1982
progress report
for the
department of land resource science
and the
ontario institute of pedology

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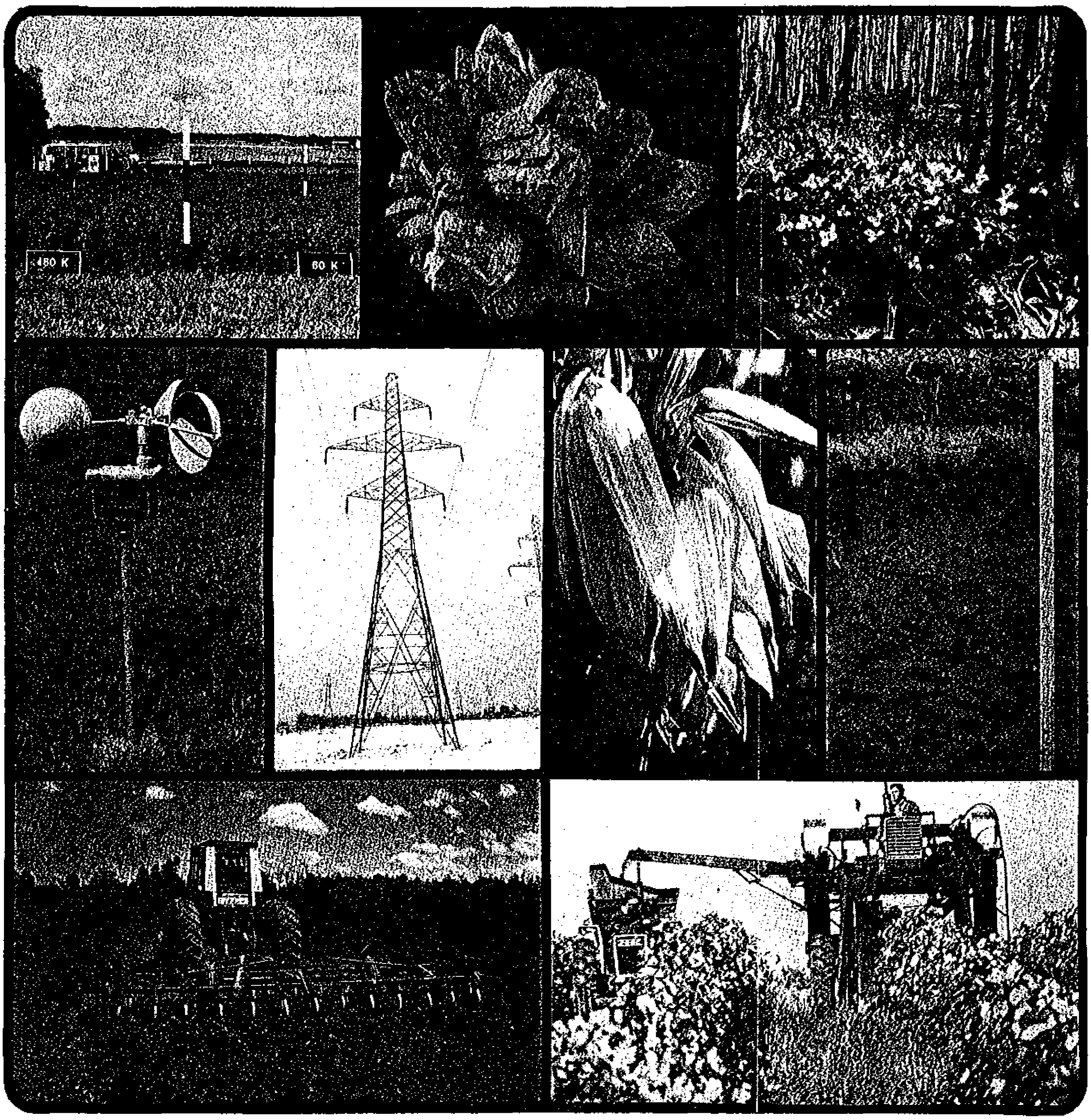

University of Guelph

ontario institute of pedology

FOREWORD

I am pleased to write a few comments as a foreword to the 1982 combined progress report of the Department of Land Resource Science and the Ontario Institute of Pedology. Members of these two units were physically separated during the past year when it became necessary, because of space reassignments at the University, for the O.I.P. members located in Blackwood Hall to move off campus to the Guelph Agriculture Centre, Ontario Ministry of Agriculture and Food at Ignatius College, just north of the city of Guelph. Several O.I.P. members remain at the University in the Land Resource Science Building. We plan to continue close coordination of activities but the physical separation of O.I.P. members and facilities makes this more difficult. The ideal arrangement would be one in which all O.I.P. and L.R.S. personnel and facilities were in the same building.

During this past winter, O.I.P. members prepared a major document entitled "Ontario Institute of Pedology - Beyond 1982". The current objectives, organization and program of the Institute were reviewed and comments made on desirable changes for the future. There were 19 specific recommendations made to improve the Institute. Discussions have been held between the cooperating agencies about the Institute and I look forward to a new formal agreement being signed which will assure the continuation of an effective coordination of the activities of federal, provincial and university soil scientists involved in or supporting the Ontario soil survey.

Faculty, staff and graduate students of the Department were involved in a large number of research projects during the year and reports on many of these are reported herein. Other projects will be reported in future issues of the Progress Report. One of the encouraging trends in our research is the effective joint participation in a project by scientists from different departments and from different disciplines within the departments. Two such groupings received major funding during the year from the Strategic Grants program of the Natural Sciences and Engineering Research Council. One project group led by Dr. M.H. Miller is doing research on modifying the soil-plant environment to maximize yield potential of maize and another, led by Dr. B.D. Kay, is investigating management of soil physical conditions under intensive corn cultivation.

We were pleased that the Department was able to fill two faculty positions during the past year with two very capable soil scientists. Dr. Pieter H. Groenevelt was appointed as an Associate Professor July 1, 1982 in the areas of applied soil physics and soil conservation. He already has developed and taught a new undergraduate course in soil and water conservation and has an active research program started in soil erosion and tillage effects in relation to soil structure. Dr. John L. Havlin joined the Department on February 21, 1983 as an Assistant Professor and as the extension coordinator for the department. He has begun research projects this spring in soil fertility management. We look forward to the contributions these new faculty members will add to the life and work of the department in future years.

It should be noted here that Professor T.H. Lane, while no longer having the responsibility for coordinating extension, ably served the Department as the coordinator of advisory services and extension in the department for nearly a quarter-century. At the beginning of that period his responsibilities included coordination of the land-use planning service. This service was provided by the Department of Soils from 1946 to 1962 and 1232 farms were planned in that period. Soil conservation practices such as improved rotations, grassed waterways, field rearrangement (including contour and field strips) were recommended for many of these farms. Interest in farm planning has been increasing again in recent years after a long period of little activity and Professor Lane is involved in advising on this as well as in other extension and teaching activities.

Professors D.E. Elrick and M.H. Miller were honoured this past year by being named Fellows of the Canadian Society of Soil Science at the annual meeting of the Society in Vancouver in July, 1982. Professor L.R. Webber, who retired from the Department in 1978, was appointed Professor Emeritus at the June, 1982 Convocation. Professor N.R. Richards was made a Fellow of the University and delivered the convocation address at the June, 1983 Convocation. Professor Richards retired from the Department in 1981; he served as Head of the Department from 1951 to 1962 and as Dean, O.A.C. from 1962 to 1972. These and other faculty, staff and O.I.P. pedologists continued to be very active in professional and international activities throughout the past year.

We are pleased that our graduate student numbers reached a record high in September 1982 and that so many have come with excellent backgrounds. This augurs well for future research, teaching and development activities in land resource science. During the year a complete review was begun of our graduate course program in soil science and new courses and new approaches to teaching our graduate courses in soil science are being considered.

Interest in our three undergraduate majors of earth science, resources management and soil science remains high and we are particularly pleased about the quality of students in the Department. Cooperative education programs of study were developed for the earth science and soil science students during the year.

I wish to acknowledge the financial support provided over the past year for our various programs. A large part of the funding is supplied by the Ontario Ministry of Agriculture and Food and we are most grateful for this sustained support year after year. We are also appreciative of the funds received from the Ministry of Colleges and Universities, the Ministry of Natural Resources and the Ministry of the Environment. Various federal agencies including Agriculture Canada, the Natural Sciences and Engineering Research Council, the Atmospheric Environment Service, Canadian International Development Agency and Atomic Energy Canada Ltd. provided support. Various industry groups contributed: Canadian Industries Ltd., Canadian Turfgrass Research Foundation, Fertilizer Institute of Ontario Inc., Imperial Oil Ltd., Ontario Corn Committee, Potash Corp. of Saskatchewan, Potash and

Phosphate Institute of Canada, and Sylvite Sales Inc. Many people in other departments at this university and at other locations helped in various ways with our teaching and research programs. We also are particularly grateful for assistance provided by individual farmers for permitting us to carry out experiments on their land in various locations.

Many readers will know already that Dr. B.D. Kay has been selected as the next Chairman of the Department of Land Resource Science and that he will begin his term July 1, 1983. Dr. Kay has been very active in teaching and research since joining the department in 1969. His research has been in physico-chemical reactions in soils, dynamics of frost heaving, and the influence of tillage and cropping practices on soil structure. Dr. Kay has demonstrated in many past projects an excellent ability to bring together ideas and people from various disciplines and departments to solve significant problems. I look forward to the leadership he will bring to this department and to land resource science in Ontario.

Many people have contributed to this 1982 edition of the Progress Report. I wish to thank particularly Kelly Beitz for the typesetting, Don Irvine for the layout work and Professor John Havlin for compiling and editing the report.

June 1983

K.M. King
Chairman, Department of Land Resource Science
Coordinating Director, Ontario Institute of Pedology

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DEPARTMENT OF LAND RESOURCE SCIENCE

Department of

Land Resource Science

University of Guelph

PERSONNEL AND INTERESTS

Faculty/Professional

K.M. KING, B.S.A. (Toronto), M.S., Ph.D. (Wisconsin), Professor and Chairman of the Department. Evapotranspiration and photosynthesis of field crops; environmental measurements. (Ext. 2447 and 2448)*.

T.E. BATES, B.S.A. (Toronto), M.Sc. (North Carolina State), Ph.D. (Iowa State), Professor. Fertilizer use and prediction of fertilizer requirements for field crops; micronutrient and metal availability; in charge of provincial soil testing laboratory. (Ext. 2452).

E.G. BEAUCHAMP, B.Sc.(Agr.), M.Sc. (McGill), Ph.D. (Cornell), Professor. Nitrogen in the soil/crop system; soil-plant relationships; fertilizers and plant nutrition. (Ext. 3239).

R.A. BOURBONNIERE, B.A. (Massachusetts), M.S. (Michigan), Ph.D. (Michigan), Adjunct Professor. Organic geochemistry.

M.E. BROOKFIELD, B.Sc. (Edinburgh), Ph.D. (Reading), Associate Professor. Palaeoecology, palaeontology, stratigraphy and tectonics. (Ext. 2654).

D.M. BROWN, B.S.A., M.S.A. (Toronto), Ph.D. (Iowa State), Professor. Climate related to land use planning, crop zonation, climatological reference stations, relationships of crop growth and development to climate and weather. (Ext. 2206).

S. BURNS, B.Sc. (Toronto), M.Sc. (Jerusalem), Teaching Associate. Instructional development for introductory soils. (Ext. 3393).

D.L. BURTON, B.Sc. (Dalhousie), M.Sc. (Guelph), Research Associate. NSERC. (Ext. 3057).

W. CHESWORTH, B.Sc., M.Sc. (Manchester), Ph.D. (McMaster), Professor. Geochemistry, petrology, mineralogy, geological mapping. (Ext. 2457).

D.E. ELRICK, B.S.A. (Toronto), M.S., Ph.D. (Wisconsin), Professor. Soil physics. (Ext. 3758).

L.J. EVANS, B.Sc. (Southampton), Ph.D. (Wales), Associate Professor. Soil genesis and clay mineralogy. (Ext. 3017).

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* Extension number at the University of Guelph. University of Guelph phone number is (519) 824-4120.
Beginning July 1, 1983 Professor B.D. Kay will be Chairman of the Department and may be reached at ext. 2447 and 2448. Dr. King's extension will be 2787.

T.J. GILLESPIE, B.Sc. (British Columbia), M.S.A. (Toronto), Ph.D. (Guelph), Associate Professor. Relationships of plant diseases and pests to weather; computer modelling of soil and air microclimates. (Ext. 2645).

W.A. GLOOSCHENKO, B.S. (California, Berkeley), M.S. (California, Davis), Ph.D. (Oregon), Adjunct Professor. Vegetation ecology and geochemistry of wetlands.

P.H. GROENEVELT, M.Sc., Ph.D. (Wageningen), Associate Professor. Applied soil physics. (Ext. 8748).

J.L. HAVLIN, B.S. (Illinois State), M.S., Ph.D. (Colorado State), Assistant Professor and Extension Co-ordinator. Soil fertility, soil chemistry, soil-plant relationships. (Ext. 2493). Commenced duties on Feb. 21, 1983.

S.G. HILTS, B.A. (Western Ontario), M.A. (Toronto), Ph.D. (Toronto), Assistant Professor. Joint appointment with University School of Rural Planning and Development. Natural resources management, environmental planning, land utilization. (Ext. 2702).

B.D. KAY, B.S.A., M.Sc. (Guelph), Ph.D. (Purdue), Associate Professor. Physico-chemical reactions in soils, dynamics of frost heaving, influence of tillage and cropping practices on soil structure. (Ext. 2487).

J.W. KETCHESON, B.S.A. (Toronto), M.S., Ph.D. (Illinois), Professor. Soil management for better tilth; tillage related to fertilizer use; runoff and erosion studies; manure and crop residues. (Ext. 2489).

G.E. KIDD, B.A.Sc., M.A.Sc. (Waterloo), Professional Assistant. Electronic instrument development; transport processes within and above plant canopies. (Ext. 3434).

T.H. LANE, B.S.A., M.S.A. (Toronto), Professor. Extension, soil management and land-use. (Ext. 2450).

E.E. MACKINTOSH, B.S.A. (Saskatchewan), M.Sc. (British Columbia), Ph.D. (Adelaide), Associate Professor. Half-time appointment. Soil survey interpretations; soils and land planning.

H. MARTIN, B.Sc.(Agr.) (Guelph), Crops Specialist. Plant Industry Branch, Ontario Ministry of Agriculture and Food. (Ext. 2454).

I.P. MARTINI, Doct. Geol. Sci. (Florence), Ph.D. (McMaster), Associate Professor. Sediments and sedimentary rocks, sedimentology, glacial and pleistocene geology. (Ext. 2488).

M.H. MILLER, B.S.A. (Toronto), M.S., Ph.D. (Purdue), Professor. Soil fertility, plant nutrition and land productivity. (Ext. 2482).

W.A. MITCHELL, Administrative Technical Officer. Controlled environment plant growth facilities. (Ext. 2484).

R. PROTZ, B.S.A., M.S. (Saskatchewan), Ph.D. (Iowa State), Professor. Soil genesis and classification; soil variability; soil clay mineralogy; mapping techniques and soil landform relationships. (Ext. 2481).

R.W. SHEARD, B.S.A. (Saskatchewan), M.S.A. (Toronto), Ph.D. (Cornell), Professor. Harvest management and fertilizer use for production, longevity and quality of perennial forage species. (Ext. 2491).

R.L. THOMAS, B.Sc., M.Sc. (Alberta), Ph.D. (Ohio State), Professor. The chemical characterization and reactions of soil organic matter. (Ext. 2459).

T.J. VYN, B.Sc.(Agr.), M.Sc. (Guelph), Lecturer, joint appointment with Department of Crop Science. Soil tillage and crop rotations. (Ext. 3397).

G.K. WALKER, B.Sc. (Reading), M.Sc. (Sask.), Ph.D. (California), Research Scientist. Land productivity modelling (NSERC). (Ext. 2484).

E.P. TAYLOR, B.Sc.(Agr.) (Guelph). Research Associate. Forest Pedology. (823-5700 Ext. 320)

G.W. THURTELL, B.S.A., M.S.A. (Toronto), Ph.D. (Wisconsin), Professor. Physics of soils, plant and atmosphere. (Ext. 2453).

Clerical Staff

P.E. Beirnes	-	Administrative Secretary. (Ext. 2448).
K.M. Beitz	-	Stenographer. (Ext. 2455).
L. Bissell	-	Clerk. (Ext. 2661).
D. Brenner	-	Stenographer. (Ext. 2455).
J.L. Cook	-	Clerk. (823-5700 Ext. 314).
S. Henry	-	Stenographer. (Ext. 2455)
M.J. Metcalf	-	Stenographer (part-time). (Ext. 2455)
F.I. Peer	-	Stenographer. (Ext. 2455).

Technical Staff

N. Baumgartner	-	Soil physics and soil management. (Ext. 8556).
I.A. Becker	-	Soil testing operations. (Ext. 2494)
J.F. Brown	-	Soil testing operations. (Ext. 2494)
J.C. Bryant	-	Soil management and plant nutrition plot work. (Ext. 2494)
L. Cosens	-	Plant analysis. (Ext. 2494).
E.L. Dickson	-	Runoff collection and analysis, research analytical laboratory. (Ext. 3025)
M.R. Evans	-	Computer data analysis. (Ext. 2458)
G.L. Fairchild	-	Soil and plant analysis, technical development. (Ext. 2494)
J.A. Ferguson	-	Soil management and plant nutrition plot work. (Ext. 2491).
E.F. Gagnon	-	Supervisor, Soil and Plant Analysis. (Ext. 2494).
A. Haw	-	Turf grass research technician. (Ext. 2491)
S.E. Hipwell	-	Soil classification. (Ext. 8170)
R.N. Hughes	-	Weather records. (Ext. 2458).
D.E. Irvine	-	Cartographer. (Ext. 3364).
B. Kingdon	-	Soil testing operations. (Ext. 2494)
J. Kwong	-	Analysis of sediments (NSERC). (Ext. 2480)
J. Lovcanin	-	Soil management and plant nutrition field plot. (Ext. 8157)
R.L. McCutcheon	-	Plant analysis. (Ext. 2494)
J.A. McLennan	-	Cartographer. (Ext. 3364)
S. Nolan	-	Remote Sensing Technician (Ext. 8175)
M.E. Ormond	-	Soil classification. (Ext. 8170)
L. Prong	-	Tillage and crop rotation research (Ag. Canada) (Ext. 3025)
R.E. Sweetman	-	Electronic instrument operations and plot work. (Ext. 2208).
D. Tel	-	Pollution control and waste management; soil and water analysis and research analytical laboratory. (Ext. 3507)
D. Thornton	-	Teaching technician. Resigned April 30, 1983.
W.G. Wilson	-	Pedology. (Ext. 8157)

LAND RESOURCE SCIENCE, EXTENSION ACTIVITIES

In cooperation with many departments and colleges within the University of Guelph, diploma agriculture colleges in Ontario, and numerous industrial and public concerns throughout the province, Land Resource Science(L.R.S.) conducts programs in Agrometeorology, Geology, and Soil Science. Through its research, teaching, and extension programs L.R.S. is committed to improving the quality of life in Ontario. However, the continuation of public and private financial support for the essential research activities can be justified only through an innovative and aggressive extension effort. Land Resource Science is dedicated to extend its research findings to the public and, wherever possible, implement more efficient and environmentally conservative food and crop production technologies.

The 1982 summary of L.R.S. extension and continuing education activities is shown below. A total of 1.33 man-years (292.7 days) was given to the L.R.S. extension effort. Extension consultations and talks represented 50% of the nearly 300 extension-days. Seven L.R.S. faculty members contributed 10% or more of their time to extension activities, while three faculty contributed greater than 25% of their time.

Land Resource Science will continue its responsibility to the public in the future and will strive for increased visibility as a leader in agricultural research and practice.

Summary of Land Resource Science Extension Activities for 1982-83.

Type of Extension Involvement	Total Extension Days	% of Total Extension Effort
Courses, Conferences, etc.	23.1	7.9
Continuing Education	7.1	2.4
Tours (groups)	18.8	6.4
Consultations	89.2	30.5
Talks (Speeches)	58.4	20.0
Publications	28.6	9.8
Radio-TV programs	9.1	3.1
Public Relations	41.1	14.0
Other Activities	17.3	5.9
TOTAL	292.7*	100.0

*Represents 1.33 man-years @ 220 days/year

J. Havlin

Soil Testing and Plant Analysis Service

Because the lowest number of samples reaching our laboratory is in June and July and as this also coincides, for most crops, with the change to fertilizer recommendations for the following cropping season the soil testing year for field samples is taken from July 1 to June 30.

A total of 52,295 farm samples were tested in 1981/82 (Table 1), similar to the number tested in 1979-80. A larger number were tested in 1980-81 chiefly due to an early spring which allowed many farmers to obtain samples. It appears that 1982-83 will be a record year (Table 2) in part due to the late onset of winter and the mild weather in late February and early March.

TABLE 1: Soil Samples Tested in the Ministry of Agriculture and Food Laboratory, Department of Land Resource Science, University of Guelph.

Source of Samples	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82
Farm	25,862	39,709	40,944	48,520	36,719	37,604	48,943	52,532	57,464	52,295
Garden	4,531	3,854	4,831	5,127	1,946	3,326	4,024	4,147	4,813	4,072
Canadian Forces Bases	853	941	852	923	860	942	828	908	829	893
Research (Federal, Provincial, University) and unclasified	7,303	11,913	8,207	7,533	10,422	17,202	18,644	14,274	16,521	16,432
Industry*	100	15	36	22	25	47	41	0	37	
TOTAL	38,659	56,432	54,870	62,125	49,972	59,121	72,480	71,861	79,664	73,692
No. of Users**	10,494	11,814	13,141	13,809	11,393	11,684	14,967	15,060	15,693	14,132

*A fee is charged for Industry samples for which the report does not go directly to local OMAF offices and to the farmer.

**This statistic is slightly inflated as users who submit samples more than once per year are counted more than once.

TABLE 2: Number of Samples Received Monthly from 1970-1980.

	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83
JULY	1,092	2,018	2,105	4,565	2,325	1,872	4,817	4,704	3,868	2,601	5,460
AUG.	2,744	2,496	2,730	3,668	3,368	4,680	7,522	2,574	4,134	3,813	4,293
SEPT.	2,926	3,432	3,988	4,212	3,908	5,696	4,825	5,978	5,360	4,757	5,936
OCT.	4,992	7,534	7,176	6,396	5,749	5,539	7,239	7,098	8,419	7,319	8,604
NOV.	6,362	13,730	11,389	8,502	9,672	10,296	18,398	13,884	14,586	14,820	14,742
DEC.	4,968	6,086	6,396	12,480	4,479	6,329	5,460	8,424	8,964	9,672	11,544
JAN.	2,340	3,276	4,446	3,432	1,677	2,646	5,854	7,410	6,899	9,113	8,267
FEB.	936	4,961	1,440	2,261	1,014	1,077	2,388	4,164	1,950	3,138	4,794
MAR.	1,872	1,638	1,404	2,886	2,340	1,097	2,418	1,560	5,204	2,253	
APRIL	3,900	2,262	6,724	5,687	5,919	4,602	4,836	7,953	10,124	7,758	
MAY	1,794	2,434	2,418	2,130	1,791	4,056	2,804	2,798	2,701	3,684	
JUNE	1,266	1,516	934	936	2,028	1,794	1,348	1,256	4,506	1,974	

TABLE 3: Numbers of samples tested and average tests for phosphorus, potassium, magnesium and pH from counties, districts and regions of Ontario from July 1, 1981 to June 30, 1982.

County or District	Samples Tested		Average Soil Test 1981/82			
	1971/72	1981/82	Phosphorus*	Potassium*	Magnesium*	pH
Algoma	281	325	18	121	163	6.0
Brant	1643	2349	37	121	168	6.8
Bruce	809	1667	19	128	199	7.4
Carleton	332	741	28	147	180	6.8
Cochrane N.	89	285	25	159	197	6.7
Cochrane S.	--	79	20	148	156	6.1
Dufferin	553	612	20	106	156	7.1
Dundas	149	639	15	127	192	6.9
Durham	621	1047	30	144	86	7.5
Elgin	922	2306	37	129	149	6.8
Essex	1087	1224	50	173	171	6.4
Frontenac	179	174	28	141	186	6.3
Glengarry	223	521	20	126	185	6.6
Grenville	370	295	22	102	181	7.0
Grey	545	1190	16	118	197	7.4
Haldimand	737	1305	19	147	193	6.4
Haliburton	16	49	14	58	57	5.7
Halton	569	711	31	146	178	6.8
Hastings	427	667	23	134	120	7.0
Huron	1144	2355	26	140	197	7.5
Kenora	37	38	12	209	199	6.1
Kent	2651	2861	38	162	171	6.8
Lambton	1156	1104	32	170	193	6.9
Lanark	234	359	17	113	180	6.6
Leeds	165	199	18	106	181	6.2
Lennox & Addington	153	429	17	151	181	6.7
Manitoulin	165	67	9	74	181	6.7
Middlesex	1326	2056	32	141	168	7.1
Muskoka	67	80	18	78	94	5.6
Niagara N.	433	513	43	203	175	6.2
Niagara S.	613	862	27	143	190	6.3
Nipissing	210	365	20	108	175	6.3
Norfolk	2304	4220	68	142	94	6.4
Northumberland	673	1112	34	105	78	7.3
Ontario	942	1706	29	135	98	7.6
Oxford	1242	2250	37	128	171	6.9
Parry Sound	161	126	18	107	123	5.7
Peel	391	512	27	123	147	6.8
Perth	940	2130	24	137	199	7.4
Peterborough	636	1099	23	100	81	7.5
Prescott	656	853	23	154	169	6.2
Prince Edward	394	625	33	149	133	7.1
Rainy River	419	478	16	180	196	6.7
Renfrew	526	434	19	132	158	6.3
Russell	294	382	16	112	174	6.5
Simcoe N.	915	1328	24	118	123	6.8
Simcoe S.	1215	1837	41	127	120	7.0
Stormont	189	293	20	107	147	7.0
Sudbury	231	455	29	112	173	6.1
Temiskaming	770	705	14	143	193	6.4
Thunder Bay	250	499	22	130	177	5.9
Victoria	478	1125	20	108	89	7.6
Waterloo	677	818	35	129	188	7.3
Wellington	1257	2195	24	121	195	7.4
Wentworth	928	1206	43	132	172	6.6
York	1739	650	28	109	104	7.5

*Phosphorus, potassium and magnesium values are read only up to 100, 400 and 200 respectively and this will affect the averages reported.

A test for zinc and manganese was initiated in September 1981 with a total of 1240 samples tested for these elements by the end of the year. More samples will be tested for these nutrients in 1982/83 but the proportion of samples with this test will still be relatively small.

A new lime requirement test was initiated in October 1982 and this will provide a more accurate measure of the amount of lime required for each individual soil than we have had in the past.

Interest in the service appears to be at least as high as in the past. Farmers realize that this service is particularly important when profit margins are small.

The number of samples tested for each county and district in the province and the average values of the tests for phosphorus, potassium, magnesium and pH are presented in Table 3. There is a general tendency for the counties using soil tests the most to have the highest phosphorus soil tests. These are undoubtedly the counties with the greatest use of fertilizers in the past. The number of samples tested for each county or district 10 years ago is also presented in Table 3 and the comparisons are interesting. The number of sampls decreased in areas where the acreage in crop production has tended to decrease such as Manitoulin, Parry Sound and York. Reasons for other changes are not so obvious. Some of the bigger users of soil tests; Norfolk, Wellington, Huron, and Bruce counties have doubled or nearly doubled their amount of soil testing during the 10 years while Kent, Lambton and Essex have not increased as much.

There is a marked increase in the number of plant analyses for field crops in 1981-82 (Table 4). The potential for increase is very

TABLE 4: Number of Samples of Plant, Manure and Other Organic Materials Analyzed by the Soil and Plant Analyses Service Laboratory (With the Exception of those from Land Resource Science Research, All Samples Were Analyzed on a Fee for Service Basis).*

Type of Material	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82
Plant Samples (Field)	150	82	49	156	317	175	263	359	307	634
Plant Samples (Greenhouse)	142	132	146	76	121	165	279	471	673	472
Manure, composts & sludge	66	39	71	82	57	80	115	276	486	372
Feeds**	95	870	1,861	3,306	3,878	4,373	5,293	5,846	5,585	5,978
Other***	58	308	260	179	303	501	437	915	842	1,855
Total Service Samples	241	1,431	2,387	3,805	4,676	5,299	6,387	7,867	7,893	9,311
Land Resource Science Research - mainly plants	4,046	5,344	4,294	4,243	2,745	3,555	4,471	3,440	3,638	2,947
Total Samples	4,287	6,775	6,681	8,048	7,421	8,854	10,858	11,307	11,531	12,258

* The period reported is May 1 to April 30.
** Analyzed for the Department of Animal and Poultry Science as part of the feed analysis service.
***Mainly plant tissue from other university departments.

great and we can only hope that this is the beginning of a trend for increased use of this service. Manure analysis appears to have leveled off after several years of increase.

Analyses available in the laboratory are listed in Table 5.

The laboratory continues to have a large number of tours and visitors as part of the ongoing process of informing the agricultural community and others about soil testing and the services available (Table 6).

TABLE 5: Analyses Available through the Soil Testing and Plant Analysis Laboratory, Department of Land Resource Science, University of Guelph, 1982-83.

Material	Analyses	Availability	Cost/sample
1. Farm soils	plant available phosphorus, potassium and magnesium + pH (calcium and salt concentration* if required)	all times	no charge - cost borne by Ontario Ministry of Agriculture and Food
2. Home garden and lawn soils	as above	all times	$1.00
3. Soil	available manganese and zinc	all times	$3.00
4. Soil	organic matter	all times	$5.00
5. Soil	texture (% sand, silt and clay)	enquire at lab	quoted on request
6. Soil	other analyses may be available for groups of over 20 samples	enquire at lab	quoted on request
7. Liming materials	calcium and magnesium content, neutralizing value, particle size analysis	all times	$15.00
8. Dried plant and other organic materials**	nitrogen, phosphorus, potassium, calcium, and magnesium	all times	$11.00
9. Dried plant and other organic materials**	boron, copper, magnanese and zinc	all times	$11.00
10. Dried plant and other organic materials**	9 elements listed in 8 and 9	all times	$14.00
11. Manure and other moist organic matter	nitrogen, phosphorus, potassium, calcium, and magnesium and % D.M.	all times	$13.00
12. Manure and other moist organic matter	boron, copper, manganese and zinc	all times	$13.00
13. Manure and other	9 elements listed in 11 and 12	all times	$16.00
14. Dried plant, manure, and other organic materials	Sulfur, sodium, iron	enquire at lab	quoted on request

* electrical conductivity
**analysis of feed samples is arranged through the Department of Animal and Poultry Science.

TABLE 6: Tours of the Soil Testing and Plant Analysis Laboratory, Department of Land Resource Science, May 1, 1981 to April 30, 1982.

