1.42	10
20-25	1	0	1	33	57	8	0	99	<1	1.48	8
25-30	1	0	1	29	59	10	0	99	<1	1.44	7
30-35	0	1	2	32	57	8	0	99	<1	1.51	7
35-40	0	0	1	29	57	13	0	100	1	1.60	8
40-45	0	0	2	24	40	34	0	100	1	1.46	8
45-50	0	1	2	32	55	10	0	99	1	1.56	8
50-55	0	0	1	42	55	2	0	99	<1	1.55	7
55-60	0	0	1	50	48	1	0	100	<1	1.48	7
60-65	1	1	1	51	47	1	0	99	<1	1.42	8
65-70	0	1	1	41	57	2	0	99	<1	1.49	9
70-75	1	1	1	33	61	5	0	99	<1	1.51	7
75-80	1	0	3	60	37	0	0	99	<1	1.32	7
80-85	0	0	3	59	35	3	0	99	<1	1.30	8
85-90	1	1	2	65	31	2	0	98	<1	1.36	8
90-95	1	0	1	31	60	8	0	99	<1	1.34	7
95-100	1	0	1	30	60	9	0	99	<1	1.38	9
100-105	0	0	2	44	48	6	0	100	<1	1.37	12
105-110	1	1	3	40	52	5	0	98	<1	1.39	12
110-115	1	0	2	17	70	11	0	99	<1	1.38	12
115-120	1	0	3	43	49	4	0	99	<1	1.35	19
120-125	1	0	4	36	53	6	0	99	<1	1.44	21
125-130	0	0	3	40	52	4	0	99	<1	1.45	23
130-135	0	1	3	23	69	4	0	99	<1	1.43	22
135-140	1	0	1	19	75	5	0	99	<1	1.49	26
140-145	1	0	2	24	69	4	0	99	<1	1.49	28
145-150	1	0	2	22	72	3	0	99	<1	.73	15

Appendix 4. Kjeldahl N, total P, total S, exchangeable cations, cation exchange capacity, base saturation, and soil pH by depth. Site 1

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	(mg/kg)								(cmole/kg)	(%)		
0-5	62	315	317	267	35.5	55.8	18.5	10.2	12.1	15	3.8	3.5
5-10	921	449	95	25	4.6	19.2	16.2	7.8	8.1	3	4.0	3.8
10-15	662	434	87	16	2.6	14.9	16.5	8.3	8.5	3	4.5	4.3
15-20	611	420	83	13	1.6	11.6	15.1	6.2	6.3	3	4.7	4.6
20-25	438	341	63	13	1.3	10.2	13.4	4.8	5.0	3	4.7	4.4
25-30	315	285	59	14	1.2	9.5	14.7	4.1	4.2	4	4.7	4.6
30-35	428	334	46	14	1.2	8.8	13.6	3.8	4.0	4	4.8	4.7
35-40	225	235	39	19	1.4	9.4	15.0	2.8	3.0	7	5.0	4.6
40-45	271	235	36	26	1.8	8.6	14.6	2.4	2.7	11	5.1	4.7
45-50	249	182	39	25	1.7	7.4	17.1	1.9	2.1	11	5.1	4.8
50-55	138	180	35	22	1.5	5.9	14.7	1.5	1.7	11	5.2	4.8
55-60	156	159	26	21	1.4	4.6	14.9	1.1	1.3	14	5.2	4.8
60-65	67	107	24	19	1.3	3.9	15.6	0.9	1.1	17	5.2	4.9
65-70	60	95	28	19	1.2	3.8	15.1	0.7	0.9	20	5.3	4.9
70-75	42	82	25	18	1.2	3.6	13.8	0.7	0.9	20	5.3	4.9
75-80	40	98	23	20	1.4	3.7	14.5	0.7	0.9	20	5.3	4.9
80-85	69	91	28	21	1.6	4.2	14.3	0.7	0.9	21	5.3	4.9
85-90	36	95	30	26	2.0	4.5	16.0	0.6	0.8	28	5.2	4.8
90-95	49	92	23	24	1.8	4.1	14.6	0.6	0.8	27	5.2	4.8
95-100	44	99	31	25	1.8	4.6	13.8	0.6	0.8	27	5.2	4.8
100-105	86	81	35	26	2.3	4.7	13.9	0.5	0.8	29	5.2	4.7
105-110	33	88	22	20	1.5	4.0	12.2	0.5	0.7	26	5.2	4.8
110-115	49	94	22	24	2.1	4.7	12.5	0.6	0.8	26	5.2	4.8
115-120	31	86	41	21	1.8	4.0	14.0	0.6	0.8	25	5.2	4.8
120-125	50	96	35	25	2.0	4.6	13.3	0.6	0.8	27	5.2	4.7
125-130	45	87	27	22	1.8	4.2	14.2	0.6	0.8	26	5.3	4.7
130-135	39	94	23	20	1.5	3.8	14.2	0.6	0.7	24	5.2	4.7
135-140	46	95	23	22	1.9	4.2	15.0	0.6	0.8	30	5.2	4.8
140-145	38	97	25	26	2.1	4.5	14.8	0.6	0.8	28	5.2	4.7
145-150	83	87	2	27	2.5	4.6	14.2	0.6	0.	29	5.4	4.9

Appendix 4. (Continued). Site 2

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	mg/kg								(meq)	(%)		
0-5	42	306	340	322	38.9	75.5	16.1	6.7	8.85	23.6	5.0	4.5
5-10	706	185	180	265	16.4	15.6	17.0	4.0	5.55	26.2	5.0	4.5
10-15	455	176	172	255	10.1	11.6	14.6	2.5	3.97	32.9	5.4	4.5
15-20	403	235	130	247	7.8	13.4	16.1	2.8	4.22	30.0	5.5	4.7
20-25	521	400	150	230	12.4	14.3	17.0	3.7	5.08	24.6	5.6	4.9
25-30	304	363	143	205	15.4	12.6	17.1	4.1	5.32	21.9	5.6	4.9
30-35	349	456	83	185	10.4	11.9	14.5	<.5	4.80	21.0	5.7	5.0
35-40	524	541	113	129	8.6	10.9	16.6	3.3	4.15	17.6	5.8	5.2
40-45	204	233	107	79	6.3	8.2	16.2	2.7	3.26	14.6	5.8	5.1
45-50	502	203	43	52	4.9	8.2	15.6	2.1	2.45	13.5	5.8	5.1
50-55	238	221	32	50	5.1	8.0	16.1	1.4	1.82	15.8	5.8	5.1
55-60	277	186	43	46	5.0	7.0	17.1	1.4	1.80	16.1	5.8	5.0
60-65	122	156	28	44	5.5	6.4	12.6	1.1	1.47	17.1	5.8	4.9
65-70	129	147	36	35	4.3	5.7	15.3	1.0	1.28	17.3	5.7	5.0
70-75	101	155	47	30	3.8	4.6	14.9	0.8	1.02	17.8	5.7	4.7
75-80	65	125	19	26	2.9	4.9	15.1	0.6	.85	17.0	5.6	4.9
80-85	52	77	46	31	2.9	5.8	14.2	0.6	.82	19.7	5.5	4.8
85-90	160	134	72	59	6.6	8.7	14.6	1.2	1.63	17.1	5.5	4.7
90-95	265	152	38	128	27.8	17.8	15.7	2.0	2.96	28.8	5.1	4.4
95-100	197	166	29	127	28.6	18.6	17.6	2.6	3.55	24.8	5.2	4.4
100-105	258	128	9	53	5.3	7.2	15.2	1.4	1.79	17.5	5.5	4.6
105-110	216	159	1	49	4.9	7.0	17.0	1.1	1.50	19.6	5.5	4.6
110-115	194	129	1	82	4.3	6.2	17.0	1.3	1.93	22.5	5.3	4.5
115-120	194	149	2	34	4.1	5.4	16.7	1.4	2.04	26.3	5.4	4.6
120-125	172	144	6	68	11.3	9.8	17.2	1.5	2.01	23.6	5.4	4.5
135-130	305	163	9	98	23.1	14.2	17.4	3.4	4.15	18.0	5.1	4.3
130-135	155	152	5	148	33.7	20.6	17.7	3.1	4.21	25.8	4.9	4.1
135-140	175	161	2	100	25.7	15.4	19.6	3.1	3.93	19.9	5.0	4.3
140-145	185	161	2	78	22.7	12.6	18.4	2.9	3.61	17.9	4.8	4.1
145-150	178	137	2	96	26.2	15.4	17.1	3.0	3.77	20.2	4.9	4.3

Appendix 4. (Continued). Site 3

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	- - - - - - - -	- - - - - -	- - - - -	mg/kg	- - - - - -	- - - - -	- - - - -	- - - -	(meq)	(%)		
0-5	58	422	212	921	41.2	84.5	21.8	1.2	17.65	32.0	4.9	4.5
5-10	43	443	136	423	31.4	31.5	19.2	11.8	14.44	18.1	4.5	4.1
10-15	1090	279	71	202	29.6	17.8	21.1	9.3	10.65	13.0	4.7	4.3
15-20	784	608	67	179	25.7	11.0	21.0	8.9	10.16	12.0 5.1	4.6	
20-25	1040	941	47	171	22.4	19.0	20.2	6.7	7.88	15.0	5.2	4.7
25-30	506	517	34	168	16.6	21.8	17.9	4.7	5.81	18.9	5.7	5.0
30-35	450	404	27	171	14.6	18.7	15.0	3.8	4.84	22.5	5.7	5.1
35-40	343	330	21	137	10.6	14.8	18.0	3.1	4.01	22.2	5.8	5.1
40-45	254	398	31	114	8.3	13.3	16.8	2.5	3.28	22.6	5.8	5.2
45-50	238	301	9	87	5.0	10.3	14.2	1.9	2.44	23.0	5.8	5.2
50-55	134	297	12	73	4.0	9.3	14.8	1.6	2.09	23.0	5.8	5.2
55-60	108	281	11	64	3.8	10.4	15.2	1.3	1.74	25.3	5.8	5.1
60-65	76	266	21	60	3.7	10.6	13.6	1.2	1.61	26.1	5.8	5.1
65-70	72	220	9	66	4.2	11.4	12.8	1.0	1.47	30.6	5.8	5.1
70-75	64	220	5	63	4.2	12.4	15.2	1.0	1.46	30.8	5.8	5.1
75-80	83	213	2	58	4.2	11.0	14.3	.8	1.25	32.8	5.8	5.1
80-85	80	219	13	57	6.2	10.8	13.4	.6	1.00	42.0	5.8	5.0
85-90	62	325	4	68	14.4	9.6	13.4	.6	1.10	49.0	5.7	4.9
90-95	73	214	15	68	16.3	8.9	14.9	.5	1.09	51.4	5.7	4.9
95-100	79	229	10	61	14.2	8.4	13.9	.5	1.04	48.0	5.6	4.8
100-105	49	193	--	54	9.0	7.4	14.1	.7	1.14	36.8	5.7	4.9
105-110	57	237	--	55	9.8	7.3	15.0	.9	1.32	33.3	5.6	4.9
110-115	45	253	--	62	12.4	7.9	14.6	.6	1.09	45.0	5.7	4.9
115-120	51	229	--	55	10.6	7.5	14.4	.6	1.04	42.3	5.7	4.9
120-125	62	181	--	56	8.4	6.7	14.7	.7	1.09	39.4	5.6	4.9
125-130	79	258	--	58	9.4	7.0	15.7	.6	1.06	42.4	5.6	4.9
130-135	73	220	--	53	9.8	7.4	14.2	.5	.90	46.7	5.6	4.9
135-140	46	217	--	60	11.8	8.3	15.4	.5	.93	51.6	5.6	4.9
140-145	66	245	--	41	5.7	7.5	14.9	.4	.78	43.6	5.6	4.9

