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Physical Characteristics of Study Plots

Across a Lake States Acidic Deposition Gradient

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Some people in the United States are concerned that atmospheric pollutants may be affecting the health of the Nation's forests (Barnard 1986). In response to that concern, we began research on the relations between forest conditions and atmospheric deposition across the Great Lakes region in 1985. Because widespread forest damage or decline is not visibly evident in this region, the research was aimed at detecting subtle regional trends related to acidic deposition in general and sulfate deposition in particular. The research consisted of a series of studies to describe: (1) the relations between sulfate (SO_4) deposition in precipitation and soil and tree woody tissue chemistry; and (2) the interaction among wet deposition, soil, tree woody tissue chemistry, climate, and tree and plot growth (Ohmann *et al.*1987, 1988; Holdaway 1988).

The hypotheses of these studies are that the wet sulfate deposition gradient across the Lake States (Nichols and Verry 1985): (1) is reflected in the amount of accumulated sulfur in the forest floor-soil system and tree woody tissue and (2) is related to differences in tree radial increment. We also hypothesized that these relations can be distinguished from those related to site and climatic variation across the region.

A knowledge of the physical character of the study plots across the sulfate deposition gradient is necessary to understand and interpret relations between sulfate deposition, sulfur accumulation, soil and tree chemistry, and tree growth and climatic variation. This report details the physical characteristics of the 171 study plots included in the Lake States acidic deposition research project. It is also a record for those who seek alternative interpretations of how site characteristics influence tree growth as represented by plot remeasurement data.

METHODS

To obtain a representative sample for extrapolating results, we screened previously measured Forest Inventory and Analysis (FIA) Lake States plots. From these plots we identified a population of forest type plots with a limited range of initial densities, ages, and site indices (table 1). The forest types we selected for study were jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), balsam fir (*Abies balsamea*), sugar maple (*Acer saccharum*), and aspen (*Populus tremuloides*), because we expectated that these forest types would not only occur in adequate numbers across the region (for sampling purposes), but would also provide representation of intolerant and tolerant conifer and hardwood forest types.

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Field

Plot Remeasurement

Field crews collected data and samples from 171 of the 438 plots that met the sampling criteria. All plots were sought, but some could not be relocated, had been disturbed, were converted to nonforest, or did not meet field-based criteria for sampling. FIA plot design is a 10-point cluster with sample (tally) trees at each point selected with a probability proportional to the squared diameter at breast height (1.4 m above ground level) using a 37.5 basal area factor prism. Species, d.b.h., crown cover, crown class, and merchantable height were recorded for each tally tree using FIA protocols for remeasuring plots (Doman *et al.* 1981). Site index, aspect, slope position, and percent slope were determined at the time the plots were established and measured in accordance with FIA protocols.

Tree Cores

At every second point of the 10-point plot cluster, core samples were collected from a nontally, dominant or codominant tree to analyze for radial growth increment and chemical concentration in woody tissues. This core tree had a diameter within 2.5 cm of the current plot mean diameter and was representative of the topographic position of the plot.

Forest Floor

Three forest floor samples were located at a distance of 1.5 m from the core tree at 45°, 135°, and 225° directions. At each location, a 12-cm diameter stainless steel ring was forced through the forest floor. Depth of the forest floor was measured at four positions within the ring and recorded. All forest floor material was collected down to the mineral soil, placed in labeled sterile plastic bags, and frozen.

Mineral Soil

At the same locations where forest floor samples were collected, the upper 25 cm of mineral soil were sampled with a bucket auger. Samples uniformly represented the entire 25 cm depth. Each sample was thoroughly mixed, the percent volume of rocks greater than 20 mm in size was estimated and removed, and a subsample of about 500 grams was placed in a labeled sterile plastic bag and frozen. At one of the forest floor sample locations, augering was continued to 1 meter and at each of three core trees and samples were collected from the 26-50 cm, 51-75 cm, and 76-100 cm depths. These deeper samples were composited to yield one sample for each 25 cm depth from each plot. These samples were treated similarly to the surface mineral soil samples.

Laboratory

Soils

All soil samples were kept frozen until processing at the preparation laboratory. Surface mineral soil samples were bulked in groups of three with each group representing one sample tree. Then they were sieved through a 3-mm stainless steel sieve (because of the difficulty of passing moist soils through finer sieves) and analyzed for percent of rock by dry weight. A subsample of soil was ovendried and bulked by sample tree to provide one sample per plot for particle-size analysis. The subsurface samples were treated similarly. Particle-size analysis was conducted by a modified hydrometer method (Grigal 1973). The specific protocol used is on file at the Forestry Sciences Laboratory in Grand Rapids, Minnesota. In general, hydrometer readings, corrected for temperature, were taken at 40 seconds, 2 hours, and 8 hours. Soils then were wet-sieved through a 300-mesh screen and ovendried for 48 hours at 105°C. The sands were weighed to determine their mass in these sandy soils. Percent clay was obtained by the 8 hour reading and percent sand from the sieving. Percent silt was the mean of the 40-second reading minus the 8 hour reading, and the difference obtained by subtracting clay and sand from 100. Six different check samples were run from 4 to 5 times each, and 45 duplicate plot samples were run for quality control on separate days scattered throughout the analysis period. The standard deviation for each set of quality assurance (QA) observations was plotted against its mean to detect outliers and to determine if precision was related to the magnitude of the observation.

Map Information

We collected maps of physiography, bedrock geology, surficial geology, and soils and used them to assign each sample plot to the most probable category for each characteristic. Only limited data were available for some plots. Categories obtained from maps included bedrock composition, glacial parent material, glacial formation, and soil mapping unit. From the latter information, we determined dominant soil series, soil taxonomic subgroup, great group, suborder, and order. Because the level of detail differed for these maps, none of the maps had delineations as small as the sample plot, and the map units contained unmapped inclusions, we cannot be sure that the plot is accurately characterized.

RESULTS AND DISCUSSION

The sulfate deposition gradient was divided into five zones to ensure sample distribution across the gradient and to enhance statistical testing of certain resulting data (fig. 1). A total of 171 plots were remeasured and sampled (table 2). All field work was completed during the 1985 growing season.

Not surprisingly, bedrock, parent material, and soils are not uniformly distributed across the gradient (table 3). This makes the search for relations between sulfate deposition, soil chemistry, and tree growth more complex.

Metamorphic bedrock types dominate plots in zones 1 and 2; sedimentary bedrock types dominate plots in zones 3 and 4 and are exclusively the bedrock type in zone 5 (table 4). Bedrock depths generally are well below tree rooting zones with a few exceptions (table 5). The predominant bedrock composition ranges from slate in zone 1 to siltstone, sandstone, and limestone in zones 2-5 (table 4). Glacial parent material variies greatly in zones 3 and 4 and varies less on either end of the gradient--plots in zone 1 all were mapped as gray calcareous drift (tables 4 and 5). These differences could be reflected in the chemistry of soils, forest floor, and tree woody tissue. The predominant

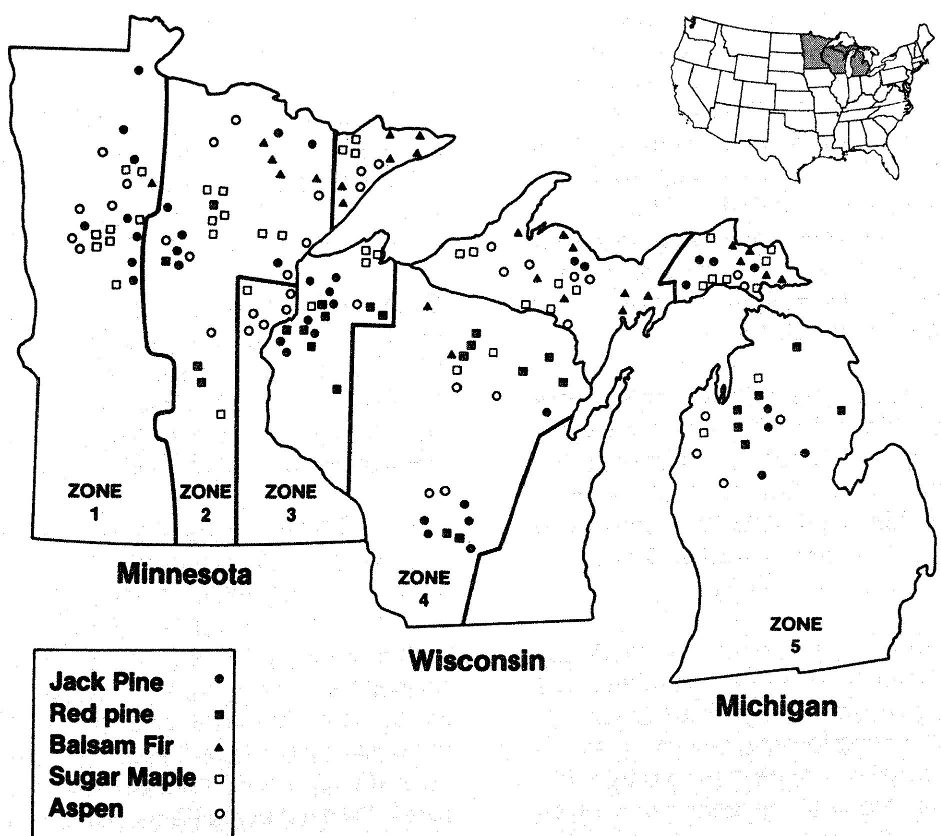

Figure 1.—*Location of plots and deposition zones across the Lake States acidic deposition gradient.*

glacial landform is outwash plain in zones 1-3, ground moraine in zone 4, and glacial lake plain in zone 5 (table 4), but a variety of types are represented in each zone (table 4).

Soil series and taxonomic groups varied greatly across the gradient (table 3), and no single soil series represents a majority of plots in any zone (tables 6 and 7). The predominant taxonomic group is Eutroboralf in zone 1, Udipsamment in zone 3, and Haplorthod in zone 5 (table 6), but groups are widely represented in all zones except zone 1 (table 6). Eutroboralfs are soils with high base saturation that have formed in cool places and have a moisture regime that is not dry for long periods, especially when soil temperatures are high (Soil Science Society of America (SSSA) 1987). High base saturation in this case is probably related to the gray calcareous drift parent material present in zone 1 (table 4). Udipsamments are soils that have formed in cool moist places that have textures of loamy sands and are not saturated with water for long periods of time (SSSA 1987). Haplorthods are soils with a horizon that has an accumulation of aluminum, iron, and organic carbon with a specific extractable iron:organic carbon elemental ratio in relation to its clay content. They also are not saturated with water for long periods of time (SSSA 1987). Eutroboralfs and Udipsamments occur in all zones, whereas Haplorthods are present only on plots in zones 3-5. Wetter groups were mapped for plots in zone 2, zone 4, and zone 5 (table 7).