Type of Visitor	No. of Tours	Aprrox. No. of Visitors
Farmers and Junior Farmers	6	120
New Ag. Reps.	1	17
Professional Agrologist	2	28
High School Students	2	60
Community College Landscape and Ecology Classes	1	30
Students from Colleges of Agric. Technology	1	25
Students other Universities	1	84
Agricultural Diploma Students Univ. of Guelph	12	200
Agricultural Degree Students Univ. of Guelph	8	180
Landscape Architecture Students Univ. of Guelph	1	20
Total	35	764

T.E. Bates and E.F. Gagnon

Weather & Climate Information 1982

Observations continued at the Elora Research Station and the Arboretum weather station, with summarized monthly data being returned to the Atmospheric Environment Service. Summaries of data were distributed locally to users on campus and to numerous individuals and businesses off campus.

There was a steady demand for meteorological information for various research projects and planning needs, with heating degree-day data requested most frequently. Data was also provided for the efficiency testing of a passive solar house, to pinpoint storm surges in the Guelph sewer system and for planning purposes in the construction of a swimming pool.

Rainfall pH was measured at Elora this year as in 1982; a mean value of pH 5.1 was obtained from 54 observations, this compares to a mean of pH 4.9 in 1981. Extremes in 1982 were pH 3.7 on October 6 and pH 6.5 on April 2.

1982 Weather Summary - Elora and Region

Climatic averages for the period 1951-1980 were published in April 1982 by the Atmospheric Environment Service, and the 1982 weather will be compared to these normals. See Figures 1 and 2 for detailed temperature data.

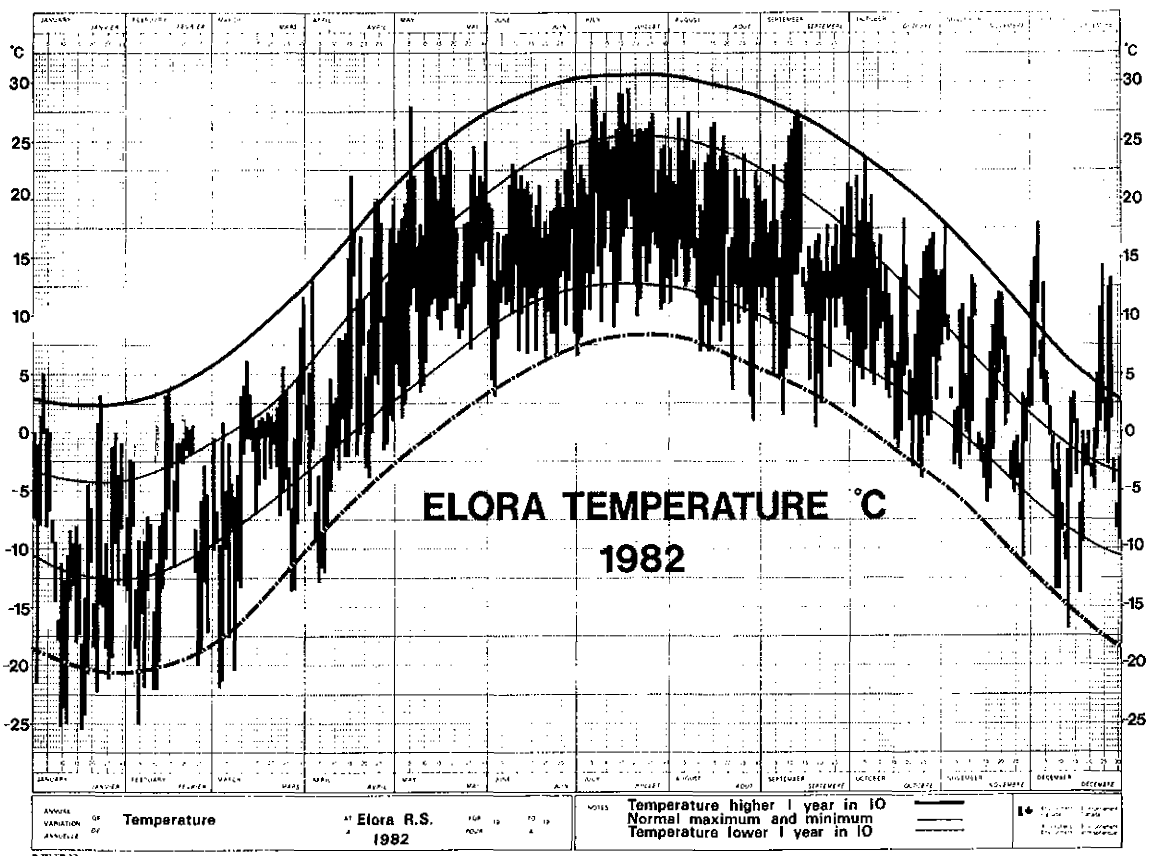

Figure 1. Daily air temperature fluctuations at the Elora Research Station in 1982.

The mean annual temperature was 6.0°C at Elora in 1982, which is average. However, the mean maximum temperature for the year was 0.4°C below normal at 10.7°C, and the minimum 0.4°C above normal at 1.3°C. This depression of daytime temperatures, coupled with warmer than usual nights, i.e. a smaller than normal daily temperature range, is symptomatic of high cloudiness, and indeed the 1982 total sunshine of 1889 hours was 2.5% below normal. With increased clouds came increased precipitation, including several heavy summer rains.

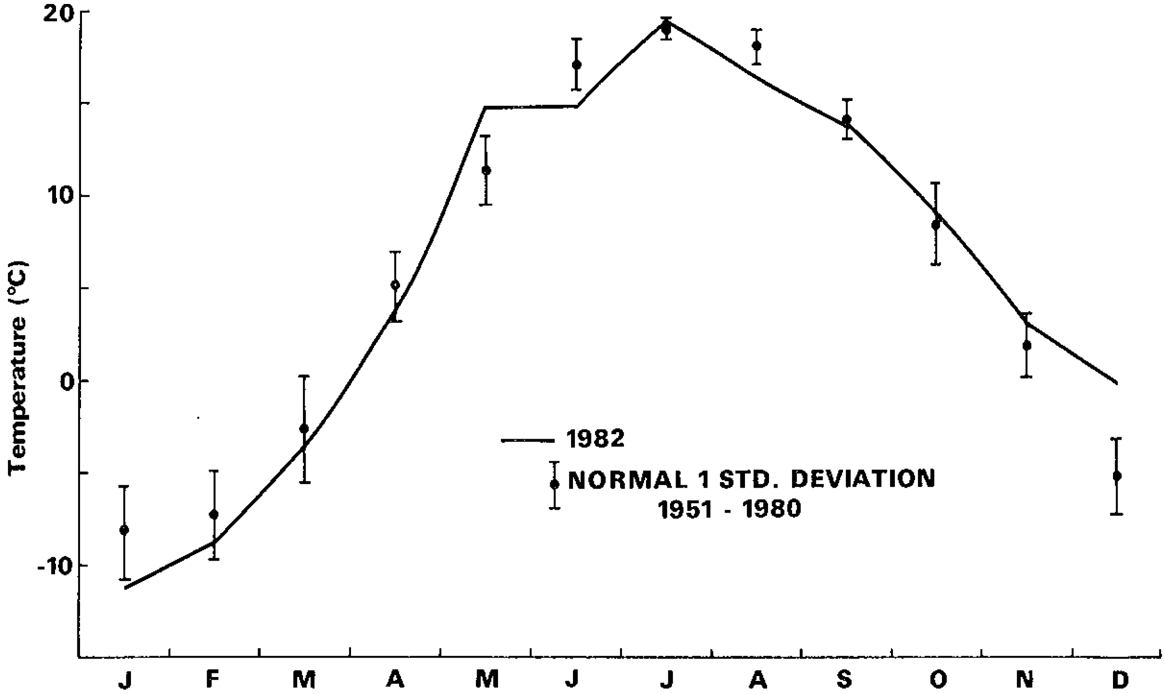

Figure 2. Monthly mean temperature at Elora in 1982 compared to normal temperatures (±1 STD. DEV.).

The rainfall of 94.5 mm on September 14th, most of which fell in three hours, was the greatest daily rainfall recorded at Elora since records began in 1969. The total annual precipitation of 1040.6 mm was 24.5% above normal and as such was definitely the wettest year since 1968 at Elora (Fig. 3). The annual total at Guelph Arboretum was

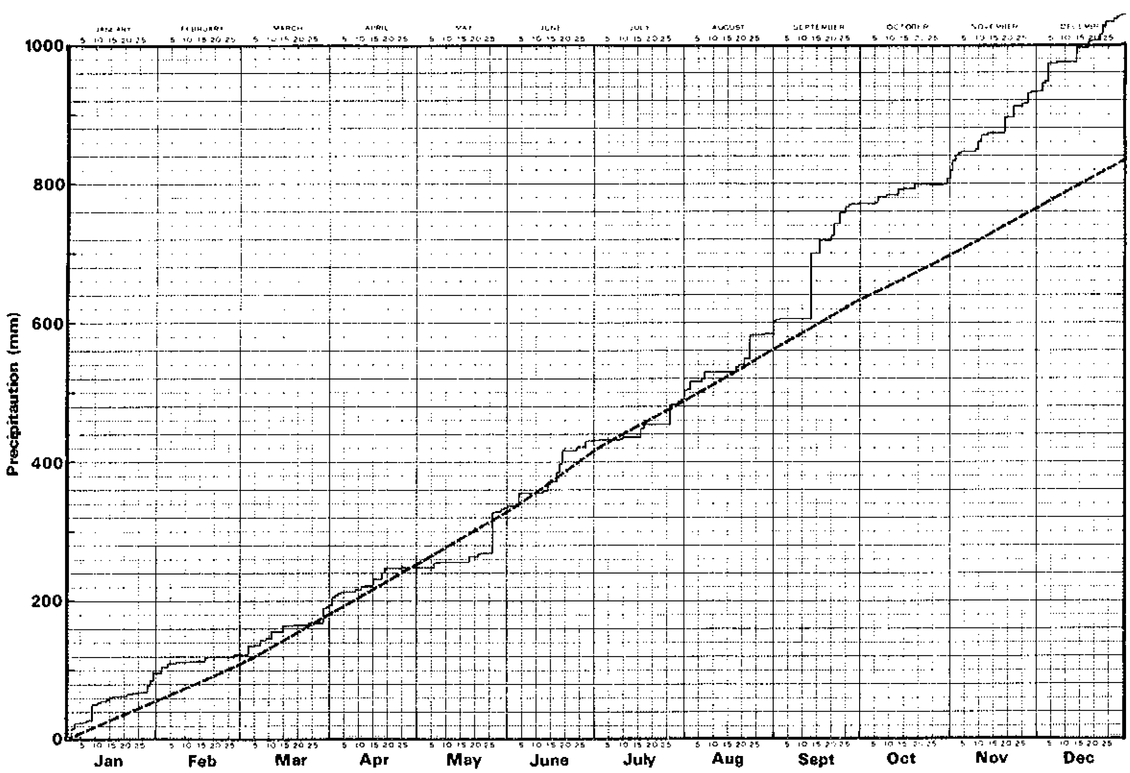

Figure 3. Accumulated precipitation at Elora in 1982 (dashed line represents normal accumulation).

1065.6 mm, or 41.95", which was the second wettest year on record since 1881, only 1926 being wetter, with 1073.4 mm. Additionally, Guelph recorded its wettest June (since 1881) with 186.6 mm (previous record 175.0 mm in 1967), and the June mean maximum temperature of 20.4°C tied with 1926 as the coolest ever recorded.

At Elora, following a winter with frequent outbreaks of severe cold with strong winds, soil temperatures fell to their lowest levels since the start of records in 1969. Soil froze at 50 cm on Jan. 23rd, and remained frozen until April 15th; freezing temperatures at this level had never been recorded before. The minimum value at 300 cm of 4.3°C at the end of April was also 0.4°C lower than the previous lowest. For summarized climatological data see Tables 7 and 8.

Table 7: Additional Climatological data at Elora Research Station for 1982.

	Mean daily max °C	Mean daily min °C	Highest max °C	Lowest min °C	Days of Air Frost *	Days of snow Δ	Days With > 0.2mm precip.	Mean Wind-speed Kmh
January	-6.5	-15.6	5.1	-25.5	30	25	20	21.9
February	-5.1	-12.6	3.6	-25.0	28	18	10	16.5
March	0.6	-7.6	11.7	-21.9	30	14	14	17.5
April	9.2	-1.4	22.1	-12.7	17	8	13	20.9
May	20.4	9.3	27.8	1.3	-	-	13	12.0
June	19.6	10.1	26.0	2.7	-	-	13	12.0
July	25.3	13.7	29.7	6.6	-	-	8	11.0
August	22.0	10.8	27.5	0.9	-	-	11	10.6
September	18.8	8.9	27.6	0.4	-	-	16	10.4
October	14.4	3.6	23.9	-3.9	6	2	13	12.4
November	6.2	-1.3	16.8	-9.4	17	10	11	14.5
December	3.2	-3.5	18.0	-16.9	19	10	18	17.3
Year	10.7	1.3	29.7	-25.5	146	87	166	14.7

*Air Frost - minimum temperature in screen - 0.1°C or lower.
Δ Day of snow - a day when snow, or rain and snow mixed was observed to fall, however small the amount.

Table 8: Climatological data at the Elora Research Station, 1982.

	Daily Mean temp. (°C)	Corn Heat Units	Degree Days >5 °C	Degree Days <18°C	Rainfall mm	Snowfall cm	Total Precip.	Total Sunshine
January	-11.1			900	19.7	95.3	95.5	88.2
Δ	-2.9			+92	78.0	278.0	164.0	107.0
February	-8.9			752	0.4	26.6	25.0	113.9
Δ	-1.6			+36	2.0	92.0	51.0	103.0
March	-3.5		3	665	44.8	29.1	73.7	115.5
Δ	-0.8		-3	+25	95.0	134.0	99.0	87.0
April	3.9		64	424	46.2	9.2	55.3	228.8
Δ	-1.2		0	+38	75.0	139.0	79.0	117.0
May	14.9	388	306	102	84.1		84.1	212.3
Δ	+3.5		+103	-113	108.0		108.0	92.0
June	14.9	510	297	98	98.1		98.1	177.2
Δ	-2.2		-66	+37	113.0		113.0	70.0
July	19.5	736	451	12	59.2		59.2	307.6
Δ	+0.4		+13	-15	81.0		81.0	110.0
August	16.4	603	356	63	92.7		92.7	239.3
Δ	-1.7		-51	+23	128.0		128.0	97.0
September	13.9	448	266	132	188.2		188.2	144.4
Δ	-0.3		-11	0	264.0		264.0	91.0
October	9.0	161	137	278	36.5		36.5	156.1
Δ	+0.5		+11	-18	57.0		57.0	122.0
November	3.1		40	447	117.2	6.1	124.8	63.2
Δ	+1.2		+15	-33	217.0	46.0	190.0	98.0
December	-0.2		28	563	98.5	19.8	115.3	42.5
Δ	+5.0		+26	-155	276.0	57.0	161.0	76.0
Year	6.0	2846	1948	4436	885.6	186.1	1048.4	1889.0
Δ	0.0	+109	+36	-80	129.0	131.0	125.0	97.0

Δ – Difference from 1951-80 average, expressed as a percentage for rainfall, snowfall, total precipitation and sunshine.

Monthly Weather Details for 1982 - Elora and Region

January

This was a very cold month, with several severe cold waves, during which effective temperatures fell below -40°C due to very high wind-chill factors. The most intense were those on the 10th and the 17th. The monthly minimum temperature of -25.5°C was recorded early on the 17th, a very low value bearing in mind that the mean wind speed at the time of the minimum was 42 km/h; the daytime maximum on this day was -22.7°C. A few days afterward (23rd) the soil froze at 50 cm for the first time since at least 1969. Snowfalls were frequent, in fact all but two days in the month had some snowfall, and heavy snow fell in a notable storm on 31st, which blocked many roads and was the cause of numerous traffic accidents; 18.8 cm fell at Elora. Precipitation was considerably above average, with almost three times the normal snowfall. Sunshine was near average.

February

This month was very cold at the start, but above-freezing temperatures were featured in the latter part of the month. The snowpack increased considerably in depth to over 35 cm, with some significant snowfalls in the first 10 days. Rain was virtually absent, only 0.4 mm being recorded on the 18th. The month ended with very cold weather again.

March

The first 9 days were very cold, with night temperatures below -20°C on several occasions. More snow fell during this period bringing the level depth on the ground to 46 cm by the 9th. The latter part of the month featured average to mild temperatures, although snow covered the ground the entire month.

April

Bitterly cold weather set in, in the first week, and the 6th was the coldest April day in 140 years at Toronto, and over much of the south. The maximum at Elora reached only -8.6°C, which would be a cold day in January. From then on, however, a vast rise in temperatures occurred, so that by the 16th the maximum reached 22.1°C (a normal early June value); a rise of over 30°C in maximum temperature in 10 days (Fig. 1). The second half of the month was mild and pleasant with many sunny days. It was a drier and sunnier month than normal, and overall a little cooler than normal.

May

Temperatures and rainfall averaged considerably above normal this month, although the bulk of the month's rain fell in a 57 mm downpour on 27th. The first two weeks were quite dry and sunshine was below normal.

June

This was a disappointing month, with very cool temperatures; in fact the mean temperature was no higher than in May (Fig. 2). Additionally, rainfall was frequent, and the monthly total of 186.6 mm was the highest on record at Guelph for June since 1881. Sunshine was well below normal, and the total of 177 hours at Elora was less than was received in April (228.8 hrs).

July

Conditions returned to near normal this month. Warm temperatures and abundant sunshine helped corn, short at the start of the month after the poor June, recover from lost time and put on some growth. It was the sunniest July at Elora since 1975.

August

Temperatures fell below normal this month and rainfall was above average, resulting in a cool summer season overall (the coolest since 1929). At Toronto the highest temperature of the season was 30°C, the lowest such value for the season in a century. On August 29th a large amount of the Southern Ontario tobacco crop was lost due to frost; the temperature fell to -0.6°C at Guelph Arboretum.

September

Excessive rainfall was the most notable feature of this month, most of which came in the second fortnight following a fine warm spell during the 10th-14th. A torrential downpour dropped 94.5 mm of rain at Elora on the 14th, the greatest daily rainfall recorded there since 1969 (Fig. 3). Overall, temperatures and sunshine were a little below normal.

October

This month was basically drier, warmer and sunnier than normal, with many warm days in the first two weeks. Light frosts became regular after the 16th.

November

November was again warmer than normal, but also wetter, with six daily rainfalls in excess of 10 mm. Only November 1979 was wetter in the last 12 years at Elora. Temperatures fell steadily later in the month, although there was no really severe weather. Total sunshine was close to normal.

December

This was a record-breaking month for temperature, with the mean value equalling the highest on record across most of Southern Ontario for over 100 years (Figs. 1 & 2). In particular the extreme maximum temperatures were new records almost everywhere. The mildest days were 2nd, 3rd, 25th and 28th. On the 3rd mercury rose to 18°C at Elora, and to 19.1°C in Guelph. Temperatures in excess of 20°C were reached in the Niagara Peninsula, an average value for mid/late September. Cold weather did persist from the 8th to 13th however, and there was a significant snowfall on the 19th. This snow was all gone by Christmas, and the 25th was the mildest Christmas Day in Toronto since 1840. Only two years before, in 1980, one of the coldest Christmases was experienced, the temperature difference between these two years was approximately 47°C in the Toronto area. Precipitation was above normal in December, while sunshine was below normal.

R. Hughes

AGROMETEOROLOGY RESEARCH

Response of Field Corn to Irrigation

Field corn was irrigated four times between mid-July and mid-August, 1982 in an experiment conducted at the Elora Research Station. Treatments in the experiment included three hybrids, two nitrogen levels (40 and 100 kg/ha), two plant populations (54,000 and 75,000 plants/ha), and from 0 to 75 mm of water applied with overhead sprinklers using the line* method. A significant positive response to irrigation resulted for silage (Table 9). Grain yields were not increased significantly with irrigation, although the lower yielding variety showed some benefit (Table 10). Table 11, 12, 13 and 14 summarize the yield responses for the high irrigation levels vs. unirrigated plots for the two N levels and plant densities.

Silage yields were increased between 1 and 9 percent, and grain yields 0 to 8 percent with irrigation, depending on hybrid (Tables 9 and 10). As in the past three years, the lowest yielding hybrid(s) showed the largest response to added water. Both grain and silage yield showed a significant increase to added N (Table 11 and 12). An increase in plant population significantly increased grain and silage yield (Table 13 and 14).

Yields in 1982 were the highest of the four years in which this experiment has been conducted, and this was the first year that no significant grain yield increase occurred. The reason for this may be partially explained on the basis of the length of the longest dry spell. Comparisons for the last five years are given in Table 15. The shortest (long) dry spell in the five years occurred in 1982, when the response to irrigation was insignificant for grain corn. This dry spell occurred before July 17th, and apparently affected the earliest hybrid more than the other two. After mid-July rainfall was plentiful, although two irrigations were applied after July 20th as shown in Table 16. These irrigations had no effect (unless they reduced yields) as demonstrated by the yield responses obtained.

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*The "line" method randomizes treatments on each side of the irrigation line providing two of the replications. Three lines were used in 1982 to provide area sufficient for four replications in all of the above treatments.

Table 9. Corn silage yields (D.M. in tonnes/ha) for irrigated and unirrigated plots for three hybrids grown with two N-levels and two plant populations at the Elora Research Station in 1982.

Treatment	Hybrids			Ratio	
	Pride 1108	Co-op S259	P.A.G. SXIII	SXIII / 1108	SXIII / 5259
Unirrigated	9.4	11.1	11.8	1.26	1.06
Irrigated	10.2	12.1	12.0	1.18	1.19
Irrigated/Unirrigated	1.09	1.09	1.01		

Table 10. Corn grain yields (t/ha) for irrigated and unirrigated plots for three hybrids grown with two N-levels and two plant populations at the Elora Research Station in 1982.

Treatment	Hybrids			Ratio	
	Pride 1108	Co-op S259	P.A.G. SXIII	SXIII / 1108	SXIII / 5259
Unirrigated	5.2	6.5	6.6	1.27	1.02
Irrigated	5.6	6.6	6.6	1.18	1.00
Irrigated/Unirrigated	1.08	1.02	1.00		

Table 11. Corn grain yields (t/ha) for irrigated and unirrigated plots for two N-levels with two populations and three hybrids at the Elora Research Station in 1982.

Treatment	Nitrogen applied (kg/ha)		Ratio 100/40
	40	100	
Unirrigated	5.9	6.4	1.08
Irrigated	6.1	6.5	1.07
Irrigated/Unirrigated	1.03	1.02	(1.10)*

*Ratio: (100 kg/ha of N with irrigation/40 kg/ha of N without irrigation)

Table 12. Corn silage yields (D.M. in t/ha) for irrigated and unirrigated plots for two N-levels with two populations and three hybrids at Elora Research Station in 1982.

Treatment	Nitrogen applied (kg/ha)		Ratio 100/40
	40	100	
Unirrigated	10.5	11.1	1.06
Irrigated	10.9	12.0	1.10
Irrigated/Unirrigated	1.04	1.08	(1.14)*

*Ratio: (100 kg/ha N with irrigation/40 kg/ha N without irrigation)

Table 13. Corn silage yields (D.M. in t/ha) for irrigated and unirrigated plots for two populations with two N-levels and three hybrids at the Elora Research Station in 1982.

Treatment	Population (plants/ha)		Ratio 75/54
	54,000	75,000	
Unirrigated	10.2	11.4	1.12
Irrigated	10.8	12.8	1.19
Irrigated/Unirrigated	1.06	1.12	(1.25)*

*Ratio: 75 M pl/ha with irrigation/54 M pl/ha unirrigated

Table 14. Corn grain yields (tonnes/ha) for irrigated and unirrigated plots for two populations with two N-levels and three hybrids at the Elora Research Station in 1982.

Treatment	Population (plants/ha)		Ratio 75/54
	54,000	75,000	
Unirrigated	6.0	6.2	1.03
Irrigated	6.0	6.5	1.08
Irrigated/Unirrigated	1.00	1.05	(1.08)*

*Ratio: 75 M pl/ha with irrigation/54 M pl/ha unirrigated

Table 15. Information on the early summer dry spells* that occurred at the Elora Research Station in 1978, 1979, 1980, 1981 and 1982.

	1978	1979	1980	1981	1982
Dry Spell -					
- began	June 13	June 10	June 21	June 23	June 22
- ended	Aug. 15	July 29	July 21	July 28	July 17
Duration (days)*	64	50	30	36	25
Rain during dry spell	41 mm	36 mm	39 mm	38 mm	20 mm
Normal rainfall in the above period	169 mm	132 mm	80 mm	95 mm	66 mm

*Days from last major rainfall to first one following dry period.

Table 16. Amount of irrigation water (mm) applied in 1982 at the Elora Research Station as measured at specified sites perpendicular to the irrigation line.

Date 1982	Sites**			
	3 m	6.8 m	11.6 m	18.1 m
July 13	22.0	14.9	5.8	0.0
July 16	16.4	12.5	3.8	0.0
July 21	21.5	14.0	4.3	0.0
Aug. 19	15.6	11.2	3.0	0.0

**Sites are defined by distance from irrigation line in metres.

D.M. Brown

Response of Irrigated Field Corn to Split Application of N

An experiment was conducted on a Fox loamy sand at the Cambridge Research Station during the summer of 1982 to determine if split applications of N increased corn yields more than preplant applications. Urea-N was applied at rates of 0, 75, 150 and 225 kg N/ha as preplant, split and 12-leaf treatments. Plants were grown at two populations of 49,200 and 72,200 plants/ha with and without irrigation.

The weather records show that the total rainfall for May to September 1982 was 571.1 mm compared to 382.3 mm averge (1951-1980)[1] for the same period. This indicated that the 1982 cropping season was wet, although the month of July was relatively dry having slightly below average rainfall. The total amount of irrigation water applied through the drip system was 116.2 mm, most of it in July.

A summary of corn grain yield response is presented in Table 17. There was a significant increase in corn grain and whole plant dry matter yields as well as % N content of the grain due to increasing levels of N. The higher rates gave higher yields but efficiency of N utilization and the largest increase in yield per each increment of N were obtained with the lowest N rate.

Table 17.

Rate and time of N application			Corn grain yield		
Preplant	Split	12-leaf	A	B	C
---------- kg N/ha ----------			---------- kg/ha ----------		
0	0	0	3709a	3647a	5389a
75	-	-	5824bc	6191c	6427ab
-	37.5	37.5	5343b	6588bcd	6711b
-	-	75	5523b	5809b	7320bc
150	-	-	6886bc	7142cd	7625bc
-	75	75	6905bc	7348cd	7470bc
-	-	150	6249bc	6776cd	7196bc
-	75	150	6836bc	7610d	8157c

PLSD (0.05) = 1272
A = Low population without Irrigation
B = Low population with Irrigation
C = High population with Irrigation

Mean yields within a column followed by the same letter are not different at the 5% level of significance.

[1]Canadian Climate Normals, 1951-1980, Ontario. A Publication of the Canadian Climate Program.

The effectiveness of the different times of N applications to increase corn grain yield indicated that preplant applications of N tended to be equivalent to split applications. However, a slight yield advantage of 2.2% was associated with split applications of N. An overall yield reduction of 7% resulted from N applied at the 12-leaf stage, but N concentration of the grain was significantly increased by split and 12-leaf treatments compared to preplant application of N.

Although the 1982 growing season was relatively wet, irrigation had a marked effect on yield - increasing corn grain yield by 9.2% and whole plant dry matter yield by 11.0%. A greater part of this response to irrigation was probably obtained during the dry spell in July. Apparent fertilizer N recovery was lower for the irrigated treatments than the unirrigated treatments. The latter also contained higher N concentration in the grain.

The whole plant dry matter and corn grain yields were increased by 13.0 and 7.7%, respectively, by increasing the population to 72,200 plants/ha. The high plant population recovered the greatest amount of applied N but the concentration of N in the grain was not different from that of the irrigated low plant population.

It can be concluded from the 1982 experiment that split applications of N would not confer significant corn yield advantage over the preplant applications under similar soil-climate situations in Southern Ontario.

C. Okoye and D.M. Brown

Studies of Ozone Flux and Leaf Temperature in Phaseolus vulgaris L.

Several aspects of energy and gas exchange between leaves and the environment have been studied. These include the development of a small infrared thermometer for remote sensing of leaf temperatures, the modelling of the energy balance of a leaf in a cuvette, and relationships between ozone flux and visual injury to *Phaseolus vulgaris*.

A new infrared thermometer that allows accurate, non-contact leaf temperature measurements has been constructed. This method of remotely sensing leaf temperature is superior to the use of thermocouples since no contact with the leaf is necessary and temperature is averaged over an area of the leaf. The small size and low cost make this infrared thermometer practical for use in leaf cuvettes, in plant chambers and in the field.

An energy balance model has been developed that predicts leaf temperature, air temperature and water vapour pressure inside a given leaf cuvette for a specific energy input. This model will help physiologists to design cuvettes and is useful for adjusting radiation, temperature and humidity inputs to achieve a desired cuvette environment. The model predictions are particularly instructive for understanding plant-environment interactions.

A leaf cuvette system has been built for reactive gas exchange studies. Special features of the design ensure that only a small portion of the total flux of gases is absorbed by the cuvette walls, which makes it ideal for work with very reactive gases such as ozone.

Data from this system indicate that the use of either ozone concentration or dosage (concentration x time) is insufficient to predict when foliar injury will occur to Phaseolus vulgaris (Fig. 4a). The onset of visual foliar injury is found to be dependent on ozone flux density and time (Fig. 4b). The length of exposure period required for visual injury to occur is found to be very sensitive to leaf diffusive conductance.

Visual injury response to ozone flux density and length of exposure has been documented for 14-day old plants of Phaseolus vulgaris cv. Seafarer and cv. Gold Crop. The latter is an ozone resistant cultivar and was found to have an absolute ozone flux density threshold below which it did not become injured. Above this threshold, it had a similar response to the ozone sensitive cultivar Seafarer. Mature fruiting plants and 14-day old Seafarer plants exhibited identical responses to ozone flux density. The flux densities used in the cuvette studies were similar to those encountered in the field although the ozone concentrations employed were higher to counteract lower leaf diffusive conductance.

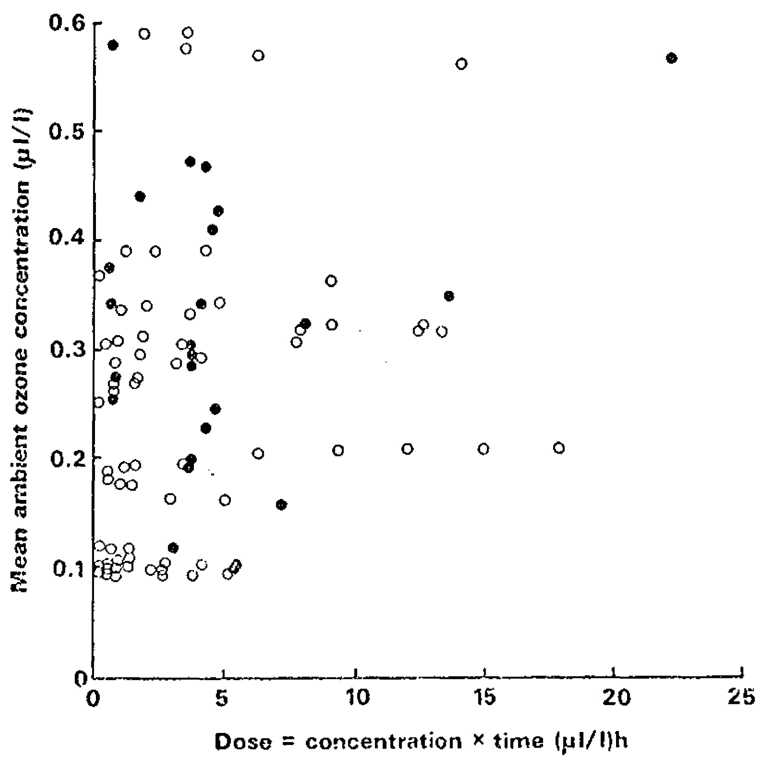


Figure 4a: Reaction of Phaseolus vulgaris leaves to ozone. Open circles are non-damaged plants, closed circles are damaged. Damage was not related to ozone concentration or concentration x time (dosage) (Fig. 4a). Discrimination between damaged and undamaged plants was greatly improved when ozone flux density was used (Fig. 4b; next page) instead of concentration.