Appendix 4. (Continued). Site 4

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	- - - - - - - -	- - - - - -	- - - - -	mg/kg	- - - - - -	- - - - -	- - - - -	- - - -	(meq)	(%)		
0-5	1540	235	127	76	21.2	30.0	15.6	10.2	10.88	6.2	4.1	3.8
5-10	998	164	119	26	10.6	12.3	16.6	8.5	8.86	3.5	4.0	3.7
10-15	767	234	43	32	16.3	13.8	14.9	5.5	5.89	6.2	4.3	4.0
15-20	714	489	65	26	1.1	10.6	15.5	6.4	6.67	4.4	4.5	4.2
20-25	639	477	79	19	6.5	9.7	15.4	6.7	6.94	3.3	4.7	4.5
25-30	584	362	58	17	3.8	9.0	15.8	5.2	5.43	3.6	4.8	4.6
30-35	266	251	47	14	2.7	6.4	13.0	3.4	3.60	4.0	4.9	4.7
35-40	255	254	55	15	2.8	4.6	13.8	2.6	2.79	5.5	5.1	4.8
40-45	162	240	44	15	2.6	3.8	13.9	2.1	2.30	6.2	5.1	4.6
45-50	120	214	37	15	2.4	3.4	14.7	1.3	1.49	9.7	5.2	4.8
50-55	160	233	74	16	2.2	3.0	14.2	1.4	1.53	9.9	5.3	4.9
55-60	208	224	27	16	1.8	2.2	11.4	1.3	1.45	9.4	5.3	4.9
60-65	120	200	27	15	1.8	2.6	12.7	1.2	1.37	10.9	5.4	4.9
65-70	186	165	23	14	1.4	2.3	14.0	.9	1.09	12.6	5.4	4.9
70-75	71	164	29	13	1.2	2.3	14.4	.8	.96	15.6	5.4	4.9
75-80	75	161	26	15	1.4	2.2	13.8	.9	1.07	12.2	5.4	4.8
80-85	63	197	28	13	.1	2.1	14.2	.6	.74	18.9	5.4	4.9
85-90	64	180	24	11	.9	2.1	12.7	.6	.74	16.2	5.3	4.9
90-95	57	146	41	12	.8	2.9	15.3	.6	.72	19.4	5.4	5.4
95-100	50	131	24	11	.9	2.4	14.6	.4	.50	26.0	5.4	5.4
100-105	50	144	24	10	.7	2.6	12.3	.4	.54	20.4	5.4	5.4
105-110	50	169	15	12	.8	2.6	18.0	.4	.55	27.3	5.4	5.4
110-115	43	140	12	11	.7	2.5	13.4	.4	.53	28.9	5.5	5.5
115-120	47	162	10	11	.8	2.6	15.8	.4	.51	27.5	5.5	5.5
120-125	40	154	12	12	.9	2.3	13.5	.4	.51	25.5	5.4	5.4
125-130	43	144	11	15	1.2	2.9	13.9	.4	.51	29.4	5.5	5.5

Appendix 4. (Continued). Site 5

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	- - - - - - - -	- - - - - - - -	- - - - - - - -	mg/kg	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	(meq)	(%)		
0-5	1010	179	114	105	18.6	40.8	17.6	6.1	6.94	11.6	4.4	3.9
5-10	997	18	78	72	7.0	14.8	13.1	5.0	5.51	8.6	4.3	3.9
10-15	1070	133	66	71	7.7	12.0	15.7	4.9	5.46	8.9	4.3	3.8
15-20	509	159	69	54	6.7	11.2	15.4	5.5	5.88	6.2	4.6	4.0
20-25	473	286	59	22	2.8	8.4	14.5	5.4	5.64	3.7	4.8	4.5
25-30	362	214	43	17	1.7	6.8	14.4	.0	4.44	3.8	5.0	4.6
30-35	250	106	32	13	1.1	4.9	13.9	2.2	2.38	5.4	5.1	4.8
35-40	216	101	29	10	.7	3.4	12.0	1.7	1.86	6.0	5.1	4.9
40-45	307	89	37	12	.7	3.0	15.7	1.4	1.50	8.8	5.2	4.9
45-50	195	75	34	11	.7	2.5	3.7	1.2	1.31	9.6	5.2	4.9
50-55	189	84	32	12	.7	2.6	15.0	.8	.96	13.9	5.2	4.9
55-60	170	70	32	10	.6	2.8	12.0	.6	.70	15.7	5.3	4.9
60-65	98	65	37	10	.6	3.1	13.9	.4	.54	22.2	5.3	4.8
65-70	64	69	28	9	.5	3.5	13.0	.2	.45	31.4	5.3	4.8
70-75	96	96	19	8	.5	3.0	12.1	.3	.43	25.6	5.3	4.8
75-80	92	92	18	9	.5	2.5	12.2	.3	.41	26.8	5.3	4.8
80-85	99	86	29	9	.5	2.2	12.9	.3	.39	28.2	5.2	4.8
85-90	89	79	31	9	.5	3.1	13.8	.3	.43	34.4	5.3	4.9
90-95	69	87	31	10	.5	2.9	14.2	.3	.44	35.3	5.3	4.8
95-100	65	74	52	11	.6	3.2	14.1	.4	.51	34.2	5.3	4.8
100-105	66	79	38	11	.5	2.7	13.8	.4	.56	29.3	5.3	4.8
105-110	53	62	43	11	.5	2.4	13.5	.4	.54	28.6	5.3	4.9
110-115	46	61	50	12	.6	3.1	13.6	.4	.55	23.6	5.4	4.8
115-120	41	73	31	12	.6	3.3	13.9	.5	.67	19.4	5.4	4.8
120-125	45	95	49	12	.6	4.4	15.0	.7	.82	17.1	5.4	4.9
125-130	44	97	25	12	.6	3.5	14.6	.5	.62	22.6	5.4	4.8
130-135	59	78	41	13	.6	3.4	14.7	.3	.42	23.3	5.4	4.9

Appendix 4. (Continued). Site 6

Depth	TKN	TP	TS	Exchangeable Cations - - - - -					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	- - - - - - - -	- - - - - - - -	- - - - - - - -	mg/kg	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	(meq)	(%)		
0-5	41	253	146	162	23.7	39.5	15.0	8.0	9.17	12.8	4.6	4.1
5-10	646	215	54	89	10.2	12.1	15.8	5.4	6.05	10.4	4.8	4.3
10-15	570	194	48	103	12.0	9.8	12.3	5.2	5.87	11.8	4.9	4.3
15-20	795	300	61	62	7.2	8.2	16.4	6.3	6.74	6.8	5.0	4.4
20-25	537	264	45	46	6.1	8.0	14.4	5.3	5.70	6.3	4.9	4.5
25-30	329	264	40	23	2.7	7.8	16.1	4.2	4.45	5.2	5.0	4.4
30-35	235	231	30	22	2.6	6.5	15.3	3.6	3.82	5.8	5.1	4.6
35-40	266	201	29	22	3.5	5.4	16.1	3.0	3.22	6.8	5.1	4.6
40-45	195	261	25	18	2.2	4.8	15.1	2.7	2.91	6.5	5.1	4.7
45-50	196	349	26	15	1.4	4.0	15.5	2.6	2.75	6.2	5.1	4.7
50-55	131	298	25	14	1.2	3.2	15.6	2.6	2.72	5.8	5.1	4.8
55-60	96	281	19	12	.9	2.6	12.1	1.9	2.01	6.5	5.1	4.8
60-65	61	230	17	14	.9	2.4	16.2	1.5	1.61	9.3	5.2	4.8
65-70	65	213	15	12	.7	2.6	15.8	1.3	1.42	9.9	5.2	4.9
70-75	77	217	13	12	.6	2.1	14.6	1.1	1.21	10.7	5.1	4.8
75-80	58	171	12	11	.6	2.1	14.9	.9	.99	13.1	5.2	4.7
80-85	45	153	13	12	.7	2.1	14.4	<.1	.76	18.4	5.2	4.8
85-90	76	130	15	17	.7	2.8	15.6	.7	.90	20.0	5.2	4.7
90-95	51	110	11	11	.6	2.3	14.6	.3	.41	31.7	5.3	4.8
95-100	58	95	9	12	.6	1.9	15.9	.3	.43	34.9	5.3	4.9
100-105	73	90	8	10	.6	2.6	14.1	<.1	.34	35.3	5.3	4.8
105-110	72	84	13	9	.5	2.4	11.4	.2	.30	33.3	5.3	4.8
110-115	59	88	11	10	.6	2.3	12.2	.3	.37	29.7	5.3	4.7
115-120	65	81	10	12	.6	3.3	14.8	.3	.44	31.8	5.3	4.7
120-125	6	81	9	11	.6	2.6	13.3	.4	.31	25.5	5.3	4.8