Limited amounts of rock greater than 20 mm in size are present in the soils of the 171 plots across the gradient, but they generally comprise less than 5 percent of the soil by volume (table 8). Plots in zone 3 and those of the balsam fir forest type have a greater percentage of rock by volume than the other zones or forest types (table 8).

The percent of rock ranging from 2 to 20 mm in plot soils is also low (table 9). No significant differences were found among zones, but significant differences were found among forest types (table 9). Plots of the pine forest types are significantly lower in percent rock than those of the other forest types, and aspen plots have a lower percentage of rock than either balsam fir or sugar maple plots (table 9).

Percent clay and silt of the upper 25 cm mineral soil are significantly lower, and percent sand is significantly higher for sites in zone 5 than in all other zones (table 10). Surface soil clay and silt fractions are significantly lower and sand significantly higher for the jack pine and red pine forest types than for the balsam fir, sugar maple, and aspen forest types (table 10). This was not surprising based on the silvics of jack pine and red pine. The proportion of all three soil fractions also differ with soil suborder (table 10), so an important point is how the suborders are distributed across the gradient (tables 6 and 7).

Surface soil fractions showed some signigicant differences within forest types across the five zones (table 11). For the jack pine type, the plots on the eastern portion of the gradient are sandier (table 11). For the sugar maple type, plots in zone 5 are significantly sandier and have less clay and silt than those of the rest of the gradient (table 11).

Although sample sizes are much smaller, demonstrable differences also were seen in surface soil fractions among forest types within zones (table 12). The differences generally follow those among forest types for all zones (table 9). Balsam fir, sugar maple, and aspen plots are more similar to each other than they are to jack pine and red pine (table 12).

Surface soil fractions were significantly different within soil taxonomic orders among zones (table 13). However, they were difficult to analyze because of low sample numbers in some zones, heterogeneous variance even after log transform, and the unequal distribution of taxa among zones.

Subsoil (26-100 cm depth) clay, silt, and sand fractions do not differ greatly from those of the surface 25 cm (tables 14, 15, and 16). Plots in zone 5 sites have more sand and less clay and silt than those in the other zones (table 14). The relation between forest types (tables 14 and 15) is the same as for the surface soil, and the fractions differ among soil taxa (table 14). Like the surface soils, the subsoils differ more within taxa across the zones than expected (table 16), but again, the sample sizes create problems.

Few significant differences were found among other physical site characteristics across the zones (table 17). Apparently, we had a good distribution of site index and other physical characteristics such as aspect, slope position, and slope gradient for each of the forest types across the gradient (table 17). Any additional stand conditions on each plot are expected to be accounted for by using a growth model.

In summary, plots in zone 5 generally are sandier than the remainder of the plots across the gradient. Soil taxa are not equally distributed across the gradient, and this might affect interpretations of differences in soil and tree wood chemistry.

ACKNOWLEDGMENTS

We thank the field crews who remeasured the Forest Inventory and Analysis plots, sampled forest floor and mineral soils, and cored the trees. We also thank Dave Alban and John Elioff who conducted the particle-size analysis of the mineral soils.

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Table 1.--Population of potential sample plots by zones representing a range of acidic deposition

Forest type	Plots	Gradient zone 1	2	3	4	5	Criteria: Basal area	Age	Site index
	No.						Ft^2/ac	Years	Feet
Jack pine	77	16	16	11	10	24	71-90	34-55	47-67
Balsam fir	93	7	32	18	27	9	82-110	45-65	43-59
Maple-birch	148	10	14	13	68	43	90-109	50-65	50-68
Aspen	82	17	28	9	18	10	80-99	40-49	60-69
Red pine (plantation)	38	0	2	5	11	20	82-109	20-45	56-75
Total	438	50	92	56	134	106			

Table 2.--Location of individual study plots across the Lake States acidic deposition gradient.

FIA plot no.	State	County	Latitude	Longitude
		ZONE 1		
		JACK PINE TYPE		
7325	MINNESOTA	BECKER	46.8350	95.2160
48	MINNESOTA	BELTRAMI	47.5406	95.0197
3721	MINNESOTA	BELTRAMI	47.5756	95.0743
6815	MINNESOTA	HUBBARD	46.9957	94.7755
6872	MINNESOTA	HUBBARD	47.1243	95.1489
5595	MINNESOTA	LAKE OF THE WOODS	48.7387	94.9313
8013	MINNESOTA	WADENA	46.7858	94.9520
8056	MINNESOTA	WADENA	46.6884	94.8569
		BALSAM FIR TYPE		
8806	MINNESOTA	BELTRAMI	47.4125	94.5774
		ASPEN TYPE		
2002	MINNESOTA	BECKER	47.1128	95.6889
2026	MINNESOTA	BECKER	47.0780	95.2129
4068	MINNESOTA	BELTRAMI	48.0213	95.2933
8206	MINNESOTA	CLEARWATER	47.2825	95.3405
8287	MINNESOTA	CLEARWATER	47.6160	95.3333
6062	MINNESOTA	MAHNOMEN	47.1575	95.7044
		SUGAR MAPLE TYPE		
2171	MINNESOTA	BECKER	46.7845	95.8690
7194	MINNESOTA	BECKER	46.9036	95.7835
7275	MINNESOTA	BECKER	46.8131	95.8050
3782	MINNESOTA	BELTRAMI	47.6033	95.0354
3920	MINNESOTA	BELTRAMI	47.6175	94.7166
1879	MINNESOTA	HUBBARD	47.0484	94.8562
738	MINNESOTA	OTTERTAIL	46.6848	95.9531
2175	MINNESOTA	BECKER	46.7312	95.8400

(Continued on next page)

(Table 2 continued)

FIA plot no.	State	County	Latitude	Longitude
		ZONE 2		
		JACK PINE TYPE		
5308	MINNESOTA	CARLTON	46.5584	92.5042
3592	MINNESOTA	CASS	46.3178	94.3248
3018	MINNESOTA	CROW WING	46.3991	94.3008
3076	MINNESOTA	CROW WING	46.3277	94.2471
3103	MINNESOTA	CROW WING	46.5995	94.0705
305	MINNESOTA	ST LOUIS	47.4394	92.3236
3278	MINNESOTA	ST LOUIS	48.0974	92.5702
		RED PINE TYPE		
210	MINNESOTA	BENTON	45.7808	94.1853
9013	MINNESOTA	CASS	47.1052	93.8566
5118	MINNESOTA	ITASCA	47.2872	93.5289
3320	MINNESOTA	SHERBURNE	45.4058	93.7407
		BALSAM FIR TYPE		
2691	MINNESOTA	ST LOUIS	48.1611	92.8386
2942	MINNESOTA	ST LOUIS	47.7802	92.1590
3060	MINNESOTA	ST LOUIS	47.7207	92.8400
3421	MINNESOTA	ST LOUIS	47.4501	92.7479
		ASPEN TYPE		
1420	MINNESOTA	CARLTON	46.5305	92.3219
3616	MINNESOTA	CASS	46.6859	94.3992
3208	MINNESOTA	CROW WING	46.3924	94.0795
4668	MINNESOTA	KOOCHICHING	48.4579	93.2028
4794	MINNESOTA	KOOCHICHING	48.1332	93.4838
1202	MINNESOTA	MILLE LACS	45.7790	93.6492
3942	MINNESOTA	ST LOUIS	46.8555	92.5408
3943	MINNESOTA	ST LOUIS	46.8555	92.5408
		SUGAR MAPLE TYPE		
6163	MINNESOTA	AITKIN	46.8543	93.6952
6168	MINNESOTA	AITKIN	46.8005	93.6683
2745	MINNESOTA	HENNIPEN	45.0001	93.6212
5050	MINNESOTA	ITASCA	47.1334	93.6724
5149	MINNESOTA	ITASCA	47.0534	93.4871
5340	MINNESOTA	ITASCA	47.2522	93.2378
784	MINNESOTA	ST LOUIS	46.7189	92.2280
2594	MINNESOTA	ST LOUIS	47.1061	92.2751

(Continued on next page)

(Table 2 continued)

FIA plot no.	State	County	Latitude	Longitude
		ZONE 3		
		JACK PINE TYPE		
848	WISCONSIN	BURNETT	45.6860	92.6918
980	WISCONSIN	BURNETT	46.0349	92.2246
1257	WISCONSIN	DOUGLAS	46.1941	91.8854
1290	WISCONSIN	DOUGLAS	46.3006	91.7404
1324	WISCONSIN	DOUGLAS	46.3803	91.6346
1338	WISCONSIN	DOUGLAS	46.2185	91.6516
1705	WISCONSIN	POLK	45.5963	92.8333
1820	WISCONSIN	POLK	45.6414	92.8460
		RED PINE TYPE		
507	WISCONSIN	BAYFIELD	46.6198	91.3674
70041	WISCONSIN	BAYFIELD	46.3235	91.4152
863	WISCONSIN	BURNETT	45.9105	92.5229
935	WISCONSIN	BURNETT	46.0971	92.1203
1294	WISCONSIN	DOUGLAS	46.1841	91.7949
441	WISCONSIN	DUNN	44.9766	91.6683
3173	WISCONSIN	WASHBURN	46.0064	92.0313
955	WISCONSIN	BURNETTE	45.8721	92.1238
		BALSAM FIR TYPE		
41	MINNESOTA	COOK	48.0008	90.5729
1516	MINNESOTA	COOK	47.8137	90.6725
2196	MINNESOTA	COOK	47.9344	90.0544
2205	MINNESOTA	COOK	47.8459	90.1129
2062	MINNESOTA	LAKE	47.1379	91.7736
5078	MINNESOTA	LAKE	47.9829	91.7001
		ASPEN TYPE		
614	WISCONSIN	BAYFIELD	46.7735	91.4151
1334	MINNESOTA	LAKE	47.9026	91.7690
2046	MINNESOTA	LAKE	46.9939	91.7769
5499	MINNESOTA	LAKE	47.9658	91.7809
525	MINNESOTA	PINE	45.9312	93.1021
672	MINNESOTA	PINE	46.1159	92.6051
3720	MINNESOTA	PINE	46.0471	92.9417
3888	MINNESOTA	PINE	46.0652	92.7750
4012	MINNESOTA	PINE	46.0217	92.4354

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(Table 2 continued)