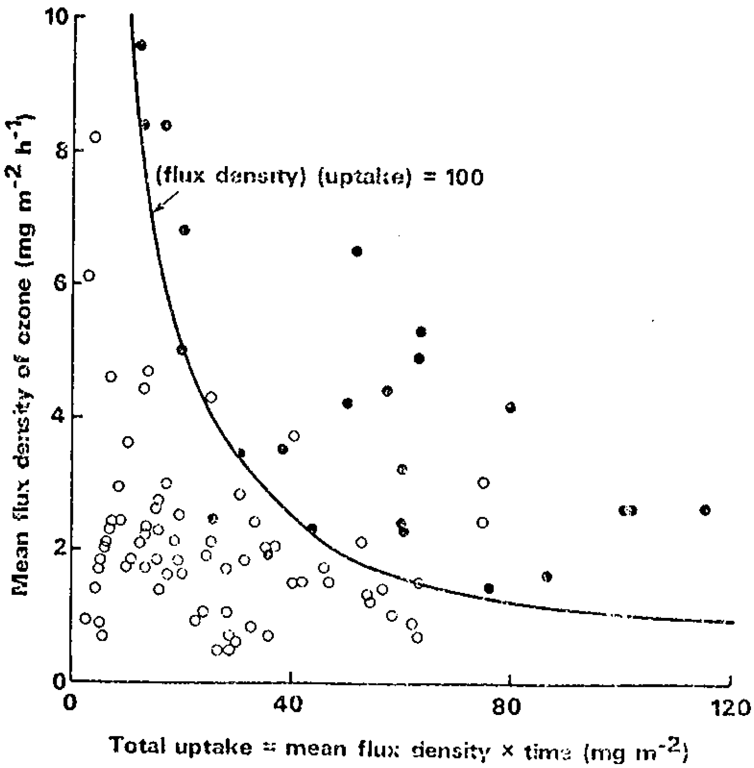


Figure 4b: See Fig. 4a for description.

B.D. Amiro and T.J. Gillespie

Evaporation of Raindrops From Leaves

Leaf surface wetness duration together with suitable leaf temperatures are often the agents responsible for spore germination and plant disease development. This is why evaporation rates of the water deposited on soybean and on corn leaves either by rainfall or by sprinkler irrigation were predicted and compared with field observation.

Two energy budget models were used, the first one using the assumption of a uniform film of water evaporating and the second model using the assumption of hemispherical water droplets evaporating from a dry leaf. The film model over-predicted the evaporation by about 3 times while the drop model under-predicted the evaporation of droplets by a similar factor. The correct value of the transfer coefficients for heat and water vapour was uncertain due to the high levels of turbulence in the field for both models and due to the presence of the leaf near the droplets in the second model. Further work is needed to determine an adequate functional form of the Nusselt number for hemispheres on flat plates under field conditions.

M. Leclerc and T.J. Gillespie

Transpiration Efficiency of Maize

Crop growth modelling efforts can benefit substantially if crop production can be accurately related to transpiration. Although previous work has indicated that maize transpiration efficiency (TE), when normalized for saturation deficit (Δe), is independent of climate, there are few data available with which to determine the TE constant. Further, the effects of soil nutrient status and water content on TE have received little attention. Soil water and nutrient status variables were incorporated into the 1982 study, which is otherwise similar to previous work (Walker et al., 1981 Progess Report).

The experiment, conducted at the Elora Research Station, consisted of four treatments replicated twice, giving eight plots. The treatments were the four combinations of soil surface either covered (C) or not covered (NC) with plastic, and either high (H) or recommended (R) fertility. Transpiration for each plot was determined from precipitation data, evaporimeter measurements of evaporation from the soil surface, estimates of leaf interception of precipitation, and changes in root zone water storage determined with the neutron scattering technique. Changes in root zone storage were calculated using data taken within and between the rows.

Estimates of "effective" nonintercepted precipitation for the plastic covered plots were made by comparing the changes in soil water contents for C and NC plots before and after a significant rainfall. This averaged 46% of the increase in water content in the NC profiles, and is in good agreement with stem flow estimates for maize (J. Steiner, pers. comm.).

Results of TE calculations for a substantial part of the growing season are presented in Table 1. Analysis of variance indicated no significant differences among treatments. The mean TE for the experiment is 0.078 (±0.010) mb. This compares with the 1981 calculations of 0.067 and 0.085 for maize grown at two densities. Tanner and Sinclair (1979, unpublished) gave figures ranging from 0.082 to 0.12 mb for maize TE, but their calculations included estimates for root growth. Subtracting their root growth estimates, their TE calculations for shoot growth would range from 0.068 to 0.1 mb, which agrees with the range of values in Table 18.

Table 18. Transpiration Efficiencies for Maize Determined for a 50-day Period Starting 8 July, 1982.

Treatment	Rep	TE
		mb
NC-H	1	0.075
	2	0.064
NC-R	1	0.076
	2	0.077
C-H	1	0.073
	2	0.093
C-R	1	0.093
	2	0.076

These results tend to confirm Tanner and Sinclair's conclusion that maize TE is genetically determined and cannot be increased by management practices. The effect of stresses arising from nutrient or water limitations requires further examination.

G.K. Walker, M.H. Miller and D.M. Brown

Greenhouse Studies on Alfalfa Transpiration Efficiency

Many agronomic studies have shown a strong correlation between evapotranspiration (evaporation from the soil + transpiration) and plant production. Of more interest to the plant physiologist, however, is the relation between transpiration (T) and production (P). Recent studies using leaf chambers have tended to confirm earlier work with whole plants, suggesting that for a given crop a relation of the form TE = $P \cdot \Delta e/T$ should apply, where Δe is the crop-to-air water vapour pressure gradient, and TE is the transpiration efficiency for the crop. Maintenance of a constant TE depends on the ability to regulate substomatal CO_2 at a constant concentration.

Potassium (K) is known to be important in controlling stomatal aperture, but it is not known if it influences TE. An experiment was conducted in which soils varying in K-supplying power were continuously cropped with alfalfa for 8 harvests with no K additions. A range of tissue K levels was anticipated, which could help determine if, and to what extent, TE depends upon K status.

The experiment was conducted, in the greenhouse, from 8 June, 1982 (alfalfa seeded) to 17 February, 1983 (8th harvest). There were 4 replications of 19 soil teatments, giving 76 pots. The pots contained 6.2 dm^3 soil, and were thinned to contain 5 plants shortly after emergence. Water applications were determined by weighing. A layer of quartz sand over the soil surface minimized evaporation. From 7 October supplemental lighting was provided to maintain a 12 hour day length. Hourly measurements of air temperature and relative humidity were recorded over the plants.

The transpiration efficiency uncorrected for Δe (i.e. TE/Δe = P/T) was obtained as the slope of a regression of plant production on water applied. This is shown graphically in Fig. 5, where the data have been separated into 3 %K classes. Low yields are generally associated with the lowest K class. The highest yields, however, did not require the highest tissue K concentration, for % K in the highest yielding pot was 1.66, only slightly higher than the mean for harvest 5, 1.58. Of more interest, though, is the observation that the data, despite a wide range in tissue K, appeared to fit a single relation. Regressions for the three K levels at all harvests are presented in Table 19. Results of tests for homogeneity of regression coefficients (TE/Δe) are also shown. Regression coefficients among K levels were only significantly different at two of the harvests, which suggests that K levels do not influence transpiration efficiency. However, when the overall regression coefficients for each harvest were compared, harvest 8 was

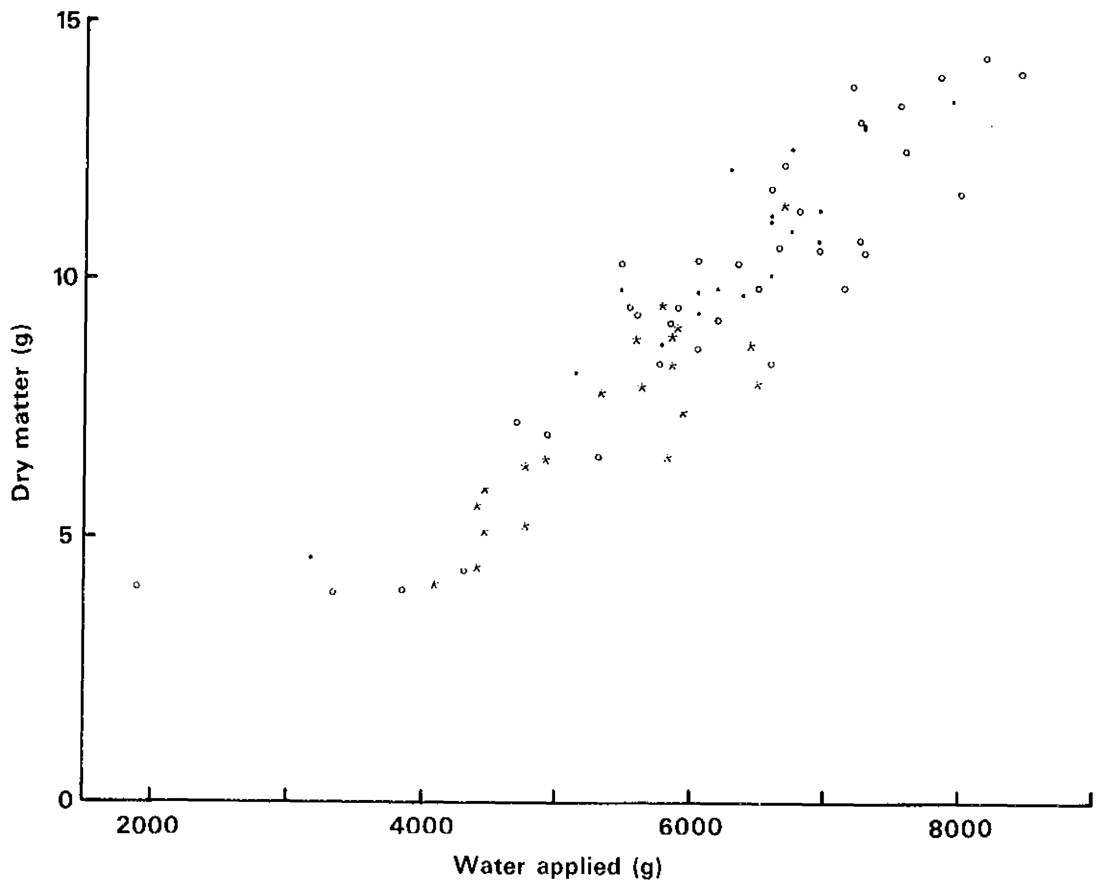


Figure 5: Dry matter production against water applied for harvest 5. Tissue K concentrations are %K ≤ 1 [*], 1 < %K ≤ 2 [o], and %K > 2 [·].

significantly different from harvests 2-6, and harvest 7 was significantly different from harvests 3-6. It is possible, then, that a general decline in K availability may have influenced relations between dry matter production and water use. Symptoms of K deficiency were observed in some pots during the final growth cycle.

Since % K in the tissue tends to decrease as more dry matter is accumulated, and as plants were not harvested at a given dry matter level or phenological stage, an accurate assessment of the effect of K on TE is not possible. Other factors could be influencing TE/Δe. Of these, Δe is not likely to have a major effect since the diurnal temperature and relative humidity regime in the greenhouse varied little. The relative areas of nonphotosynthesizing (shaded) and photosynthesizing (unshaded) tissue could influence TE/Δe, but this does not seem likely since mean dry matter production was 4.12 g at harvest 7 and 12.02 g at harvest 8. These are, respectively, the lowest and highest mean dry matter levels for all harvests, and represent the extremes in proportions of unshaded and shaded tissue.

Although it cannot be concluded that tissue K levels influence plant TE, it does appear that TE is not a constant over the full range of conditions of this experiment. In other studies TE has decreased when soil nutrient levels were sufficiently low. Further experiments may be necessary to determine why in this study transpiration efficiency declined at the final two harvests.

Table 19. Linear regressions and tests for homogeneity of regression coefficients over three potassium levels for seven harvests.

Harvest	% K	n	a	b	r^2	F
			g	$\frac{\text{g plant}}{\text{g water}} \times 10^{-3}$		
2	<1	14	-0.03	1.19	0.87	1.56
	1-2	27	-0.80	1.70	0.66	
	>2	34	-0.33	1.71	0.56	
3	<1	12	-2.25	2.03	0.95	4.42*
	1-2	28	0.21	1.32	0.51	
	>2	30	-2.68	2.22	0.84	
4	<1	31	-2.87	1.69	0.87	2.86
	1-2	29	-5.52	2.08	0.77	
	>2	15	-0.39	1.40	0.73	
5	<1	20	-4.18	2.14	0.77	0.34
	1-2	35	-1.73	1.87	0.83	
	>2	19	-1.54	1.92	0.87	
6	<1	1	-	-	-	0.09
	1-2	51	-2.63	1.97	0.51	
	>2	21	-2.60	2.13	0.78	
7	<1	2	-	-	-	0.08
	1-2	51	-1.66	1.33	0.61	
	>2	22	-0.71	1.24	0.56	
8	<1	50	-2.87	1.27	0.76	4.53*
	1-2	19	4.14	0.79	0.48	
	>2	4	-	-	-	

SOIL SCIENCE RESEARCH

Soil Physics

Measuring the Saturated Hydraulic Conductivity above the Water Table

A number of field methods have been developed to measure the saturated hydraulic conductivity of soils (K_{fs}) above the water table. These methods include ring or cylinder infiltrometer methods, the air-entry permeameter method, the double tube method, and various well permeameter methods. All of these techniques have been used with varying degrees of success.

Due to serious drawbacks in its initial theoretical and practical development, the constant head well permeameter method (also known as the shallow well pump-in method, or the dry auger hole method) has seen very little application in soil science and other disciplines over the past 25 years.

The major theoretical problem has been that the procedure underestimates the saturated hydraulic conductivity relative to other methods. Workers in the 1960's reported that conductivities from the constant head well permeameter method were 33 to 61% lower than corresponding conductivities measured by the auger hole method. This discrepancy was attributed to extensive approximations in the well permeameter theory.

Past practical limitations of the constant head well permeameter procedure are detailed in the established manuals. The most significant of these limitations include an installation time of up to several hours, a measurement period of up to several days, and a water requirement of up to 1000 liters per measurement. In addition, considerable equipment and at least two operators were required to conduct a test.

The recent development of an "in-hole" Mariotte-type permeameter (Talsma and Hallam 1980) has removed the above practical limitations. The apparatus is lightweight, simple and inexpensive to construct, and can be operated by one person. Usually, only very small quantities of water (about one or two liters) are required per measurement, and can be made within 10 to 20 minutes. In areas of limited accessibility, one person can carry two or three permeameters and sufficient water to operate them for the better part of a day. Vertical profiles of hydraulic conductivity of more than one meter depth can be obtained in deep, stone-free soils.

Even though these advances in practical application greatly increased the usefulness of the technique, the theoretical limitations remained. Consequently, the method has still not seen wide-spread application. In this study improvements in both the theory and field application of the well permeameter method are described. The theoretical improvements increase the calculated value of the hydraulic conductivity by approximately 60%, an increase sufficient to produce good correspondence between the permeameter and auger hole method conductivities reported by previous workers.

Refinements of the basic permeameter have increased its efficiency and range of operation. The sand-filled tip reduces erosion of the well during the initial filling, the shut-off valve allows easier filling and starting of the permeameter, and the removable water reservoir allows, through the use of different sized reservoirs, the measurement of a wider range of field-saturated conductivities. In addition, compaction and smearing of the well walls during construction of the well, both of which can significantly affect the K_{fs} determination, can be reduced by using a soil probe with a reversed bevel cutting edge to dig the well, and by reeming the well with a large test tube brush.

A preliminary field comparison of the modified constant head well permeameter method to the air entry permeameter and the constant head infiltrometer methods on a structureless, medium sand soil produced comparable K_{fs} values.

Due to the relative ease and speed with which K_{fs} values can be obtained and to the ready ability to do depth profiling, the modified constant head well permeameter method has great potential for efficient measurement of vertical and horizontal K_{fs} distributions in the field. Such distributions are now recognized to be essential for the realistic evaluation of the irrigation and drainage properties of soils at the field scale.

A paper based on this study has been submitted for publication.

Reference

Talsma, T. and P.M. Hallam. 1980. Hydraulic conductivity measurement of forest catchments. Aust. J. Soil Res. 30: 139-148.

D.E. Elrick

Water and Solute Movement in Soils

We have continued our studies on the combined movement of water and solutes in soil. The analysis of hydrodynamic dispersion of solutes during one-dimensional absorption (horizontal flow) of solution into soil columns was extended to solutes which interact with the soil particle surfaces. The exchange process involved was assumed to be instantaneous and was described by a nonlinear adsorption isotherm. The relevant equations were solved using a computer program written in system/360 CSMP. A paper on this study has been published (Laryea, Elrick and Robin, 1982).

Recently, two papers have been accepted by the Journal of Hydrology (Elrick, Robin and Laryea; and Robin, Laryea and Elrick) on the concept of immobile water in three model soil-water profiles.

The numerical model uses the Crank-Nicolson finite - difference form of equation (1), and a central finite - difference form for equation (2). As is evident from equations (1) and (2), flow is assumed one-dimensional and gravity, vapour flow and heat flow have been neglected. Features of the model include:

1. A variable time step routine that maximizes the time step while satisfying a mass balance criterion. This simultaneously minimizes computer time and mass balance error associated with inappropriate time step size. Cumulative mass balance calculations are also made at each time step, which allows the overall accuracy of the model to be assessed at any point in time.

2. The SOR iterative solution method which minimizes numerical roundoff error. The SOR relaxation factor is re-optimized at each time step in order to maintain the maximum rate of convergence at all times.

3. The highly nonlinear boundary condition at the soil surface is accurately represented in the model and is solved by the method of false position at each time step.

4. The nodal spacing can be varied. This allows high nodal densities in the regions of the core where large water content gradients exist (such as near the soil surface and at boundaries between soil layers of differing hydrologic properties), and low nodal densities where the water content gradients are small (such as at the core base). Such a discretization scheme maintains accuracy throughout the core while simultaneously maximizing economy.

5. The necessity of solving a surface energy balance in the model is avoided by specifying soil surface temperature as a forcing function. This is practical because it is now possible, with the advent of infrared thermometry, to easily measure soil surface temperature in the field.

To date, most of the effort has been concerned with model development and validation. Model runs have been made using clay loam and sandy loam soil cores of different lengths and initial water contents. Runs with constant and diurnally varying surface temperature have also been completed. Discretization analyses indicate that although nodal spacings as small as 0.2 cm are required in the top 1 cm of the soil core to maintain acceptable accuracy, the spacing can be rapidly increased with depth. It has been found that a 10 cm core can be accurately simulated with only 21 nodes. Model predictions agree with theory in that for dry soil surface conditions, cumulative evaporation is linear with the square root of time until the impermeable core base is felt. The error induced by the neglect of vapour and heat flow in equation (1) has not yet been completely evaluated. Preliminary investigations suggest, however, that the error is small as long as the soil temperature does not become very high.

Model predictions of the valid period of hypothetical soil cores have been successful and have improved understanding of this phenomenon. It has been found that in addition to the above mentioned factors influencing the length of the valid period, the previous

These studies will help in our understanding of solute movement (such as nitrogen and potassium compounds) through soils and their effects on plant growth.

D.E. Elrick

Development and Validation of a Model to Predict Evaporation from Finite-Length Soil Columns

Recent field studies have indicated the viability of a simple core weighing technique to determine evaporation from the soil surface (Walker et al., 1981 Prog. Rep.). The major limitation to the field application of this technique stems from the finite length of the soil cores. Once the soil-limiting phase of soil water evaporation has been entered, the evaporation rate from the soil core will match that of the surrounding soil only until the evaporation - induced water content gradient within the core intersects the core's impermeable base. From this point on, the evaporation rate from the core falls increasingly below that of the surrounding soil, resulting in an increasing underestimation of evaporation from the soil surface. The accuracy and usefulness of this technique is therefore critically dependent on accurate estimates of the length of time before the base of the core significantly affects the evaporation rate. This time duration, or "valid period" is dependent on the initial water content and water content distribution in the core, the length of the core, the type of soil in the core and the evaporative conditions at the core surface.

Attempts to measure valid periods in the field by using cores of different lengths were not successful due to excessive heterogeneity within the cores. As a result, a numerical modeling approach was adopted. Liquid water movement within the core is predicted according to the equation,

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z}\left[D(\theta,z)\ \frac{\partial\theta}{\partial z}\right] \qquad (1)$$

where θ = volumetric water content
$D(\theta,z)$ = soil moisture diffusivity function
z = vertical space coordinate
t = time

Evaporation at the core (soil) surface is predicted according to the boundary condition,

$$E = h\ (e_s - e_a) \qquad (2)$$

where E = evaporation rate (flux) at the core surface
h = water vapour transfer coefficient (presently assumed to be constant)
e_s = water vapour pressure at the soil surface
e_f = atmospheric water vapour pressure.

evaporation history of the soil core and the time of day that the cores are started also have an important effect. Thus, guidelines for the use of this technique in the field may not be straight forward.

Although the model is specifically designed to measure the valid period, it has the potential to contribute to the understanding of many other aspects of water flow in finite-length soil cores.

W.D. Reynolds and G.K. Walker

A Constant-Flux Air Permeameter

The geometry of the "body" of pores in soil is so complex that a precise physical or mathematical "picture" is beyond reach. Changes in soil structure due to tillage, compaction or natural subsidence have a dramatic effect on the geometry of the soil matrix and consequently on the geometry of the body of pores. This, in turn, influences many soil properties such as water and air permeability as well as penetrability.

The total porosity, which is usually obtained from the saturated water content or via the bulk and particle density, is a measure of the size of the body of pores, but does not provide information about its shape. Some information about the shape can be obtained from the moisture release function, which can be interpreted as an "equivalent" pore size distribution. The knowledge of the percentage of bulk space that is air-filled at a certain water tension is indeed an important indication of the state of compaction and of possible aeration problems. However, the geometry of the body of air-filled pores is still unknown. Changes in the structure of a soil can have a profound effect on the geometry (e.g. the continuity) of the air-filled pores. Useful information about this geometry can be obtained by measuring the air permeability. This information relates directly to such processes as aeration and root penetration.

Flow of air through soil

If the flow of air through the air-filled pore spaces in a soil is slow, so that turbulence does not occur, the flow process obeys a Darcy-type law. The condition for laminar flow is expressed as an upper limit for the Reynolds number (Re < 1). Thus, we want to perform the air permeability measurements at low air fluxes.

Darcy's law for laminar gas flow has a slightly different form than the well-known form for liquid flow. This is because of the expansion of the gas while it flows through the soil column from high to low gas pressure. For gas flow:

$$v = -K \frac{P_{out}^2 - P_{in}^2}{2\,\rho_w g L\, P_{o/i}} \qquad (1)$$

where v = air flux (cm^3air.cm^{-2} bulk.sec^{-1})
K = air permeability (cm.sec^{-1})
P_{out} = air pressure at outflow side (dyne cm^{-2})
P_{in} = air pressure at inflow side (dyne cm^{-2})
$P_{o/i}$ = air pressure at either outflow or inflow side depending on at which side v is measured
ρ_w = density of water (g.cm^{-3})
g = acceleration of gravity (cm sec^{-2})
L = length of soil column (cm)

For small pressure differences Eqn. (1) may be approximated by:

$$v = -K \frac{P_{out} - P_{in}}{\rho_w gL} = K \frac{\Delta h}{L} \quad (2)$$

where Δh is the difference in gas pressure between inflow and outflow side expressed in cm H_2O pressure. This approximation is within 1% error for $\Delta h < 20$ cm H_2O pressure. Thus, we want to perform the air permeability measurements at low pressure gradients. There is another reason for this experimental condition. The air pressure difference itself may cause water redistribution within the soil sample. The higher the pressure difference, the more water movement towards the outflow side and the lower the resulting K value would be.

Apparatus

The apparatus used here consists of a constant flux device combined with a magnehelic pressure device (Fig. 6). The magnehelic could be replaced by a water manometer. A constant-velocity, motor-driven piston pushes air from a cylinder (syringe) through a soil sample. The outflow side of the soil sample is at atmospheric pressure, P_a. At the inflow side the air presure, P, is measured with the magnehelic. An examination of the data collected to date shows in most cases (about two thirds of all cases), immediately after

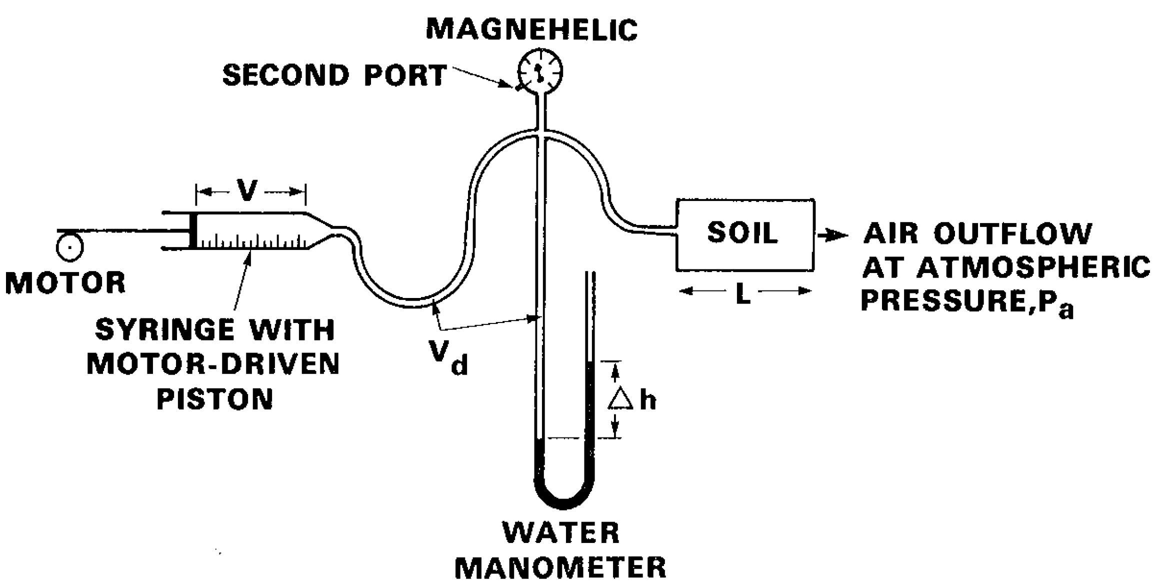


Figure 6: Set-up for air-permeability measurements (V = volume in syringe; V_d = "dead" volume).

the piston is set in motion, P rises quickly to a constant value. Those cases are straight forward. The value of K is calculated directly from the imposed value of Q (cm^3air.sec^{-1}) and the measured value of P using Eqn. (2), with Q = vA. A is the cross-sectional area of the soil sample (cm^2bulk) and $P = \rho_W\ g\ \Delta h$. P is measured with respect to atmospheric pressure, P_a. It has been noticed experimentally, that after P comes to a constant value, continued air flow at the same value of Q shows the P value decreasing slightly and very slowly. As an example of these "straight forward" cases we present the results for a soil core taken from the Puslinch experimental field and equilibrated at 50 cm suction. For this sample L = 5 cm.

Results

After the piston is set in motion at v = 1.42 (cm^3 air.cm^{-2} bulk.sec^{-1}) the pressure rises quickly to 18.8 cm water pressure, where it stays for quite a while (Table 20). Repeated measurements at the same value of v show the pressure rising to lower and lower values of Δh, indicating that evaporation of water in the soil core is occuring, resulting in increasing values of K. At lower values of v the resulting K values are slightly higher indicating that less water redistribution in the soil core has occured. From these results we conclude that the first measurement at the lowest possible flux results in the most representative K value.

Table 20.

Imposed flux, v = Q/A (cm^3air.cm^{-2} bulk.sec^{-1})	Measured pressure difference, Δh (cm H_2O pressure)	Calculated air permeability, K (cm.sec^{-1})
1.42	18.8	0.378
1.42	18.8	0.378
1.42	18.5	0.384
1.42	18.3	0.389
1.42	17.8	0.399
0.708	7.6	0.466
2.12	27.9	0.380
2.12	27.9	0.380
2.12	27.7	0.383
1.42	16.8	0.423
1.42	16.5	0.430
0.708	7.4	0.478
0.708	7.4	0.478

"Rising-pressure" method

In some cases (roughly one third of all cases) the pressure rises slowly and seems to keep on rising. Technical limitations, such as the magnehelic reaching full scale or the syringe "running out of breath" prohibit the establishment of a steady state flow process. In these cases the air permeability, K, of the soil sample can be determined from two pressure readings during the transient state flow process.

This procedure may be called the "rising-head" method. While the piston is moving at constant velocity the rising pressure is measured at two points in time, P_1 at t=o and P_2 at t=t. The air permeability is then calculated from a combination of the Darcy equation and the gas law, which dictates that:

$$P\ (V + V_d) = MRT \tag{3}$$

where V is the air volume in the syringe,
V_d is the "dead" volume between the syringe and the soil sample,
M is the number of "moles" of air in $(V + V_d)$,
R is the gas constant and
T is the absolute temperature.

During the transient state air flow process the pressure rises and air "leaks" through the soil core so that P and V as well as M are functions of time.

The air volume in the syringe obeys the following function of time

$$V(t) = V_o - Qt \tag{4}$$

where V_o is the volume at t = o and
Q is the discharge rate ($cm^3.sec^{-1}$)

Differentiating Eqn. (3) with respect to time gives

$$\frac{d}{dt} P(V + V_d) = RT \frac{d}{dt} M \tag{5}$$

The RHS of Eqn. (5) can be replaced by the Darcy flux according to

$$\frac{dM}{dt} = - \alpha Q = - \alpha vA \tag{6}$$

where α is the inverse of the molar volume of air (moles cm^{-3}) or

$$\alpha = M/(V + V_d) = P/(RT)$$

By using Eqn. (1) one now finds for the RHS of Eqn. (5)

$$RT \frac{dM}{dt} = - vAP = \frac{KA}{2\rho_w gL} (P_a^2 - P^2) \tag{7}$$

The LHS of Eqn. (5), using Eqn. (4) can be written as

$$\frac{d}{dt} P(V + V_d) = (V_o + V_d - Qt) \frac{dP}{dt} - PQ \tag{8}$$

Combination of Eqns. (5), (7) and (8) gives, after separation of the variables P and t,

$$2C(P^2 - 2CP - P_a^2)^{-1}\, dP = \{t - (V_o + V_d)/Q\}^{-1}\, dt \tag{9}$$

where

$$C = \rho_w gL\ Q/(KA) \tag{10}$$

Integration of Eqn. (9) from ($t=o$, $P=P_1$) to ($t=t$, $P=P_2$) gives

$$\ln\{1-tQ/(V_o+V_d)\} = CB^{-1} \ln\{(P_2-C-B)(P_1-C+B)(P_2-C+B)^{-1}(P_1-C-B)^{-1}\} \quad (11)$$

where $B = (P_a^2 + C^2)^{1/2}$

After substituting the experimental values of P_1, P_2, and t, the value of C can be found from Eqn. (11) by trial and error. Subsequently the value of K can be calculated from Eqn. (10). Note that P_a, P_1 and P_2 are absolute pressures. The pressure readings with the magnehelic or the water manometer are relative to atmospheric pressure. Thus, when the reading at $t=o$ is Δh, (cm H_2O pressure), then $P_1 = P_a + \rho_w g\ \Delta h$, and $P_a = 1.013 \times 10^6$ dyne/cm^2.