Appendix 4. (Continued). Site 7

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	mg/kg								(meq)	(%)		
0-5	122	656	261	1910	49.1	105.6	18.2	20.4	32.41	37.1	4.6	4.4
5-10	335	399	78	472	36.8	33.8	16.0	11.3	14.24	20.4	4.2	3.9
10-15	1420	1050	92	233	29.5	30.4	17.3	15.2	17.13	11.5	4.3	4.1
15-20	1070	1050	80	180	20.6	20.6	17.0	15.5	16.68	7.2	4.7	4.4
20-25	883	1020	74	162	14.7	15.1	15.5	11.7	12.74	8.2	5.0	4.5
25-30	718	619	64	122	9.8	13.4	17.2	8.5	9.28	8.6	5.1	4.6
30-35	458	633	38	90	6.9	10.1	15.2	6.7	7.28	8.2	5.1	4.6
35-40	431	585	32	81	6.2	8.6	16.2	5.2	5.67	8.8	5.2	4.7
40-45	227	406	23	57	4.3	6.6	13.5	4.0	4.38	9.1	5.2	4.7
45-50	314	359	19	41	3.0	6.6	15.0	3.0	3.27	9.5	5.2	4.7
50-55	300	325	17	34	2.9	5.6	13.8	2.7	2.97	9.1	5.3	4.8
55-60	137	331	17	31	2.6	5.4	15.7	2.3	2.54	10.2	5.3	4.7
60-65	122	222	18	30	2.9	6.0	13.2	2.0	2.25	11.1	5.4	4.7
65-70	211	297	18	31	3.1	8.6	12.8	2.9	3.17	7.9	5.3	4.8
70-75	142	256	17	28	2.7	8.6	14.6	2.4	2.68	9.0	5.4	4.8
75-80	156	286	16	27	2.2	7.4	15.4	1.8	2.02	11.9	5.3	4.7
80-85	172	282	14	33	2.6	7.1	15.7	2.3	2.55	10.6	5.3	4.7
85-90	133	279	17	29	2.0	5.4	16.5	2.2	2.50	10.4	5.3	4.6
90-95	344	285	14	30	2.2	5.6	15.8	2.2	2.41	10.4	5.3	4.7
95-100	236	253	25	40	4.6	6.1	14.5	4.1	4.40	7.3	4.6	4.3
100-105	138	255	23	44	5.8	6.1	14.0	3.5	3.82	8.9	4.8	4.2
105-110	131	224	18	26	2.0	5.8	14.6	2.5	2.70	8.1	4.9	4.5
110-115	143	308	22	39	3.8	6.6	13.8	2.6	2.89	11.4	4.9	4.4
115-120	76	298	17	29	2.0	6.5	14.6	2.4	2.64	9.1	5.0	4.5
120-125	68	286	16	27	1.8	5.4	15.4	1.5	1.77	13.0	5.1	4.6
125-130	64	296	15	23	1.5	5.5	13.8	1.9	2.10	9.5	5.1	4.6
130-135	80	288	18	27	2.2	5.1	13.9	2.2	2.46	8.9	5.1	4.6
135-140	69	310	18	31	2.2	6.5	14.7	2.5	2.72	9.6	5.2	4.6
140-145	56	293	18	32	2.5	6.5	16.5	2.4	2.67	10.1	5.1	4.6
145-150	71	282	17	44	3.0	6.8	15.6	2.1	2.43	13.6	5.4	4.8

Appendix 4. (Continued). Site 8

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	mg/kg								(meq)	(%)		
0-5	48	324	103	176	29.2	34.1	16.2	9.9	11.17	11.4	4.4	3.9
5-10	787	280	58	85	12.6	1.2	13.9	5.7	6.32	9.8	4.2	3.8
10-15	909	379	75	104	9.0	16.9	15.4	10.6	11.28	6.2	4.5	4.2
15-20	515	358	77	46	3.0	7.3	15.4	7.7	8.06	4.2	4.7	4.2
20-25	346	296	38	27	1.8	5.3	14.4	5.4	5.62	3.9	4.8	4.5
25-30	310	266	35	24	1.4	3.7	15.5	4.9	5.11	3.7	4.9	4.5
30-35	238	209	39	25	1.3	3.6	13.6	4.3	4.48	4.5	5.0	4.5
35-40	219	187	27	20	1.0	3.4	15.0	3.4	3.55	5.4	4.9	4.6
40-45	535	130	28	16	1.0	3.9	14.0	3.4	3.54	4.5	4.8	4.4
45-50	290	180	19	15	.9	4.2	14.5	3.3	3.50	4.6	4.9	4.4
50-55	247	140	22	12	.7	3.9	12.6	2.4	2.53	5.1	5.0	4.5
55-60	191	156	21	13	.8	4.4	12.6	1.9	2.00	7.0	4.9	4.5
60-65	180	151	20	13	.7	4.2	1.3	1.8	1.92	7.3	5.0	4.6
65-70	97	163	14	13	.6	4.2	13.4	2.0	2.12	5.7	5.0	4.6
70-75	37	154	14	11	.6	4.1	11.6	2.1	2.18	5.5	5.1	4.7
75-80	49	150	17	14	.7	4.1	12.6	2.1	2.20	6.4	5.1	4.7
80-85	59	154	15	15	.8	4.2	12.9	1.8	1.93	7.8	5.1	4.7
85-90	139	111	12	16	.8	4.0	12.4	1.8	1.93	7.8	5.2	4.7
90-95	216	152	11	17	.7	3.9	13.0	1.3	1.48	10.8	5.4	4.8
95-100	395	146	13	17	.6	4.1	11.5	1.1	1.23	12.2	5.4	4.8
100-105	192	132	14	17	.6	4.0	14.0	1.1	1.30	12.3	5.5	4.8
105-110	127	189	11	17	.6	3.9	13.0	1.1	1.30	12.3	5.5	4.8
110-115	203	190	10	17	.6	3.8	12.6	1.0	1.15	14.5	5.5	4.8
115-120	128	159	14	18	.7	3.7	14.2	1.2	1.34	11.9	5.3	4.7
120-125	103	143	11	12	.6	3.4	10.7	1.3	1.40	10.0	5.2	4.8
125-130	119	193	11	16	.7	3.7	12.7	1.1	1.29	11.6	5.3	4.7
130-135	96	112	14	17	.8	3.8	13.4	1.2	1.32	12.1	5.2	4.7
135-140	123	87	14	15	.8	3.6	13.2	1.3	1.45	10.3	5.2	4.7
140-145	153	73	14	15	.9	4.6	11.5	1.2	1.36	10.3	5.2	4.8

Appendix 4. (Continued). Site 9

Depth	TKN	TP	TS	Exchangeable Cations					CEC	Base sat.	pH	
				Ca	Mg	K	Na	H			Water	$CaCl_2$
(cm)	- - -	- - -	- - -	- - - mg/kg	- - -	- - -	- - -	- - -	(meq)	(%)		
0-5	40	97	141	58	6.8	16.8	15.4	10.4	10.80	4.9	3.8	3.4
5-10	619	160	59	8	2.6	10.3	14.8	8.0	8.15	2.2	4.3	4.1
10-15	427	182	64	8	1.7	6.1	16.2	6.2	6.30	2.9	4.6	4.5
15-20	384	207	46	9	1.2	4.7	15.8	4.3	4.40	4.1	4.8	4.5
20-25	257	192	34	10	1.0	4.5	15.3	2.9	3.03	6.5	4.8	4.6
25-30	187	179	20	10	.7	3.1	14.7	1.2	1.29	10.1	4.9	4.6
30-35	334	126	30	8	.6	2.4	12.4	1.1	1.25	10.4	5.0	4.7
35-40	331	118	26	10	.6	2.4	15.0	1.1	1.23	10.6	5.1	4.8
40-45	221	101	20	10	.5	2.7	15.4	1.1	1.19	10.9	5.0	4.8
45-50	96	91	15	9	.4	2.5	14.2	1.2	1.30	10.0	5.0	4.7
50-55	76	73	69	10	.4	2.5	15.5	1.1	1.25	10.5	5.0	4.5
55-60	38	72	12	9	.3	2.2	13.7	.4	.55	20.0	5.1	4.7
60-65	74	71	9	9	.3	2.2	14.6	.4	.56	21.0	5.1	4.7
65-70	67	80	10	8	.3	2.2	14.5	.5	.57	19.3	5.1	4.6
70-75	127	97	11	9	.3	2.0	15.8	.7	.80	15.0	5.1	4.7
75-80	213	93	9	10	.5	2.6	15.8	.5	.61	21.3	5.1	4.7
80-85	181	72	12	13	.6	2.9	17.0	.9	1.07	14.0	5.0	4.6
85-90	166	70	9	12	.7	3.0	15.5	.8	.92	15.2	5.0	4.6
90-95	204	83	16	13	.9	3.8	17.0	.7	.82	19.5	5.0	4.7
95-100	306	82	10	14	.8	2.7	16.2	.6	.79	19.0	5.0	4.7
100-105	231	79	6	11	.7	3.0	17.0	.6	.72	19.4	5.1	4.7
105-110	44	73	5	11	.7	3.4	17.1	.6	.70	20.0	5.1	4.7
110-115	76	80	6	11	.6	3.0	15.6	.5	.62	22.6	5.1	4.7
115-120	32	59	5	12	.6	2.9	15.6	.6	.75	14.7	5.1	4.7
120-125	53	59	6	13	1.2	3.1	14.2	.9	1.08	13.0	5.1	4.6
125-130	44	69	4	14	1.1	3.1	15.5	.9	1.04	15.4	5.1	4.7
130-135	29	81	6	13	1.0	3.1	17.0	.7	.86	18.6	5.0	4.6
135-140	83	81	2	11	.9	2.6	12.8	.7	.83	15.7	5.0	4.7
140-145	59	71	2	12	.9	3.0	15.6	.6	.78	17.9	5.0	4.6
145-150	637	78	2	11	.9	3.5	15.4	.5	.60	20.3	.9.1	4.7