FIA plot no.	State	County	Latitude	Longitude
		SUGAR MAPLE TYPE		
656	WISCONSIN	BAYFIELD	46.7694	91.1402
749	WISCONSIN	BAYFIELD	46.8640	90.8876
70047	WISCONSIN	BAYFIELD	46.3225	90.9688
1395	WISCONSIN	DOUGLAS	46.5015	92.0486
1484	MINNESOTA	LAKE	47.4090	91.1841
1490	MINNESOTA	LAKE	47.5325	91.0336
2060	MINNESOTA	LAKE	47.1558	91.7731
617	MINNESOTA	PINE	45.8170	92.8396
		ZONE 4		
		JACK PINE TYPE		
19	WISCONSIN	ADAMS	43.9568	89.9164
39	WISCONSIN	ADAMS	44.0945	89.8107
1111	WISCONSIN	JACKSON	44.3566	90.6284
1216	WISCONSIN	JACKSON	44.2184	90.4838
2152	MICHIGAN	MARQUETTE	46.4782	87.2605
2442	MICHIGAN	MARQUETTE	46.3698	87.4030
80072	WISCONSIN	OCONTO	45.1659	88.3106
3203	WISCONSIN	WOOD	44.3112	89.7834
		RED PINE TYPE		
12	WISCONSIN	ADAMS	44.1379	89.8753
80145	WISCONSIN	FOREST	45.4971	88.4590
1391	WISCONSIN	JUNEAU	44.0771	90.2150
972	WISCONSIN	MARINETTE	45.5544	88.1786
1660	WISCONSIN	ONEIDA	45.6169	89.7704
1661	WISCONSIN	ONEIDA	45.5713	89.7938
1663	WISCONSIN	ONEIDA	45.6358	89.7328
1272	WISCONSIN	MARINETTE	45.3310	88.0081
		BALSAM FIR TYPE		
1468	MICHIGAN	BARAGA	46.5603	88.3698
665	MICHIGAN	DELTA	45.8752	87.2577
745	MICHIGAN	DELTA	46.0373	87.1809
746	MICHIGAN	DELTA	46.0284	87.1421
3139	MICHIGAN	DICKINSON	46.1136	88.0611
1679	WISCONSIN	IRON	46.2477	90.2628
1884	MICHIGAN	IRON	46.0648	88.4092
2204	MICHIGAN	MARQUETTE	46.1721	87.2850
2795	MICHIGAN	MARQUETTE	46.6445	88.0714
1606	WISCONSIN	ONEIDA	45.5674	89.9473

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(Table 2 continued)

FIA plot no.	State	County	Latitude	Longitude
		ASPEN TYPE		
1353	MICHIGAN	BARAGA	46.7654	88.5191
629	WISCONSIN	CLARK	44.4581	90.3352
3091	MICHIGAN	DICKINSON	45.9170	87.8897
483	WISCONSIN	LANGLADE	45.1856	89.3293
585	WISCONSIN	LINCOLN	45.4361	89.7999
2154	MICHIGAN	MARQUETTE	46.4511	87.3124
2391	MICHIGAN	MARQUETTE	46.0809	87.5949
624	MICHIGAN	ONTONAGAN	46.5375	89.2430
792	MICHIGAN	ONTONAGAN	46.8189	89.5562
3122	WISCONSIN	WOOD	44.4827	90.2335
		SUGAR MAPLE TYPE		
1832	MICHIGAN	IRON	46.3527	88.4166
1982	MICHIGAN	IRON	46.4008	88.1447
554	WISCONSIN	LINCOLN	45.2601	90.0048
2215	MICHIGAN	MARQUETTE	46.1092	87.2458
2557	MICHIGAN	MARQUETTE	46.3323	87.7145
52717	WISCONSIN	ONEIDA	45.4750	89.2645
688	MICHIGAN	ONTONAGAN	46.7579	89.0034
725	MICHIGAN	ONTONAGAN	46.8887	89.2314
		ZONE 5		
		JACK PINE TYPE		
346	MICHIGAN	CHIPPEWA	46.3679	84.8288
6047	MICHIGAN	CLARE	44.1289	84.9625
159	MICHIGAN	CRAWFORD	44.6240	84.5041
287	MICHIGAN	CRAWFORD	44.7114	84.3867
2564	MICHIGAN	LUCE	46.6690	85.6927
2797	MICHIGAN	LUCE	46.7272	85.3249
546	MICHIGAN	OGEMAW	44.4470	84.2478
934	MICHIGAN	SCHOOLCRAFT	46.3684	86.3109
		RED PINE TYPE		
80077	MICHIGAN	ALCONA	44.7006	83.6884
3347	MICHIGAN	CHEBOYGAN	45.5279	84.2723
3725	MICHIGAN	GRAND TRAVERSE	44.5702	85.5643
4822	MICHIGAN	KALKASKA	44.6102	85.2104
1923	MICHIGAN	MACKINAC	46.0741	85.0085
2478	MICHIGAN	WEXFORD	44.3161	85.4075
81127	MICHIGAN	WEXFORD	44.2715	85.6566

(Continued on next page)

(Table 2 continued)

FIA plot no.	State	County	Latitude	Longitude
		BALSAM FIR TYPE		
1583	MICHIGAN	CHIPPEWA	46.0781	84.3229
1658	MICHIGAN	CHIPPEWA	46.1081	84.0756
1667	MICHIGAN	CHIPPEWA	46.0342	84.0020
1754	MICHIGAN	MACKINAC	46.1382	85.7053
1989	MICHIGAN	MACKINAC	45.9761	84.1988
		ASPEN TYPE		
3558	MICHIGAN	BENZIE	44.7094	85.9396
262	MICHIGAN	CRAWFORD	44.8031	84.5136
1796	MICHIGAN	MACKINAC	46.1729	85.6009
1952	MICHIGAN	MACKINAC	46.0808	84.4392
1511	MICHIGAN	MASON	43.9272	86.0657
2174	MICHIGAN	NEWAYGO	43.6075	85.6122
		SUGAR MAPLE TYPE		
4504	MICHIGAN	ANTRIM	45.0523	85.2729
1352	MICHIGAN	CHIPPEWA	46.3924	85.2051
1573	MICHIGAN	CHIPPEWA	46.1302	84.2427
2784	MICHIGAN	LUCE	46.3149	85.4414
1863	MICHIGAN	MACKINAC	46.1337	85.3559
1878	MICHIGAN	MACKINAC	46.2217	85.2236
1897	MICHIGAN	MACKINAC	46.1211	85.1233
1295	MICHIGAN	MANISTEE	44.4479	85.8940

Table 3.--Soils and geologic information for the 5 zones across the Lake States acidic deposition gradient (Total number of classes in each category, and the most common class (and the number of plots), are noted)

		Soil			Bedrock geology		Glacial geology	
Zone	No. Plots	Series	Subgroup	Great group	Type	Composition	Surface	Formation
1	23	15 Nebish (7)	6 Typic (14)	3 Eutroboralf (16)	2 M[2] (13)	4 Slate (12)	1 GCD[3] (23)	4 Outwash (11)
2	31	20 Menahga (7)	9 Typic (17)	8 Udipsamment (9)	3 M (14)	10 Siltstone-Argillite(7)	4 GCD (14)	7 Outwash (10)
3	39	17 Omega (12)	6 Typic (20)	8 Udipsamment (16)	2 S (20)	6 Sandstone (20)	8 RBNCD (15)	7 Outwash (14)
4	44	2 5 series (2 each)	7[1] Typic (12)	8[1] Udipsamment (7)	3 S (20)	8[1] Sandstone (15)	10[1] GBD (20)	5[1] Moraine (19)
5	3	4 Rubicon (7)	19 Typic (11) Entic (11)	8[1] Haplorthod (15)	9[1] S (34)	13 Limestone (18)	4[1] BMD (19)	5[1] Sediment (11)

[1]Information not available for all plots in the zone.
[2]Bedrock geology type M=metamorphic, S=sedimentary.
[3]Surface geology type GCD=gray calcareous drift, RBNCD=red-brown noncalcareous drift, GBD=gray-brown drift, and BMD=brown medium-textured drift.

Table 4.--Geologic map information for the study plot locations in 5 zones across the Lake States acidic deposition gradient (number of plots in parentheses)

Type	Bedrock composition	Glacial surface	Glacial landform
		ZONE 1	
Metamorphic (13)	Slate (12)	Gray calcareous drift (23)	Outwash plain (11)
Igneous (10)	Basalt (2)		Glacial lake plain (2)
	Granite (6)		End moraine (6)
	Undifferentiated precambrian rock (3)		Stagnation moraine (4)
		ZONE 2	
Sedimentary (11)	Siltstone-argillite (7)	Gray calcareous drift (14)	Outwash plain (10)
Metamorphic (14)	Graywacke (4)	Brown-gray noncalcareous drift (9)	End moraine (8)
Igneous (6)	Granite (4)	Red-brown noncalcareous drift (7)	Ground moraine (4)
	Gneiss (3)	Red-gray mixed drift (1)	Glacial lake plain (4)
	Shist (3)		Lake modified till (2)
	Sandstone (3)		Ground moraine w/drumlins (2)
	Quartzite (2)		End moraine w/eskers (1)
	Shale (3)		
	Basalt (1)		
	Gabbro (1)		

(Continued on next page)

(Table 4 continued)

Type	Bedrock composition	Glacial surface	Glacial landform
		ZONE 3	
Sedimentary (20)	Sandstone (20)	Red-brown noncalcareous drift (15)	Outwash plain (14)
	Basalt (9)	Brown-gray noncalcareous drift(13)	Ground moraine (9)
Igneous (19)	Diabase-gabbro (7)	Yellow-red coarse drift (2)	Ground moraine w/drumlins (7)
		Red-brown calcareous drift (1)	End moraine(5)
	Tuff-breccia(1)	Gray-brown coarse textured drift(1)	Lake modified till (2)
	Volcanic-undivided (1)	Thin till over bedrock, mixed lithology (1)	Glacial lake sediment (1)
	Gabbro (1)	Yellow-brown coarse drift (1)	River terrace (1)
		Red-gray mixed drift (1)	
		Not determined (4)	
		ZONE 4	
Sedimentary (20)	Sandstone (15)	Gray-brown coarse textured drift (9)	Ground moraine (19)
Metamorphic (14)	Mafic, metavolcanic(7)	Gray-brown medium textured drift (7)	Outwash plain (10)
Igneous (10)	Granite (6)	Thin till over bedrock,mixed lithology (6)	Glacial lake plain (9)
	Gneiss (5)	Brown medium textured drift(4)	End moraine (2)
	Limestone (5)	Gray-brown fine textured drift (4)	Ground moraine w/drumlins(2)
	Slate (3)	Yellow-brown coarse drift (4)	Not determined (2)
	Gabbro (1)	Red-brown noncalcareous drift (3)	
	Diorite-andesite (1)	Driftless area (1)	
		Red-brown calcareous(1)	
		Yellow-red coarse drift(1)	
	Not determined (1)	Not determined (4)	

(Continued on next page)

(Table 4 continued)

Type	Bedrock composition	Glacial surface	Glacial landform
		ZONE 5	
Sedimentary (34)	Limestone (18)	Brown medium textured drift (19)	Glacial lake plain (11)
	Shale (11)	Gray-brown coarse textured drift (11)	Outwash plain (10)
	Sandstone (5)	Thin till over bedrock, mixed lithology (2)	Ground moraine (6)
		Gray-brown fine textured till (1)	End moraine (5)
		Not determined (1)	Ground moraine w/drumlins (1)
			Not determined (1)

Table 5.--Bedrock and glacial geology information for individual study plots across the Lake States acidic deposition gradient.