Discussion

It was pointed out in the section "Results" that the first measurement at the lowest possible flux gives the most representative value of the air permeability, K. It is therefore important to be able to find K from the first run regardless whether steady state air flow can be established or not. The above formulations provide the means to do this by reading the pressures at the beginning and the end of a known time interval.

The "rising-pressure" method relies on the gas law. It is therefore mandatory that no air leaks are present except for the air escape through the soil core. Rising-pressure measurements with the magnehelic indicated that air was leaking somewhere other than through the soil core. It was found that the magnehelic "bleeds" air through the second port (Fig. 6) while the pressure is rising. No air escapes through that port when the pressure is steady. Therefore, the rising-pressure method can only be used with a water manometer.

P.H. Groenevelt, R.G. Donald
C.D. Grant and B.D. Kay

Soil Chemistry

Calcium Carbonate Solubility in the C Horizon of a Southern Ontario Luvisol

A technique involving immiscible displacement with carbontetrachloride under high speed centrifugation was used to isolate 23 soil solutions from the C horizon of a Brunisolic Gray Brown Luvisol in Southern Ontario. The solutions were analysed for Ca, Mg, Na, K, Si, SO_4, Cl, alkalinity and pH. The analytical data was speciated using the computer program, WATSPEC. Preliminary tests indicated that CO_2 degassing was not a significant problem during sampling and extraction in this study.

The 23 soil solutions are plotted on a phase diagram in the system CaO-MgO-CO_2-H_2O. A range of thermodynamic data and specified uncertainties available in the literature were used to establish phase boundary uncertainties in the diagram, which is shown as Figure 7. The expanded inset in Figure 7 shows the solutions evolving towards a cluster of composition invariance, which is composed of 11 of the 23 solutions. If these 11 solutions represent equilibrium with a $CaCO_3$ phase more soluble than calcite, the pKsp of this hypothetical phase would be 7.69. Such an enhanced solubility would affect the equilibrium pH of soil waters in contact with this phase.

Alternatively, Figure 7 suggests that the solutions may be compositionally poised in a steady state between dolomite dissolution kinetics and calcite precipitation kinetics.

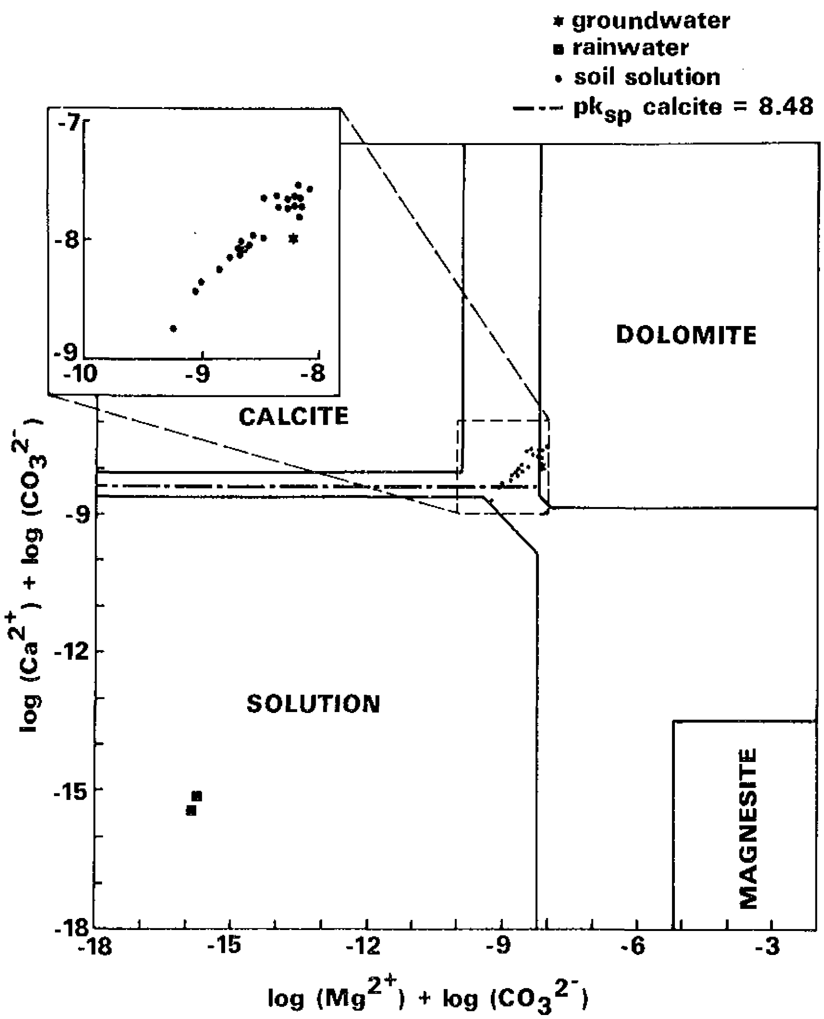


Figure 7: Solution compositions of groundwater, rainwater and soil solutions plotted on a CaO-MgO-CO_2-H_2O phase diagram.

The Effect of Clay Minerals on $CaCO_3$ Precipitation

Studies conducted here and elsewhere indicate that supersaturation with respect to calcite is common in soil waters. The possibility that such a condition is effected by $CaCO_3$ precipitation/dissolution in the presence of clay minerals was investigated.

Experiments involved precipitation of $CaCO_3$ in the presence and absence of a Wyoming Bentonite. The pH was monitored throughout the experiment to document reaction progress and the final solutions were analysed for Ca, Mg, alkalinity and pH. Graphs such as that in Figure 8 were produced. The pH change in such a system is stoichiometrically related to $CaCO_3$ precipitation. Figure 8 indicates a catalysis of $CaCO_3$ precipitation by the clay. Analyses of final solutions consistently showed that carbonate precipitated in the presence of clay to be more soluble than that precipitated in the absence of clay.

Extrapolation to the field is made difficult by the unrealistic laboratory conditions of these experiments but they do suggest that clay minerals play a role in carbonate equilibria in soils.

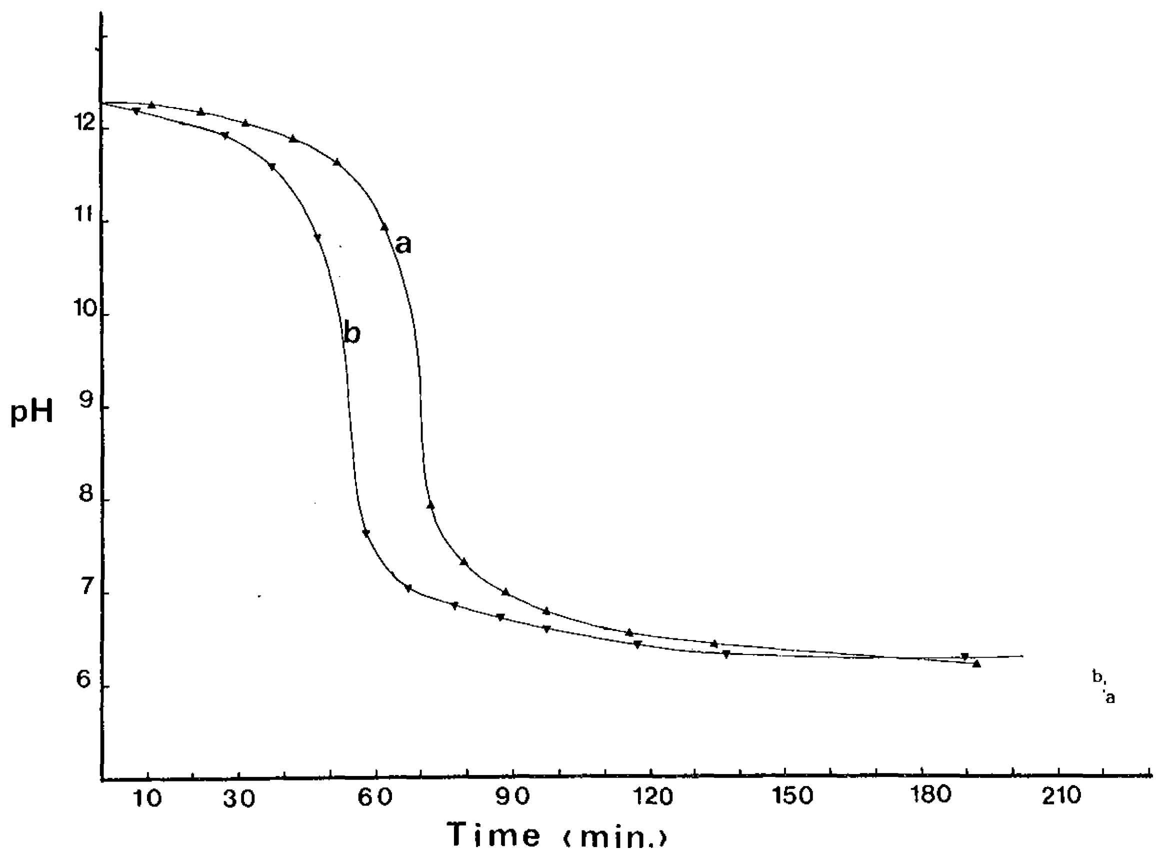


Figure 8: Precipitation of $CaCO_3$ in the presence and absence of clay (a = no clay present; b = clay present).

Daniel Schulman

Soil Acidity and Lime Requirement to Neutralize Acid Soils

The majority of Ontario soils are almost neutral, neither acid nor alkaline, with the average pH of samples tested in the Ontario Ministry of Agriculture and Food's soil testing laboratory being 6.9 in 1981/82. Soil pH values above 7.0 are alkaline and below 7.0 they are acid. Of the samples tested 16% had pH values of 6.0 or less and 5% had values of 5.5 or lower.

It is well known that most crops do not grow well on acid soils and the application of finely ground calcitic or dolomitic limestone is the normal method of neutralizing the acidity (raising the pH). Soils become acid naturally over the centuries but this process is greatly accelerated by the use of nitrogen fertilizers so that the need for lime in Ontario has increased along with the acreage of highly nitrogen fertilized crops such as corn. Transport of lime from the quarries makes up a major portion of the cost of liming soils and this has increased greatly in recent years. In 1983 a common cost of lime spread on the farm fields in southern Ontario is $20/metric tonne with recommended rates of lime application commonly being in the 5 to 12 t/ha range. It is therefore important that we have an accurate measure of the need for lime. Deficiencies of micronutrients such as zinc and manganese are more likely when soils are over-limed and this adds to the need for accurate lime recommendations.

A number of factors are involved in measuring the need for lime.

1. It is common to set minimum or optimum pH limits for crops so that an accurate measure of soil pH is required. In many cases, however, the effect of soil acidity on crops is rather indirect so soil acidity, or soil pH, itself may not always provide a precise answer for the need for lime.

2. Both aluminum and manganese may be toxic in acid soils and they may therefore need to be measured.

3. The amount of lime required to raise the soil pH to the desired level, or to lower the level of plant-available aluminum and manganese to a desired level must be measured. In the past, amounts of lime have been recommended based on soil pH and a rough estimate of texture. This is known to be a very rough measure of lime requirement because the latter will vary with clay content, even within a textural class, as well as with organic matter content and type of clay.

4. We need to know the desirable pH range, or the desirable aluminum or manganese concentration for each crop and what other factors may affect this.

It is apparent then, that determining whether lime should be applied and the amount that should be applied is a fairly complex problem made up of at least four rather distinct components. Some work has been done over the last several years on various aspects of the general problem. This work has been done on a very minimum budget with various undergraduate students and part-time help when they were available.

A. Exchangeable Aluminum, Manganese and pH Distribution with Depth on Some Acid Ontario Soils

Soil acidity is normally measured in our soil testing program by measuring the pH of the surface 15 cm of the soil. If the pH is acid a lime requirement (buffer pH test) is also run to determine the amount of lime required to raise the pH of the surface soil to 6.5, and for some crops, to pH 6.0 or 5.5.

Based on observations by OMAF Soils and Crops Specialists there appear to be differences in crop response to soil acidity that are not explained by surface soil pH alone. The objective of this brief study was to explore the differences in depth of acidity and exchangeable aluminum and manganese in soil profiles; elements which are known to influence the growth of crops.

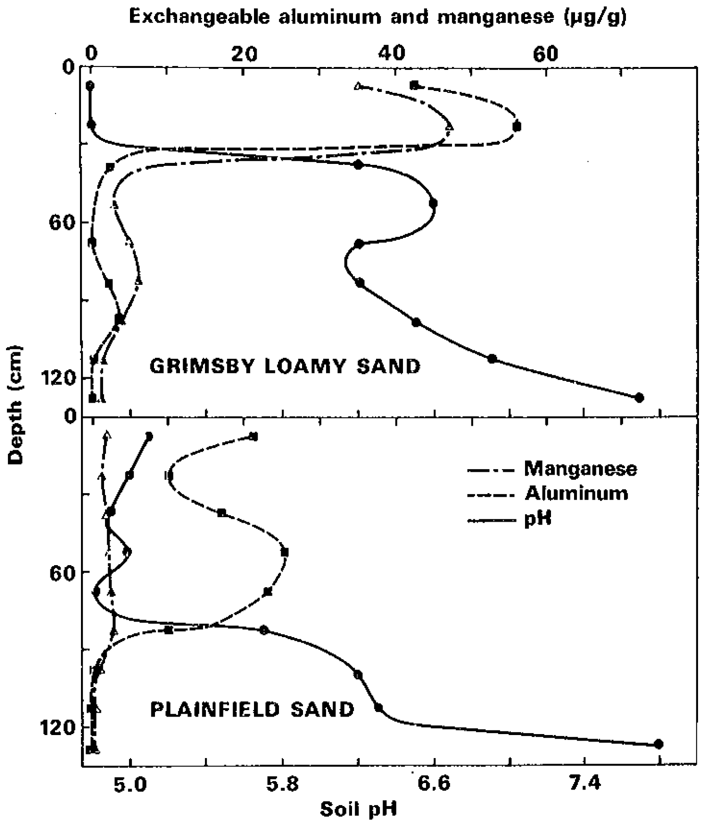
The soil profiles studied came from Niagara North, Wentworth, Elgin and Kent counties and ranged in texture from sands to clays. Most of the clay and clay loam samples were obtained from the Ontario Institute of Pedology's soil survey sample bank. Soil pH was measured in a water paste. Exchangeable aluminum and manganese were extracted by leaching with 1 M KCl.

The soil pH and the exchangeable aluminum and manganese concentrations in four of these profiles are plotted against depth in Figure 9.

On the clay and clay loam soils with surface pH values of 5.0 or less, the pH at 50 cm depth was well above 7.0. On the sands, loamy sands and some loams with surface pH values of 5.0 or below the pH was rarely as high as 7.0 at depths of 100 cm; in several cores it was below 7.0 at 135 cm. From these data and from other observations it was obvious that there was a large difference in the depth of acidity in acid Ontario soils, depending on texture, with the acidity usually extending at least twice as deep in the coarse textured soils. The profiles presented in Figure 9 are fairly typical in this regard.

It is well known that aluminum is toxic to plants; is more soluble at low soil pH; and is one of the reasons for liming acid soils. However, we wanted to know how consistent aluminum concentrations were in acid Ontario soils. Aluminum is rarely toxic to plants if the soil concentration of exchangeable aluminum is less than 50 μg/g. In most cases plants will tolerate much higher concentrations.

In this study the exchangeable aluminum concentrations were less than 5 μg/g in any portion of the profile where the soil pH was 5.5 or above. We obviously do not need to be concerned about soluble aluminum for most crops if lime is applied as recommended. In the more acid horizons of the profiles, exchangeable aluminum concentrations were very erratic with values as high as 148 μg/g in one Chinguacousy soil



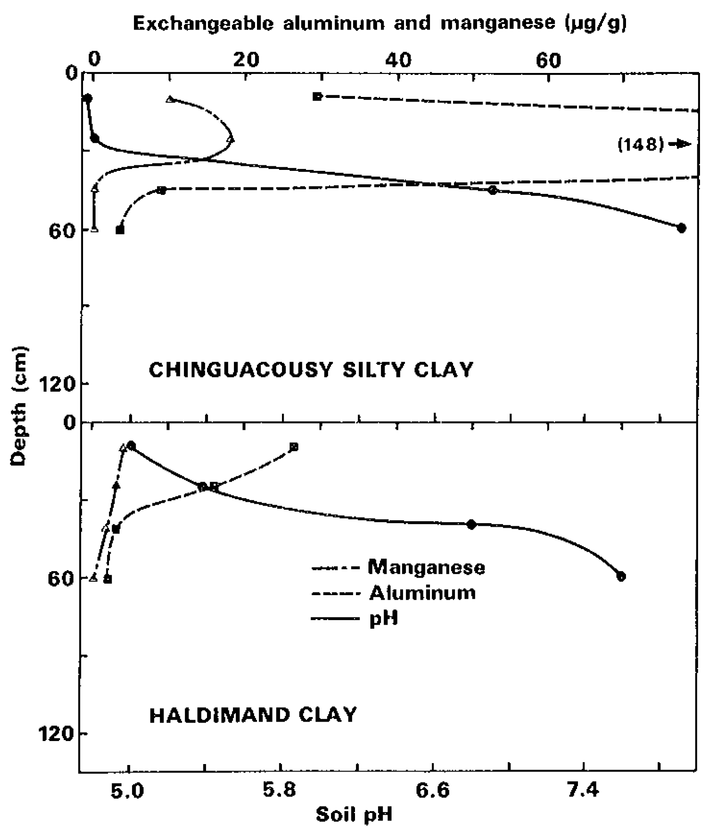


Figure 9: Soil pH, exchangeable aluminum and manganese plotted against soil depth in four acid soils from Southern Ontario.

profile (Figure 9) but quite low in others such as the Plainfield sand profile. In acid Ontario soils exchangeable aluminum can apparently range from quite low to quite high.

Manganese is known to reach toxic concentrations in some acid soils. In this study, as with aluminum, exchangeable manganese was at very low concentrations where the pH was 5.5 or higher. There were wide variations in exchangeable manganese in the acid portions of the profiles. An extreme example of this is shown by a comparison of the Grimsby and Plainfield profiles in Figure 9.

T.E. Bates and Jan Hassink

B. Variability in Soil pH

It is well known that soil pH values from any one field vary over the season and that this affects the determination of lime requirement. Collins et al. (1970) found a maximum variation in pH values measured in a 1:2 soil water suspension of 1.6 pH units and an average variation of 0.8 units over the season measured at 19 sites in Michigan. A 0.01 M $CaCl_2$ solution is often recommended instead of water for pH measurement as it more closely approximates the salt concentration in a normal soil at field moisture content. However, Collins et al. (1970) found as much variability through the season in pH measured in 0.01 M CaCl as in pH measured in water. They found that measurement of pH in 1.0 N KCl produced appreciably less variablity (0.2 pH units) through the season than water (0.8 pH units) or 0.01 M $CaCl_2$.

Anne Rowsell as part of the requirements for a B.Sc. degree at the University of Guelph sampled the top 15 cm of soil in a 10 m^2 section of each of three sandy loam soils in Durham County in each of 16 weeks. The samples were air-dried and at the end of summer pH was determined in a soil water paste and in a 1:2 suspension of 0.01 M $CaCl_2$. Conductivity was also measured as an indicator of salt concentrations. The rainfall records presented are supplied by Environment Canada from the town of Bowmanville in Durham County as rainfall was not recorded at the farm sites.

In the OMAF soil testing laboratory pH is measured in a soil water paste rather than in a 1:1 or 1:2 water suspension. While much of the published literature suggests that pH measured in a 1:2 soil: 0.01 M $CaCl_2$ suspension is more meaningful than when measured in a 1:1 or 1:2 water suspension there are few comparisons reported with measurements in a soil water paste. It seems probable that much of the criticism of a soil water suspension is not applicable to a soil water paste.

From Figure 10 it is apparent that there is appreciable variation in soil pH through the summer months and that this variation is of the same order of magnitude with 0.01 M $CaCl_2$ as with the soil water paste. Although fertilizer applications were not recorded, it seems probable that the very large changes in pH in the corn field in May and early

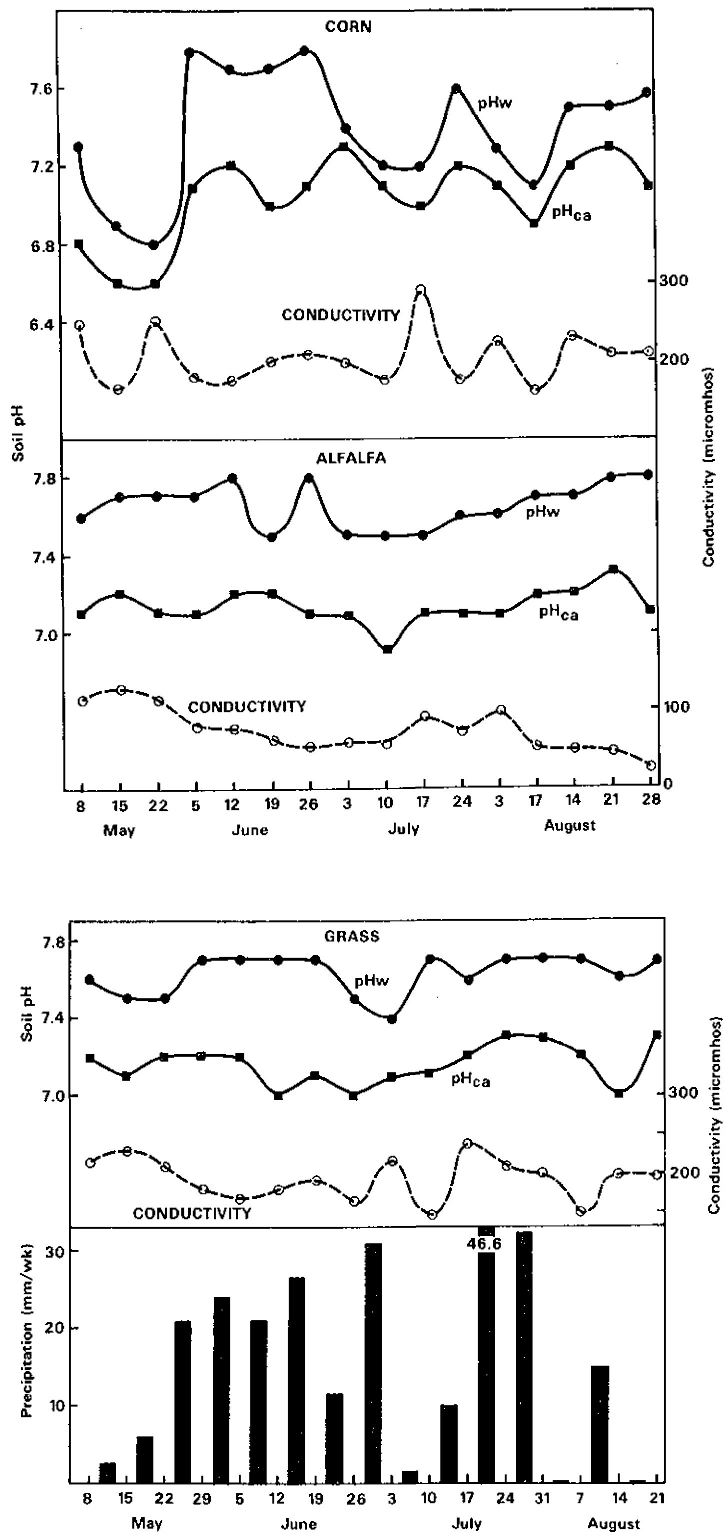


Figure 10: Soil pH and conductivity values on three sandy loam soils in Durham County (pH_W = pH measured in a soil water paste; pH_{Ca} = soil pH in a 1:2 soil:0.01 M $CaCl_2$ suspension).

June were related to nitrogen fertilizer applications which would normally be applied in the first half of May.

There appears to be little relation between rainfall or conductivity and soil pH on any of the three sites. It is unfortunate that the project did not include measurement of pH in 1N KCl.

As a further part of the comparison of different methods of measuring soil pH, a group of 245 mineral soil samples from across Ontario were used to compare paste, $CaCl_2$ and KCl pH values. The average pH values are presented in Table 21. The correlations between values from the paste pH and from the other two methods are quite high (Table 21) and from this it appears that one could predict the paste pH

Table 21: Comparisons of soil pH values on 245 farm soils measured in different ways.

pH Measurement	Average pH	Standard Error	Difference from paste pH	Correlation with paste pH
Soil-water paste	5.77	0.91		
1:2 soil:sol'n in 0.01 M $CaCl_2$	5.26	0.91	-0.51	0.951
1:2 soil:sol'n in 1 N KCl	5.00	0.95	-0.77	0.936

by simply adding 0.51 to the pH_{CaCl_2} and similarly with the pH_{KCl}. A regression equation developed to predict paste pH from the $CaCl_2$ pH was as follows:

$$pH_{paste} = 0.82 + 0.94\ pH_{CaCl_2} \qquad R^2 = 0.904$$

From this it is apparent that the difference between pH_{CaCl_2} and pH paste varies with pH. From the equation the pH_{paste} at a pH_{CaCl_2} of 4.0 is 4.58 and at pH_{CaCl_2} of 8.0 it is 8.34. Thus some error would be involved in applying an adjustment equal to the average difference.

When pH_{paste} was predicted from pH_{KCl}, soil texture and pH_{KCl} X texture also contributed significantly, to the equation, at the 1% and 5% levels of significance. Soil texture was evaluated by feeling the moist soils and course, medium and fine textures were assigned values of 1, 2 and 3, respectively.

The equation developed was:

$$pH_{paste} = 0.43 + 1.01\ pH_{KCl} + 0.47\ \text{Tex.} - 0.061\ pH_{KCl} \times \text{Tex.} \quad R^2 = 0.894$$

The relationship is fairly complex with the equation predicting a pH paste of 4.68 with a sandy soil at pH_{KCl} of 4.0 and a pH_{paste} of 9.02 with a clay or clay loam soil at pH_{KCl} of 7.0.

When organic soils were included in the analysis and given a texture rating of four the R^2 values for the equations were reduced only slightly but the equations developed were more complex.

Conclusion

Soil pH measured in 0.1 M $CaCl_2$ provides little advantage over pH measured in a soil water paste in terms of reducing the variability in pH readings through the year. The pH_{CaCl_2} reading averaged 0.5 lower than pH paste readings but the difference decreases as pH increases.

Soil pH measured in 1.0 N KCl is reported to greatly reduce the variation in pH readings through the year. The pH_{KCl} readings averaged 0.77 lower than pH_{paste} readings but the difference could be as much as 2.0 lower at high pH values on fine textured soils. Use of pH_{KCl} in soil testing would require adjustment of the readings or a complete re-education of everyone using the system.

We need to know whether pH_{KCl} is as good or better than the pH paste as a measure of the need for lime along with further evaluation of the stability of readings through the season.

Collins, J.B. E.P. Whiteside and C.E. Cross. 1970. Seasonal variability of pH and lime requirements in several southern Michigan soils when measured in different ways. Soil Sci. Soc. Amer. Proc. 34: 56-61.

T.E. Bates, Jan Hassink, Martin McAlpine, Anne Rowsell and E.F. Gagnon

C. Routine Measurement of Soil pH

Soil samples are occasionally brought to the Guelph soil testing laboratory and a pH reading is wanted immediately, without time for air drying or an equilibration period. A very brief study was run to compare this with the normal procedure. The following three treatments were compared on 79 random soil samples which arrived at the laboratory in August 1982:

a) The soil sample was mixed, an aliquot taken and water added to form a paste. This was stirred and pH read immediately.

b) The same sample was re-read 1/2 hour later.

c) Normal laboratory procedure. The sample was air dried, passed through a 2 mm sieve and mixed. Water was added to an aliquot to form a paste, stirred, left 15 minutes and the pH read. Although not intended this treatment was read by a different technician and on a different pH meter.

Average pH values for treatments a, b and c were 7.11, 7.06 and 7.14 respectively. The maximum variation was 0.3 pH units. Samples are usually only read to one decimal and therefore the three averages would be identical. However, there may be a small difference in treatments on some soils.

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D. Changes in Soil Test for Lime Requirement

For many years in the Guelph soil testing laboratory lime requirement has been based on soil pH with a different recommendation for coarse, medium, fine textured and organic soils. A more accurate method was desired which would estimate the amount of lime required to raise the pH of any individual soil by adjusting for factors affecting lime requirement such as organic matter, clay content and type of clay. The Shoemaker, et al. (1961) (SMP) buffer pH method was chosen after a study of the literature. This method consists of shaking a 1:3 slurry of soil and buffer for 10 minutes and reading the pH. The buffer consists of paranitrophenol, triethanolamine, potassium chromate and calcium chloride and is adjusted to pH 7.5 with sodium hydroxide. The SMP buffer has been reported to give less accurate predictions of lime requirement when the lime requirement is small (McLean et al. 1978). A modified buffer, adjusted to pH 7.3 instead of pH 7.5 was tested as one means of alleviating this problem. The SMP double buffer has been reported to give more accurate predictions of lime requirement (MacLean et al. 1978) and this was also tested.

These authors also reported that equilibration of soils with $Ca(OH)_2$ over a 3 day period is the equivalent to equilibration with lime in the field. Equilibration with $Ca(OH)_2$ was therefore used as the standard measure of lime requirement to corroborate the buffer pH method. Seven samples were also mixed with powdered $CaCO_3$, water was added to bring to saturation, the soils were then allowd to dry to 20% (w/w) moisture content on sandy soils and 40% for loam and clay loam soils and incubated for 30 days.

In the three day equilibration with $Ca(OH)_2$ a range of volumes of 0.02 M $Ca(OH)_2$ and two drops of chloroform were added to 10 g samples of each soil and the volume was made up to 50 ml with water or with 5 ml of 0.1 M $CaCl_2$ plus water to bring the final concentration of $CaCl_2$ to 0.01 M. The slurry was shaken for 2 hours per day for three days.

Results and Discussion

A comparison of lime requirement measured by 3 day incubation with $Ca(OH)_2$ in water and 0.01 M $CaCl_2$ is shown in Table 22 along with seven samples incubated moist for 30 days with $CaCO_3$. The water suspension gave lime requirements for a few soils that were much lower than with $CaCl_2$ and they are believed to be in error due to the inherent problems in measurement of pH in water suspensions. The $CaCO_3$ incubation produced lime requirements somewhat higher than obtained with $Ca(OH)_2$ and this is believed to be due to nitrification in the 30 day incubation as nothing was added to prevent microbial action. The

Table 22: Lime requirement of 30 soils obtained by 3 day equilibration with $Ca(OH)_2$ in water and in 0.01M $CaCl_2$ and of seven soils equilibrated for 30 days with $CaCO_3$.