Appendix 5. Total element concentrations by depth. Site 1

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	(mg/kg)													
0-5	1104	741	395	46	5285	5.5	0.4	11.5	4.5	8260	272	3.3	17.7	21.0
5-10	569	837	291	37	6379	4.5	0.3	5.1	3.1	9942	191	4.4	8.7	18.2
10-15	702	1043	302	43	7935	4.7	0.4	4.4	3.8	9962	132	6.5	9.0	22.2
15-20	674	1165	327	44	9567	5.2	0.2	6.0	4.8	11319	102	8.5	9.7	22.6
20-25	737	1266	373	47	9637	5.4	0.1	8.9	5.3	11606	91	8.1	11.0	19.0
25-30	937	1250	334	46	8837	5.0	0.3	7.0	5.3	10383	81	7.3	9.8	15.9
30-35	848	1390	341	47	8992	5.4	0.8	7.9	6.1	11660	79	8.2	10.2	16.3
35-40	792	1385	329	45	8050	5.2	0.6	6.9	6.0	10614	76	7.6	9.6	14.6
40-45	736	1380	317	42	7109	5.0	0.4	5.9	6.0	9566	72	6.9	9.1	12.8
45-50	710	1260	297	42	6713	4.6	0.3	7.3	5.9	9501	70	6.6	8.6	11.6
50-55	709	1150	266	40	5660	4.4	0.3	4.9	5.5	8396	63	5.5	7.4	8.8
55-60	683	1114	275	35	4584	3.9	0.4	4.1	4.9	6692	54	5.5	6.5	7.7
60-65	996	1216	259	42	4048	3.9	0.4	3.6	4.8	6258	66	4.4	6.3	7.6
65-70	941	1366	264	34	4056	3.8	0.2	4.3	5.6	7058	75	5.6	6.7	8.8
70-75	983	1144	259	89	3937	4.3	0.1	3.7	5.0	5600	62	4.4	6.3	6.8
75-80	929	1490	300	66	4484	4.7	0.3	4.4	6.4	7630	77	5.5	7.9	9.2
80-85	1075	1836	333	44	5032	5.0	0.5	5.0	7.8	9660	107	6.6	9.0	11.5
85-90	1553	1998	370	78	5584	5.1	0.6	6.2	6.9	8768	85	8.0	8.9	10.7
90-95	1751	1547	283	41	4603	3.5	0.6	4.4	5.8	7380	132	6.8	7.3	8.7
95-100	1184	1576	260	44	4326	3.9	0.5	4.2	7.5	7877	91	5.7	7.5	9.4
100-105	1222	2171	342	47	5297	4.1	0.3	4.4	7.7	8896	88	7.2	9.5	11.7
105-110	978	1437	271	35	3948	4.4	0.2	5.7	5.9	6823	66	5.9	7.1	8.0
110-115	1300	1647	275	40	4355	4.3	0.3	4.7	7.4	7697	84	5.7	7.5	9.7
115-120	1655	2064	307	40	5263	4.8	0.4	7.8	8.2	8914	92	8.0	8.8	11.5
120-125	2010	2481	339	39	6171	5.2	0.5	10.9	8.9	10132	99	10.1	10.2	13.3
125-130	1579	1601	287	102	4672	4.3	0.3	4.5	6.7	6708	79	6.0	7.4	7.9
130-135	1455	2392	447	58	6391	7.6	0.9	6.8	12.5	11525	155	9.4	12.4	15.3
135-140	801	1037	210	31	3205	3.3	0.2	2.8	4.5	5955	74	3.7	5.9	6.7
140-145	1055	1334	241	36	3714	3.4	0.2	4.2	5.1	5813	81	4.6	6.8	6.5
145-150	1337	1131	245	28	3534	3.5	0.4	3.5	4.6	5689	83	4.3	6.3	6.1

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	(mg/kg)								
0-5	7.9	102	.25	4.2	3.2	2.6	14.9	701	27.2
5-10									
10-15									
15-20									
20-25	12.4	53	.41	5.9	6.0	3.9	11.4	823	35.0
25-30	11.4	54	.40	5.6	5.6	3.8	12.8	752	31.3
30-35	10.2	53	.34	5.1	5.2	3.3	11.8	632	25.6
35-40	9.6	48	.35	4.7	4.5	3.1	10.5	577	24.9
40-45	9.1	45	.35	5.3	4.5	3.2	11.2	731	29.4
45-50	9.7	43	.37	5.5	4.4	3.3	12.6	680	29.4
50-55	7.4	68	.28	4.1	3.4	2.5	10.7	449	17.6
55-60	7.6	30	.31	4.8	3.6	2.4	12.0	598	23.7
60-65	6.6	23	.26	3.8	3.3	2.1	17.0	307	18.1
65-70	6.0	25	.25	4.0	3.6	2.0	11.3	413	15.3
70-75	6.8	25	.25	4.5	3.6	2.1	11.5	401	18.3
75-80	7.0	30	.26	4.7	4.2	2.3	13.2	467	19.5
80-85	10.7	67	.41	6.2	11.2	3.4	19.5	413	23.9
85-90	10.2	54	.39	6.7	5.7	3.3	17.8	502	30.7
90-95	10.1	42	.36	6.5	6.8	3.1	19.5	713	26.3
95-100	8.0	33	.32	5.5	4.6	3.2	12.7	681	22.9
100-105	10.5	38	.33	6.9	6.0	3.2	16.3	726	31.3
105-110	8.2	36	.31	5.0	4.5	2.6	9.1	391	23.7
110-115	9.5	46	.40	6.9	8.4	3.2	12.8	606	25.9
115-120	8.1	35	.29	5.4	5.3	2.7	11.8	447	21.0
120-125	7.4	49	.27	4.4	3.7	2.4	11.3	493	17.8
125-130	8.4	31	.33	5.8	4.4	2.7	11.5	594	22.7
130-135	6.4	23	.25	4.1	3.5	2.1	10.8	374	14.4
135-140	7.9	33	.30	5.0	5.6	2.7	12.9	459	22.1
140-145	7.9	32	.30	5.2	5.8	2.5	15.9	500	21.5
145-150	4.5	24	.19	3.2	2.8	1.6	9.0	309	12.8

Appendix 5. (Continued). Site 2

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	(mg/kg)													
0-5	701	488	298	33	3764	3.5	0.3	4.4	2.6	4873	165	2.2	9.5	21.7
5-10	600	393	256	37	3834	3.6	0.5	3.6	1.9	4588	131	1.8	6.5	16.8
10-15	581	410	251	34	4038	3.5	0.4	3.7	1.8	4898	137	1.8	5.9	13.6
15-20	563	428	245	32	4243	3.3	0.3	3.7	1.7	5208	144	1.8	5.3	10.4
20-25	670	643	308	47	6287	3.9	0.3	3.8	2.3	7500	150	2.9	6.6	12.4
25-30	629	798	321	44	7224	4.4	0.3	3.7	2.6	7894	118	4.3	7.6	14.9
30-35	833	977	335	47	8109	4.4	0.4	4.2	3.3	8493	110	5.6	8.2	16.5
35-40	786	1370	364	51	9170	5.4	0.6	5.4	4.1	9913	101	7.7	9.4	20.0
40-45	737	1250	282	44	6589	4.5	0.4	5.0	3.6	7635	74	6.7	7.5	15.3
45-50	614	1100	297	43	6476	4.8	0.5	5.3	4.3	7106	73	6.5	7.0	16.9
50-55	719	1151	289	40	6048	5.0	0.4	5.8	4.0	7087	67	6.1	6.9	15.55
55-60	804	1210	281	36	5260	5.2	0.4	6.2	3.7	7068	62	5.8	6.9	14.1
60-65	792	1118	279	30	4750	4.3	0.2	4.4	3.4	6189	48	4.8	5.7	9.8
65-70	629	1096	290	30	4480	4.9	0.2	4.8	3.4	6556	47	5.0	5.7	8.5
70-75	662	1134	274	32	4080	4.2	0.2	3.6	3.3	5799	52	4.8	5.7	8.6
75-80	743	1251	287	40	4250	5.1	0.3	3.7	4.3	7079	62	5.1	6.5	8.8
80-85	663	1378	303	38	4230	5.2	0.5	3.5	4.4	6442	52	5.3	6.2	7.7
85-90	948	1850	369	56	6430	6.4	0.1	6.8	6.3	9398	70	7.5	9.3	10.5
90-95	1056	2142	458	62	7990	8.5	0.3	7.8	9.0	11205	81	9.7	10.8	13.1
95-100	1163	2435	548	68	9550	10.6	0.4	8.9	12.3	13012	93	10.0	12.3	15.8
100-105	1609	1604	377	46	6250	5.9	0.3	6.4	5.4	9771	79	7.1	8.7	10.2
105-110	789	1532	324	50	5600	6.2	0.4	6.0	5.5	8329	74	6.7	7.9	10.0
110-115	985	1814	402	52	6600	6.1	0.4	6.7	6.7	8578	72	7.3	8.8	10.8
115-120	908	1520	330	42	5350	6.0	0.3	5.4	5.3	8350	66	6.5	7.2	9.1
120-125	915	1740	378	52	6950	6.1	0.3	5.7	7.1	9130	79	7.5	9.0	11.7
125-130	913	2230	590	73	9930	8.2	0.5	7.9	13.0	11500	81	8.9	11.7	15.1
130-135	975	2212	552	69	9406	7.8	0.5	8.4	11.9	11737	86	8.8	11.2	14.8
135-140	1037	2194	515	65	8882	7.3	0.5	9.0	10.9	11974	90	8.8	10.7	14.5
140-145	707	1560	363	45	6673	5.5	0.2	6.3	9.5	9091	73	7.2	7.8	11.6
145-150	841	2090	468	64	8280	6.4	0.4	5.9	10.4	10898	79	7.8	9.4	14.6

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	(mg/kg)								
0-5									
5-10									
10-15									
15-20									
20-25									
25-30	9.4	53	.30	5.0	5.0	3.2	11.4	616	24.1
30-35	9.3	52	.28	4.4	5.4	3.2	12.2	537	23.4
35-40	9.6	54	.32	5.0	5.6	3.3	10.7	574	22.0
40-45	8.2	44	.29	4.4	4.5	2.8	12.9	483	19.8
45-50	7.2	37	.27	4.1	3.7	2.4	10.6	443	18.6
50-55	7.6	43	.28	4.4	4.1	2.6	8.7	470	19.3
55-60	8.2	41	.30	5.2	4.7	2.8	10.1	556	24.0
60-65	7.4	36	.28	3.8	3.2	2.3	13.1	428	18.6
65-70	6.5	27	.26	4.1	3.3	2.1	11.8	318	14.6
70-75	7.0	31	.25	4.5	4.0	2.2	12.7	370	15.4
75-80	7.4	30	.26	4.9	3.6	2.2	8.2	467	20.3
80-85	6.4	30	.25	4.4	3.8	2.1	9.4	399	18.9
85-90	9.9	57	.37	5.9	4.8	3.2	13.7	766	31.8
90-95	4.2	77	.44	5.3	6.8	4.0	17.1	769	32.3
95-100	4.8	71	.44	5.9	6.5	4.2	14.9	802	38.4
100-105	5.4	40	.34	5.2	4.9	3.0	15.7	591	27.7
105-110	2.9	36	.27	4.0	4.4	2.3	9.2	500	20.1
110-115									
115-120	2.9	32	.27	4.2	4.2	2.3	9.3	421	21.2
120-125	4.0	51	.32	4.4	4.8	2.9	11.2	645	26.0
125-130	5.1	70	.44	5.1	6.5	4.0	15.2	850	38.1
130-135	4.3	86	.46	5.8	7.3	4.3	17.2	725	32.1
135-140	4.2	61	.36	4.7	5.2	3.2	12.0	732	30.6