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
				ZONE 1
				JACK PINE TYPE
7325	M[1]	S[2]	OP[3]	WADENA LOBE GRAY CALCAREOUS DRIFT
48	M	S	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
3721	M	S	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
6815	I	B	OP	WADENA LOBE GRAY CALCAREOUS DRIFT
6872	I	B	OP	WADENA LOBE GRAY CALCAREOUS DRIFT
5595	I	G	LP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
8013	I	G	OP	WADENA LOBE GRAY CALCAREOUS DRIFT
8056	I	G	OP	WADENA LOBE GRAY CALCAREOUS DRIFT
				BALSAM FIR TYPE
8806	M	S	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
				ASPEN TYPE
2002	M	S	EM	ITASCA MORAINE/WADENA LOBE GCD[4]
2026	M	S	EM	ITASCA MORAINE/WADENA LOBE GCD
4068	I	G	LP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
8206	I	G	EM	ITASCA MORAINE/WADENA LOBE GCD
8287	I	G	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
6062	I	PR	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
				SUGAR MAPLE TYPE
2171	M	S	OP	ALEXANDRIA MORAINE/WADENA LOBE GCD
7194	M	S	EM	ITASCA MORAINE/WADENA LOBE GCD
7275	M	S	EM	ITASCA MORAINE/WADENA LOBE GCD
3782	M	S	SM	BIG STONE MORAINE/DES MOINES LOBE GCD
3920	M	S	SM	BIG STONE MORAINE/DES MOINES LOBE GCD
1879	I	PR	EM	ITASCA MORAINE/WADENA LOBE GCD
738	I	PR	SM	ALEXANDRIA MORAINE/WADENA LOBE GCD
2175	M	S	SM	ALEXANDRIA MORAINE/WADENA LOBE GCD

(Continued on next page)

(Table 5 continued)

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
				ZONE 2
				JACK PINE TYPE
5308	S	GW	OP	SUPERIOR LOBE RED-BROWN NONCALC.DRFT.
3592	M	Q	OP	RAINY LOBE BROWN-GRAY NONCALC.DRFT.
3018	M	Q	OP	RAINY LOBE BROWN-GRAY NONCALC.DRFT.
3076	M	SI/ARG	OP	RAINY LOBE BROWN-GRAY NONCALC.DRFT.
3103	M	GN	OP	RAINY LOBE BROWN-GRAY NONCALC.DRFT.
305	M	SI/ARG	LP	DES MOINES LOBE GCD
3278	M	SH	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
				RED PINE TYPE
210	M	GN	OP	SUPERIOR LOBE RED-BRN NONCALC. DRIFT
9013	I	G	EM	SUGAR HILLS MORAINE/DES MOINES LOBE GCD
5118	M	SH	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
3320	S	SST	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
				BALSAM FIR TYPE
2691	I	G	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
2942	I	B	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
3060	S	GW	LMT	ERSKINE MORAINE/DES MOINES LOBE GCD
3421	M	SI/ARG	EM	CULVER MORAINE/DES MOINES LOBE GCD
				ASPEN TYPE
1420	S	SST	LP	SUPERIOR LOBE RED-BRN NONCALC. DRIFT
3616	M	GN	GM/D	ST. CROIX MORAINE/RAINY LOBE BGNCD
3208	M	SI/ARG	OP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
4668	M	SH	LMT	ERSKINE MORAINE/DES MOINES LOBE GCD
4794	I	G	LP	AGASSIZ LACUSTRINE PLAIN GCD
1202	I	G	GM	ST. CROIX MORAINE/SUPERIOR LOBE RBNCD
3942	S	GW	EM	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
3943	S	GW	EM	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
				SUGAR MAPLE TYPE
6163	S	SA	EM	SUGAR HILLS MORAINE/DES MOINES LOBE GCD
6168	S	SA	EM	SUGAR HILLS MORAINE/DES MOINES LOBD GCD
2745	S	SST	EM	PINE CITY MORAINE/DES MOINES LOBE RGMD
5050	M	SI/ARG	EM	ITASCA MORAINE/WADENA LOBE GCD
5149	M	SI/ARG	LP	DES MOINES LOBE GRAY CALCAREOUS DRIFT
5340	S	SA	EM/E	SUGAR HILLS MORAINE/DES MOINES LOBE GCD
784	I	GA	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
2594	M	SI/ARG	OP	RAINY LOBE BROWN-GRAY NONCALC.DRFT.

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(Table 5 continued)

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
				ZONE 3
				JACK PINE TYPE
848	S	SST	OP	NOT DETERMINED
980	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1257	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1290	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1324	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1338	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1705	S	SST	OP	YELLOW-RED COARSE DRIFT
1820	S	SST	OP	YELLOW-RED COARSE DRIFT
				RED PINE TYPE
507	S	SST	LP	SUPERIOR LOBE GRAY-BROWN COARSE DRFT.
70041	I	B	OP	NOT DETERMINED
863	S	SST	OP	NOT DETERMINED
935	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
1294	S	SST	OP	BROWN-GRAY NONCALCAREOUS DRIFT
441	S	SST	GM/D	THIN TILL OVER BEDROCK
3173	S	SST	OP	YELLOW-BROWN COARSE DRIFT
955	I	B	OP	NOT DETERMINED
				BALSAM FIR TYPE
41	I	D-G	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
1516	I	D-G	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
2196	I	B	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
2205	I	B	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
2062	I	D-G	EM	MILLE LACS-HIGHLAND MORAINE/SURERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
5078	I	T-B	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
				ASPEN TYPE
614	S	SST	LMT	SUPERIOR LOBE RED-BROWN CALC. DRIFT
1334	I	B	GM	VERMILLION MORAINE/RAINY LOBE BGNCD
2046	I	D-G	GM	NICKERSON MORAINE/SUPERIOR LOBE RBNCD
5499	I	D-G	GM/D	VERMILLION MORAINE/RAINY LOBE BGNCD
525	S	SST	GM	ST. CROIX MORAINE/SUPERIOR LOBE RBNCD
672	I	B	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
3720	S	SST	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
3888	I	B	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
4012	I	B	RT	SUPERIOR LOBE RED-BROWN NONCALC. DRIFT

(Continued on next page)

(Table 5 continued)

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
				SUGAR MAPLE TYPE
656	S	SST	EM	SUPERIOR LOBE RED-BROWN NONCALC. DRIFT
749	S	SST	LMT	SUPERIOR LOBE RED-BROWN NONCALC. DRIFT
70047	I	GA	EM	SUPERIOR LOBE RED-BROWN NONCALC. DRIFT
1395	I	B	EM	RED-BROWN NONCALCAREOUS DRIFT
1484	I	D-G	GM/D	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
1490	I	V	GM	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
2060	I	D-G	EM	MILLE LACS-HIGHLAND MORAINE/SUPERIOR LOBE RED-BROWN NONCALCAREOUS DRIFT
617	S	SST	GM	PINE CITY MORAINE/DES MOINES LOBE RGMD
				ZONE 4
				JACK PINE TYPE
19	S	SST	LP	NOT DETERMINED
39	S	SST	LP	NOT DETERMINED
1111	S	SST	OP	YELLOW-BROWN COARSE DRIFT
1216	S	SST	NA	DRIFTLESS AREA
2152	S	SST	LP	BROWN MEDIUM TEXTURED DRIFT
2442	M	GN	OP	GRAY-BROWN MEDIUM TEXTURED DRIFT
80072	I	G	GM	GREEN BAY LOBE GRAY-BRN COR.TEX.DRIFT
3203	M	GN	OP	YELLOW-BROWN COARSE TEXTURED DRIFT
				RED PINE TYPE
12	S	SST	LP	NOT DETERMINED
80145	I	GA	OP	GREEN BAY LOBE RED-BRN NONCALC. DRIFT
1391	S	SST	OP	BROWN MEDIUM TEXTURED DRIFT
972	M	M,M	OP	LANGLADE LOBE GRAY-BRN COR.TEX.DRIFT
1660	M	M,M	OP	WISCONSIN VALLEY LOBE YBCD
1661	M	M,M	OP	WISCONSIN VALLEY LOBE YRCD
1663	M	M,M	OP	WISONSIN VALLEY LOBE YBCD
1272	M	M,M	GM	GREEN BAY LOBE RED-BROWN CALC. DRIFT
				BALSAM FIR TYPE
1468	M	S	GM	MARENISCO MORAINE/MICHIGAMME LOBE GBCT
665	S	L	EM	GRAY-BROWN MEDIUM TEXTURED DRIFT
745	S	L	GM	GRAY-BROWN MEDIUM TEXTURED DRIFT
746	S	L	GM	GRAY-BROWN MEDIUM TEXTURED DRIFT
3139	M	S	GM	GRAY-BROWN COARSE TEXTURED DRIFT
1679	I	G	OP	WINEGAR MORAINE/ONTONAGON LOBE RBNCD
1884	M	S	GM	LANGLADE LOBE GRAY-BRN MED.TEX.DRIFT
2204	S	L	ND	NOT DETERMINED
2795	I	G	GM	MICHIGAMME LOBE THIN TILL OVER BEDROCK
1606	M	M,M	GM	WISCONSIN VALLEY LOBE BMTD

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(Table 5 continued)