Sample No.	3 day $Ca(OH)_2$ Equilibration: Water Suspension	3 day $Ca(OH)_2$ Equilibration: 0.01M $CaCl_2$	30 day $CaCO_3$ incubation
	Lime requirement - me/100 g		
101	1.0	5.3	
103	5.5	4.4	
107	1.8	4.0	
111	0.0	3.3	
112	2.0	3.3	4.7
113	3.5	4.3	
114	2.7	7.0	
115	1.2	4.1	4.7
117	0.7	2.7	2.9
129	10.5	9.7	
143	1.2	2.2	
145	2.6	2.8	
146	10.0	10.2	
147	1.1	1.3	
149	2.1	2.7	
150	1.4	1.8	1.3
152	0.9	1.0	
153	3.5	3.6	4.6
157	1.6	1.8	
159	2.7	2.6	
167	0.5	1.0	
169	4.5	4.3	
171	11.5	8.9	
177	0.4	0.8	1.2
178	5.3	5.8	
189	5.3	6.4	
190	3.3	3.4	3.5
194	7.3	7.4	
195	13.8	11.9	
202	8.5	8.1	

$Ca(OH)_2$ 3-day incubation in 0.01 M $CaCl_2$ suspension was used throughout the remainder of the study as the reference method for lime requirement.

The lime requirement to pH 6.5 of 40 soils measured by $Ca(OH)_2$ equilibration is plotted against SMP buffer pH in Figure 11 along with linear and quadratic equations predicting lime requirement from SMP buffer pH. The quadratic equation gave a very good prediction of lime

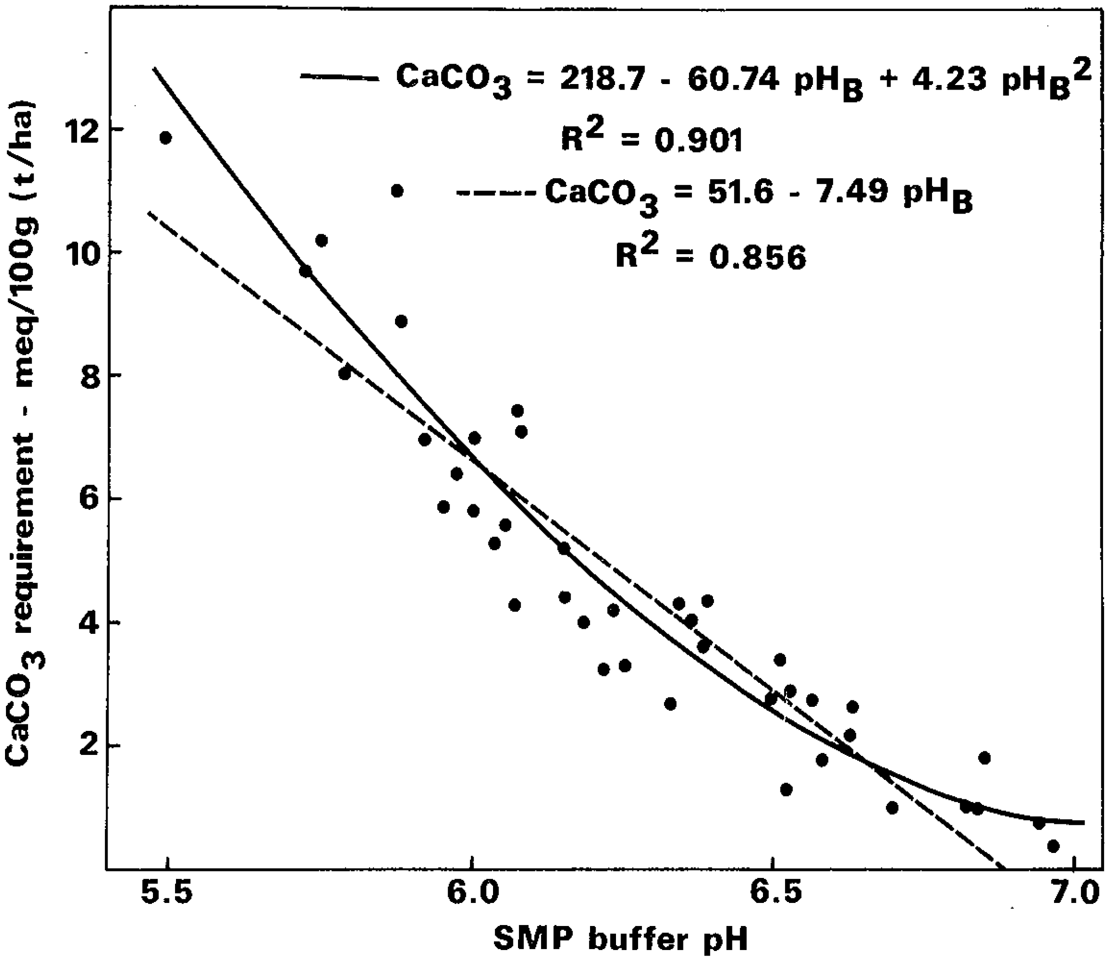

Figure 11: Quadratic and linear equations for the prediction of lime requirement (to pH 6.5) using the Shoemaker, McLean, Pratt (SMP) buffer.

requirement ($R^2 = 0.901$), which was better than the linear equation. A square root equation was not appreciably poorer, but in no case was it better, than the quadratic equation.

The modified SMP buffer (adjusted to pH 7.3) was no better than the original SMP buffer. The double buffer was tested in this study and requires the accurate reading of pH to ±0.01 pH units. Even when pH was carefully measured to ±0.01 pH units the double buffer did not appear to be appreciably better than the single buffer using the quadratic equation shown in Figure 11. When the quadratic equation was used the SMP single buffer seems to work rather well at all levels of lime requirement tested.

In Ontario, liming is recommended to pH values of 6.5, 6.0 and 5.5 for different groups of crops. Linear and quadratic equations for these pH values and for pH 7.0 are presented in Table 23. Lime in Ontario is recommended on the basis of an "Agricultural Index" or effectiveness (based on purity and particle size) of 75, or 75% of pure $CaCO_3$.

The lime requirement equations adjusted for this are presented in Table 24. The equation for a target pH value of 6.0 in Table 23 is quite different than the pH 6.5 and pH 5.5 equations. It was, therefore, replaced by the average of the pH 6.5 and 5.5 equations for use in the laboratory (Table 24 and Figure 12). Although the quadratic equation for pH 5.5 has a higher R^2 value than the linear equation, a closer examination showed that many of the soils used in calculating the equation for pH 5.5 had pH values above 5.0. For crops with a target pH of 5.5 lime is only recommended when the pH falls to 5.0 or below.

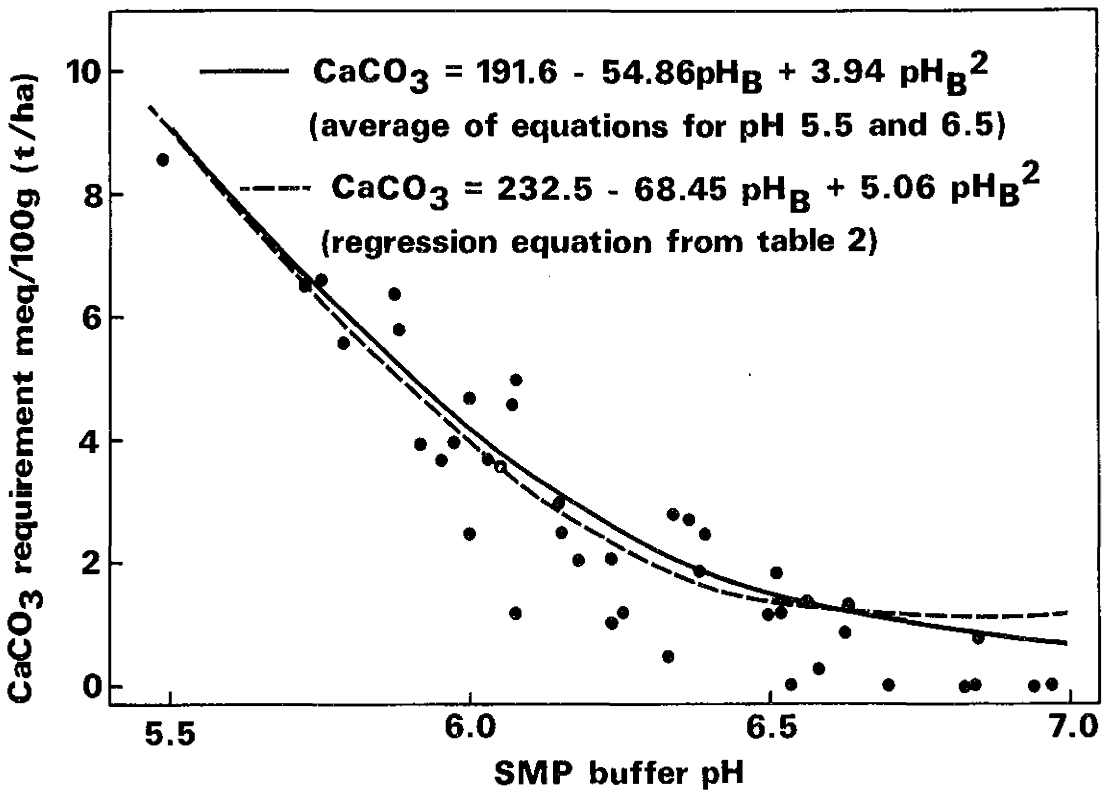

Figure 12: Two quadratic equations for the prediction of lime requirement (to pH 6.0) of Ontario Soils using the Shoemaker, McLean, Pratt (SMP) buffer.

All the above equations were developed on mineral soils. On organic soils lime is only recommended to a target pH of 5.5 and only when the pH falls to 5.0 or lower. When mineral and organic soils with pH values of 5.0 were included the linear equation in Table 23 appeared to fit both quite well but the organic soils did not fit the quadratic equation. Therefore, the linear equation was chosen for a target pH of 5.5 as shown in Table 24.

The lime requirement equations in Table 24 have been used to develop the lime requirements in Tables 25, 26 and 27 which are currently used for lime recommendations in Ontario. The initiation of this test in the Guelph soil testing labortory in October 1982 has appreciably improved the estimate of lime requirements. On coarse and medium textured soils lime requirement will on the average be somewhat higher than before.

Table 23: Lime Requirement for Different Target pH Values in meq/100 g, or tonne $CaCO_3$/ha as Predicted by SMP Buffer pH.

$CaCO_{3(7.0)}$ =	250.9 - 68.09 pH + 4.64 pH^2 ± 67.2 ± 21.41 ± 1.70	R^2 = 0.844 n = 41
$CaCO_{3(7.0)}$ =	67.6 - 9.64 pH ± 4.7 ± 0.74	R^2 = 0.813 n = 41
$CaCO_{3(6.5)}$ =	218.7 - 60.74 pH + 4.23 pH^2 ± 40.7 ± 12.94 ± 1.03	R^2 = 0.901 n = 41
$CaCO_{3(6.5)}$ =	51.6 - 7.49 pH ± 3.1 ± 0.49	R^2 = 0.856 n = 41
$CaCO_{3(6.0)}$ =	232.5 - 68.45 pH + 5.06 pH^2 ± 51.0 ± 16.52 ± 1.33	R^2 = 0.827 n = 35
$CaCO_{3(6.0)}$ =	39.3 - 5.86 pH ± 3.7 ± 0.59	R^2 = 0.750 n = 35
$CaCO_{3(5.5)}$ =	164.3 - 48.98 pH + 3.66 pH^2 ± 49.2 ± 16.13 ± 1.32	R^2 = 0.828 n = 24
$CaCO_{3(5.5)}$ =	28.3 - 4.31 pH ± 3.1 ± 0.51	R^2 = 0.765 n = 24

Table 24: Lime Requirement Equations for Lime with an Agricultural Index of 75.

L.R. (pH 7.0)* = 334.5 - 90.79 pH_B** + 6.19 pH_B^2

L.R. (pH 6.5) = 291.6 - 80.99 pH_B + 5.64 pH_B^2

L.R. (pH 6.0) = 255.4 - 73.15 pH_B + 5.26 pH_B^2 This equation calculated by averaging the pH 6.5 and pH 5.5 equations

L.R. (pH 5.5) = 37.7 - 5.75 pH_B

*L.R.(pH 7.0) = the tonnes of lime per hectare with an Agricultural Index of 75 required to raise the pH of the top 15 cm of soil to pH 7.0

**pH_B = the soil pH measured in the Shoemaker, McLean and Pratt (SMP) buffer with an original pH of 7.5.

Table 25: Lime Requirement to raise pH to 6.5; for all crops grown on mineral soil except those in table 5 or 6).

Buffer pH	Tonnes/ha	Buffer pH	Tonnes/ha
		6.1	7
7.1 or higher	0	6.0	9
7.0	2	5.9	10
6.9	2	5.8	12
6.8	2	5.7	13
6.7	2	5.6	15
6.6	3	5.5	17
6.5	3	5.4	19
6.4	4	5.3 or lower	20
6.3	5		
6.2	6		

Table 26: Lime Requirement to raise pH to 6.0; for continuous corn, gardens, winter rye, flue-cured and barley tobacco on mineral soils.

Buffer pH	Tonnes/ha	Buffer pH	Tonnes/ha
6.8 or higher	0	5.9	7
6.7	2	5.8	8
6.6	2	5.7	9
6.5	2	5.6	11
6.4	3	5.5	12
6.3	3	5.4	14
6.2	4	5.3	15
6.1	5	5.2	17
6.0	6	5.1	19
		5.0 or lower	20

Table 27: Lime Requirement to raise pH to 5.5; for potatoes, grass for seed, tree fruits and grapes on mineral soils, plus all crops on organic soils.

Buffer pH	Tonnes/ha	Buffer pH	Tonnes/ha
		5.6	6
6.5 or higher	0	5.5	8
6.4	2	5.4	9
6.3	2	5.3	10
6.2	2	5.2	11
6.1	2	5.1	13
6.0	3	5.0	15
5.9	4	4.9	16
5.8	4	4.8	18
5.7	5	4.7 or lower	20

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McLean E.O., D.J. Eckert, G.Y. Reddy and J.F. Trierweiler. 1978. An improved SMP soil lime requirement incorporating double buffer and quick-test features. Soil Sci. Soc. Amer. J. 42: 311-316.

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Soil Plant Relations

Grain Corn Response to Tile Drainage and Nitrogen

Blocks of an imperfectly drained Conestoga silt loam and a poorly drained Colwood silt loam, with and without tile drainage, were planted to corn at increasing increments of nitrogen as ammonium nitrate. In 1981 the planting date varied according to the moisture content of the surface and the depth of the water table (Table 28, Fig. 13). In 1982

Table 28: Influence of tile drainage on the nitrogen requirement and production of grain corn.

Year	Soil Drainage Classification	Drainage	Planting Date	N Requirement @ Max. Yield	Maximum Yield	% Moisture @ Harvest*
				(kg N/ha)	(kg/ha @ 15.5% H_2O)	
1981	Poor	With	May 14	166	6453	34.1
		Without	June 2	149	5328	50.5
	Imperfect	With	May 14	137	6507	31.8
		Without	May 23	158	5922	39.7
1982	Poor	With	May 13	207	5819	30.8
		Without	May 13	272	6172	35.8
	Imperfect	With	May 13	176	6190	31.9
		Without	May 13	197	6088	33.0

*Based on an application of 150 kg N/ha

the planting date was the same for all drainage treatments due to the dry spring and low water table (Table 28, Fig. 14).

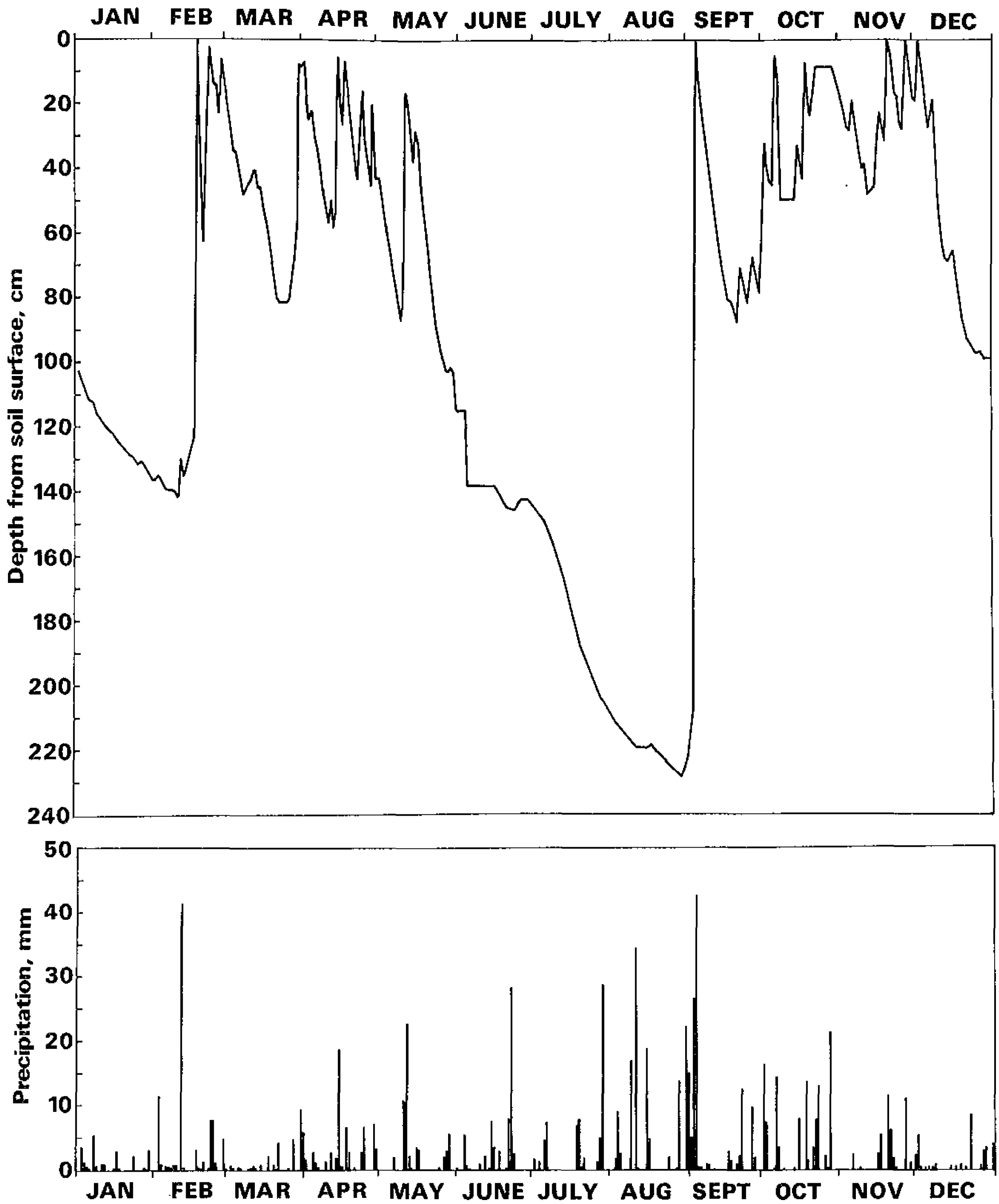

Figure 13: The depth of the water table and daily precipitation during 1981.

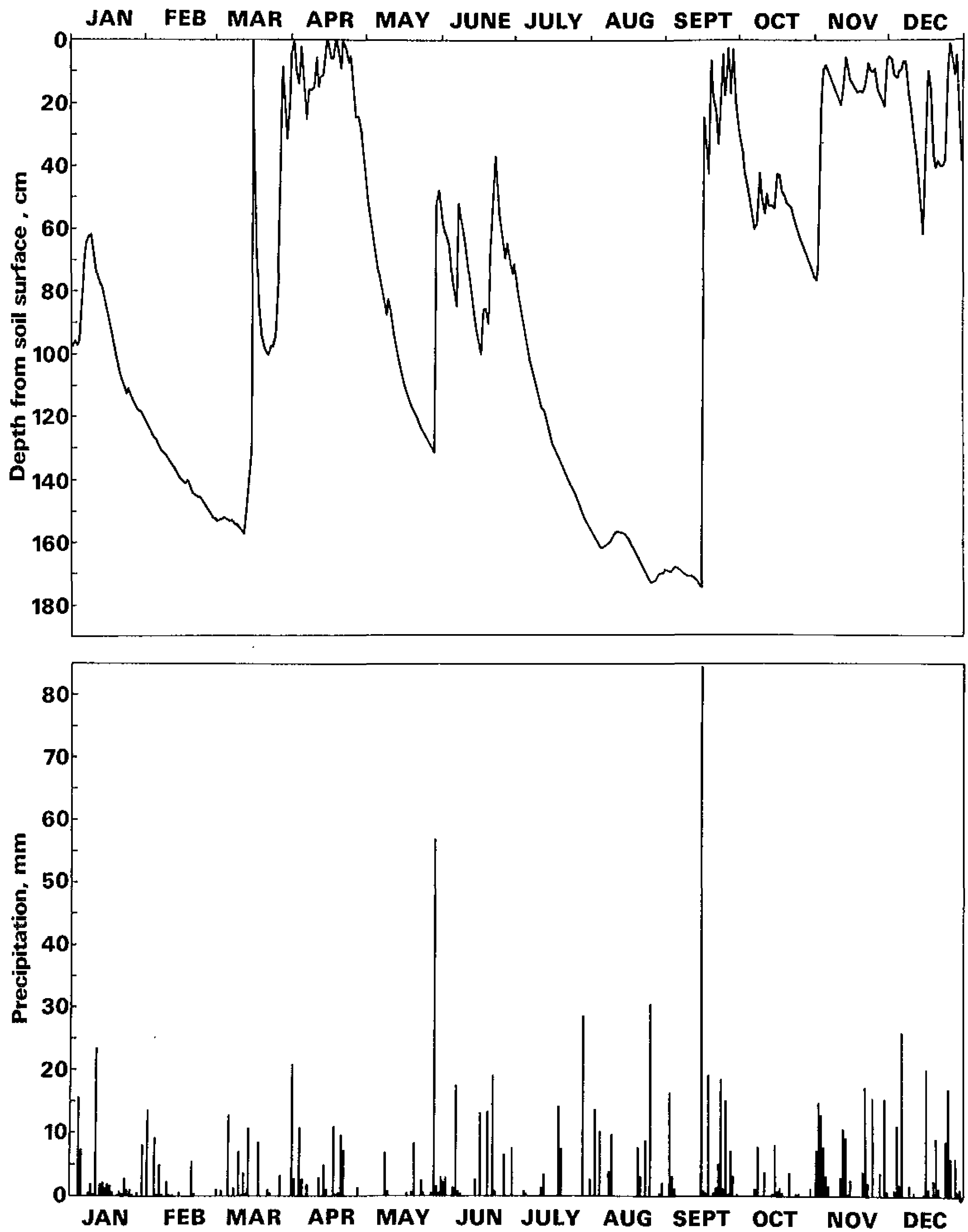

Figure 14: The depth of the water table and daily precipitation during 1982.

In 1981, with differential planting dates, tile drainage increased grain yields on both soils, the increase being greater on the poorly drained Colwood silt loam (Fig. 15). Regression equations (Table 29) of

Table 29: Regression equations for the relationship of rate of nitrogen application to yield of grain corn.

Year	Yield Drainage Classification	Drainage	Regression Equation	R^2
1981	Poor	With	$Y = 4197 + 27.0999N - .08139\ N^2$	94.36
		Without	$Y = 3745 + 21.1826N - .07089\ N^2$	88.36
	Imperfect	With	$Y = 4322 + 31.88917N - .11636\ N^2$	92.83
		Without	$Y = 3961 + 25.61222N - .08077\ N^2$	91.08
1982	Poor	With	$Y = 2127 + 35.72331N - .0864\ N^2$	97.27
		Without	$Y = 1555 + 33.87341N - .06213\ N^2$	97.30
	Imperfect	With	$Y = 2161 + 45.69553N - .12957\ N^2$	96.05
		Without	$Y = 2125 + 40.25461N - .10222\ N^2$	97.85

the relationship of nitrogen rate to yield (Fig. 15) were used to compute the nitrogen requirement for maximum yield and the maximum yield resulting from the drainage treatments (Table 28). The nitrogen requirement for maximum yield was reduced by 21 kg N/ha on the imperfectly drained soil whereas 17 kg N/ha more nitrogen was required on the poorly drained soil. The yield level attained with drainage, however, was essentially the same on both soils.

In 1982, with the same planting date, tile drainage increased grain yields slightly on the poorly drained soil but not on the imperfectly drained soil (Fig. 15). The nitrogen requirement for maximum yield on the non-tiled, poorly drained soil was 31.4% higher compared to the tiled soils in contrast to 11.9% higher on the imperfectly drained soil.

A major effect of drainage on the moisture percentage in the corn at harvest was observed in 1981 on both the imperfect and poorly drained soils (Table 28). The effect was attributed to differential planting dates. In 1982, however, a five percent higher moisture percentage was measured on the non-tiled, poorly drained soil in contrast to the drained soil. The effect was attributed to retarded corn development by a wet period from May 27 to July 1.

Water table measurements on the poorly drained soil in 1981 and 1982 illustrate two contrasting seasons (Fig. 13 & 14). In 1981, the water table was above 60 cm until May 20 which delayed planting, and was followed by a falling water table until Sept. 3 when it rose rapidly after a 42.7 mm rain. In 1982 the water table was below 60 cm by May 1, dropping to 130 cm by May 27 when it rose rapidly to 60 cm and remained high until July 1. It is suggested that during this period excess water occurred in the rooting zone of the non-tiled treatments restricting the growth of the corn.

Accepting 60 cm as the depth of the water table as necessary to carry heavy harvesting machinery on silt loam soils (Paul and DeVries, Can. J. Soil Sci. 59: 313, 1979) it is evident that the non-tiled, poorly drained soil would not permit harvesting from Oct. 2 to Dec. 11, 1981. Similarly, harvesting would have been restricted from Sept. 15 onward in 1982. These delays would have resulted in further significant production losses.

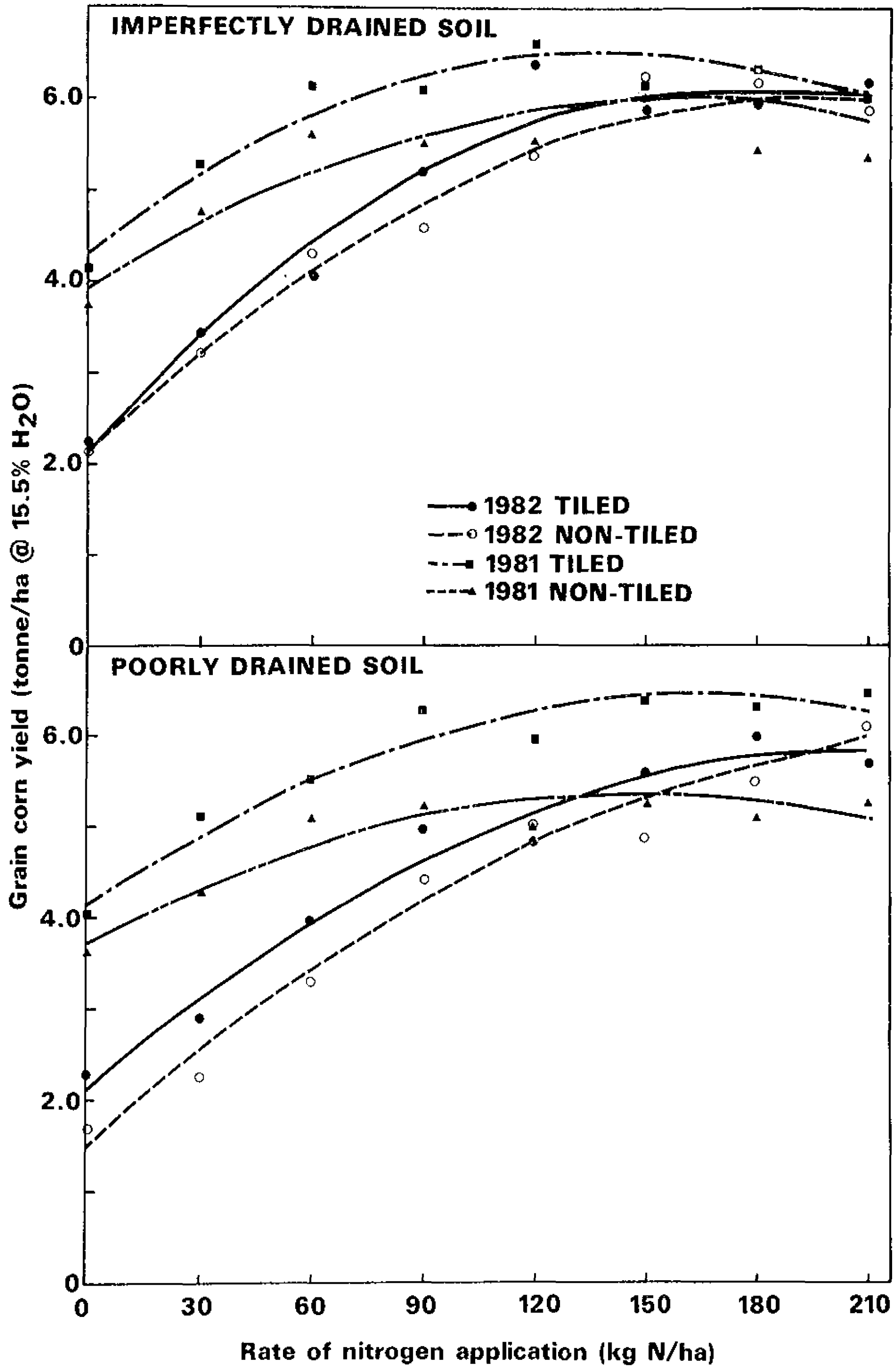

Figure 15: The relationship of grain yield to rate of nitrogen application on poor and imperfectly drained soil, with and without tile, in 1981 and 1982 (See table 29 for equations of best fit).

Although removal of excess water by tile drainage may directly influence plant growth (1982 data), the major benefit of drainage is attributed to timeliness of planting, accessibility for harvesting and reduced requirement for nitrogen fertilizer.

Response of Corn to Nitrogen on Ontario Soils

More nitrogen fertilizer is required to produce the same yield of corn in Southwestern Ontario than the rest of Ontario. Hypotheses involving differences in hybrid requirements, climatic conditions or the N supplying potential of the soils have been proposed. The research data reported here were obtained while testing the latter hypothesis.

Table 30: Dry matter weights of shoots and roots, total N concentration and N derived from fertilizer in shoots and shoot/root ratios of corn seedlings grown on six soils from across Southern Ontario.