Appendix 5. (Continued). Site 3

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)							(mg/kg)							
0-5	2423	1591	619	94	9554	4.8	0.3	8.6	6.8	8229	557	8.8	18.8	50.2
5-10	1839	1167	480	104	8742	4.6	0.3	6.7	4.7	6526	510	5.7	9.9	40.0
10-15	1435	1377	486	106	10840	4.7	0.1	6.9	4.2	8396	141	7.3	8.9	34.6
15-20	1571	1768	522	107	12692	4.8	0.2	8.7	5.2	10110	113	11.0	10.1	34.5
20-25	1839	2010	608	122	13952	4.8	0.1	8.9	6.2	10673	118	13.3	10.3	28.1
25-30	1967	2164	590	122	13190	4.7	0.3	9.0	6.6	10322	119	13.1	10.2	23.9
30-35	2137	2246	599	127	12423	4.8	0.3	7.1	7.4	9997	110	12.8	10.7	21.7
35-40	1787	1979	497	113	9739	4.0	0.6	9.0	6.6	8108	88	10.3	8.3	15.9
40-45	2008	2207	540	125	9979	4.3	0.4	7.1	7.4	8650	99	11.6	9.3	16.1
45-50	1789	2091	498	112	8420	3.9	0.2	6.7	6.9	7650	84	10.4	8.2	13.8
50-55	1817	2123	563	118	8093	3.8	0.1	6.0	6.9	7530	93	10.3	7.9	13.4
55-60	1826	2234	599	117	8045	3.7	0.2	7.6	7.2	7730	98	11.0	8.4	14.0
60-65	1765	2266	613	112	7839	3.8	0.3	6.6	7.2	7530	101	11.1	8.1	14.9
65-70	1794	2498	692	119	8774	3.8	0.4	6.3	8.1	8250	112	11.9	9.0	16.0
70-75	1872	2299	634	117	8058	3.6	0.4	6.1	7.1	7930	102	11.0	8.0	14.9
75-80	1761	1909	532	108	6780	3.3	0.2	5.4	6.4	7100	98	9.4	7.3	12.5
80-85	1929	2030	550	123	6562	3.5	0.1	5.7	6.3	7180	101	9.5	7.5	12.4
85-90	1639	1881	510	100	5889	2.7	0.4	4.0	5.5	6100	84	8.6	6.4	11.3
90-95	1906	2103	587	106	6592	3.4	0.4	6.3	6.2	7180	107	9.5	7.8	13.0
95-100	1796	2065	556	102	6183	3.0	0.3	5.4	5.8	7050	99	8.9	7.1	13.0
100-105	1779	2115	504	100	6402	3.6	0.2	8.0	6.2	7203	101	9.8	7.4	13.1
105-110	1967	2140	552	110	6777	3.7	0.2	7.1	6.3	7387	107	10.0	7.3	13.5
110-115	1686	2094	524	101	6207	3.0	0.2	4.9	6.3	6910	98	9.8	7.4	13.8
115-120	1715	2190	520	100	6334	3.9	0.2	4.9	6.4	7113	104	10.1	7.2	13.2
120-125	1644	2256	558	105	6641	3.0	0.2	4.7	6.4	6916	101	10.1	7.8	13.9
125-130	1712	2190	540	111	6637	4.6	0.3	5.3	6.6	7200	103	10.4	7.7	13.5
130-135	1930	1931	498	105	6045	3.8	0.2	7.3	5.9	7203	104	9.0	7.4	12.3
135-140	1809	2118	526	106	6391	3.7	0.2	6.5	6.0	7126	94	9.6	7.3	13.3
140-145	1808	1848	436	97	5408	3.4	0.2	6.5	5.9	6778	100	8.6	6.5	11.6

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)					(mg/kg)				
0-5	2.9	205	.44	4.5	7.8	3.8	35.3	532	19.6
5-10	2.6	202	.39	3.4	6.4	3.5	32.8	600	18.9
10-15	2.8	173	.49	4.8	10.0	4.5	29.2	765	24.8
15-20	2.6	115	.50	5.2	10.9	4.7	29.2	602	22.5
20-25	2.7	97	.53	5.4	10.9	4.9	25.7	582	22.1
25-30	2.9	82	.53	5.7	11.0	4.8	28.6	558	22.8
30-35	2.5	68	.50	5.4	9.7	4.1	25.3	546	20.8
35-40	2.9	67	.54	5.7	10.0	4.0	29.2	572	21.8
40-45	2.6	57	.49	5.4	9.1	3.6	25.4	535	20.4
45-50	2.1	54	.49	5.6	9.3	3.4	28.3	526	20.4
50-55	2.4	50	.46	5.2	9.0	3.2	23.9	560	19.1
55-60	2.2	56	.44	5.1	9.9	3.1	25.3	444	17.4
60-65	2.3	57	.47	5.6	10.7	3.3	23.8	473	18.5
65-70	2.5	66	.51	6.0	11.7	3.5	26.3	483	18.9
70-75	2.3	55	.47	5.4	10.5	3.1	23.4	468	18.9
75-80	2.2	54	.42	5.2	9.0	2.9	23.0	434	18.0
80-85	2.4	55	.44	5.5	9.1	2.9	26.5	542	21.1
85-90	2.3	59	.41	5.3	9.2	2.8	24.0	506	17.9
90-95	1.7	64	.42	4.9	9.3	2.8	23.8	449	17.0
95-100	1.9	61	.40	4.8	8.9	2.5	25.5	455	16.9

Appendix 5. (Continued). Site 4

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	(mg/kg)													
0-5	293	621	267	30	4532	4.1	0.3	5.5	2.6	7384	165	2.9	11.5	15.5
5-10	196	554	204	25	3715	3.8	0.4	5.4	2.0	6684	138	2.2	7.2	12.1
10-15	248	625	260	33	4983	4.0	0.2	5.8	2.0	9403	98	2.5	6.6	10.8
15-20	211	732	259	31	6839	4.0	0.2	5.3	2.5	10307	93	3.7	7.2	12.8
20-25	230	835	286	34	8397	6.1	0.2	5.7	3.2	10611	96	5.5	7.1	16.3
25-30	191	745	251	27	6999	3.8	0.2	5.4	3.1	8161	67	5.4	5.7	12.7
30-35	204	751	220	28	5889	3.6	0.2	4.6	3.1	7327	58	4.7	5.2	10.1
35-40	216	757	188	28	4799	3.4	0.2	3.9	3.1	6493	49	4.1	4.7	7.5
40-45	462	870	225	35	4852	4.0	0.3	4.8	3.6	8099	60	4.3	5.3	7.8
45-50	342	728	206	31	3850	3.4	0.1	7.0	3.2	7169	59	3.5	4.4	6.5
50-55	342	688	177	26	3047	3.1	0.2	3.0	3.0	6349	55	3.1	4.1	5.6
55-60	349	665	190	34	3150	3.0	0.2	3.3	3.2	6401	53	3.0	4.1	5.4
60-65	423	755	200	36	3424	3.1	0.2	3.9	3.7	6273	57	3.2	4.1	5.4
65-70	438	805	210	40	3305	3.4	0.2	4.3	3.8	6576	65	3.4	4.6	5.7
70-75	730	735	184	36	3106	3.0	0.1	3.4	3.3	5454	62	2.7	6.0	4.9
75-80	693	1010	274	53	4269	3.9	0.2	5.3	4.6	8691	81	4.0	5.7	7.7
80-85	507	768	220	50	3009	3.1	0.1	3.9	3.5	6432	68	3.0	4.1	5.9
85-90	420	705	217	40	2847	3.1	0.2	3.6	3.4	6282	72	2.7	3.9	5.0
90-95	360	673	183	41	2574	2.6	0.1	2.7	3.1	5103	59	2.4	3.4	4.7
95-100	352	618	173	33	2292	2.5	0.2	2.9	2.7	5105	53	2.2	3.4	5.0
100-105	502	810	219	45	2916	3.3	0.2	4.5	3.2	6508	63	2.9	4.2	6.5
105-110	371	748	190	34	2485	2.7	0.3	4.1	2.7	5509	55	3.2	3.7	5.8
110-115	443	758	185	40	2760	3.2	0.3	3.9	3.2	6843	69	2.9	4.1	5.4
115-120	555	836	228	46	2905	3.5	0.2	4.5	3.4	7617	70	3.1	4.6	6.5
120-125	430	664	163	30	2367	2.5	0.2	3.3	2.7	5514	58	2.4	3.7	4.9
125-130	443	758	186	41	2967	2.9	0.1	3.8	3.3	6418	63	2.8	4.4	6.5