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
			ASPEN TYPE	
1353	S	SST	GM	KEEWEENAW BAY LOBE GBCTD
629	S	SST	GM/D	THIN TILL OVER BEDROCK
3091	I	G	GM	THIN TILL OVER BEDROCK
483	M	M,M	GM/D	LINCOLN FORMATION/WISCONSIN VALLEY LOBE THIN TILL OVER BEDROCK
585	I	D-A	GM	WISCONSIN VALLEY LOBE TTOB
2154	S	SST	LP	BROWN MEDIUM TEXTURED DRIFT
2391	S	SST	GM	GRAY-BROWN MEDIUM TEXTURED DRIFT
624	S	SST	LP	ONTONAGON LOBE GBFTD
792	S	SST	LP	ONTONAGON LOBE GBFTD
3122	I	G	GM	GRAY-BROWN COARSE TEXTURED DRIFT
			SUGAR MAPLE TYPE	
1832	M	ND	GM	LANGLADE LOBE GRAY-BRN COR.TEX.DRIFT
1982	M	GN	GM	LANGLADE LOBE GRAY-BRN COR.TEX.DRIFT
554	M	GN	GM	WISCONSIN VALLEY MORAINE/WISCONSIN VALLEY LOBE THIN TILL OVER BEDROCK
2215	S	L	GM	GRAY-BROWN MEDIUM TEXTURED DRIFT
2557	M	GN	GM	GRAY-BROWN COARSE TEXTURED DRIFT
52717	I	G	EM	ELCHO MORAINE/WISCONSIN VALLEY LOBE RED-BROWN NONCALCAREOUS DRIFT
688	S	SST	LP	ONTONAGON LOBE GRAY-BRN FINE TEX.DRFT
725	S	SST	LP	ONTONAGON LOBE GRAY-BRN FINE TEX.DRFT
			ZONE 5	
			JACK PINE TYPE	
346	S	L	OP	BROWN MEDIUM TEXTURED DRIFT
6047	S	SA	OP	BROWN MEDIUM TEXTURED DRIFT
159	S	SA	OP	BROWN MEDIUM TEXTURED DRIFT
287	S	SA	OP	BROWN MEDIUM TEXTURED DRIFT
2564	S	SST	LP	BROWN MEDIUM TEXTURED DRIFT
2797	S	SST	LP	BROWN MEDIUM TEXTURED DRIFT
546	S	SA	OP	SAGINAW LOBE BROWN MEDIUM TEX. DRIFT
934	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
			RED PINE TYPE	
80077	S	SA	GM	GRAY-BROWN COARSE TEXTURED DRIFT
3347	S	L	LP	LAKE NIPPISSING PLAIN BMTD
3725	S	SA	EM	PORT HURON MORAINE/LAKE MICHIGAN LOBE GRAY-BROWN COARSE TEXTURED DRIFT
4822	S	SST	EM	PORT HURON MORAINE/LAKE MICHIGAN LOBE GRAY-BROWN COARSE TEXTURED DRIFT
1923	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
2478	S	SST	EM	GRAY-BROWN COARSE TEXTURED DRIFT
81127	S	SA	EM	GRAY-BROWN COARSE TEXTURED DRIFT

(Continued on next page)

(Table 5 continued)

FIA		Bedrock geology		Glacial geology
Plot	Type	Composition	Landform	surface
		BALSAM FIR TYPE		
1583	S	L	GM	THIN TILL OVER BEDROCK
1658	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
1667	S	L	GM	THIN TILL OVER BEDROCK
1754	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
1989	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
		ASPEN TYPE		
3558	S	SA	GM	MANISTEE MORAINE/LAKE MICHIGAN LOBE GRAY-BROWN COARSE TEXTURED DRIFT
262	S	SA	GM	BROWN MEDIUM TEXTURED DRIFT
1796	S	L	LP	GRAY-BROWN FINE TEXTURED DRIFT
1952	S	L	GM	GRAY-BROWN COARSE TEXTURED DRIFT
1511	S	SST	OP	BROWN MEDIUM TEXTURED DRIFT
2174	S	L	EM	GRAY-BROWN COARSE TEXTURED DRIFT.
		SUGAR MAPLE TYPE		
4504	S	SA	GM/D	MANISTEE MORAINE/LAKE MICHIGAN LOBE GRAY-BROWN COARSE TEXTURED DRIFT
1352	S	L	OP	GRAY-BROWN COARSE TEXTURED DRIFT
1573	S	L	OP	GRAY-BROWN COARSE TEXTURED DRIFT
2784	S	L	OP	BROWN MEDIUM TEXTURED DRIFT
1863	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
1878	S	L	LP	BROWN MEDIUM TEXTURED DRIFT
1897	S	L	ND	NOT DETERMINED
1295	S	SA	OP	BROWN MEDIUM TEXTURED DRIFT

[1]Bedrock geology type--I=Igneous, M=Metamorphic, S=Sedimentary

[2]Bedrock geology composition--S=Slate, B=Basalt, G=Granite, PR=Precambrian rock, GW=Graywacke, Q=Quartzite, SI/ARG=Siltstone-Argilite, GN=Gneiss, SH=Shist, SST=Sandstone, GA=Gabbro, D-G=Diabase-Gabbro, V=Volcanic, T-B=Tuff-Breccia, M-M=Mafic-Metavolcanic, D-A=Diorite-Andesite, L=Limestone, SA=Shale, ND=Not determined.

[3]Glacian geology landform--OP=Outwash Plain, LP=Lake Plain, EM=End moraine, SM=Stagnant moraine, GM=Ground moraine, LMT=Lake modified till, GM/D=Ground moraine with Drumlins, EM/E=End moraine with eskers, RT=River terraces, NA=Not applicable, ND=Not determined.

[4]Glacial geology surface--GCD=Gray calcareous drfit, RBNCD=Red-brown noncalcareous drift, BGNCD=Brown-gray noncalcareous drift, RGMD=Red-gray mixed drift, YRCD=Yellow-red coarse drift, GBCTD=Gray-brown coarse textured drift, YBCD=Yellow-brown coarse drift, RBCD=Red-brown calcareous drift, BMTD=Brown medium textured drift, GBMTD=Gray-brown medium textured drift, GBFTD= Gray-brown fine textured drift, TTOB=Thin till over bedrock.

Table 6.--Soils taxonomic information for the study plot locations in 5 zones across the Lake States deposition gradient (Total number of plots in each category (in parentheses) and total number of categories are noted)

Soil types	Taxonomic subgroup	Great group, suborder, order
	ZONE 1	
15	Typic (14)	Eutroboralf (16)
	Aquic (3)	Udipsamment (6)
	Psammentic (2)	Haploboroll (1)
	Mollic (1)	
	Arenic (1)	
	Udic (1)	
TOTALS		
15	6	3
	ZONE 2	
20	Typic (17)	Udipsamment (9)
	Glossic (4)	Eutroboralf (7)
	Aquic (4)	Dystrochrept (6)
	Spodic (1)	Fragiochrept (4)
	Udorthentic (1)	Ochraqualf (2)
	Alfic (1)	Haploboroll (1)
	Aeric (1)	Fragiorthod (1)
	Udollic (1)	Glossaqualf (1)
	Anenic (1)	
TOTALS		
20	9	8
	ZONE 3	
17	Typic (20)	Udipsamment (16)
	Spodic (14)	Fragiochrept (10)
	Entic (2)	Eutroboralf (4)
	Alfic (2)	Dystrochrept (2)
	Glossic (1)	Haplorthod (2)
	Eutric (1)	Fragiorthod (2)
		Udorthent (2)
TOTALS		Glossoboralf (1)
17	6	8

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(Table 6 continued)

Soil types	Taxonomic subgroup	Great group, suborder, order
	ZONE 4	
28	Typic (12)	Udipsamment (7)
	Alfic (8)	Haplorthod (6)
	Entic (5)	Haplaquod (5)
	Aquic (3)	Haplaquept (4)
	Glossic (2)	Glossoboralf (4)
	Eutric (2)	Fragiorthod (3)
	Humic (2)	Eutroboralf (3)
		Quartzipsamment (2)
		Not determined (10)
TOTALS 28	7[1]	8[1]
	ZONE 5	
19	Typic (11)	Haplorthod (15)
	Entic (11)	Udipsamment (4)
	Mollic (2)	Haplaquod (3)
	Alfic (2)	Psammaquent (2)
	Eutric (1)	Eutroboralf (2)
	Aquic (1)	Glossoboralf (1)
	Hemic (1)	Haploboroll (1)
	Udorthentic (1)	Eutrochrept (1)
		Borosaprist (1)
		Not determined (4)
TOTALS 19	8[1]	9[1]

[1]Information not available for every plot in the zone.

Table 7.--Soil taxonomic information for individual study plots across the Lake States acidic deposition gradient

FIA plot	Soil series	Soil	Taxonomy subgroup
		ZONE 1	
		JACK PINE TYPE	
7325	ROCKWOOD	MOLLIC	EUTROBORALF[1]
48	GRAYCALM	ALFIC	UDIPSAMMENT[1]
3721	ANDRUSIA	ARENIC	EUTROBORALF
6815	TODD	TYPIC	EUTROBORALF[1]
6872	NEBISH	TYPIC	EUTROBORALF[1]
5595	REDBY	AQUIC	UDIPSAMMENT
8013	MENAHGA	TYPIC	UDIPSAMMENT
8056	FRIENDSHIP	TYPIC	UDIPSAMMENT
		BALSAM FIR TYPE	
8806	MENAHGA	TYPIC	UDIPSAMMENT[1]
		ASPEN TYPE	
2002	MAHTOMEDI	TYPIC	UDIPSAMMENT
2026	ROSY	AQUIC	EUTROBORALF[1]
4068	KARLSTAD	AQUIC	EUTROBORALF
8206	NEBISH	TYPIC	EUTROBORALF[1]
8287	MARQUETTE	PSAMMENTIC	EUTROBORALF[1]
6062	MARQUETTE	PSAMMENTIC	EUTROBORALF[1]
		SUGAR MAPLE TYPE	
2171	ARVILLA	UDIC	HAPLOBOROLL[1]
7194	NEBISH	TYPIC	EUTROBORALF[1]
7275	NEBISH	TYPIC	EUTROBORALF
3782	SNELLMAN	TYPIC	EUTROBORALF
3920	LENGBY	TYPIC	EUTROBORALF
1879	NEBISH	TYPIC	EUTROBORALF[1]
738	NEBISH	TYPIC	EUTROBORALF
2175	NEBISH	TYPIC	EUTROBORALF

(Continued on next page)

(Table 7 continued)