		Eastern and Central Ontario Soils			Southwestern Ontario Soils		
	N Rate	North Gower	Manotick	Harriston	Berrien	Brookston (Merlin)	Brookston (Woodslee)
	(kg/ha)						
Shoot Wt (g/pot)	0	2.79	1.88	1.85	1.83	1.99	1.48
	50	3.83	2.88	3.20	2.41	3.18	3.02
	100	4.81	3.51	3.65	3.03	4.93	4.14
		LSD (.05) = 0.68 g/pot					
Root Wt (g/pot)	0	2.13	1.69	1.79	1.34	1.34	1.09
	50	2.32	2.06	2.12	0.93	1.52	1.48
	100	2.34	2.01	2.04	0.65	1.87	1.72
		LSD (.05) = 0.42					
S/R	0	1.31	1.11	1.03	1.37	1.49	1.36
	50	1.65	1.40	1.51	2.59	2.09	2.04
	100	2.06	1.75	1.79	4.66	2.64	2.41
Shoot N Conc.(%)	0	2.04	1.18	1.25	1.17	1.24	1.54
	50	2.38	1.50	1.48	1.84	1.28	1.56
	100	3.21	1.84	1.62	2.55	1.29	1.55
		LSD (.05) = 0.54%					
Ndff (%)	50	32.6	44.4	38.9	34.2	43.0	43.4
Soil N Conc.(%)	-	0.26	0.16	0.27	0.12	0.31	0.27

Soil samples were obtained from check plots of field experiments located in Southwestern Ontario (courtesy of C.K. Stevenson), the Elora Research Station, and Eastern Ontario (courtesy of W.E. Curnoe). A greenhouse study was done with these samples involving 3 rates of N fertilization (equivalent to 0, 50, and 100 kg N/ha) as ammonium sulfate. A fourth treatment involving an application of 50 kg N/ha labelled with ^{15}N was included to provide further information on the ability of the 6 soils to supply native soil N to corn plants. Sufficient P and K (as K_2SO_4) were added to avoid deficiencies of these nutrients. Corn seedlings (3 per pot) were grown to the 7- to 8-leaf stage to provide response data.

There were large but variable shoot and root yield responses to N fertilization (Table 30). Also, as expected, N concentration increased with increasing N applied but the data were unexplainably variable. The ^{15}N labelled treatment provided a means of measuring the percentage N derived from the N fertilizer (% Ndff). None of these data showed any consistent differences between the soils from Southwestern Ontario and the rest of Ontario.

The shoot/root (S/R) ratios of the plants on the Southwestern Ontario soils appeared to be higher than those grown on the other soils. Although the reason for this difference is not clear, there is a possibility that reduced root growth could conceivably result in a larger available N requirement to satisfy the growth of shoots.

The total N concentration in the soils essentially reflect the organic N content of the soils. These data show that the size of the organic N pool in the soil does not provide any clear indications of the quantity of mineralizable or available N. A comparison of the Ndff and N concentration data of the North Gower and Berrien soils with the two Brookston soils supports this conclusion.

E.G. Beauchamp, J. Lovcanin and D. Tel

Availability of Manure Nitrogen

A field study was conducted to determine the availability of nitrogen in three different manures relative to that in fertilizer urea. This study was conducted at the Elora Research Station for the third successive year. The results for the three years are considered herein. The manures differed significantly with respect to the relative quantities of ammonium and "organic" N and included liquid poultry manure (LPM), liquid dairy cattle manure (LCM) and solid beef cattle manure (SBM). The percentage of the total N occurring as ammonium N at the time of application over the 3 years were as follows: LPM, 84 to 94%; LCM, 41 to 60%; SBM, 0.3 to 27%. Corn grain yields were determined to obtain response curves.

The average yield data generally showed that a variable response occurred to nitrogen in the manures (Table 31). The response from ammonium N in LPM and LCM manures compared quite closely with that from fertilizer urea N. It was evident that the ammonium N content of the manure was most important in terms of immediate availability to a corn crop.

Table 31: Average corn grain yields (1980, '81, '82) with rates of N from urea, liquid poultry manure (LPM), liquid dairy cattle manure (LCM) and solid beef cattle manure (SBM).

N Rate*	Urea	LPM	LCM	SBM
(kg/ha)		(kg grain/ha; 15.5% H_2O)		
0	4510			
50	6000			
100	6830	6550	5320	4360
150	6950			
200		7130	6570	5450
300		7040	6580	5920
600			6890	

* Manures applied on a total N basis.

The apparent decrease in yield when 100 kg N/ha was applied as SBM is difficult to explain. This result was quite pronounced in two out of the three years of the study. While the possibilities of a high C/N ratio tying up available N or the presence of a phytotoxic substance exist, the response curve with the 200 and 300 kg N/ha treatments appeared to be normal although displaced downwards. Further research will be undertaken to determine the cause of this peculiar response to SBM nitrogen.

E.G. Beauchamp

Soil Limitations to Corn Yield in Ontario

The highest yields of corn obtained in a region are much lower than the theoretical potential based on radiation received. In the Guelph region, the theoretical potential for grain yield is in excess of 20 t/ha (320 bu/ac). The highest yields obtained are less than 10 t/ha (160 bu/ac). One possible limitation to yield is the restriction of root growth by high subsoil bulk densities. This restriction, if it occurred, could reduce yield by reducing water or nutrient absorption or by creating an imbalance in plant hormone production.

A project was begun at the Elora Research Station in 1981 to:

1. establish the potential yield of corn under the temperature and radiation regime at Elora, and

2. to determine the extent to which surface and subsurface soil structure, fertility and moisture availability limit the yield.

A series of treatments was established in which possible limitations due to soil fertility, soil moisture and soil physical conditions have been removed. The possible physical limitations were eliminated by replacing the soil to a depth of one meter with a highly fertilized soil:peat:perlite (3:1:1 by volume) mixture. Shoot and root growth and final yield on these plots have been compared in 1981 and 1982 with that on the natural soil at two fertility levels. In 1981, unirrigated treatments were included whereas in 1982 all plots were irrigated with a trickle system to maintain the moisture content close to field capacity at all times.

The yields (Hybrid PAG SXIII) obtained in 1981 are presented in Table 32.

Table 32: Corn yield at Elora Research Station - 1981.

Treatment	Yield	
	Total Dry Matter	Grain (15.5% moisture)
	(kg/ha)	
Soil-Normal Fertility[1]	10765 a	6276 a
Soil-Normal Fertility-Irrigated	11615 a	6357 a
Soil-Very High Fertility[2]	12199 b	7443 b
Soil-Very High Fertility-Irrigated	13070 b	7543 b
Artificial Medium-Irrigated	13546 b	7973 b

Note: Values in each column followed by same letter are not significantly different at P = 0.05.

[1]Fertilized according to soil test 100 kg N, 70 kg P_2O_5, 70 kg K_2O/ha.

[2]900 kg P_2O_5 and 900 kg K_2O_5/ha in fall of 1980, 350 kg N during growing season.

Although the yield on the artificial medium was slightly higher than that on the soil, the difference was not significantly different (P = 0.05). Irrigation did not increase yield in spite of a dry period in July during vegetative growth. The very high fertility treatment significantly increased yield. Plant analysis indicated that this increase was due primarily to increased phosphorus absorption during the early growth period.

In 1982, the non-irrigated treatment was replaced by a second hybrid (Pride 1169). This hybrid became severely infected with yellow spot in the very wet weather during June. As a result the yields were considerably below those of PAG SXIII. The yields of PAG SXIII in 1982 are presented in Table 33.

The yields in 1982 were considerably greater than in 1981, as were corn yields generally in Ontario. The highest yield (in excess of 150 bu/ac) was obtained on the very high fertility soil treatment although this yield was not significantly higher than that on the artificial medium. The difference in yield between the high and low soil fertility treatments was greater than in 1981 and was due to a combination of nitrogen and phosphorus deficiency.

Table 33: Corn yield at Elora Research Station - 1982.

Treatment	Yield	
	Total Dry Matter	Grain (15.5% moisture)
	(kg/ha)	
Soil-Normal Fertility-Irrigation[1]	10999 a	6544 a
Soil-High Fertility-Irrigation[2]	15070 b	9711 b
Artificial Medium-Irrigation	13284 b	9186 b

[1]Fertilized according to soil test - 100 kg N, 30 kg P_2O_5 and 60 kg K_2O/ha.

[2]100 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha mixed with top 15 cm prior to planting, 250 kg N during growing season.

Root distribution with depth directly below the plant at silking is presented for 1981 and 1982 in Figures 16 and 17. The root distribution pattern was very similar in the two years. There was greater root development in the upper 30 cm of the soil medium than in the artificial medium. From 30 to 60 cm the root density was similar for the two media. There was no root growth in the soil below 60 cm; whereas in the artificial medium roots were present at the deepest depth sampled (100 cm in 1981, 75 cm in 1982). There was no difference in root growth in the soil between the two fertility treatments nor for the irrigated vs. unirrigated treatments in 1981.

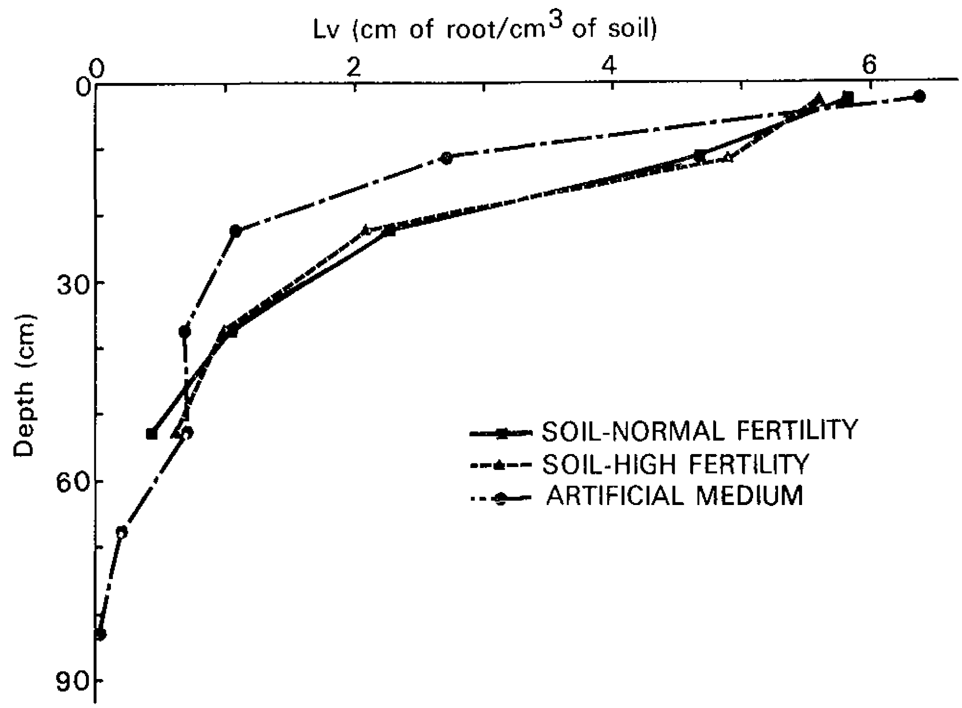

Figure 16: Root distribution with soil depth directly below the plant at silking in 1981.

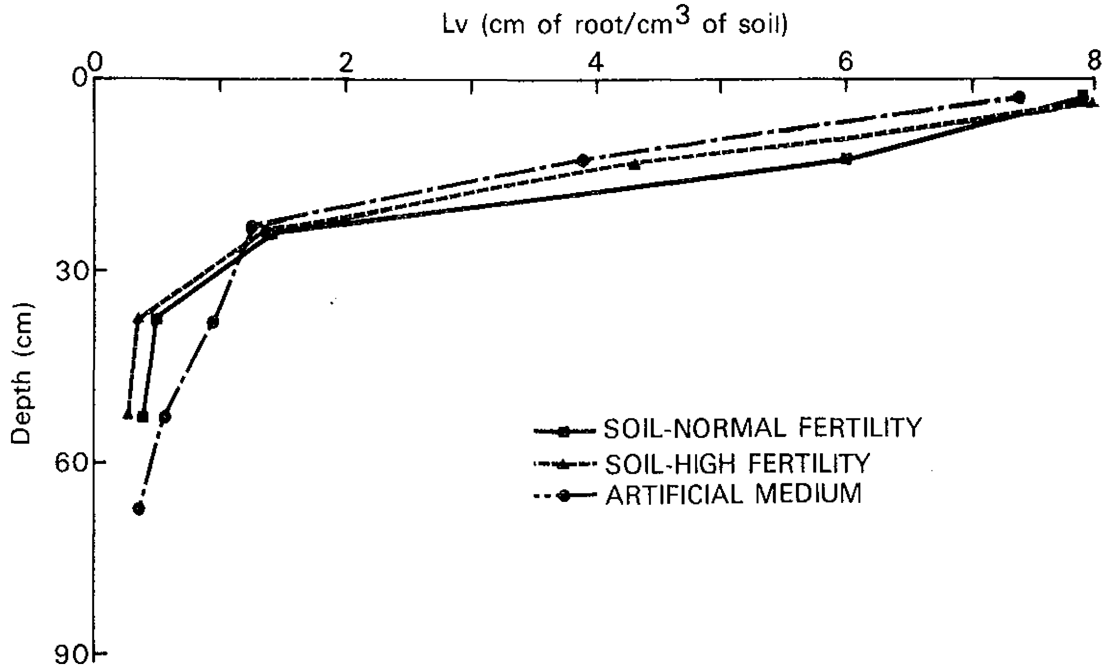

Figure 17: Root distribution with soil depth directly below the plant at silking in 1982.

The root density at the 30 to 60 cm depth in soil was somewhat surprising in view of the soil bulk densities at these depths (Table 34).

Table 34: Bulk density of soil and artificial medium.

Depth	Soil	Artificial Medium
	$g.cm^{-3}$	
0 - 7.5	1.33	1.12
7.5-15	1.35	1.10
15 -30	1.46	0.98
30 -45	1.54	1.07
45 -60	1.80	0.97
60 -75	1.82	1.09
75 -90	1.83	1.07

A bulk density of 1.5 g cm^{-3} or higher is thought to greatly restrict root growth. It is possible that, on this soil, there is sufficient structural development in the upper 60 cm to permit root development in interpedal planes. There is little structural development below 60 cm which may account for the rather abrupt cessation of root penetration.

The yield of corn was not reduced on the high fertility soil in spite of the reduction in depth of root penetration. During a dry period in 1981, the soil moisture content in the unirrigated treatment was reduced too close to the wilting point in the upper 40 cm. Although a slightly lower leaf water potential, stomatal conductance and plant growth was measured during this period, the reduction was not sufficient to reduce final yields. It appears that there was adequate root growth in deeper soil layers where water was available to avoid severe water stress.

The information obtained in this study to date suggests that subsoil density is not a limitation to corn yield at Elora Research Station.

M.H. Miller, W.A. Mitchell
M. Stypa and A. Nunez Barrios

Phosphorus Absorption by Corn in Relation to Tillage

The practice of zero-tillage causes numerous changes in the physical and chemical characteristics of surface soil including an increased bulk density, higher organic matter content, changes in microbial population and changes in nutrient distribution. In a field study in 1981, it was observed that phosphorus absorption by young corn plants growing on soil that had not been tilled for several years was considerably higher than that of plants growing on tilled soil having a similar content of $NaHCO_3$-extractable phosphorus. A series of growth room experiments were conducted in an attempt to determine the cause of the different P absorption.

Plants were grown for 22 days in 15 cm deep undisturbed cores taken from the no-till plots in November 1981 and in soil taken at the same time from the top 15 cm of the plowed plots. To simulate spring growing conditions, air temperature was maintained at 20°C day (17 h) and 13°C night. The data are presented in Table 35.

Table 35: Plant growth and P content in 22 day old corn plants growing on zero-till or plowed soil.

	Zero-till	Plowed
Shoot DM (g/pl)	0.21	0.17
Root length (m/pot)	56	98
P in shoot - (%)	0.34	0.20
(mg/pl)	0.70	0.34
$NaHCO_3$ - Ext. P in Soil (µg/g)		
0-5 cm depth	17.0	16.6
5-10 cm depth	6.5	16.6
10-15 cm depth	6.0	16.6

The P content (mg/plant) of the shoots on the undisturbed zero-till soil was 2X that on the plowed soil although the root growth (m/pl) was 45% less. The $NaHCO_3$-extractable P (Table 35) in the top 5 cm of the zero-till soil was similar to that in the plowed soil while at the 5-10 and 10-15 cm depths it was considerably lower. A parameter accessible-P (Acc-P) was calculated for each 5 cm layer in the two soils to account for the differences in both root growth and $NaHCO_3$-extractable P with depth. This parameter, which is the product of root density x $NaHCO_3$-extractable P, was summed over the three depths to give a total Acc-P for each pot. The root density (L_V - cm of root/cm^3 of soil) provides a measure of the root surface in contact with soil. The product of L_V x $NaHCO_3$-extractable P therefore is an indication of the total available soil P in contact with the root. The relation between P content (mg/pot) in corn shoots and Acc-P is shown in Figure 18. The much greater absorption from the zero-till soils at a given level of Acc-P is quite apparent.

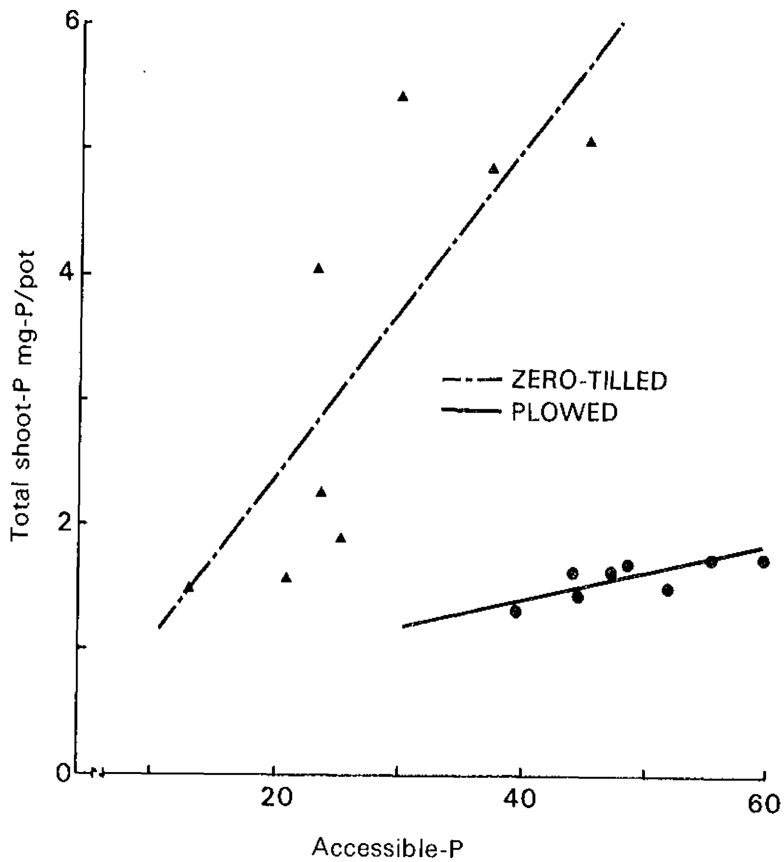

Figure 18: Relationship between corn shoot P content and accessible-P in plowed and zero-tilled plots.

In a subsequent experiment, the soil was removed in 5 cm layers from 4 of the zero-till pots, mixed and repacked in the same order. Soil from the plowed pots was also removed, mixed and repacked to two bulk densities; 1.2 and 1.4 g cm^{-3}. The higher bulk density was similar to that of the undisturbed zero-till cores. Corn plants were grown under similar conditions as the first experiment. The results are shown in Table 36.

Table 36. Plant growth and P content of corn plants in relation to soil disturbance.

	Zero-till		Plowed	
	Dist.	Undist.	Lo B.D.	Hi B.D.
Shoot DM (g/pl)	0.24	0.39	0.21	0.19
P in Shoot (%)	0.16	0.25	0.16	0.16
(mg/pl)	0.38	0.98	0.32	0.29
NaHCO$_3$-ext. P in Soil (µg/g)				
0-5 cm depth	10.5	11.0	13.7	13.7
5-10 cm depth	4.8	6.0	13.7	13.7
10-15 cm depth	4.0	4.0	13.7	13.7

The P content of corn shoots (mg/pl) growing on the undisturbed zero-till soil was 3X that on the plowed soil. Disturbing the zero-till soil and repacking reduced the P absorption to a value close to that of the plowed soil. Differences in bulk density of the plowed soil did not significantly alter the P absorption.

A second set of cores, obtained from the field plots in June of 1982, gave similar results. Drying the plowed soil prior to potting did not change the P absorption compared to maintaining the soil in the field moist state.

Studies are continuing to determine the cause of the greater absorption of P from the undisturbed zero-till soils.

I.P. O'Halloran and M.H. Miller

The Purple Corn Syndrome in Ontario

Reports of corn seedlings turning purple at about the 4th leaf stage have occurred with increasing frequency in Ontario in recent years. The purpling is sometimes confined to sections of a field while in other cases the entire field may be affected. In many instances, the crop had been fertilized at rates well above those recommended from

Table 37. Plant and Soil characteristics of Areas of Purple and Non-purple plants.

	SITE 1		SITE 2		SITE 3	
	Purple	Non-Purple	Purple	Non-Purple	Purple	Non-Purple
Shoot dry wt* (g/plant)	0.30a**	0.45b	0.27a	0.31a	0.38a	0.97a
Root Length* (m/plant)	7.70a	5.60a	5.40a	7.90a	8.30a	16.20a
% P*	0.22a	0.34b	0.20a	0.30b	0.24a	0.49a
Grain Yield (kg/ha 15.5% moisture)	10436a	11254a	9305a	8299a	6350a	7859b
Soil pH	6.80	6.70	5.80	5.60	5.70	5.90
$NaHCO_3$-Ext P (µg/g)	18(m)	18(m)	43(VH)	23(H)	28(H)	44(VH)
Exch. K. (µg/g)	179(VH)	187(VH)	213(VH)	175(VH)	109(m)	140(H)

* At 4-6 leaf stage
Site 1 - Kent Co. - clay soil - Pioneer 3732
Site 2 - Kent Co. - clay soil - Pioneer 3732
Site 3 - Brant Co. - sandy loam soil - Pioneer 3901

**Values within a site followed by same letter not significantly different (P = 0.05)

Table 38. Dry Matter and P Concentration at Seedling Stage and Final Yield of Corn Hybrids at Three Sites.

	SITE 1		SITE 2		SITE 4	
	Pioneer 3732	Pioneer 3780A	Pioneer 3732	Pioneer 3780A	Pride 1169	PAG SXIII
Short Dry Wt** (g/plant)	0.45	0.44	0.31	0.45	0.46	0.52
% P*	0.34	0.41	0.30	0.47	0.28	0.32
Grain Yield (kg/ha) (15.5% moisture)	11254	11694	9305	8299	6339	6544

* Sites 1 and 2 - Kent Co. - clay soil
Site 4 - Elora Research Station - silty clay loam

**At 4-6 leaf stage

soil tests. There have also been reports that some hybrids are more likely to show the syndrome than others.

The purple colouration is due to an accumulation of anthocyanin in response to an accumulation of sugars. The accumulation of sugars may occur in response to a number of factors, phosphorus deficiency being a dominant one. There is a definite interaction with temperature. Young corn plants growing at temperatures of 20°C do not develop purple colouration even if severely deficient in P. These plants will develop the purpling quickly if transferred to a temperature of 15°C or lower. This may explain the observation in the field that the appearance of purpling frequently follows a period of cool weather. There are reports that plants will develop the purple colouration in response to temperature or other factors even when adequately supplied with P. Some hybrids appear to produce anthocyanins more readily than others. In fact some inbreds remain purple throughout their growth.

Studies began in the spring of 1982 to characterize this syndrome more completely and to determine the cause or causes. Four locations were investigated where purple corn was observed in late May or early June; two locations were on a clay soil in Kent Co., one was a sandy loam soil in Brant Co. and the fourth was at the Elora Research Station on a silty clay loam. Plant and soil samples were collected shortly after the purpling appeared and final grain yields were taken at maturity.

Two hybrids (Pioneer 3732 and Pioneer 3780A) were planted at sites 1 and 2 in Kent Co. There were very distinct bands of purple corn about 5 m in width running perpendicular to the direction of planting in the Pioneer 3732 at site 1. These bands were not present in an adjacent planting of 3780A. At site 2 an 8-row strip of 3780A showed no sign of purpling whereas 3732 on either side was severely purpled. At site 3 in Brant Co. there were several irregular areas of severely purpled corn (Pioneer 3901). Site 4 (Pride 1169) showed marked purpling while PAG SXIII growing on similarly treated adjacent plots showed only very slight purpling.

The soil and plant characteristics on the areas of purple and non-purple plants within the same hybrid are shown in Table 37. It is apparent that, at all three sites, the purpled plants had lower dry matter and a lower P concentration. The P concentration required to give maximum growth rate at this stage is thought to be at least 0.4%. The reduced P concentration can not be explained by reduced root growth or lower available P in the soil. At all three locations, fertilizer P was applied in a band at a rate considerably in excess of that required according to the soil test. At site 3 the rate of N and K in the band exceeded the guidelines for safe rates so some root damage may have occurred to reduce the absorption of phosphorus.

The final yields were not significantly affected by the lower P absorption at the Kent Co sites. It has been observed frequently that responses to P at this stage do not necessarily result in increased final yields. In the Brant Co. site, yield was significantly reduced by the lower P content. This may have been due to a delay in maturity. This site was damaged by frost in late August, 1982.

The comparison of hybrids at three sites is shown in Table 38. The values for Pioneer 3732 at sites 1 and 2 are those for the non-purple corn. Because there were not replicated areas of the hybrids at each site, statistical analysis was done using sites as replicates. The % P in Pioneer 3780A was significantly higher than that in 3732 indicating that this hybrid has a greater ability to absorb P during the very early growth period. This increased ability could explain why 3780A did not develop purple colour in the areas in which 3732 did. At the Elora site, Pride 1169, which developed much more severe purpling, had a lower % P as well as a reduced seedling dry matter. These results indicate that, on these hybrids, the development of purple colour is related to a reduced phosphorus absorption.

The final yields of 3732 and 3780A were not significantly different, again indicating that the lower P content at the seedling stage does not necessarily result in lower yield. Pride 1169 at Elora yielded significantly less than PAG SXIII although this may have been due, at least in part, to a severe infection of eye spot which did not affect PAG SXIII. Yields of both hybrids were increased by higher fertilizer application indicating for these hybrids a P content greater than 0.30% at the seedling stage is required for maximum yields. It also indicates that phosphorus deficiency may exist even though little or no purpling is evident.

Studies are continuing to improve our understanding of these relations.

J. Cobbina and M.H. Miller

Maize Grain Yield Response To Thinning

Application of the source-sink concept can further understanding of grain yield limitations in maize. Experiments were designed to assess the effects of enhanced assimilate supply during grain development on two components of grain yield, kernel weight and kernel number per plant, and to determine the extent of source limitation to yield.

All experiments were conducted at the Elora Research Station during 1982. In the main experiment the short season maize (Zea mays L.) hybrid PAG SX 111 was grown at a density of 53,000 plants ha^{-1}. To increase photosynthate supply per plant, 6 m by 8 row plots were thinned to 19,800 plants ha^{-1}. A control (unthinned) and three thinning treatments were replicated thrice in a randomized block design. Thinning dates were: 9 Aug., 1 week after midsilking; 24 Aug, during mid grain fill; and 7 Sept., during late grain fill. Associated experiments were conducted at 80,000 plants ha^{-1}, without thinning, under a range of fertility and soil water regimes.

In the main experiment kernel number per plant was only influenced by the first thinning. That treatment raised kernel number by 110 plant^{-1} (a 30% increase relative to the control), with the increase entirely due to more kernels on the lower ear. In all thinned treatments the mean weight per kernel was approximately 226 mg, compared to 196 mg in the control. At 80,000 plants ha^{-1} there were always fewer kernels per plant, but kernel weights were usually in the 200-220 mg range.

These results confirm that a plant's grain sink capacity (kernel number x potential kernel weight) is strongly influenced by the photosynthate supply during the lag period, prior to rapid grain filling. In thinning treatments, effects on sink capacity were confined to kernel number, for kernel weight was unaffected by the time of thinning. As kernel weight determined from thinning treatments represents the potential kernel weight, the thinning technique provides a ready assessment of the degree of source limitation to grain yield. Since mean kernel weights in all unthinned plots always exceeded 85% of the mean potential kernel weight, yields were not strongly source limited. Sink limitation remains a possibility.

G.K. Walker, M.H. Miller and D.M. Brown

Tillage, Crop Rotation, Soil Structure and Soil Erosion

Long-term Tillage Experiments

The 1982 yield results for on-going tillage systems investigated on sandy loam, silt loam and clay loam soil types (at Acton, Elora and Milton, respectively) are presented in Table 39. On the sandy loam soil, zero tillage resulted in approximately 30% lower yields than conventional fall moldboard plowing and secondary tillage; most of the yield decline was associated with a much slower rate of crop development with zero tillage. On the silt loam soil, corn yields with zero tillage were approximately 12% lower than with conventional tillage; over the past seven years on this site (initiated in 1976), grain yields with the zero tillage treatment have ranged from 12 to 19% lower than those achieved following conventional tillage. Grain yield differences among tillage treatments on the clay loam soil were insignificant; the predominant factor influencing corn yields at this site was the excessive rainfall in June and July.

The longest-term study on tillage practices for Ontario corn production was initiated on a silt loam soil at the Elora Research Station in 1968 (see earlier Progress Reports). This experiment compared various tillage practices (eg. ridging, chisel plowing, wide-sweep plowing, etc.) and tillage-fertility relationships. Each year, however, zero tillage was compared to the conventional tillage practice of fall moldboard plowing with secondary tillage for seedbed preparation. Figure 19 shows the trends in corn grain yields since 1969 for this experiment. Although considerable variation occurred from year to year, yield differences since 1977 appear to be decreasing. Soil structural stability (as determined by the wet sieving technique) was considerably higher in 1982 on the zero tillage treatment (64%) than on the conventional treatment (39%). There is no

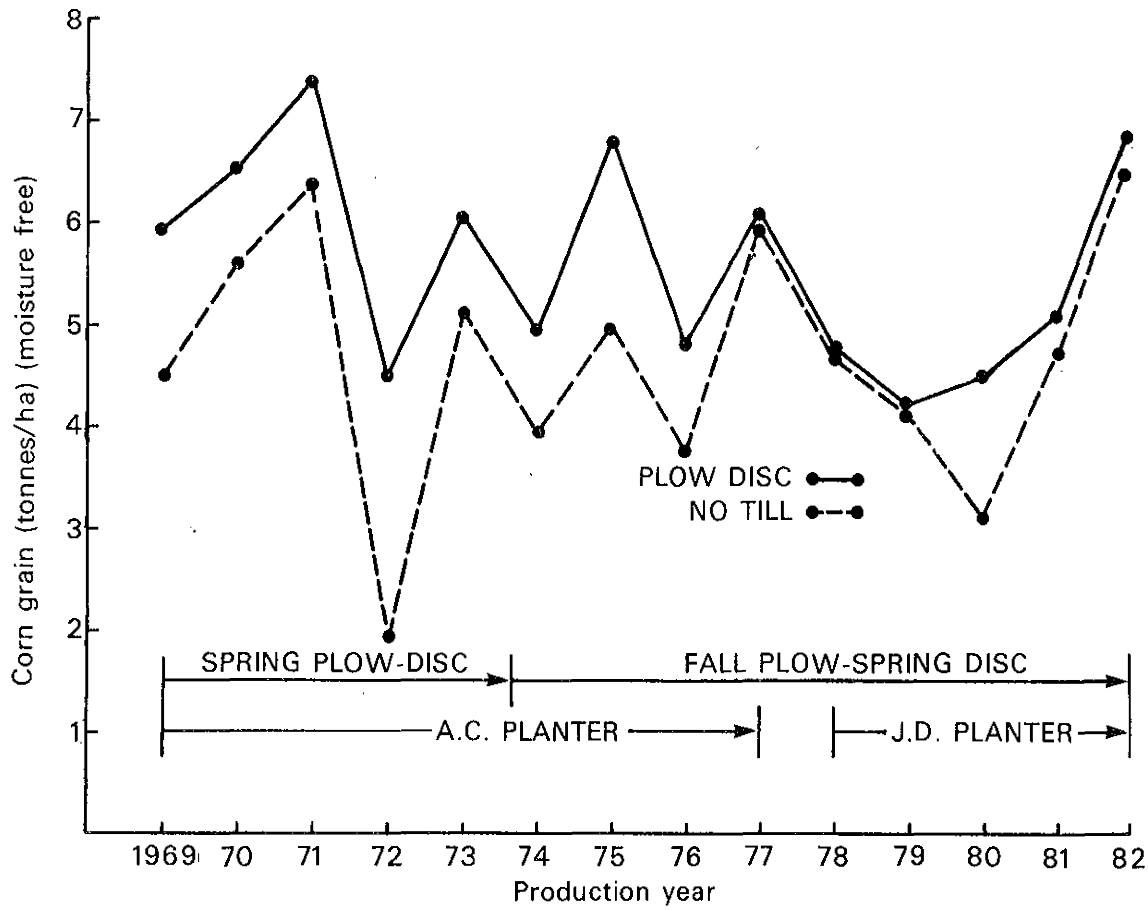

Figure 19: Long-term effects of conventional and zero-till plots on corn yields at Elora, initiated in 1969.