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	(mg/kg)								
0-5	5.1	77	.31	2.9	3.3	2.6	13.7	763	26.4
5-10	3.6	87	.26	2.3	2.1	2.0	11.5	662	19.6
10-15	3.3	40	.23	2.1	2.7	1.9	11.7	582	20.0
15-20	5.5	57	.42	3.9	5.5	3.7	12.2	877	36.5
20-25	5.0	52	.43	4.6	6.2	4.1	10.6	944	36.0
25-30	4.0	48	.43	3.5	4.7	3.4	10.3	557	24.1
30-35	3.4	39	.38	3.6	4.0	2.9	9.5	690	24.1
35-40	3.6	28	.34	3.3	2.9	2.4	9.3	610	23.3
40-45									
45-50	3.1	21	.32	3.0	2.1	1.8	8.8	698	24.8
50-55	3.4	20	.28	2.5	1.7	1.6	10.3	478	19.5
55-60	2.6	19	.28	2.5	1.7	1.5	9.5	663	22.7
60-65	2.7	16	.22	1.8	1.3	1.2	10.6	383	13.7
65-70	2.7	17	.24	2.1	1.6	1.2	9.0	444	15.7
70-75	3.3	18	.28	2.6	1.7	1.6	10.1	603	23.6
75-80	3.1	18	.26	2.4	1.6	1.4	9.7	473	22.6
80-85	3.4	19	.26	2.3	1.7	1.3	12.2	453	17.2
85-90	4.0	19	.31	2.9	1.8	1.7	10.5	655	26.6
90-95	3.3	18	.27	2.4	1.8	1.5	10.0	534	20.0
95-100	4.2	18	.29	2.2	1.6	1.3	12.2	534	19.6
100-105	3.2	35	.28	2.6	1.9	1.4	10.8	402	17.2
105-110	2.3	15	.24	2.1	1.5	1.2	8.6	370	17.6
110-115	2.9	18	.26	2.4	1.6	1.3	9.0	426	22.3
115-120	2.6	14	.19	1.7	1.3	.9	9.4	243	13.0
120-125	2.9	16	.24	2.2	1.5	1.3	8.6	378	22.1
125-130	3.0	23	.23	2.3	1.4	1.2	9.4	320	19.5

Appendix 5. (Continued). Site 5

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	- (mg/kg) -													
0-5	226	300	169	17	2568	2.6	0.2	3.3	1.9	6049	63	1.6	7.4	9.2
5-10	167	258	166	15	2546	2.4	0.2	3.6	1.5	6121	42	1.4	6.0	6.9
10-15	189	295	172	18	2887	2.9	0.3	5.6	1.8	8181	49	1.9	5.4	7.6
15-20	173	451	172	20	4803	3.0	0.2	5.3	1.9	8816	44	2.9	4.9	8.6
20-25	262	650	189	54	5828	3.7	0.2	5.2	2.5	8869	49	4.7	5.3	8.3
25-30	352	850	206	87	6852	4.4	0.2	5.2	3.2	8922	54	6.6	5.7	8.0
30-35	568	516	165	25	4461	2.9	0.3	3.1	2.1	5377	37	3.7	3.5	5.1
35-40	165	404	101	21	3048	2.4	0.1	2.1	2.0	4237	33	2.8	2.9	3.4
40-45	284	520	142	36	3296	2.7	0.3	3.4	2.2	7255	55	3.6	3.7	5.2
45-50	289	443	116	30	2525	2.5	0.2	2.8	2.0	6262	49	2.9	3.1	4.6
50-55	357	418	125	43	2384	2.8	0.1	3.7	2.2	7351	52	2.8	3.7	4.3
55-60	324	421	116	39	2009	2.6	0.1	3.1	2.3	6646	48	2.4	3.3	4.2
60-65	291	425	107	35	1634	2.5	0.1	2.6	2.5	5941	45	2.0	3.0	4.2
65-70	296	471	92	32	1484	2.2	0.2	1.9	2.0	3897	35	1.6	2.4	3.3
70-75	178	308	78	25	1333	2.1	0.2	2.1	1.9	3954	36	1.4	2.0	3.3
75-80	360	603	133	45	1989	2.9	0.2	2.3	2.7	4702	43	1.9	2.9	4.1
80-85	198	354	90	22	1511	1.9	0.2	2.1	2.8	4507	39	1.6	2.3	3.3
85-90	195	346	100	24	1400	2.0	0.2	1.5	2.1	3649	33	1.4	2.2	2.7
90-95	258	369	93	28	1519	1.8	0.2	1.8	2.0	3859	32	1.5	2.0	2.6
95-100	289	465	118	33	1905	2.0	0.2	2.0	2.5	4326	37	1.8	2.6	3.6
100-105	430	514	120	57	1963	2.4	0.1	2.4	2.7	5122	41	2.2	3.1	4.0
105-110	362	508	134	29	1763	2.4	0.1	3.0	2.3	4340	38	2.0	2.6	4.1
110-115	467	643	124	80	2208	2.0	0.1	2.0	3.4	4194	37	2.3	2.8	5.2
115-120	303	511	136	32	2147	2.7	0.1	2.8	2.6	4582	36	1.9	2.8	3.7
120-125	320	529	147	33	2163	2.5	0.1	2.4	2.7	4604	38	1.9	3.1	3.7
125-130	406	592	133	39	2180	2.4	0.1	2.4	3.0	4886	39	2.0	3.1	4.1
130-135	339	506	117	31	1785	2.2	0.1	1.8	2.3	4137	35	1.9	2.5	4.0

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	- - - - - - - - - - - - - (mg/kg) - - - - - - - - - - - - -								
0-5	4.0	29	.21	1.8	1.7	1.6	12.6	487	23.4
5-10	2.3	25	.12	.9	.9	.9	10.5	244	9.5
10-15	3.2	32	.18	1.7	1.3	1.3	11.9	358	22.4
15-20	4.2	37	.24	2.2	3.5	2.3	15.4	510	29.6
20-25	3.3	25	.21	2.4	4.2	2.4	12.1	365	18.9
25-30	4.8	29	.31	3.5	4.1	2.8	19.2	483	29.1
30-35	2.7	19	.26	3.4	3.1	2.2	10.6	312	16.4
35-40	3.8	17	.22	2.6	1.9	1.6	14.2	312	15.1
40-45	2.8	13	.20	2.4	1.3	1.3	10.7	310	18.5
45-50	2.6	14	.18	2.2	1.3	1.2	13.2	246	12.1
50-55	3.3	15	.23	2.5	1.2	1.3	12.2	516	25.2
55-60	2.8	16	.30	3.5	1.5	1.5	13.6	494	34.0
60-65	5.0	23	.21	2.1	1.0	1.0	20.4	392	21.9
65-70	2.6	15	.18	1.7	1.0	.9	13.7	318	14.8
70-75	3.2	15	.18	1.8	1.1	.9	11.6	319	13.8
75-80	3.2	14	.22	2.7	.8	1.0	12.4	328	19.5
80-85	3.0	14	.18	1.7	1.2	.9	14.8	249	11.1
85-90	3.4	12	.16	1.6	.8	.9	14.4	228	11.8
90-95	3.1	16	.19	1.9	1.1	1.1	13.4	383	15.9
95-100	3.5	19	.21	2.2	1.2	1.2	15.1	415	15.6
100-105	2.6	15	.17	1.6	1.0	.9	12.9	314	12.9
105-110	1.9	14	.17	1.7	.8	.8	14.4	256	14.7
110-115	2.5	23	.20	2.2	2.7	1.3	12.5	420	15.8
115-120	2.8	20	.22	2.6	1.6	1.3	15.1	470	17.0
120-125	2.3	22	.22	2.3	1.6	1.3	15.3	361	11.0
125-130	2.9	20	.23	2.3	1.6	1.9	13.1	468	16.4
130-135	3.0	17	.18	1.7	1.3	1.0	14.3	333	13.0

Appendix 5. (Continued). Site 6

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	- -						(mg/kg)	- -						
0-5	412	572	239	25	4515	3.6	0.2	3.5	2.9	6995	109	2.6	9.6	17.3
5-10	254	464	193	21	3956	3.5	<.1	3.8	1.9	6367	76	2.2	4.5	12.6
10-15	271	449	176	20	3865	3.0	<.1	3.8	1.9	6049	100	2.3	4.7	11.2
15-20	294	761	251	31	7348	4.6	0.2	4.9	3.0	9564	101	4.5	6.9	18.4
20-25	196	557	190	23	5243	3.2	0.1	4.4	2.3	6827	75	3.2	4.9	12.1
25-30	411	851	206	26	6060	3.1	0.2	3.2	3.6	7463	68	4.9	5.3	11.8
30-35	353	733	212	24	5977	3.5	0.2	3.3	3.3	7436	50	4.3	4.8	11.1
35-40	224	667	180	23	5054	2.8	0.1	3.5	3.0	6967	47	3.7	4.3	10.0
40-45	208	605	171	22	4188	2.8	0.1	2.9	2.7	5783	42	3.1	3.5	8.9
45-50	213	618	174	22	3793	3.1	0.1	3.4	2.9	6721	45	3.1	3.7	7.3
50-55	301	661	163	22	3585	3.1	0.1	4.3	3.0	6472	45	3.1	3.8	8.2
55-60	238	524	128	19	2670	2.4	0.1	3.0	2.5	4914	36	2.3	2.8	3.9
60-65	300	601	176	23	2865	2.7	<.1	3.5	3.2	5941	45	2.8	4.3	6.6
65-70	223	531	176	21	2556	2.6	<.1	2.9	3.1	4849	38	2.5	3.5	5.2
70-75	198	507	178	21	2508	2.5	<.1	2.7	3.2	5280	40	2.3	3.6	4.8
75-80	176	501	173	22	2337	2.4	<.1	2.0	3.2	4363	36	2.1	3.3	3.9
80-85	242	481	171	28	2103	2.4	<.1	2.5	3.1	4675	43	2.1	3.3	4.8
85-90	206	400	161	24	1949	2.5	<.1	1.8	2.4	3419	39	1.6	3.4	4.2
90-95	275	525	175	30	1886	3.2	<.1	2.7	3.5	4307	49	1.9	3.5	4.1
95-100	248	462	191	33	1739	2.5	0.1	1.5	2.7	3432	38	1.6	3.2	3.6
100-105	276	400	156	27	1528	2.4	0.1	1.8	2.4	3337	35	1.3	2.8	3.2
105-110	199	415	156	23	1609	2.4	0.1	1.2	2.7	3394	37	1.4	2.7	3.4
110-115	208	385	137	22	1469	2.1	0.1	1.2	2.5	3064	33	1.3	2.5	3.0
115-120	217	452	144	34	1593	2.4	0.1	1.5	2.5	3407	37	1.6	3.2	3.7
120-125	268	465	186	33	1761	2.8	<.1	1.9	2.8	3721	41	1.6	3.3	3.4