FIA plot	Soil series	Soil	Taxonomy subgroup
		ZONE 2	
		JACK PINE TYPE	
5308	OMEGA	SPODIC	UDIPSAMMENT
3592	MENAHGA	TYPIC	UDIPSAMMENT
3018	MENAHGA	TYPIC	UDIPSAMMENT[1]
3076	MENAHGA	TYPIC	UDIPSAMMENT[1]
3103	MENAHGA	TYPIC	UDIPSAMMENT[1]
305	MENAHGA	TYPIC	UDIPSAMMENT
3278	MESABA	TYPIC	DYSTROCHREPT[1]
		RED PINE TYPE	
210	HUBBARD	UDORTHENTIC	HAPLOBOROLL
9013	MENAHGA	TYPIC	UDIPSAMMENT
5118	MENAHGA	TYPIC	UDIPSAMMENT[1]
3320	ZIMMERMAN	ALFIC	UDIPSAMMENT
		BALSAM FIR TYPE	
2691	MESABA	TYPIC	DYSTROCHREPT[1]
2942	CONIC	TYPIC	FRAGIORTHOD[1]
3060	CLOQUET[2]	TYPIC	DYSTROCHREPT
3421	HIBBING	TYPIC	EUTROBORALF
		ASPEN TYPE	
1420	ONTONAGAN	GLOSSIC	EUTROBORALF
3616	BRAINERD	AQUIC	FRAGIOCHREPT[1]
3208	BRAINERD	AQUIC	FRAGIOCHREPT[1,3]
4668	INDUS	TYPIC	OCHRAQUALF
4794	TAYLOR	AQUIC	EUTROBORALF[1]
1202	BRAINERD	AQUIC	FRAGIOCHREPT[1]
3942	CLOQUET[2]	TYPIC	DYSTROCHREPT
3943	AHMEEK	TYPIC	FRAGIOCHREPT
		SUGAR MAPLE TYPE	
6163	CUTAWAY[2]	ARENIC	EUTROBORALF
6168	ALSTEAD[2]	AERIC	GLOSSOAQUALF
2745	LERDAL	UDOLLIC	OCHRAQUALF[1]
5050	ITASCA	GLOSSIC	EUTROBORALF[1]
5149	CROMWELL	TYPIC	DYSTROCHREPT
5340	ITASCA	GLOSSIC	EUTROBORALF
784	DULUTH	GLOSSIC	EUTROBORALF[1]
2594	TOIMI	TYPIC	DYSTROCHREPT

(Continued on next page)

(Table 7 continued)

FIA plot	Soil series	Soil	Taxonomy subgroup
		ZONE 3	
		JACK PINE TYPE	
848	OMEGA	SPODIC	UDIPSAMMENT[1]
980	OMEGA	SPODIC	UDIPSAMMENT[1]
1257	OMEGA	SPODIC	UDIPSAMMENT[1]
1290	OMEGA	SPODIC	UDIPSAMMENT[1]
1324	OMEGA	SPODIC	UDIPSAMMENT[1]
1338	OMEGA	SPODIC	UDIPSAMMENT[1]
1705	OMEGA	SPODIC	UDIPSAMMENT
1820	OMEGA	SPODIC	UDIPSAMMENT
		RED PINE TYPE	
507	OMEGA	SPODIC	UDIPSAMMENT[1]
70041	OMEGA	SPODIC	UDIPSAMMENT[1]
863	OMEGA	SPODIC	UDIPSAMMENT[1]
935	OMEGA	SPODIC	UDIPSAMMENT[1]
1294	OMEGA	SPODIC	UDIPSAMMENT[1]
441	PLAINBO	TYPIC	UDIPSAMMENT[1]
3173	OMEGA	TYPIC	UDIPSAMMENT[1]
955	OMEGA	SPODIC	UDIPSAMMENT[1]
		BALSAM FIR TYPE	
41	MESABA	TYPIC	FRAGIOCHREPT[1]
1516	NEWFOUND	TYPIC	FRAGIOCHREPT
2196	MESABA	TYPIC	FRAGIOCHREPT[1]
2205	ONTONAGAN	TYPIC	EUTROBORALF
2062	TOIVOLA	TYPIC	UDORTHENT
5078	MESABA	TYPIC	FRAGIOCHREPT[1]
		ASPEN TYPE	
614	ONTONAGAN	TYPIC	EUTROBORALF[1]
1334	MESABA	TYPIC	DYSTROCHREPT[1]
2046	ONTONAGAN	GLOSSIC	EUTROBORALF
5499	MESABA	TYPIC	DYSTROCHREPT[1]
525	MILACA	TYPIC	FRAGIOCHREPT[1]
672	AHMEEK	TYPIC	FRAGIOCHREPT[1]
3720	AHMEEK	TYPIC	FRAGIOCHREPT[1]
3888	AHMEEK	TYPIC	FRAGIOCHREPT[1]
4012	CHETEK	EUTRIC	GLOSSOBORALF

(Continued on next page)

(Table 7 continued)

FIA plot	Soil series	Soil	Taxonomy subgroup
	SUGAR MAPLE TYPE		
656	HIAWATHA	ENTIC	HAPLORTHOD[1]
749	HIAWATHA	ENTIC	HAPLORTHOD[1]
70047	GOGEBIC	ALFIC	FRAGIORTHOD
1395	GOGEBIC	ALFIC	FRAGIORTHOD[1]
1484	DULUTH	TYPIC	EUTROBORALF
1490	AHMEEK	TYPIC	FRAGIOCHREPT
2060	TOIVOLA	TYPIC	UDORTHENT
617	MILACA	TYPIC	FRAGIOCHREPT[1]
	ZONE 4		
	JACK PINE TYPE		
19	DELTON	TYPIC	UDIPSAMMENT[1]
39	BREMS	AQUIC	UDIPSAMMENT[1]
1111	TARR	TYPIC	QUARTZIPSAMMENT
1216	BOONE	TYPIC	QUARTZIPSAMMENT
2152	NOT DETERMINED		
2442	NOT DETERMINED		
80072	MENAHGA	TYPIC	UDIPSAMMENT
3203	PLAINFIELD	TYPIC	UDIPSAMMENT[1]
	RED PINE TYPE		
12	PLAINFIELD	TYPIC	UDIPSAMMENT
80145	PADUS	ALFIC	HAPLORTHOD
1391	MEEHAN	AQUIC	UDIPSAMMENT[1]
972	MENAHGA	TYPIC	UDIPSAMMENT
1660	SAYNER	ENTIC	HAPLORTHOD
1661	VILAS	ENTIC	HAPLORTHOD
1663	SAYNER	ENTIC	HAPLORTHOD
1272	ONAWAY	TYPIC	EUTROBORALF[1]
	BALSAM FIR TYPE		
1468	CHAMPION	TYPIC	FRAGIORTHOD
665	EMMET	ALFIC	HAPLORTHOD[1]
745	CHARLEVOIX	ALFIC	HAPLAQUOD
746	CHARLEVOIX	ALFIC	HAPLAQUOD
3139	NOT DETERMINED		
1679	CABLE	TYPIC	HAPLAQUEPT[1]
1884	CHANNING	ENTIC	HAPLAQUOD
2204	NOT DETERMINED		
2795	NOT DETERMINED		
1606	CABLE	TYPIC	HAPLAQUEPT

(Continued on next page)

(Table 7 continued)

FIA plot	Soil series	Soil Taxonomy subgroup	
	ASPEN TYPE		
1335	MUNISING	ALFIC	FRAGIORTHOD[1]
629	VESPER	HUMIC	HAPLAQUEPT
3091	NOT DETERMINED		
483	MAGNOR	AQUIC	GLOSSOBORALF
585	TULA	ALFIC	HAPLAQUOD
2154	NOT DETERMINED		
2391	NOT DETERMINED		
624	ONTONAGAN	GLOSSIC	EUTROBORALF[1]
792	WATTON	EUTRIC	GLOSSOBORALF
3132	VESPER	HUMIC	HAPLAQUEPT[1]
	SUGAR MAPLE TYPE		
1832	BARAGA	ALFIC	FRAGIORTHOD
1982	CHANNING	ENTIC	HAPLAQUOD
554	FREEON	TYPIC	GLOSSOBORALF[1]
2215	NOT DETERMINED		
2557	NOT DETERMINED		
52717	ALCONA	ALFIC	HAPLORTHOD
688	ONTONAGAN	GLOSSIC	EUTROBORALF
725	WATTON	EUTRIC	GLOSSOBORALF
	ZONE 5		
	JACK PINE TYPE		
346	RUBICON	ENTIC	HAPLORTHOD
6047	GRAYLING	TYPIC	UDIPSAMMENT
159	RUBICON	ENTIC	HAPLORTHOD[1]
287	GRAYLING	TYPIC	UDIPSAMMENT
2564	RUBICON	ENTIC	HAPLORTHOD
2797	RUBICON	ENTIC	HAPLORTHOD
546	EAST LAKE	ENTIC	HAPLORTHOD
934	ROSCOMMON	MOLLIC	PSAMMAQUENT[1]
	RED PINE TYPE		
80077	NOT DETERMINED		
3347	EAST LAKE	ENTIC	HAPLORTHOD
3725	MONTCALM	EUTRIC	GLOSSOBORALF[1]
4822	EMMET	TYPIC	EUTROBORALF
1923	RUBICON	ENTIC	HAPLORTHOD[1]
2478	RUBICON	ENTIC	HAPLORTHOD
81127	RUBICON	ENTIC	HAPLORTHOD

(Continued on next page)

(Table 7 continued)

FIA plot	Soil series	Soil Taxonomy subgroup	
	BALSAM FIR TYPE		
1583	WAINOLA	ENTIC	HAPLAQUOD
1658	GRANBY	TYPIC	HAPLAQUOD
1667	SHELTER	UDORTHENTIC	HAPLOBOROLL[1]
1754	KALKASKA	TYPIC	HAPLORTHOD[1]
1989	DETOUR	AQUIC	EUTROCHREPT[1]
	ASPEN TYPE		
3558	NOT DETERMINED		
262	ROSELAWN	NOT DETERMINED	
1796	BRIMLEY	ALFIC	HAPLAQUOD[1]
1952	CARBONDALE	HEMIC	BOROSAPRIST[1]
1511	PLAINFIELD	TYPIC	UDIPSAMMENT
2174	COLOMA	ALFIC	UDIPSAMMENT[1]
	SUGAR MAPLE TYPE		
4504	EMMET	TYPIC	EUTROBORALF[1]
1352	AMASA	TYPIC	HAPLORTHOD
1573	KALKASKA	TYPIC	HAPLORTHOD
2784	KALKASKA	TYPIC	HAPLORTHOD
1863	ROSCOMMON	MOLLIC	PSAMMAQUENT[1]
1878	KALKASKA	TYPIC	HAPLORTHOD[1]
1897	RUBICON	ENTIC	HAPLORTHOD[1]
1295	ROSELAWN	NOT DETERMINED	

[1]Mapped unit name includes at least one other soil series.
[2]Series is unnamed but is similar to the noted series.
[3]Called eutroboralf in a later source.