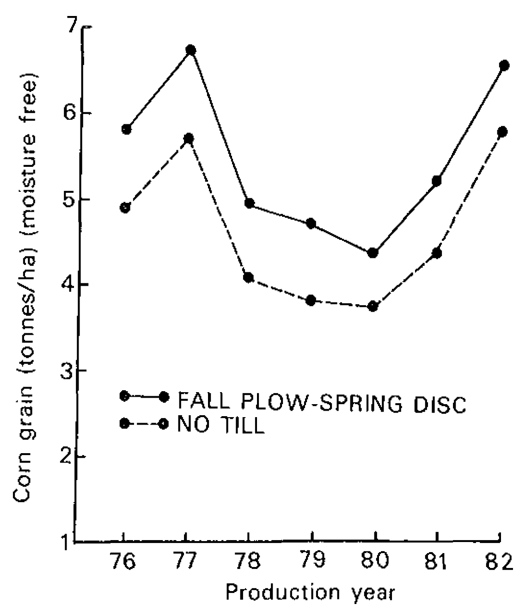

Figure 20: Long-term effects of conventional and zero-till plots on corn yields at Elora, initiated in 1976.

Table 39. Effect of various tillage practices on corn grain yields on three soil types in 1982.

Tillage treatment*	Grain yields (t/ha)**		
	Sandy loam	Silt loam	Clay loam
Fall moldboard plow; spring 2°	7.8	6.7	6.3
Fall modified moldboard plow; spring 2°	-	6.2	6.3
Spring moldboard plow only	-	6.3	-
Spring moldboard plow and 2°	7.3	6.6	6.1
Spring offset disc, harrow	7.8	6.0	-
Fall offset disc; spring 2°	-	-	6.0
Fall rotary digger; spring 2°	-	6.4	6.5
Fall chisel plow; spring 2°	6.9	6.5	5.3
Fall modified chisel plow; spring 2°	-	6.3	6.0
Fall wide-sweep plow; spring 2°	-	6.0	6.0
Zero tillage	5.4	5.9	6.2
S.E. (difference)	0.52	0.37	0.44

* Spring 2° refers to spring secondary tillage with a tandem disc. One pass of a tandem disc was used on sandy loam soil, whereas two passes of tandem disc plus cultipacker were used on the silt loam and clay loam soils.

** Grain yields in this and subsequent tables are reported as dry matter tonnes/ha (i.e. 0% moisture). To convert to bu/ac @ 15.5% moisture, multiply yield value by 18.9.

evidence of convergence in grain yields for these two tillage practices after seven years in the shorter-duration experiment initiated in 1976 on a similar soil type at the same research station (Figure 20). Figure 19 suggests that, after nine years of continuous corn production on silt loam soil, either the relative yields of corn with conventional tillage decline due to gradual deterioration in soil structure or relative yields with zero tillage increase for the opposite reason. It could be a bit of both; yearly fluctuations in yield make it impossible to ascertain which situation applies. However, grain yields for these two treatments would not necessarily be similar if there were a late spring frost (eg. 1972) or if there were poor plant establishment with zero tillage (eg. 1980).

Summaries of corn yield results obtained for tillage systems, which were common to the sandy loam, silt loam and clay loam soils during the past four to seven years, are presented in Table 40. Long-term tillage trials are no longer being conducted on loam and clay soil types; summaries of corn grain yield response to various tillage practices on these soil types are available in previous progress reports. All of the corn yield results referred to above are pertinent to continuous corn situations. Where corn follows corn in the rotation, therefore, tillage systems based on chisel plowing or offset discing may be expected to result in yield declines, relative to conventional tillage, ranging from 3 to 9% on these soils. (Previous research over a four

Table 40. Effect of various tillage practices on average corn grain yields for three soil types in Ontario.

Tillage treatment*	Soil texture (years)		
	Sandy loam (1976-82)	Silt loam (1976-82)	Clay loam (1979-82)
	Grain dry matter yield (t/ha)		
Fall moldboard plow; spring disc	6.5	5.6	6.2
Fall chisel plow; spring disc	6.2	5.2	5.7
Spring moldboard plow and disc	6.3	5.4	5.9
Spring offset disc**	6.3	5.2	5.8
Zero tillage	5.5	4.7	5.7
S.E. (difference)	0.15	0.13	0.22

* Secondary tillage usually consisted of one pass with tandem disc on the sandy loam soil and two passes with tandem disc and cultipacker on silt loam and clay loam soils.

** Fall offset disc in 1982 on clay loam soil.

year period on loam soil indicated that grain yields following chisel plowing or offset discing were similar to those achieved following moldboard plowing.) If chisel plowing or other reduced tillage systems were adopted for corn production following crops other than corn in the rotation, little or no yield reduction (relative to moldboard plowing) may result. This possibility is currently under investigation.

T.J. Vyn, T.B. Daynard and J.W. Ketcheson

Modifications to Primary Tillage Implements

Research on modifications to the chisel and moldboard plows continued on two soil types in 1982. Modifications were made to both implements in the fall of 1979 in an attempt to overcome the problem of yield reduction, particularly on fine textured soils, associated with chisel plowing (relative to moldboard plowing), and yet retain a level of residue cover on the soil surface similar to that achieved with the chisel plow system. Table 41 summarizes the corn yields obtained with conventional and modified primary tillage equipment after the first three years of investigation on two soil types.

Modifications to the moldboard plow (i.e., the removal of trash covers and 70% of each actual moldboard) resulted in yields which were similar to conventional moldboard plowing. Attaching wider teeth to the chisel plow resulted in corn grain yields which were no greater than normal chisel plowing on the silt loam soil, but similar to conventional moldboard plowing on the clay loam soil. Corn grain

Table 41. Effect of modified tillage systems on corn grain yields on two soil types (average of 1980-82).

Fall tillage treatment*	Grain dry matter yield (t/ha)	
	Silt loam	Clay loam
Moldboard plow	5.5	6.5
Modified moldboard plow	5.3	6.6
Chisel plow	5.1	6.0
Modified chisel plow	5.1	6.5
Wide-sweep plow	5.1	6.5
S.E. (difference)	0.19	0.23

* All treatments were tandem disced twice in spring prior to planting.

yields following primary tillage with the wide-sweep plow were similar to those following moldboard plowing on the clay loam soil, but not on the silt loam soil.

Residue cover actually left on the soil surface, both before and after secondary tillage and planting, was somewhat lower for the modified moldboard and chisel plows relative to the residue cover after normal chisel plowing (Table 42). However, both modified implements left considerably more residue cover than that left after conventional moldboard plowing. The wide-sweep plow left significantly more overwinter residue cover than all tillage systems with the exception of zero-tillage, but following secondary tillage, residue cover with the wide-sweep plow system was similar to the normal chisel plow treatment.

Table 42. Effect of various tillage systems on surface residue cover with continuous corn production on two soil types (average of 1981-82).

Fall tillage treatment*	Silt loam		Clay loam	
	April	June	April	June
	---- Residue cover (%) ----			
Moldboard plow	5	5	6	4
Modified moldboard plow	18	14	20	13
Chisel plow	30	20	31	17
Modified chisel plow	24	19	22	13
Wide-sweep plow	37	20	50	20
Zero tillage	57	42	66	49
S.E. (difference)	2.6	1.9	2.5	2.4

* All treatments, with the exception of zero tillage, were tandem disced twice just prior to planting in early May.

Although these implements must be tested for at least one additional year, the results to date suggest that possibilities exist for simultaneously increasing surface residue cover for erosion prevention and eliminating the yield declines associated with standard "mulch" tillage systems on these soils, even in continuous corn.

T.J. Vyn, T.B. Daynard, J.W. Ketcheson and J.H.A. Lee

Research on Strip Tillage

Previous research on the effects of reduced tillage depth on loam soil, and on reduced width and depth of seedbed preparation on silt loam soil, indicated that substantial reductions in the width and depth of spring tillage could occur without detrimental effects on corn grain yield, unless tillage was eliminated completely (i.e. zero tillage). Research activity on strip tillage techniques for corn increased in 1982 as a result of an Agriculture Canada contract. The concept of strip tillage was tested by using various PTO-powered and passive tillage implements to prepare seedbeds approximately 20-cm wide and 8-cm deep for corn planted in either 76- or 89-cm row widths on three soils in central Ontario. Strip tillage treatments on sandy loam and silt loam sites were not preceded by primary tillage; corresponding treatments on the clay loam soil were preceded by fall moldboard plowing. The first year's results are presented in Table 43.

Table 43. Effect of various strip tillage systems on corn grain yields on three soil types in 1982.

Tillage treatment*	Dry matter yield (t/ha)		
	Sandy loam	Silt loam	Clay loam
Fall moldboard plow and spring secondary tillage	7.8	6.6	6.3
Howard Rotovator strip	7.1	6.1	5.3
Howard Rotospike strip	6.9	5.2	6.4
Lely Roterra strip	7.0	5.7	6.5
Strip-till cultivator	6.8	5.5	5.5
S.E. (difference)	0.52	0.41	0.65

* Strip tillage treatments followed fall moldboard plowing on clay loam soil.

Grain yield differences among treatments were significant (at $P = 0.05$) at the sandy loam and silt loam sites, but not at the clay loam site. All strip tillage systems resulted in yields inferior to those with conventional tillage on the sandy loam and silt loam soils. However, strip tillage with either the Howard Rotospike or the Lely

Roterra on clay loam soil, which had been tilled the previous fall, resulted in yields similar to conventional tillage. Although a minimum of two years of further testing is necessary to determine the merits of the various strip tillage systems, it is possible that fall primary tillage may need to precede spring strip tillage in order for corn development and yield to be equal to that occurring following conventional tillage.

T.J. Vyn and T.B. Daynard

Crop Residues May Interfere with Corn Growth in No-till Plantings

Clearing corn stover residue from the planting row increased corn grain yield 325 kg/ha at the Elora Research Station plots in 1982. Most of the clearing operation had to be done by hand, although we tried residue-moving discs attached to the planter. Growth of young corn plants showed a marked improvement in vigor, uniformity, and reduced slug damage by July.

Although lack of tillage does not lower soil temperature, residue shading does. The reason for our improved growth may have been higher soil temperature (as much as 5°C on warm sunny days), reduced slug damage, elimination of phytotoxic damage, or simply less mechanical interference by the old stover. It could also be a combination of two or more of these factors.

We plan to continue investigations with this situation and look for practical ways to reduce crop residue accumulations in the planting row for reduced and no-till situations.

J. VanRoestel and J. Ketcheson

Corn Stover Decomposition and Area Cover as Influenced by Tillage

The effectiveness of corn stover in controlling erosion depends on its rate of decomposition and the resulting soil area covered. With no-till, on a glacial till soil at Guelph, 23 and 60% of stover (by wt.) decomposed May to July and May to October, respectively. The bottom portion of plants decomposed more rapidly than entire plants during winter and more slowly during summer, but the loss in surface area cover was greater for entire plants in the period July to October.

Horizontal blade tillage (10 cm below soil surface) in May incorporated 8% of the entire plants, but only 1% of stalks with leaf sheaths. Disc-chisel tiller plus tandem disc-packer (2 passes) incorporated 45% of the entire plants, and 42% of the stalks with leaf sheaths. Between May and July, 16 and 34% of the stover decomposed, with each of the two tillage treatments, respectively, on the soil surface in July. However, a unit weight of residue after chisel-discing (stover cut and shredded) covered 50% more soil surface area than a similar unit of residue after blade tillage.

By October, 63 and 67% of the residue was decomposed, leaving only 1.0 and 0.6t of residue/ha after blade and chisel-disc tillage, respectively. The trend in decomposition was chisel-disc > blade > no-till.

A.L. Santos, and J.W. Ketcheson

Research on Soil Erosion

Erosion measurements continued in 1982 on the hydrology plots at Guelph (Table 44). Because of a graduate student thesis project, some of the treatments were altered from those of the previous two years. Results from the previous years had demonstrated that surface residue cover was far more effective than surface roughness in preventing soil erosion. High rainfall intensities caused substantially higher soil losses in 1982 than in previous years. Removal of 50% of the corn residue prior to spring chiseling increased both water and soil loss significantly; incorporation of all of the previous year's corn residue resulted in water and soil losses approximately 4 and 43 times greater, respectively, than after chisel plowing plus secondary tillage.

Actual soil losses over this period were considerably higher than those predicted by the Universal Soil Loss Equation (USLE) for those treatments with minimal residue cover. However, where surface residue cover was greater than 20%, less soil erosion occurred than was predicted by the USLE. This suggests that, for the conditions prevailing in 1982, the equation may underestimate the erosion protection afforded by intermediate amounts of residue cover.

J.W. Ketheson, T.J. Vyn and A.L. Santos

Table 44. Effect of various spring tillage treatments on surface residue cover, water runoff and soil erosion with corn production on loam soil (May - July 1982).

Tillage treatment	Residue cover (%)		Water loss (cm)	Soil loss (t/ha)
	May 5	July 15		
Wide-sweep plow	46	36	0.55	1.4
Moldboard plow				
- no secondary tillage	1	1	6.01	69.7
- disced and cultipacked twice	1	1	4.40	78.4
Chisel plow and secondary tillage				
- 50% residue removed	14	7	4.06	18.7
- all residue left	40	27	1.08	1.8
S.E. (difference)	3.5	1.1	1.39	18.40

J.W. Ketcheson, T.J. Vyn, and A.L. Santos

Soil Erosion and Crop Productivity

The increasing emphasis on row crops, particularly corn, in Ontario during the past two decades has resulted in soil structure degradation as well as increased exposure of the soil to erosive forces. While crop rotations and reduced tillage practices will control erosion, the cost associated with them in terms of reduced acreage and/or reduced yields of corn has been a major limitation to their adoption. Little or no quantitative data have been available on either the extent of erosion or the resulting yield loss to allow calculation of cost/benefit ratios for control practices.

In the spring of 1982 a field program was initiated to determine the effect of past erosion on soil productivity in a selected area of Waterloo Co. Eight field research sites were established in farm fields with a history of soil erosion. Corn yield and soil properties were compared between non-eroded, eroded and depositional landform types on replicated plots in each field. Table 45 presents the location and dominant topography at each site, as well as the soil series and average fertility of the non-eroded plots at each site.

Table 45. Soil Characteristics at Erosion/Productivity Sites in Waterloo Co.

Site	Location	Topography*	Soil Series	Average Fertility
1	Bamberg	B	Huron Perth Complex	very low
2	New Prussitt	B	Huron CL	high
3	St. Agatha	B to d	Waterloo Heidelberg	high → eE
4	Wilmot Center	B to c		high
5	Wilmot Center	B to c	Bookton Berrien	high
6	New Dundee	B to c	Burford SL → CL	medium
7	New Dundee	B to c	Bront-Tuscola	high/med.
8	Cambridge	D to d	Burford gravelly loam	medium

*Topography simple complex

Slope Class		
simple	complex	% slope
A	a	0-3%
B	b	3-6
C	c	6-12
D	d	>12

Yield of corn on eroded soils was significantly lower than on non-eroded plots at each site. No significant yield increase was evident on depositional soils; some yield decreases were observed on depositional soils. Table 46 summarizes the yield response and the major limitations to yield that were evident on the eroded soils. The average yield reduction associated with the eroded plots was 32.4%. The major causes of yield reduction on eroded soils varies with each soil series. No single soil variable is dominant at all sites. Rather, yield reductions appear to be caused by either reduced soil

Table 46. Effect of Soil Erosion on Corn Yield at 7 Sites in Waterloo Co. in 1982.

Site	Non-Eroded	Grain Yield (O.M.) (kg ha) Eroded	Depositional	% Yield Reduction	Major Limitation To Yield on Eroded Soil*
1	3614	2566	3650	29	Fertility (P and K)
2	6407	3972	6023	38	Fertility (N,P,K)
3	7377	4205	7377	43	Available H_2O
4		--		--	
5	5935	4036	5401	32	Available H_2O, Fertility
6	6556	2885	7146	56	Fertility(N), Available H_2O
7*	6260	a) 5321	b) 6823	a)15 b)+9	Fertility (P and N)
8	5427	4341		20	Fertility (P and N)

* a) severe erosion (exposed Ck)
b) slight erosion (exposed Bt)

fertility, reduced water holding capacity or a combination of both. The importance of each variable is dependent on the soil properties of the non-eroded soil series. In general, on coarse and fine textured soils, reduction in available moisture appears to be the major limiting factor to crop growth. On medium textured soils, such as deep silts, reduced fertility becomes more significant. At site 7, slight soil erosion (exposed Bt horizon) resulted in a yield increase. This is due to a 15-20 cm thick sand cap with low moisture holding capacity that existed on the non-eroded soil. Removal of this sandy A horizon by erosion resulted in the exposure of a silty Bt horizon. Given adequate fertility, the high water holding capacity of the Bt results in a more favorable plant growth medium. It is important to note, however, that more severe erosion (exposed Ck horizon) at the same site resulted in a significant yield decrease.

The ultimate aim of this program is to develop a model that will permit the estimation of the yield reduction in relation to degree of erosion for the major soil series in Ontario. A model has been developed which estimates (1) the soil loss using the Universal Soil Loss Equation (U.S.L.E.), (2) the change in available water holding capacity resulting from the soil loss and (3) the change in yield associated with the change in available water holding capacity. This model has been applied to the major soils in Huron Co. Assuming a 25 year period of continuous corn production and assuming that erosion is limited to one-quarter of the field, the total soil loss on the eroded portion of the field would range from 2 to 60 cm. Soil losses of greater than 40 cm could be expected on three series, Dumfries, Donnybrook and Harriston. In terms of expected changes in yield, the Huron soil is the most sensitive to erosion. Over the 25 year period, it is estimated that erosion would remove 21 cm of soil, and that grain corn on the eroded area would be reduced by more than 40%, or about 2100 kg ha^{-1}.

On the assumption that grain corn production is distributed according to the availability of each of 13 selected soil series in Huron County and that soil erosion affects 25 per cent of the field, it is estimated that 25 years of continuous corn in Huron County would result in a loss in annual corn production of about 2.5 per cent. Given current production levels for grain corn in Huron County, this represents a loss in annual production of about 10,000 tonnes. Under these assumptions and given current prices for corn, it is estimated that the erosion resulting from 25 years of corn monoculture would reduce the value of the grain corn crop by approximately $1.1 million per annum.

These assessments of the effects of soil erosion on productivity are attributed solely to the impact of erosion on plant-available moisture, and thus yields. As indicated in Table 46, yields on eroded sites are frequently reduced due to nutrient stress as well. Thus the reductions indicated are considered to be minimum values.

The program is continuing with the objective of incorporating factors other than available moisture into the model.

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Crop Rotations and Soil Structure

Two long-term rotation experiments were established in 1980, funded by an NSERC Stategic grant, in order to derive a better understanding of the effects of various preceding crops on soil structure and productivity, particularly as it relates to corn production. One experiment was established on a silt loam soil at the Elora Research Station, and the other on a clay loam soil east of Milton. Each test involves eight crop sequences:

1. continuous corn
2. continuous alfalfa (reseeded by direct seeding as required)
3. corn-corn-barley-barley
4. as #3 except both barley crops seeded to red clover for late autumn plow down
5. corn-corn-soybeans-soybeans
6. corn-corn-soybeans-winter wheat
7. as #6 except wheat seeded to red clover for autumn plow down
8. corn-corn-alfalfa-alfalfa.

Treatments 3 to 8 are repeated out of phase so that yield data can be collected from corn in each rotation (except continuous alfalfa) every year. Each replicate, therefore, contains 14 plots. Each plot, in turn, is divided to permit a comparison of conventional (involving moldboard plowing) and minimum (involving either chisel plowing or discing) tillage techniques for establishing the various crops. The first meaningful yield measurements were available in 1982 when the first crops of corn were grown after the various crop sequences. Results at Elora are shown in Table 47. Despite the very high yields obtained, differences among treatments were not statistically significant.

Table 47. Effect of two tillage treatments on corn grain yields following various crops in rotation on silt loam soil in 1982.

Rotation system*	Dry matter yield (t/ha)	
	Fall chisel plow	Fall moldboard plow
Continuous corn	7.3	7.5
Barley-barley-corn	7.5	7.8
Barley + RC - barley + RC - corn	7.8	7.6
Soybeans-soybeans-corn	8.0	7.8
Soybeans-winter wheat-corn	7.5	7.3
Soybeans-winter wheat + RC - corn	7.2	7.3
Alfalfa-alfalfa-corn	7.8	7.2
S.E. (difference)	0.35	0.32

*RC = Red Clover

Wet aggregate stability (i.e. ability of soil granules to resist structural breakdown caused by water) was measured in 1981 and 1982 in rotation experiments at both Elora and Milton. The results for both years at Elora (Table 48) demonstrate the greater structural stability of soil seeded to alfalfa and cereals (especially winter wheat) vs. corn and soybeans.

Table 48. Wet aggregate stability of soil seeded to various crop sequences on silt loam soil.

Crop grown			Aggregate stability (%)**	
1980	1981	1982	1981	1982
corn	corn	corn	17.7	26.8
alfalfa	alfalfa	alfalfa	23.6	40.6
barley	barley	corn	19.5	27.3
corn	corn	barley	--	30.8
barley*	barley*	corn	21.1	27.3
soybeans	soybeans	corn	18.8	26.4
soybeans	winter wheat	corn	23.0	34.7
soybeans	winter wheat*	corn	21.4	32.5
alfalfa	alfalfa	corn	--	34.9
S.E. (difference)			1.20	1.59

* Interseeded to red clover in spring.

** Aggregate stability values represent means from three measurement dates in 1981 and five measurement dates in 1982. The technique for measuring aggregate stability was altered slightly for 1982.

Measurements were taken in 1981 and 1982 at Elora of root concentrations in the upper 7 cm of soil; root length density (i.e., cm of root length per cm^3 of soil volume) in surface soil is considered to be of vital importance in producing and maintaining a stable, granular soil structure. As shown in Table 49, roots were more numerous in surface soil with cereal crops than with corn, soybeans, and alfalfa in June and July of 1981 and in July of 1982. Surface root density was especially low with corn and soybeans in June, a period of the year when severe soil erosion can occur.

Table 49. Concentration of roots in upper 7 cm of soil in plots seeded to five crops on silt loam soil in 1981 and 1982.

Crop	1981			1982	
	June	July	August	July	September
	------- cm of root length/cm^3 of soil ------				
corn	0.2d*	1.7b	2.1a	1.7c	2.0b
alfalfa	0.8c	1.5b	1.2b	2.9b	4.6a
barley	1.4b	3.6a	2.7a	7.9a	4.7a
soybeans	0.2d	0.6c	0.9b	0.9d	1.6c
winter wheat	1.9a	3.3a	1.2b	--	--

* Values in each column followed by the same letter do not differ significantly at P = 0.05 according to Duncan's Multiple Range Test. Data were analyzed as log (x + 1); detransformed means are presented.

An experiment was established at the Elora Research Station in 1981 and 1982 to study whether an improvement in wet aggregate stability would result if the concentration of roots near the surface in soil seeded to corn could be increased. The test involved six treatments: corn planted at a normal density (60,000 plants/ha) in 75 cm rows; corn planted at high density (180,000 plants/ha) in 25 cm rows; corn planted at high density, but thinned to normal density in early July; corn planted at normal density but with a straw mulch applied in early June; bare soil; bare soil plus straw mulch applied in early June. Measurements of root length density from the surface 7 cm were taken in July and August of each year with wet aggregate stability measured on several dates. Treatments did affect root length density in the surface soil (Table 10) especially in the mid-row area; no effect on wet aggregate stability was detected.

Table 50. Concentration of roots in surface soil as affected by corn plot treatments in 1981 and 1982.

Treatment	Mean root density*			
	Within row		Mid row	
	1981	1982	1981	1982
	--- cm of root/cm^3 of soil --			
Normal corn	2.9a**	2.2	0.6c	0.5
High density corn	2.3b	2.3	1.2a	1.1
High density corn, thinned in early July	2.6a	2.4	0.8b	0.8
Normal corn with mulch	2.7a	2.7	0.9b	0.7
Bare soil	--			
Bare soil plus mulch	--			

* Average of three dates of measurement in 1981 and two dates of measurement in 1982.

** Values in early column followed by the same letter do not differ significantly at P = 0.05 according to Duncan's Multiple Range Test. Root data anlyzed as log (x + 1).

T.B. Daynard and T.J. Vyn

Rye-Corn Sequences for Biomass Production

A comprehensive research program, funded by the ERDAF program of Agriculture Canada, was established (1) to determine how much crop dry matter per hectare per year could be produced using agricultural, or potentially agricultural, plant species (2) to assess cultural requirements needed to optimize dry matter production and (3) to explore means of converting resultant biomass into usable forms of energy. Results of research in 1980 and 1981 demonstrated that rye was capable of producing up to 10 t/ha of dry matter by June 1. Dry matter production by corn was minute during this interval because of a slow rate of leaf area establishment. Corn-rye double-crop sequences could be potentially advantageous for maximizing the seasonal capture of solar energy, for prevention of erosion during the fall and spring, and for amelioration of soil structure.

Although several experiments are involved in various aspects of this project, the following discussion will be restricted to the influence of certain cultural practices (i.e., rye cultivar, tillage system, rye harvest procedure, and corn planting date) on the response of corn following the rye cover crop. Experiments in 1981 demonstrated that rates of corn development and growth were reduced by the preceding rye crop, especially if the corn was planted without tillage in rye stubble. In 1981-82, experiments were established at Elora and

Woodstock to measure dry matter yield of this two-crop rotation and to investigate possible cultural procedures to overcome the negative effects of the preceding rye crop.

One factorial experiment at Elora compared the effects of four rye cultivars, a winter wheat cultivar, a no-cereal control, two rates of N fertility, and rye residue removal vs. on-plot retention in the spring on yield and maturity of corn and winter cereal biomass. A summary of the results (Table 51) demonstrates that corn grown in plots following a winter cover crop had significantly lower total dry matter yields and higher moisture percentages than when corn did not follow a winter cereal. The removal or retention of cereal biomass averaged over cereal treatments, had no effect on any of the parameters measured.

Table 51. Effect of various winter cover crop treatments on yields of cereal biomass and the succeeding corn crop in 1982.*

Previous cover crop	Cereal dry matter biomass (t/ha)	Total corn dry matter yield (t/ha)	Whole plant moisture (%)	Total biomass yield (t/ha)
Wheeler rye	3.3	13.8	78.7	17.1
Cougar rye	1.7	13.8	78.4	15.5
Kodiak rye	2.0	14.2	78.2	16.2
Puma rye	2.5	13.8	77.9	16.3
Gordon winter wheat	0.9	14.1	77.6	15.0
None	0.0	14.7	76.8	14.7
S.E. (difference)	0.18	1.3	1.3	--

* All values shown for corn values are means of two nitrogen rates and of the cereal-removal and cereal-retention treatments. Corn was planted after rototilling on May 18.

Two factorial experiments were established at Elora and Woodstock to compare the effects of three dates of rye harvesting and corn planting in the spring, two corn hybrids of differing maturities and conventional versus zero-till planting of corn on development and yield of both rye and corn. Total dry matter corn yield (Table 52) indicated a significant yield decrease and higher moisture content for the zero-till treatment relative to the tilled treatments at Elora. At Woodstock, tillage treatments had no effect on yield or whole plant moisture. Total biomass yield (corn and rye) at Elora averaged 14.2 and 14.6 t/ha for the second and third planting dates respectively. Total (corn and rye) biomass yield at Woodstock ranged from 19.2 to 21.1 t/ha.

Other factorial experiments, established at both Elora and Woodstock, compared the effects of three tillage treatments (zero-tillage, disc and moldboard plow) and various rye management practices on corn development and yield. First year results at Elora (Table 53) suggested that the combination of zero-till seeding of corn into rye, whether or not rye was harvested as a silage crop, resulted in severe yield depressions of corn. Alleopathy is suspected as being the casual factor.

Table 52. Effect of tillage treatments and rye cover crops on corn yields and maturity at Elora and Woodstock in 1982.*

Tillage treatment	Elora		Woodstock	
	Corn dry matter yield (t/ha)	Whole plant moisture (%)	Corn dry matter yield (t/ha)	Whole plant moisture (%)
Zero-till, rye stubble	9.0	78.4	13.5	72.5
Rototill, rye stubble	12.3	76.1	14.4	74.0
Rototill, no rye	12.6	77.1	15.4	74.1
S.E. (difference)	1.0	1.2	2.0	1.7

* Elora values are means of three planting dates; Woodstock values are for one planting date in late May. All values are means for two hybrids.

Table 53. Effect of three tillage treatments and rye cover crop management on corn yields and maturity at Elora in 1982.

Rye management	Spring tillage*	Total corn dry matter yield (t/ha)	Whole plant moisture (%)
No rye	Zero-till	13.4	80.1
	Tandem disc	12.7	80.8
	Moldboard plow, disc	12.9	80.7
Rye biomass removed	Zero-till	9.7	80.2
	Tandem disc	11.6	79.9
	Moldboard plow, disc	11.9	79.6
Rye biomass not harvested	Zero-till	9.9	82.0
	Tandem disc	11.3	81.2
	Moldboard plow, disc	12.3	81.2
S.E. (difference)		0.6	0.8

* Fall tillage for the entire experiment consisted of moldboard plowing the red clover stand and secondary tillage prior to seeding rye.

J.F. Muldoon, T.B. Daynard, M. Tollenaar, T.J. Vyn and J.H. Dekker

A Comparison of Fall Plowing and Frost Action in the Alteration of Soil Bulk Density

The production of row crops using minimum tillage offers significant opportunities for diminishing erosion and energy costs. However, experience in Ontario suggests that when zero tillage is used in a continuous corn program, average yields are below yields obtained when conventional tillage (fall moldboard plow, spring disc, harrow) is practiced (see previous Progress Reports). The yield reduction is most pronounced on the medium and fine textured soils. Soil bulk densities and penetrometer resistance are higher on soils on which zero tillage is practiced. Although corn yields are not consistently correlated with bulk density and strength in the different tillage treatments, the higher values recorded on zero tillage treatments are reason for concern.