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	- - - - - - - - - - - - -				(mg/kg)	- - - - - - - - - - - -			
0-5	3.8	50	.22	2.0	3.1	2.0	12.4	395	18.8
5-10	3.2	43	.21	2.0	2.8	1.9	11.0	346	19.3
10-15	2.4	43	.19	1.9	2.8	1.8	10.4	281	17.4
15-20	3.4	75	.27	2.7	5.0	2.9	12.7	459	22.0
20-25	2.9	43	.25	2.5	4.0	2.4	11.3	423	21.4
25-30	3.3	44	.33	3.1	4.4	2.9	12.2	505	23.9
30-35	3.4	39	.33	2.7	3.4	2.5	12.6	437	20.2
35-40	3.5	41	.32	2.7	3.1	2.3	12.4	444	20.5
40-45	3.1	32	.30	2.6	2.6	2.0	11.9	363	19.8
45-50	6.2	34	.27	2.2	2.1	1.6	31.9	258	14.7
50-55	2.9	32	.31	3.1	2.6	2.0	9.2	293	19.6
55-60	3.0	25	.27	2.8	2.1	1.6	11.9	429	21.1
60-65	2.9	29	.25	2.5	1.8	1.4	13.7	384	17.9
65-70	3.1	22	.24	2.4	1.6	1.3	12.9	396	20.0
70-75	3.1	22	.23	2.1	1.5	1.2	13.4	316	17.1
75-80	2.9	20	.22	2.0	1.4	1.2	11.7	274	16.0
80-85	3.1	19	.22	2.1	1.7	1.3	13.0	203	14.7
85-90	2.4	17	.18	1.5	1.4	1.0	10.0	141	9.8
90-95	1.8	15	.14	1.2	.9	.7	8.1	98	6.7
95-100	2.5	15	.17	1.5	1.2	.9	10.2	222	10.6
100-105	2.9	14	.18	1.5	1.0	.8	11.2	249	12.3
105-110	3.2	17	.20	1.6	1.2	1.0	13.4	259	12.5
110-115	2.4	17	.17	1.4	1.1	.8	11.2	210	10.4
115-120	2.6	15	.18	1.5	1.2	.9	12.0	205	11.0
120-125	2.3	14	.16	1.3	1.0	.8	11.4	163	8.7

Appendix 5. (Continued). Site 7

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)	(mg/kg)													
0-5	3524	3900	622	53	6031	6.1	0.7	8.6	7.7	5628	972	3.9	23.5	50.2
5-10	1084	6470	416	48	5468	4.3	0.2	6.5	3.5	5402	158	2.6	7.3	14.1
10-15	1066	1275	549	65	11999	5.9	0.3	9.4	4.0	11959	125	5.4	13.2	22.7
15-20	1178	1559	552	73	16024	6.3	0.4	9.7	5.0	12789	110	9.1	14.3	25.3
20-25	1275	1687	518	75	15354	6.2	0.2	8.7	5.6	11880	87	10.3	13.2	25.5
25-30	1223	1596	466	68	12619	5.5	0.2	7.7	5.9	9975	76	9.4	11.4	20.6
30-35	1161	1575	429	64	10694	5.6	0.3	9.8	5.8	8920	72	8.3	10.5	16.9
35-40	1297	1554	407	62	9159	4.8	0.3	7.5	6.0	8216	78	7.5	9.9	13.7
40-45	1127	1383	343	53	7025	5.3	0.3	8.2	5.3	6846	69	6.4	8.6	10.5
45-50	1361	1482	381	64	7059	6.0	0.3	8.6	5.6	7506	75	6.8	8.9	11.0
50-55	1280	1361	337	58	5869	4.6	0.3	7.5	5.0	7182	73	6.0	8.5	9.4
55-60	1238	1300	284	54	5438	4.5	0.3	6.7	5.1	7077	74	5.7	7.9	8.6
60-65	1226	1389	310	51	5173	4.1	0.4	5.5	5.3	7418	71	5.7	8.1	8.8
65-70	1478	1526	358	65	6067	4.4	0.3	6.4	6.5	8304	84	6.2	8.7	9.8
70-75	1475	1713	396	67	5990	5.3	0.1	6.6	6.8	8416	85	6.6	9.2	10.7
75-80	1586	1655	360	69	5802	5.0	0.2	5.9	7.4	8429	87	6.6	7.7	10.4
80-85	1401	1649	353	70	5471	8.2	0.2	7.0	7.9	7683	86	6.9	7.4	10.2
85-90	1466	1634	353	75	5310	5.4	0.3	6.4	8.3	7963	93	7.1	7.4	10.2
90-95	1370	1577	346	71	5106	5.0	0.2	5.6	7.9	7503	87	6.8	6.9	10.6
95-100	1416	1774	362	64	5757	5.0	0.3	6.1	9.4	8984	74	7.8	7.8	10.7
100-105	1473	1881	371	71	5962	5.5	0.4	6.2	10.3	9321	77	8.3	9.2	11.6
105-110	1245	1466	317	62	4727	4.7	0.2	3.9	9.2	7025	65	6.8	6.3	8.4
110-115	1386	1703	344	63	5163	5.1	0.2	5.2	9.3	8144	75	7.4	7.7	10.9
115-120	1319	1636	332	65	5079	4.4	0.1	4.6	8.8	7504	76	7.2	7.0	10.1
120-125	1210	1353	291	61	4115	5.1	<.1	5.0	7.4	6189	66	5.8	5.9	8.9
125-130	1432	1593	336	68	4961	4.6	0.1	5.4	9.7	7503	81	7.3	7.1	9.4
130-135	1396	1412	318	65	4354	4.5	0.2	5.2	7.5	7456	76	6.2	6.4	8.8
135-140	1636	1681	368	76	5573	4.8	0.1	5.2	9.5	8093	92	7.9	7.3	10.1
140-145	1718	1597	358	72	5103	4.7	<.1	6.1	9.0	8312	90	7.5	7.3	10.2
145-150	1809	1682	381	80	5522	5.0	0.1	7.1	9.6	9269	102	7.7	8.0	10.6

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)	(mg/kg)								
0-5	3.0	259	.21	2.3	2.2	2.4	25.8	670	18.7
5-10	2.5	140	.21	1.8	2.8	2.4	16.7	801	20.8
10-15	4.3	95	.55	5.4	10.9	5.9	16.7	1146	37.2
15-20									
20-25	4.7	82	.55	5.2	8.8	5.3	16.0	1115	34.7
25-30	3.3	72	.47	5.0	6.7	4.5	14.8	1074	32.8
30-35	3.4	68	.46	5.0	5.8	4.1	16.3	1192	34.0
35-40	3.0	58	.41	4.8	5.0	3.5	14.8	1097	32.7
40-45	2.7	39	.32	3.8	3.9	2.7	12.4	934	27.2
45-50	2.7	34	.31	3.6	3.6	2.5	11.8	945	27.1
50-55	2.7	33	.33	4.0	3.6	2.5	13.6	1190	33.6
55-60	3.7	34	.37	4.3	3.9	2.7	14.8	1201	38.1
60-65	2.9	32	.38	4.5	4.5	2.3	13.7	1154	37.6
65-70	2.6	35	.33	4.7	3.9	2.5	14.1	1060	32.6
70-75	2.7	34	.34	4.3	3.8	2.4	14.1	1105	35.2
75-80	3.2	30	.36	4.9	4.0	2.6	15.2	1082	39.1
80-85	2.5	28	.34	5.3	4.2	2.4	13.4	699	23.4
85-90	2.6	23	.31	5.0	3.8	2.1	12.0	597	19.6
90-95	3.3	26	.37	5.5	4.2	2.4	13.7	845	31.0
95-100	3.4	29	.34	4.6	4.3	2.3	12.7	895	31.5
100-105	3.1	28	.34	4.7	4.2	2.4	13.5	903	31.4
105-110	2.8	24	.31	4.6	3.8	2.0	11.5	754	26.9
110-115	3.1	29	.37	5.0	4.2	2.4	13.9	931	32.8
115-120									
120-125	2.1	26	.30	4.4	3.6	1.9	12.4	679	20.5
125-130	2.4	25	.31	5.0	3.9	2.0	12.9	681	23.1
130-135	2.5	25	.30	4.2	3.4	2.0	12.5	826	28.0
135-140	2.9	32	.36	5.0	4.2	2.4	15.1	989	32.3
140-145	3.1	29	.35	4.9	4.2	2.3	14.8	1007	33.2
145-150	3.1	36	.39	5.1	4.1	2.5	15.7	1137	36.4

Appendix 5. (Continued). Site 8

Depth	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
(cm)							(mg/kg)							
0-5	460	405	234	29	3210	4.4	0.2	4.8	4.2	6239	315	1.9	8.0	12.9
5-10	393	456	243	27	3032	4.9	<.1	4.1	2.5	6883	86	1.8	5.0	7.7
10-15	649	832	250	27	4839	4.8	0.1	5.0	4.3	7804	95	3.2	5.9	7.9
15-20	602	842	216	23	4872	4.3	0.2	3.5	4.8	6251	96	3.6	4.8	6.7
20-25	503	783	202	25	4002	4.2	0.1	3.0	4.3	5308	75	3.5	4.0	6.4
25-30	508	755	182	22	3508	4.1	0.1	2.9	4.2	5019	67	3.5	3.6	5.8
30-35	618	864	214	28	3973	4.7	0.1	3.5	5.0	5674	78	4.2	4.0	7.1
35-40	476	934	176	20	3210	4.6	0.1	2.5	4.9	4510	57	3.3	3.7	5.5
40-45	470	812	171	21	2852	4.1	0.1	2.7	4.2	4018	48	3.2	2.8	4.7
45-50	529	809	189	23	2858	4.4	0.2	3.2	4.0	4863	53	3.1	3.8	5.2
50-55	482	755	183	20	2654	4.2	0.4	2.5	4.0	4328	50	2.8	3.5	5.0
55-60	436	700	177	18	2449	4.1	0.7	1.9	4.0	3792	48	2.6	3.3	4.8
60-65	515	807	190	22	2746	4.4	0.1	2.4	4.4	4561	53	3.1	3.6	5.0
65-70	611	813	188	24	2823	4.3	0.1	2.8	4.4	4500	61	3.0	3.7	4.9
70-75	582	848	188	23	2827	4.0	0.1	4.0	4.4	4459	69	3.0	3.5	5.1
75-80	576	800	195	27	2700	4.4	0.1	2.6	4.1	4316	53	2.9	3.8	5.3
80-85	629	901	217	24	2876	4.5	0.2	3.0	4.6	4939	60	3.3	4.0	5.1
85-90	586	887	208	26	2746	4.8	0.2	2.9	4.6	4253	57	3.1	3.9	5.6
90-95	637	870	198	27	2456	4.5	0.2	2.8	4.7	4458	58	3.0	4.1	5.4
95-100	687	854	188	28	2468	4.2	0.2	2.7	4.8	4663	59	3.0	4.3	5.3
100-105	632	699	165	23	2149	3.5	0.1	1.8	4.0	3693	52	2.6	3.6	4.7
105-110	758	882	194	37	2566	4.2	0.2	2.6	4.8	5273	66	3.3	5.2	5.9
110-115	800	996	212	37	2736	4.3	0.2	3.3	4.9	5129	69	3.3	5.2	5.8
115-120	808	818	206	60	2781	4.7	0.2	2.6	5.1	5681	66	3.5	4.9	5.6
120-125	728	936	221	36	3058	4.8	0.2	3.1	4.9	5195	66	3.6	5.3	5.6
125-130	726	907	194	35	2773	4.5	<.1	2.5	4.9	4505	59	3.3	4.6	5.5
130-135	705	853	195	34	2706	4.4	<.1	2.8	4.9	5129	61	3.3	4.8	5.6
135-140	684	801	196	33	2638	4.3	0.1	3.2	5.0	5753	63	3.3	4.9	5.6
140-145	669	846	202	32	2667	4.1	0.1	2.3	5.0	4930	60	3.3	4.9	5.2