Table 8.--Frequency of rock greater than 20 mm by volume in mineral soils of 171 plots across a Lake States acidic deposition gradient

Percent Volume Class		Zone					Mean
		1	2	3	4	5	
	n=	23	31	39	44	34	
		--Percent frequency--					
0		47.8	58.1	53.9	61.4	41.2	52.5
0.1-5.0		52.2	35.5	25.6	38.6	55.9	41.6
5.1-10.0		--	3.2	5.1	--	2.9	2.2
10.1-25.0		--	3.2	7.7	--	--	2.2
25.1-50.0		--	--	2.6	--	--	0.5
50.1-100.0		--	--	5.1	--	--	1.0

Percent Volume Class		Forest Type					Mean
		JP	RP	BF	SM	A	
	n=	39	27	26	41	38	
		--Percent frequency--					
0		69.2	66.7	34.6	39.1	55.3	53.0
0.1-5.0		30.8	33.3	34.6	58.5	39.5	39.2
5.1-10.0		--	--	15.4	--	--	3.1
10.1-25.0		--	--	7.8	2.4	2.6	2.6
25.1-50.0		--	--	3.8	--	--	0.8
50.1-100.0		--	--	3.8	--	2.6	1.3

Zones: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the sulfate deposition gradient.

Forest type: JP=Jack pine RP=Red pine BF=Balsam fir SM=Sugar maple A=Aspen.

Table 9.--Percent rock between 2 and 20 mm in the mineral soil of 171 plots across a Lake States acidic deposition gradient

	Zone					ANOVA		
	1	2	3	4	5	d/f	F	P
n=	23	31	39	44	34			
	4.2	4.3	6.8	3.5	2.8	4/166	1.295	0.274
	Forest type					**ANOVA**		
	JP	RP	BF	SM	A	d/f	F	P
n=	39	27	26	41	38			
	1.5a	1.5a	8.1b	7.1b	4.3c	4/166	13.910	0.000

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of percent rock values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the sulfate deposition gradient.

Forest type: JP=Jack pine, RP= Red pine, BF= Balsam fir, SM= Sugar maple, A= aspen.

Table 10.--Percent clay, silt, and sand fractions of the surface soil (1-25 cm depth) of 171 plots across a Lake States acidic deposition gradient

Fraction — Characteristic — ANOVA

I. Zone

	1	2	3	4	5	d/f	F	P
n=	25	30	39	43	34			
CLAY	6.3a	9.6a	8.7a	7.5a	3.4b	4/164	9.138	0.000
SILT	27.5a	32.6a	26.9a	28.8a	13.5b	4/164	6.701	0.000
SAND	66.2a	57.8a	64.4a	63.7a	83.1b	4/164	5.490	0.000

II. Forest Type

	JP	RP	BF	SM	A	d/f	F	P
n=	39	26	25	41	38			
CLAY	3.3a	4.0a	10.1b	7.4b	11.0b	4/164	14.686	0.000
SILT	9.2a	13.2a	34.2b	36.3b	34.5b	4/164	50.216	0.000
SAND	87.5a	82.8a	55.7b	56.3b	54.5b	4/164	19.203	0.000

III. Soil Suborders

	PSAM	OCRT	OROD	BROL	BALF	ORNT	OTHER	d/f	F	P
n=	45	23	28	3	39	2	29			
CLAY	3.6a	9.3bc	4.7a	7.1abc	12.2c	11.0bc	6.4b	6/162	8.364	0.000
SILT	10.1a	41.5ce	21.0b	28.8bc	35.1cde	42.2cde	28.2cd	6/162	20.764	0.000
SAND	86.3ab	49.2f	74.4acd	64.1adef	52.6def	46.9df	65.4acd	6/162	13.542	0.000

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Table 10, continued

I. Zones: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the sulfate deposition gradient.

II. Forest Type: JP=Jack pine RP=Red pine BF=Balsam fir SM=Sugar maple A=Aspen.

III. Soil Suborders: PSAM=Psamments OCRT=Ochrepts OROD=Orthods BROL=Borolls BALF=Boralfs ORNT=Orthents OTHER=includes Aquods, Aquepts, Aqualfs, Aquents, Saprists, and not determined.

Table 11.--Percent clay, silt, and sand fractions of the surface soil (1-25 cm depth) for 5 forest types within zones across a Lake States deposition gradient

Fraction	Zone					ANOVA		
I. Jack pine								
	1	2	3	4	5	d/f	F	P
n=	8	7	8	8	8			
CLAY	3.7a	4.6a	3.2a	3.2a	2.1b	4/34	4.004	0.009
SILT	13.5a	13.6ab	8.0bc	5.7c	5.5c	4/34	5.246	0.002
SAND	82.8ab	81.8a	88.8bc	91.1c	92.4c	4/34	3.706	0.013
II. Red pine								
	1	2	3	4	5	d/f	F	P
n=	0	3	8	8	7			
CLAY	---	5.2	4.4	3.7	3.2	3/22	1.690	0.198
SILT	---	20.2	9.7	18.6	8.2	3/22	1.257	0.313
SAND	---	74.6	85.9	77.7	82.6	3/22	1.178	0.341
III. Balsam fir								
	1	2	3	4	5	d/f	F	P
n=	1	4	6	9	5			
CLAY	3.8	19.3	13.2	7.2	5.6	4/20	2.136	0.114
SILT	11.4a	32.6bc	40.7c	36.9bc	27.4ab	4/20	4.240	0.012
SAND	84.8	48.1	46.1	55.9	67.0	4/20	1.293	0.306

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(Table 11 continued)

Fraction	Zone					ANOVA		
IV. Sugar maple								
	1	2	3	4	5	d/f	F	P
n=	8	8	8	9	8			
CLAY	8.7a	7.4a	8.8a	9.5a	2.6b	4/36	12.976	0.000
SILT	39.6a	44.5a	39.4a	44.9a	12.2b	4/36	19.116	0.000
SAND	51.7a	48.1a	51.8a	45.6a	85.2b	4/36	6.420	0.001
V. Aspen								
	1	2	3	4	5	d/f	F	P
n=	6	8	9	9	6			
CLAY	7.0	13.0	14.2	13.1	4.8	4/33	1.192	0.333
SILT	32.7a	41.7a	39.0a	34.1a	20.5b	4/33	4.027	0.009
SAND	60.3	45.3	46.8	52.8	74.7	4/33	1.853	0.142

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the sulfate deposition gradient.

Table 12.--Percent clay, silt, and sand fractions of the surface soil (1-25 cm depth) for 5 forest types within zones across a Lake States acidic deposition gradient

Fraction	Forest type					ANOVA		
I. Zone 1								
	JP	RP	BF	SM	A	d/f	F	P
n=	8	0	1	8	6			
CLAY	3.7a	---	3.8ab	8.7c	7.0bc	3/19	9.349	0.001
SILT	13.5a	---	11.4a	39.6b	32.7b	3/19	19.855	0.000
SAND	82.8a	---	84.8ab	51.7c	60.3bc	3/19	7.586	0.002
II. Zone 2								
	JP	RP	BF	SM	A	d/f	F	P
n=	7	3	4	8	8			
CLAY	4.6	5.2	19.3	7.4	13.0	4/25	1.578	0.211
SILT	13.7a	20.2ab	32.6bc	44.5c	41.8c	4/25	7.932	0.000
SAND	81.8a	74.6ab	48.1b	48.1ab	45.3b	4/25	2.752	0.050
III. Zone 3								
	JP	RP	BF	SM	A	d/f	F	P
n=	8	8	6	8	9			
CLAY	3.2a	4.4a	13.2b	8.8b	14.2b	4/34	7.442	0.000
SILT	8.0a	9.6a	40.7b	39.4b	38.9b	4/34	41.832	0.000
SAND	88.8a	85.9a	46.1b	51.8b	46.8b	4/34	9.477	0.000
IV. Zone 4								
	JP	RP	BF	SM	A	d/f	F	P
n=	8	8	9	9	9			
CLAY	3.2a	3.7a	7.2b	9.5b	13.1b	4/38	7.731	0.000
SILT	5.7a	18.6b	36.9c	44.9c	34.1c	4/38	24.154	0.000
SAND	91.1a	77.7ab	55.9bc	45.6c	52.8c	4/38	7.403	0.000

(Continued on next page)

(Table 12 continued)

Fraction	Forest type					ANOVA		
V. Zone 5								
	JP	RP	BF	SM	A	d/f	F	P
n=	8	7	5	8	6			
CLAY	2.1a	3.2ab	5.6b	2.6ab	4.8b	4/29	2.197	0.094
SILT	5.5a	8.1ab	27.3d	12.2bc	20.5cd	4/29	8.296	0.000
SAND	92.4a	88.6ab	67.0c	85.2ab	74.7bc	4/29	3.707	0.015

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

Forest Types: JP= jack pine, RP= red pine, BF= balsam fir, SM= sugar maple, A= aspen.

Table 13.--Percent clay, silt, and sand fractions of the surface (1-25 cm depth) for selected soil suborder units within zones across a Lake States acidic deposition gradient

Fraction	Zone					ANOVA		
I. Psamments								
	1	2	3	4	5	d/f	F	P
n=	6	8	16	11	4			
CLAY	3.3	4.2	3.8	3.2	2.8	4/40	1.181	0.334
SILT	13.5a	14.3a	8.8ab	6.6b	11.1ab	4/40	2.461	0.061
SAND	83.2ab	81.5a	87.4b	90.2b	86.1ab	4/40	2.388	0.067
II. Ochrepts								
	1	2	3	4	5	d/f	F	P
n=	0	10	12	0	1			
CLAY	---	11.7a	7.9a	---	0.8b	2/20	5.643	0.011
SILT	---	39.9a	45.2a	---	14.3b	2/20	6.975	0.005
SAND	---	48.4	46.9	---	84.9	2/20	0.944	0.406
III. Orthods								
	1	2	3	4	5	d/f	F	P
n=	0	1	4	8	15			
CLAY	---	7.9ab	8.9a	4.8ab	3.2b	3/24	4.964	0.008
SILT	---	46.5a	28.9a	33.5a	10.5b	3/24	6.181	0.003
SAND	---	45.6a	62.2a	61.7a	86.3b	3/24	6.153	0.003
IV. Boralfs								
	1	2	3	4	5	d/f	F	P
n=	16	8	5	7	3			
CLAY	7.4a	13.1ab	25.0b	17.7b	1.5c	4/34	8.321	0.000
SILT	32.7a	41.3ab	33.5ab	45.9b	9.5c	4/34	8.881	0.000
SAND	59.9ab	45.6bc	41.5c	36.4c	89.0a	4/34	4.003	0.009

(Continued on next page)

(Table 13 continued)

Fraction	Zone					ANOVA		
V. Others								
	1	2	3	4	5	d/f	F	P
n=	0	2	0	17	10			
CLAY	---	9.4a	---	7.4a	4.2b	2/26	5.471	0.010
SILT	---	39.9a	---	33.8a	16.1b	2/26	6.616	0.005
SAND	---	50.7a	---	58.8a	79.7b	2/26	5.081	0.014

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

OTHERS=includes Aquods, Aquepts, Aqualfs, Aquents, Saprists, and Not determined.

Table 14.--Percent clay, silt, and sand fractions of the subsoil (26-100 cm depth) of 171 plots acaross a Lake States acidic depositon gradient

Fraction	Characteristic					ANOVA		
I. Zone								
	1	2	3	4	5	d/f	F	P
n=	23	29	39	44	32			
CLAY	10.6a	12.1a	13.0a	8.0a	4.3b	4/162	5.782	0.000
SILT	17.9a	22.9a	18.1a	20.0a	6.3b	4/162	7.240	0.000
SAND	71.5ab	64.1a	68.4a	72.0ab	89.6b	4/162	3.392	0.011
II. Forest Type								
	JP	RP	BF	SM	A	d/f	F	P
n=	37	27	25	41	37			
CLAY	2.8a	3.3a	12.0b	10.8b	17.7b	4/162	17.432	0.000
SILT	4.2a	7.3a	24.4b	26.1b	22.4b	4/162	35.568	0.000
SAND	93.0a	89.4a	63.0b	62.9b	59.3b	4/162	9.567	0.000

III. Soil Suborders									
	PSAM	OCRT	OROD	BROL	BALF	ORNT	OTHER	d/f	F	P
n=	45	22	29	2	37	2	30			
CLAY	3.4a	13.7bcd	5.6a	6.5ab	17.2bd	9.4abcd	10.2bc	6/160	8.177	0.000
SILT	5.2a	28.8ce	15.0b	8.2abc	24.6cde	35.6cde	18.7cd	6/160	15.048	0.000
SAND	91.5ab	56.7d	79.2abc	85.3abcd	57.5d	55.0ad	71.3ac	6/160	6.832	0.000

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

Forest Type: JP=Jack pine RP=Red pine BF=Balsam fir SM=Sugar maple A=Aspen.

III. Soil Suborder Units:PSAM=Psamment OCRT=Ochrept OROD=Orthods BROL=Borolls BALF=Boralfs ORNT=Orthents OTHER includes Aquods, Aquepts, Aqualfs, Aquents, Saprists, and Not determined.

Table 15.--Percent clay, silt, and sand fractions of the subsoil (26-100 cm depth) for 5 forest types within zones across a Lake States acidic deposition gradient

Fraction	Zone					ANOVA		
I. Jack pine								
	1	2	3	4	5	d/f	F	P
n=	8	6	8	8	7			
CLAY	3.9a	3.8a	2.9ab	2.1bc	1.5c	4/32	9.004	0.000
SILT	6.3a	5.9ab	4.5b	2.0c	2.2c	4/32	8.457	0.000
SAND	89.8a	90.3a	92.6ab	95.9b	96.2b	4/32	5.186	0.002
II. Red pine								
	1	2	3	4	5	d/f	F	P
n=	0	4	8	8	7			
CLAY	---	3.4	3.5	3.2	3.1	3/23	0.724	0.549
SILT	---	9.6	4.1	12.5	3.8	3/23	0.877	0.468
SAND	---	87.0	92.7	84.3	93.1	3/23	0.792	0.511
III. Balsam fir								
	1	2	3	4	5	d/f	F	P
n=	1	4	6	10	4			
CLAY	3.8	22.8	16.9	8.3	4.8	4/20	0.872	0.498
SILT	2.9a	23.8b	32.5b	28.1b	8.8a	4/20	10.040	0.000
SAND	93.3	53.3	47.6	63.6	86.4	4/20	1.351	0.286
IV. Sugar maple								
	1	2	3	4	5	d/f	F	P
n=	8	8	8	9	8			
CLAY	17.8a	12.2a	12.7a	8.9a	2.6b	4/36	4.432	0.005
SILT	29.5a	36.1a	27.3a	31.9a	4.9b	4/36	24.430	0.000
SAND	52.6a	51.7a	59.2a	59.2a	92.5b	4/36	4.699	0.004

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(Table 15 continued)

Fraction	Zone					ANOVA		
V. Aspen								
	1	2	3	4	5	d/f	F	P
n=	6	7	9	9	6			
CLAY	11.0	17.9	28.1	16.3	10.7	4/32	0.709	0.592
SILT	20.3	29.5	24.7	21.5	14.2	4/32	1.157	0.348
SAND	68.8	48.9	47.2	62.2	75.8	4/32	1.484	0.230

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Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

Table 16.--Percent clay, silt, and sand fractions of the subsoil (26-100 cm depth) faor selected soil suborder units within zones across a Lake States acidic deposition gradient

Fraction	Zone					ANOVA		
I. Psamments								
	1	2	3	4	5	d/f	F	P
n=	6	9	16	11	3			
CLAY	4.1a	3.7a	3.2a	2.2b	6.4ab	4/40	2.340	0.071
SILT	7.0a	7.7a	4.3a	2.2b	9.8a	4/40	4.509	0.004
SAND	88.9abc	88.6ab	92.6bc	95.6c	83.7a	4/40	2.890	0.034
II. Ochrepts								
	1	2	3	4	5	d/f	F	P
n=	0	9	12	0	1			
CLAY	---	15.1	13.7	---	1.1	2/19	1.609	0.226
SILT	---	38.0a	30.1a	---	1.6b	2/19	23.390	0.000
SAND	---	54.9	54.6	---	97.2	2/19	0.365	0.699
III. Orthods								
	1	2	3	4	5	d/f	F	P
n=	0	1	4	9	15			
CLAY	---	5.8ab	16.1a	5.3b	2.9b	3/25	4.972	0.008
SILT	---	38.5a	21.1a	27.3a	4.4b	3/25	8.303	0.001
SAND	---	55.7a	61.1ab	67.3ab	92.7ac	3/25	6.049	0.003
IV. Boralfs								
	1	2	3	4	5	d/f	F	P
n=	16	7	4	7	3			
CLAY	13.1a	17.6a	36.5a	21.5a	2.4b	4/32	2.389	0.072
SILT	22.4a	31.4a	24.8a	31.6a	4.1b	4/32	2.789	0.043
SAND	64.6a	47.3ab	38.7b	47.0ab	93.5a	4/32	2.888	0.038

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(Table 16 continued)

Fraction	Zone					ANOVA		
V. Others								
	1	2	3	4	5	d/f	F	P
n=	0	2	1	17	10			
CLAY	---	24.4a	61.4a	7.6b	6.6b	3/26	6.390	0.002
SILT	---	31.4a	19.8ab	22.7a	9.1b	3/26	6.105	0.003
SAND	---	44.2a	18.8b	69.7ac	84.7c	3/26	7.802	0.001

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Oneway ANOVAs based on (ln + 1) transform of clay, silt, and sand values to improve homogeneity of variance.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

OTHERS=includes Aquods, Aquepts, Aqualfs, Aquents, Saprists, and Not determined.

Table 17.--Physiographic characteristics of 171 plots across a Lake States acidic deposition gradient by zone and forest type

Characteristic	Zone					ANOVA		
I. Site Index (feet)								
	1	2	3	4	5	d/f	F	P
JP	59.0	57.0	56.1	57.4	54.2	4/34	0.969	0.437
RP	---	65.7	71.1	66.5	64.0	3/22	2.014	0.141
BF	53.0	50.0	48.5	52.1	50.8	4/20	0.676	0.616
SM	56.1	60.4	58.0	60.8	62.0	4/36	0.978	0.432
A	63.3	63.6	66.4	65.3	63.8	4/33	0.839	0.511
II. Aspect (degrees)								
	1	2	3	4	5	d/f	F	P
JP	219	144	170	222	135	4/34	1.462	0.235
RP	---	170	200	145	124	3/22	0.810	0.502
BF	60	260	208	189	135	4/20	1.351	0.286
SM	175	183	148	151	145	4/36	0.177	0.949
A	83a	146ab	213bc	162ab	279c	4/33	4.231	0.007
III. Position on Slope (mean index value)								
	1	2	3	4	5	d/f	F	P
JP	4.0a	3.9a	2.9b	2.9b	3.5ab	4/34	4.033	0.009
RP	---	3.0	2.8	3.2	2.6	3/22	0.410	0.748
BF	4.0	3.8	2.5	3.2	3.2	4/20	1.628	0.206
SM	2.8	2.6	2.2	2.9	2.0	4/36	1.194	0.330
A	3.0	3.8	2.8	3.1	2.8	4/33	0.453	0.769

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(Table 17 continued)

Characteristic		Zone			ANOVA		
IV. Slope (percent)							
	1	2	3	4	5	d/f	F	P
JP	4.1	8.4	5.1	6.1	10.0	4/34	1.040	0.401
RP	---	4.0	4.4	4.8	6.7	3/22	0.304	0.822
BF	10.0	6.8	8.2	9.9	8.6	4/20	0.105	0.979
SM	8.0	7.5	8.1	7.2	12.8	4/36	1.007	0.417
A	5.5	5.4	9.3	6.4	10.0	4/33	1.575	0.204

Values in the same row followed by the same letter are not significantly different by 95% LSD multiple range analysis. Test applied only where ANOVA P=<0.10.

Zone: Deposition zones 1 through 5 from northwestern Minnesota to southeastern Michigan across the acidic deposition gradient.

Site Index is the mean index value in feet based on height at 50 years attained by the average dominant and codominant trees of the forest type on all plots of that forest type within each zone.

Aspect is the mean azimuth of direction of drainage from the site for all plots of that forest type within each zone.

Position on Slope: Index Value 1=top 1/4 of slope, 2=upper 1/4 of slope, 3=lower 1/4 of slope, 4=level or lowest 1/4 of slope. Value is the mean index value for all plots of that forest type within each zone.

Slope is the mean percent slope of all plots of that forest type within each zone.

Forest Type: JP=jack pine RP=red pine BF=balsam fir SM=sugar maple A=aspen.

Ohmann, Lewis F.; Grigal, David F.; Brovold, Sandra.
1989. **Physical characteristics of study plots across a Lake States acidic deposition gradient**. Resour. Bull. NC-110. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 47 p.

Describes the location and physical setting of the 171 plots that were remeasured and sampled for a study of the relation between various aspects of forest conditions and atmospheric deposition across the northwestern Minnesota to southeastern Michigan acidic deposition gradient.

KEY WORDS: Sulfate deposition, forest inventory, forest soils, acid rain, and soil particle size analysis

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

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