Depth	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
(cm)					(mg/kg)				
0-5	3.9	44	.18	1.7	1.2	1.6	10.0	667	19.0
5-10	2.6	50	.18	1.6	1.3	1.4	9.8	570	16.9
10-15	2.6	24	.23	2.8	2.7	2.2	8.1	640	23.2
15-20	3.2	25	.31	4.4	3.4	2.8	10.0	848	30.2
20-25	2.3	17	.24	3.3	2.6	1.8	7.9	506	17.6
25-30	2.1	19	.25	3.4	2.7	1.8	8.3	462	14.2
30-35	2.3	19	.27	3.8	3.0	2.7	8.2	603	21.0
35-40	2.0	19	.25	3.1	2.7	1.7	7.2	451	16.6
40-45	2.2	21	.26	3.0	2.5	1.7	8.9	471	20.9
45-50	2.2	18	.24	2.6	2.4	1.5	8.0	285	9.3
50-55	1.6	18	.23	2.6	2.0	1.4	7.5	434	16.9
55-60	3.4	20	.27	3.0	2.2	1.6	9.0	657	23.7
60-65	1.8	19	.23	2.6	1.9	1.3	7.3	536	17.8
65-70	1.6	18	.23	2.5	2.1	1.3	7.0	439	13.9
70-75	2.0	19	.25	2.6	1.9	1.4	7.2	471	12.2
75-80	2.2	25	.24	2.3	1.8	1.2	7.3	432	12.5
80-85	1.6	20	.24	2.8	1.9	1.3	7.8	352	8.2
85-90	1.7	19	.21	2.2	1.9	1.1	7.1	236	6.9
90-95	1.7	18	.23	2.4	1.6	1.1	7.6	362	10.3
95-100	2.3	19	.26	2.7	1.8	1.3	8.8	664	23.5
100-105	2.6	22	.30	3.4	2.0	1.6	9.7	835	30.4
105-110	2.0	31	.24	2.4	1.8	1.2	9.3	518	18.0
110-115	2.2	21	.25	2.7	1.7	1.2	8.9	595	18.0
115-120	2.4	26	.29	3.1	1.8	1.3	9.5	772	26.9
120-125	1.2	19	.26	2.9	1.8	1.3	9.2	492	16.2
125-130	1.3	21	.27	3.2	1.8	1.3	9.8	440	16.8
130-135	1.5	23	.25	2.7	1.6	1.2	9.4	546	15.7
135-140	2.5	22	.31	3.4	1.8	1.5	9.3	873	32.8
140-145	2.2	19	.26	2.7	1.7	1.3	8.0	654	22.5

Appendix 5. (Continued). Site 9

Depth (cm)	Ca	Mg	K	Na	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
	(mg/kg)													
0-5	237	448	185	21	3334	3.4	0.3	2.9	3.6	4346	39	1.6	9.3	9.4
5-10	169	609	205	22	5770	3.6	0.1	3.4	2.4	5986	45	2.3	5.6	8.7
10-15	127	561	192	20	6104	3.5	0.2	3.7	2.6	5364	40	2.7	4.8	7.8
15-20	149	669	205	20	6042	3.8	0.3	3.4	2.9	5249	40	3.3	5.0	7.8
20-25	122	648	172	15	4582	3.7	0.1	2.8	2.4	4605	37	3.0	4.2	6.0
25-30	132	658	178	15	3789	4.2	<.1	2.7	2.3	4182	39	2.7	4.1	5.2
30-35	141	668	184	16	2992	4.6	<.1	2.5	2.2	3760	42	2.4	4.0	4.5
35-40	172	721	185	15	2879	4.3	0.1	2.8	2.2	4052	60	2.5	3.9	5.6
40-45	302	710	179	17	2786	3.8	<.1	2.7	2.7	4637	60	2.3	4.0	5.0
45-50	500	914	232	25	3193	4.5	0.1	5.2	3.1	7053	81	3.0	5.7	6.7
50-55	160	620	175	12	2257	3.8	<.1	1.5	2.0	3585	45	1.6	3.1	4.4
55-60	180	684	241	13	2483	3.7	<.1	1.9	2.2	3622	46	1.6	3.0	4.9
60-65	190	721	231	12	2483	3.9	0.2	2.1	2.0	3584	45	1.7	2.8	5.2
65-70	219	684	218	13	2388	3.6	0.1	2.1	2.0	3548	46	1.8	2.7	4.8
70-75	248	648	205	14	2294	3.3	<.1	2.2	2.0	3511	47	1.9	2.7	4.3
75-80	192	640	222	12	2394	3.8	<.1	1.7	2.1	2971	38	1.6	2.6	5.3
80-85	160	602	208	12	2434	3.1	<.1	1.9	1.6	3410	35	1.5	2.7	4.3
85-90	166	613	197	12	2459	3.0	<.1	1.9	1.7	3254	34	1.6	2.7	4.4
90-95	122	545	176	9	2093	2.7	<.1	1.4	1.4	2658	29	1.3	1.9	3.8
95-100	184	621	188	10	1998	2.1	<.1	1.5	1.6	2845	30	1.4	2.6	3.5
100-105	244	680	230	15	2434	3.1	0.2	2.3	2.1	4092	44	1.9	3.5	5.0
105-110	244	669	224	15	2290	3.1	0.2	2.4	2.1	3694	42	1.8	3.2	4.4
110-115	245	658	218	16	2147	3.1	0.2	2.6	2.0	3296	40	1.7	3.0	3.9
115-120	243	667	228	14	2376	3.6	0.1	2.5	2.1	3846	44	1.7	3.4	4.4
120-125	176	567	196	13	2255	2.6	0.3	2.2	1.6	3925	39	1.5	3.0	4.2
125-130	147	558	196	12	2250	2.2	0.2	2.8	1.5	3584	34	1.4	2.8	3.9
130-135	191	581	213	13	2263	2.9	<.1	2.2	1.9	4267	40	1.5	3.1	4.5
135-140	138	505	176	9	1884	2.1	0.1	1.5	1.3	2612	24	1.2	2.2	3.6
140-145	135	525	155	11	1872	2.7	<.1	1.8	1.6	2759	26	1.3	2.0	4.7
145-150	234	576	193	15	2037	2.6	<.1	4.1	2.2	3972	41	1.7	2.9	5.3

Depth (cm)	As	Ba	Be	Co	Li	Mo	Sr	Ti	V
	(mg/kg)								
0-5	2.6	35	.16	1.1	1.8	1.4	4.7	453	11.8
5-10	2.1	27	.24	2.2	4.9	2.2	5.9	787	18.0
10-15	2.7	29	.31	3.0	5.3	2.9	7.4	1107	26.2
15-20	1.4	27	.28	3.0	5.0	2.6	5.8	437	10.3
20-25	1.7	24	.26	2.6	4.1	2.1	5.1	595	12.8
25-30	1.2	19	.23	2.3	3.1	1.6	4.9	329	6.1
30-35	2.3	17	.27	2.5	2.9	1.6	5.0	749	19.2
35-40	2.3	17	.30	2.7	2.7	1.6	4.8	927	25.2
40-45	1.7	17	.26	2.5	2.5	1.3	4.8	719	17.3
45-50	1.4	18	.26	2.5	2.6	1.3	4.9	567	15.6
50-55	1.4	15	.20	1.4	2.2	.9	3.8	360	8.8
55-60	1.2	17	.24	1.8	2.4	1.1	4.0	539	12.7
60-65	1.2	16	.24	2.2	2.5	1.2	4.9	409	10.9
65-70	1.7	24	.28	3.6	2.5	1.6	8.1	449	15.9
70-75	1.8	13	.23	1.8	2.3	1.1	3.6	626	15.9
75-80	1.6	14	.21	1.6	2.5	1.1	4.1	473	11.0
80-85	1.5	15	.22	1.8	2.4	1.1	4.4	502	10.0
85-90	1.2	15	.20	1.5	2.3	.9	3.5	301	5.4
90-95	1.8	25	.34	2.8	4.0	1.7	7.7	447	9.4
95-100	1.2	21	.25	2.2	2.6	1.2	6.1	362	11.1
100-105	1.3	17	.24	2.1	2.5	1.1	4.9	463	10.7
105-110	1.3	14	.21	1.7	2.2	.9	3.8	517	12.3
110-115	1.9	14	.20	1.4	2.1	.9	3.9	397	11.1
115-120	1.7	15	.22	1.7	2.3	1.0	4.0	538	12.3
120-125	1.4	14	.23	1.7	2.2	1.0	4.0	592	14.0
125-130	1.4	15	.21	1.5	2.1	1.0	4.6	451	10.9
130-135	1.2	14	.20	1.6	2.1	.9	3.4	405	9.6
135-140	1.2	13	.20	1.6	2.0	.9	4.6	393	7.9
140-145	1.2	12	.18	1.3	1.8	.8	4.4	238	5.6
145-150	1.2	11	.16	1.2	2.0	.7	3.4	243	7.2

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Harris, Alfred Ray; Stone, Douglas M.
1990. **Using column lysimetery to evaluate acid precipitation effects.** Res. Pap. NC-291. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 38 p.

Describes methodology for collecting, instrumenting, and measuring acid soils using soil columns as lysimeters and reports the effects of varying acid precipitation and litter-humus treatments.

KEY WORDS: Sensitive soils, pH depression, sulfate loading, negative alkalinity.