The observation that bulk densities are consistently higher on soils on which zero tillage is practiced is somewhat anomalous when conventional wisdom indicates that ground freezing loosens soil, alleviates compaction and can thus improve seedbed conditions. The effects of frost action should be greatest on soils whose texture make them frost susceptible, and which have access to an abundant water supply during freezing. This should result in extensive ice lens formation which can break up and expand the soil matrix. The higher bulk densities under zero tillage therefore must be considered particularly unusual in light of observations of ground surface displacements over winter as large as 7 cm on soils which are texturally similar to soils exhibiting high bulk densities under zero tillage. These data would suggest that either (1) ground freezing is reduced under zero tillage due to increased snow accumulation, (2) ground freezing occurs in soils under zero tillage but ice lens formation is much less because compaction has resulted in hydraulic conductivities which are reduced to the level that water flow during freezing is limiting or (3) ground freezing and ice lens formation occurs, but soils under zero tillage reconsolidate during the melt périod and/or early in the growing season and quickly return to the pre-freezing state.

The objective of this study was to evaluate the relative significance of ground freezing, ice lens formation and post-freezing reconsolidation in the retention of high bulk densities on zero tilled soils used in the continuous production of corn.

Methods

Two field sites were selected for the study; both sites are part of an ongoing study on the relation between tillage practices and crop response (see previous Progress Report). The soil at the one site was silt loam; the soil at the second site was a clay loam.

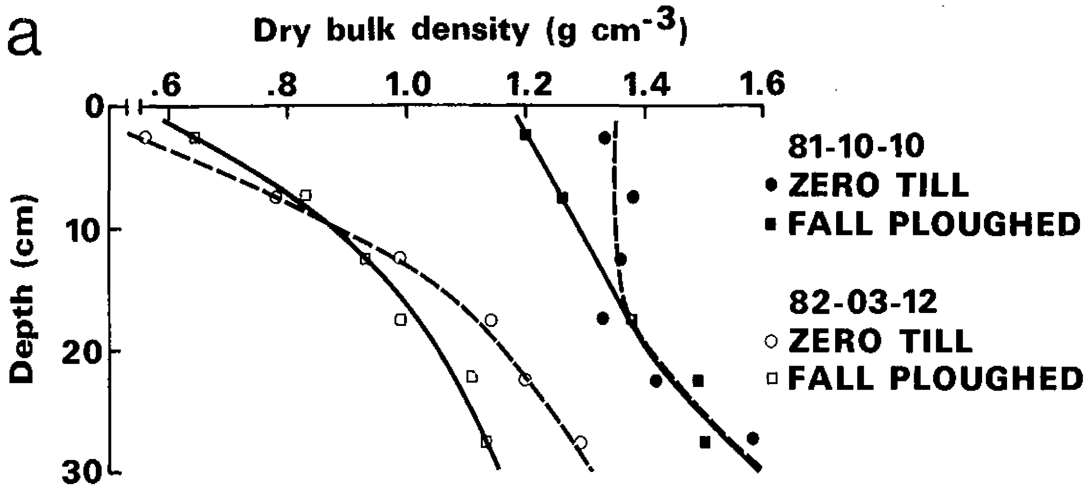
Two tillage treatments were compared, zero tillage and conventional tillage (fall moldboard plow, plus spring secondary tillage).

Results and Discussion

The presence of a ground cover on soils which are not fall ploughed resulted in increased snow accumulation, decreased depth of freezing and less frost heaving. However, it appears that these factors do not account for the observation that soils, on which zero tillage is practiced, are capable of retaining higher bulk densities than soils which are ploughed in the fall.

The influence of ground freezing on bulk densities is illustrated in Figure 21. The two different textured soils behaved similarly with slightly lower bulk densities being observed on the clay loam soil under frozen conditions. Fig. 21(a) illustrates the reduction in the bulk densities to a depth of 30 cm when the profiles prior to ground freezing (81-10-10) are compared to the profiles late in the winter (82-03-12). The greatest reduction in the bulk density occurred in the surface 15 cm but no major influence of tillage treatment was obvious. The changes in bulk density following thawing of the silt loam soil are shown in Figure 21(b). Bulk densities averaged over two 15 cm depth intervals are shown. The most significant feature of these data is the fact that the bulk densities, subsequent to thawing, have returned to prefreezing values prior to spring tillage. Although ground freezing caused bulk densities to drop 20-30% in the surface 15 cm on both zero tilled and fall ploughed soils, the soils quickly reconsolidate upon thawing. The intriguing aspect of this observation is that reconsolidation occurs at different degrees for the different tillage treatments so that the differential in bulk density caused by tillage is retained during reconsolidation. That such behaviour should occur is perhaps not entirely unexpected considering the laminar nature of ice lenses which are responsible for the decrease in bulk density. Between ice lenses, the frozen soil retains its prefreezing bulk density. Once thawing begins, drainage of the meltwater results in consolidation in a manner analagous to the removal of a slice of meat from between two slices of bread. The peds or aggregates within a ped return to a position similar to that which existed prior to freezing. This implies that the pores created by ice lenses are inherently unstable. This is in marked contrast to pores created by fall ploughing. The difference relates to differences in movement of aggregates relative to one another in the process of creating pores. Ploughing results in fracturing with both vertical and lateral displacement of the aggregates. Thus the aggregates or peds cannot return to their original position.

The extent to which those pores, which are created by tillage, are retained during thaw consolidation will be related to the inherent water stability of the aggregates. Aggregates which are reasonably stable are expected to retain their integrity during the condition of supersaturation which exists after the surface thaw but before drainage becomes significant. Therefore pores which are created by tillage could remain intact during the consolidation of the peds which were enriched with ice. The soils under study would appear to be sufficiently stable that the differences in porosity introduced by fall ploughing are retained through expansion and subsequent consolidation of the matrix due to freezing and thawing. However, soils which are not



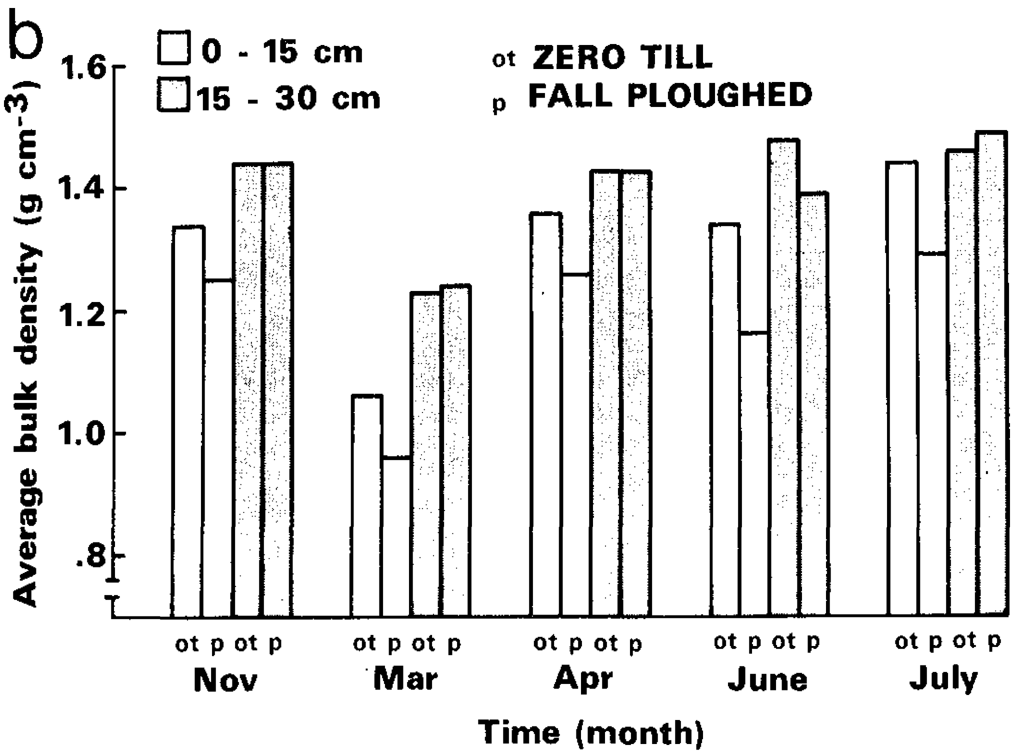


Figure 21a & b: Effect of freezing and thawing on soil bulk density (0-30 cm depth).

structurally stable under supersaturated conditions may undergo extensive consolidation during drainage as the pores created by tillage collapse.

Micromorphological Characterization of Void Arrangement Under Two Tillage Treatments

Currently within the department the effect of tillage on soil physical properties is being investigated. The impetus for this project is provided by the observations that (1) corn yields in Southern Ontario are lower on no-till plots than on tilled plots and (2) corn yields are lower on plots in continuous corn than on plots in which corn is grown in rotation with other crops, particularly forage crops. Therefore, treatments consisting of conventionally tilled corn (i.e. fall plow, spring disc and harrow) and no till corn were investigated. The tilled plots have consistently yielded higher than the no-till plots with yields for the period 1976-1982 averaging 5.6 vs. 4.7 tonnes corn grain/ha. One hypothesis is that the observed yield reduction under no-till is due to poor soil structure with its consequential effect on void size, shape and orientation.

In order to test the above hypothesis undisturbed samples of the upper 5 cm of soil under the two treatments were taken in July 1982. The samples were impregnated with a plastic resin (3-Hydroxybutal methacrylate) containing a UV fluorescent dye (Uvitex OB, Ciba-Giegy). The hardened samples were cut into 1-2 cm thick vertically oriented slabs. The polished surfaces of these slabs were then photographed under UV illumination. The images thus obtained were analyzed using a manually operated image analyzer (Zeiss MOP-3).

At the level of magnification currently used only pores greater than 500 μm equivalent circular diameter could be investigated. The results (Table 54) indicate that pores >500 μm occupy a larger percentage of the total area in the tilled treatment than in the no-till treatment. In addition, the pore area in the centers of the tilled rows was approximately half that of the edge (i.e. ≈ 10 cm from the corn row) suggesting that some compaction of the central portion of the rows has occurred although only non-trafficed rows were sampled. Because of these apparently large differences between the centers and edges of the rows all further data was separated on this basis.

Table 54. Percent of total area of vertical sections occupied by pores >500 μm equivalent circular diameter for centers and edges of rows under till and no-till treatments.

Treatment	Centre		Edge	
	Mean	Standard Deviation	Mean	Standard Deviation
Till	7.5	4.7	15.1	2.4
No-Till	5.9	3.9	4.4	3.0

When the numbers of pores were examined in terms of various size ranges (Table 55), it was noted that there were more pores in the smallest size range under the no-till treatment than under the tilled treatment. This suggests a decrease in mean pore size under the no-till treatment.

Table 55. Percent by number of various size classifications for vertically oriented sections under till and no-till treatments.

	Till		No-Till	
	Centre	Edge	Centre	Edge
		500-1000 μm		
Mean	56.1	60.3	64.3	74.5
Standard Deviation	11.5	8.6	9.8	10.4
		1000-2000 μm		
Mean	33.4	33.1	26.8	22.1
Standard Deviation	7.9	6.6	7.4	8.9
		≥2000 μm		
Mean	10.5	6.7	9.2	3.5

The orientation of the longest chord of the pores against the horizontal (Table 56) indicates that under the no till treatment there is a slight preferred orientation to the horizontal, whereas for the tilled treatment there is a preferred orientation to the vertical.

Table 56. Orientation of longest chord of pores against the horizontal in vertical sections from till and no-till treatments. Percent by number.

	Till		No-Till	
Angle	Mean	Std. Dev.	Mean	Std. Dev.
		Center		
0-30	26.5	11.3	33.9	16.2
30-60	29.9	5.5	36.5	5.9
60-90	43.0	7.7	30.1	12.0
		Edge		
0-30	15.9	2.9	34.8	12.4
30-60	40.8	3.8	36.5	7.0
60-90	43.4	4.2	28.8	8.6

In summary the analysis of pores ≥500 μm indicates (1) that the centres of the tilled rows differ from the edges in total pore space, (2) total area of pores decreases with no-till treatment, (3) mean pore size decreases with no-till treatment and, (4) pores tend to be preferentially oriented to the horizontal in the no-till treatment. At this time it is not possible to correlate these changes in pore pattern with the decreases in corn yield observed with the no-till treatment. In the future it is hoped that further analysis of the samples can be made using an automated image analyzer, thus more information can be obtained for a wider range of pore sizes.

Martin Shipitalo and Richard Protz

Development of Methods to Characterize the Stability of Soil Structure

The deterioration of soil structure represents a possible limitation to high sustainable yields in Ontario when row crops are grown on a continuous basis. The deterioration of soil structure affects plant growth through a variety of ways, such as increased mechanical resistance to root growth, altered nutrient and water uptake and reduced porosity. Reductions in porosity and permeability will alter the drainage, aeration and water supply characteristics of the soil. Spring tillage offers the potential of creating optimum conditions for root growth in the seedbed. The ability of the seedbed to retain this structure then becomes very important in determining the soil potential for corn production. It is therefore necessary to have a method by which the seedbeds ability to retain an "optimum structure" under normal field conditions can be measured.

An aggregate is a composite particle of 50 to 250 μm in diameter containing primary sand, silt and clay size particles held together by physical and chemical bonds. These aggregates are not necessarily stable and may be further organized into peds of several millimeters in diameter by roots and fungal hyphae. A well structured soil contains a regular pattern of peds composed of stable aggregates resistant to dispersion and compaction under normal field conditions. Excessive cultivation and exposure of the soil to alternating intense drying by the sun and rapid wetting will weaken the stabilizing bonds. Degradation of the structure follows so that the definition between aggregates and peds become less distinct. These conditions are observed under continuous corn where the reduced aggregate stability lowers the ability of the seedbed to retain "optimum rooting conditions" and leaves the soil susceptible to compaction, loss of porosity and erosion.

The traditional approach of characterizing the ability of a soil to retain a structure has been wet sieving. This method involves the mechanical dispersion of the 1-2mm fraction of air dried aggregates in water. It is assumed that the stability of the 1-2mm fraction corresponds to the stability of the whole soil, and that the mechanism of aggregate dispersion is identical to the mechanisms operative below the soil surface under field conditions. Neither of these assumptions may be valid.

Approach

In the field, changes to the seedbed occur under alternate wetting and drying cycles. A laboratory method was developed where the stability of hand packed soil cores could be determined. Gradual wetting and drying cycles were used as the driving force behind consolidation and aggregate dispersion. Preliminary measurements were done on a Conestoga silt loam obtained from the rotation plots of Dr. R. Sheard at the Elora Research Station. Each core was packed with moist soil aggregates less than 5mm in diameter and then placed on a sintered glass funnel. The cores were saturated, and then drained by increasing the matric tension to a maximum of 150 cm with a hanging water column. The process was then reversed to permit rewetting. The drying and wetting cycle was carried out three times. Moisture release and the amount of surface subsidence were measured during the cycles.

Interpretation

The development of moisture release and pore size distribution curves rest firmly on the assumption that the structure is rigid. When this is not the case, as with cultivated soils of various stability, some other approach is needed. It was apparent that during a drying cycle the internal matric forces of the soil water under tension pulled the peds together into a closer packing; where the aggregate stabilities were low, peds and aggregates may deform and break. Through a comparison with a theoretically stable and rigid system it was possible to compare the air-water balance for a given degree of saturation with the air-water balance of the rigid system at the same degree of saturation. In the non-rigid system, for any given change in degree of saturation, the volume of air replacing the volume of water removed is less due to subsidence than would be the case if the structure was rigid. By taking the ratio between the observed value and the theoretical value we can characterize the degree of stability of a sample.

Results and Discussion

The results show that 60-90% of the consolidation of a sample takes place during the first wetting and drying cycle. This change was more apparent in the less stable soil which had been used to produce corn on a monoculture basis than in the soil which had been in sod (continuous Brome). The difference between cores on further cycles was reduced. The greatest structural collapse takes place at very low tensions when the degree of saturation of a sample is between 80-90 %.

Preliminary data on the structural stability of soil as characterized by wet sieving and the use of wetting and drying cycles are presented in Table 57. The biggest differences in the stability of these soils exist in the first cycle. To make a comparison with the data from wet sieving our results for the different soils are expressed relative to the value for continuous corn which was arbitrarily assigned a value equal to the wet sieving value. The table suggests that the stability data has been more "spread out" using the wetting and drying method. In this way it may be possible to detect subtle

Table 57. A comparison of methods to characterize the structural stability of soil.

SAMPLE	% STABILITY	
	WET SIEVING	WETTING AND DRYING
CONT. CORN *	28.81	28.81
BROME-CORN **	36.92	48.46
CONT. BROME	65.33	76.79

* Stability relative to continuous corn which was arbitrarily set equal to the wet sieving value.

**Continuous Brome Grass Followed by Two Years of Corn

differences between the stabilities of different samples. Unlike the wet sieving method we can make some extrapolation to field conditions regarding changes in porosity and bulk density during a growing season.

N.H.E. Allen, B.D. Kay and P.H. Groenevelt

LAND USE

The Ontario Mystery of Planning

The land use planning system of Ontario affects every resident of Ontario to some extent. Yet this complex system is not well documented and is thus not well understood by the average resident of Ontario.

The Ontario Mystery of Planning, a land use planning simulation game, has been under development in the department for some time. Begun as an undergraduate project in Decision Making in Resources Management (87-415) in the winter of 1982, the project was extended by a research grant and will be completed in the spring of 1983. Supervised by Dr. S.G. Hilts, the Ontario Mystery of Planning is the result of the work of 3 graduates of the Resources Management program: Greg Shields, Kate Macolm and Kim McGuire.

The simulation game is currently undergoing final revisions and testing in preparation for publication. It is hoped that it can be ready for distribution to high schools within the next year.

G. Shields and S.G. Hilts

Survey of Woodlots and the Forest Industry in Wellington County

Future hardwood forest production in Southern Ontario is of considerable concern, but relatively little is known about the proportion of woodlots which contribute directly to the forest industry. Nor is it known in detail to what extent forest products contribute to the farm economy, though most woodlots are owned by farm operators.

This survey is examining the extent to which woodlot acreage in Wellington County is increasing or decreasing, and how products from these woodlots feed the forest industry of the county. Surveys of both secondary and primary industry operators, rural landowners, and firewood consumers are complete. Analysis is ongoing.

S.G. Hilts

Survey of Natural Areas in Middlesex County

Final analysis of data collected in past field seasons is now nearing completion and the final report is being prepared and edited. It is expected that it will be published shortly. Sixty-five sites within Middlesex County are described in the report, and evaluated according to a set of ecological criteria. The data provides a biophysical basis for potential designation of environmentally sensitive areas in the County.

S.G. Hilts

Biophysical Inputs to Official Plans

Examination of a sample of rural Official Plans in Southwestern Ontario is now complete. Current analysis is focused upon the extent to which technical information on soil quality and agricultural capability is a deciding factor in rural severance decisions. Ontario Municipal Board decisions have been reviewed and selected county files on severance decisions are currently being analyzed.

S.G. Hilts

GEOLOGY RESEARCH

Studies in the Geochemistry of Podzolisation

1. An Eh-pH Approach

The central geochemical problem in podzolisation is how to effect the vertical separation of Si, Al and Fe, that produces the albic/spodic combination of horizons. One school believes that organic constituents mobilise Al and Fe at the expense of Si. An opposed view is that the separation is achieved by inorganic means.

Here we examine the problem in terms of Eh and pH as master variables to investigate a similar (though inverse) geochemical problem posed by the formation of laterites and bauxites. Eh-pH diagrams are drawn in which the first step is to ignore the organic component. Later the effect of adding organic constituents is studied. Details of the construction of such diagrams is to be presented by Chesworth and Macias at the International Colloquium on Petrology of Weathering and Soils (Paris, July 1983).

The following table shows normal ranges of Eh and pH for podzols, few recorded measurements fall outside the extremes shown.

Horizon	Eh (volts)	pH	Figures 8, 9
Organic	0.3-0.5	3-4.5	Box 1
Albic	0.4-0.7	3.8-5	Box 2
Spodic	0.4-0.6	4.2-6	Box 3

The 'inorganic' diagrams are of the form shown in Figure 22(1), in which quartz, gibbsite and geothite are taken as phases controlling the solubility of Si, Al and Fe. Such a diagram might explain the formation of spodic horizons since box 3 falls within fields where Fe and Al are less mobile than Si. Unmodified it cannot offer a reasonable mechanism for the formation of albic horizons since little of box 2 falls in fields where Si is less mobile than Fe and Al. Substituting imogolite for gibbsite makes matters worse in that all of box 2 now lies outside a field in which Si is least mobile of the three elements. Only by choosing an amorphous phase to control Al solubilities can the diagram be modified to place box 2 in a requisite field to allow formation of an albic horizon.

Figure 22(2) shows the effect of increasing Al and Fe mobilities by adding organic ('fulvic') components. Clearly, this optimises the possibility of forming an albic horizon, while at the same time minimising the possibility of forming a spodic horizon. In essence this lends support to the classic view that organic constitutents, important in producing an albic horizon, need to be destroyed or immobilised lower down the profile in order for a spodic horizon to form.

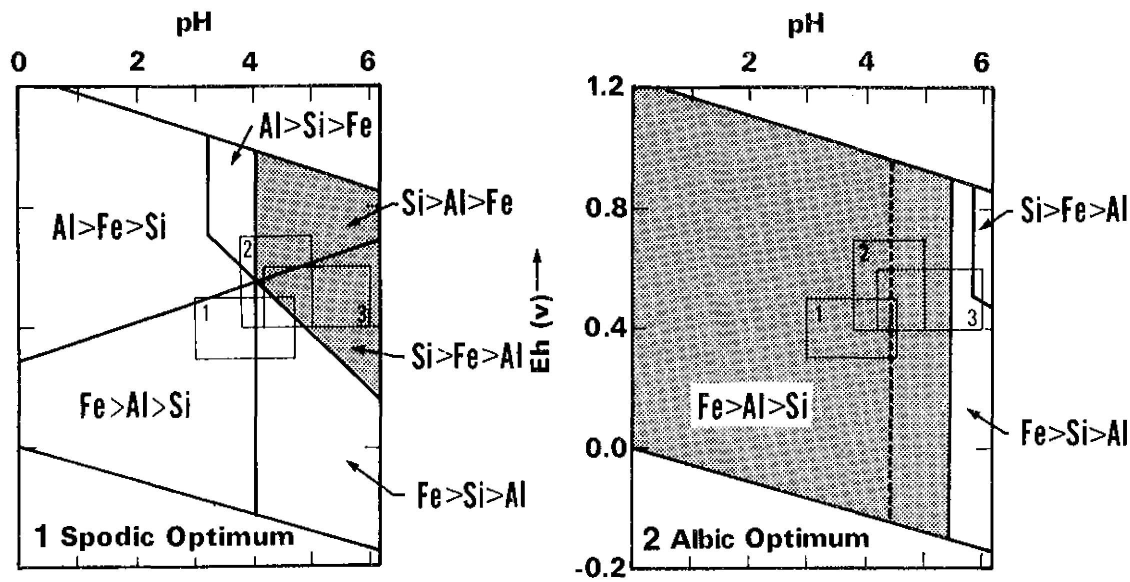


Figure 22(1) & 22(2): Eh-pH diagrams for the process of podzolisation and sequences such as Fe > Al > Si are to be read as "iron is more mobile than aluminum, which is more mobile than silicon". Boxes 1, 2 and 3 are taken from table 2. (Chesworth and Macias-Vazques, unpublished manuscript, 1983).

This analysis offers support for the organic theory without entirely ruling out the possibility of an inorganic mechanism of elemental transfer, especially under extreme, acid conditions.

Ward Chesworth and Felipe Macias-Vazques
(Univ. of Santiago, Spain)

2. Boreal Podzols from the Lake Nipigon Region

Table 58 summarises the major element compositions of the albic and spodic horizons and the parent material in 17 podzols from the region.

Table 58. Composition of albic and spodic horizons and parent materials: (data from 17 profiles).

	ALBIC		SPODIC		PARENT MATERIAL	
	Mean	Range	Mean	Range	Mean	Range
SiO_2	79.4	67-82%	74.4	68-78%	74.3	65-76.5%
Al_2O_3	9.9	8.9-13.9	12.3	10.7-14	11.7	10.9-13.4
Fe_2O_3	2.1	1-4.7	3.8	4.1-5.9	3.4	2.2-5.3
MgO	1.2	.7-2.4	1.5	.7-2.4	1.7	.8-3.0
CaO	2.0	1.1-3.7	2.5	1.7-3.8	3.0	1.8-5.2
Na_2O	3.1	2.5-5.2	3.0	1.7-4.1	3.4	2.8-3.9
K_2O	1.8	1.2-2.2	1.9	1.1-2.1	1.8	.9-2.1
TiO_2	0.4	.3-.8	0.4	.3-.8	0.4	.3-1.2

These compositions are displayed graphically in Figure 23.

The parent material is predominantly granitoid with a significant basic component derived from greenstone lithologies or diabase. The albic horizon has evolved toward a simpler, quartzo-feldspathic mineralogy, while the spodic horizon is higher, and richer in Al and Fe than the parent material.

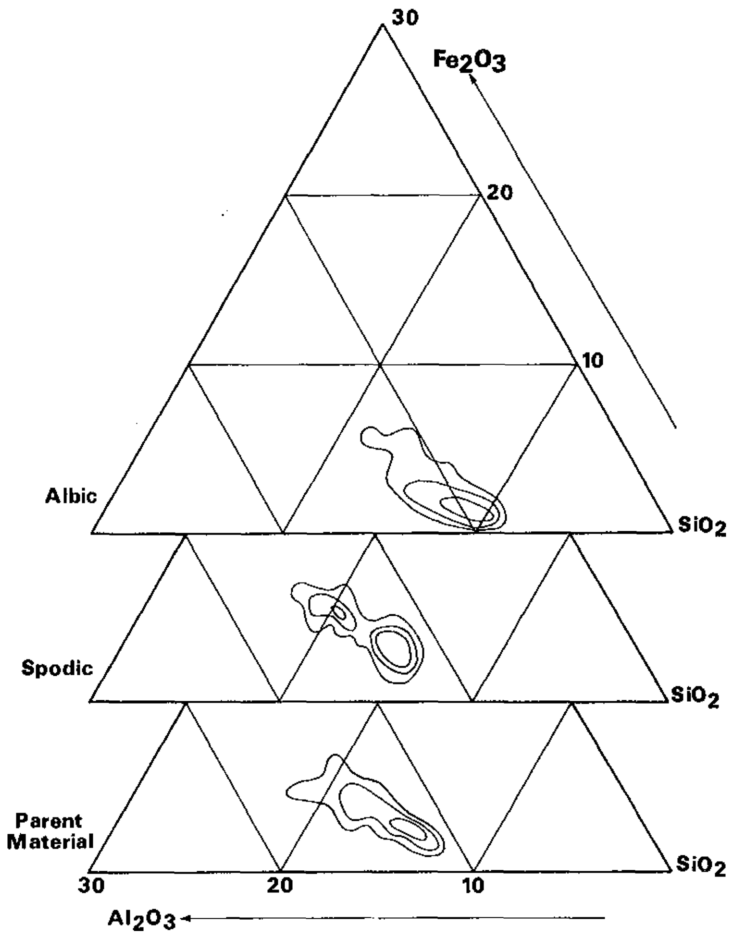


Figure 23: Analyses of albic, spodic and parent material horizons. The frequency distributions are contoured at 2, 4 and 6 points per 1% area of the triangle.

Ward Chesworth, Sue Ellen Shipitalo,
Marsha Sheppard
(Whiteshell Nuclear Research
Establishment, Manitoba)

3. Atlantic Podzols from Asturias, Northern Spain

Five profiles were collected in December 1982. They have since been analysed for major elements. A representative analysis is shown in Figure 24 where it is contrasted with average compositions of the 17 profiles reported on above.

The Spanish podzols are evidently more geochemically mature than the boreal podzols, as evidenced by the close approach of the albic horizon to a quartz endpoint.

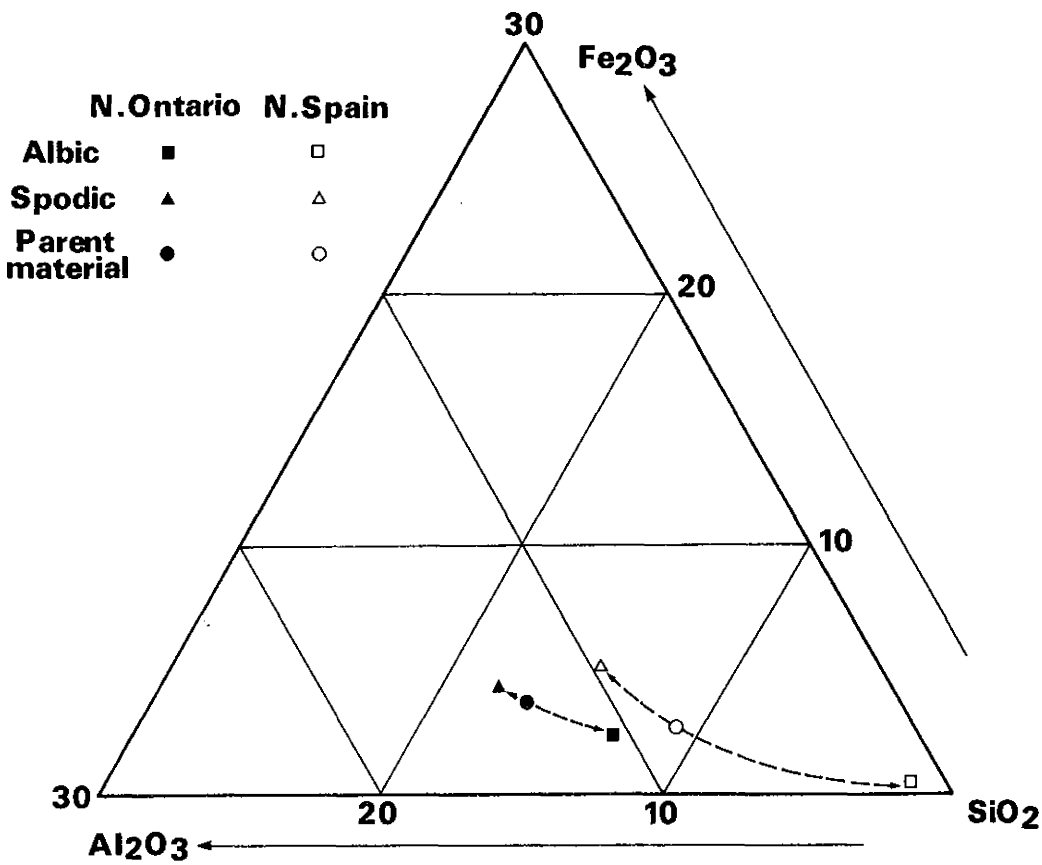


Figure 24: Compositional relations in the boreal podzols from northern Ontario (black symbols) compared with a typical Atlantic podzol (open symbols) from northern Spain.

Ward Chesworth, Felipe Marcias-Vazquez,
Eduardo Garcia-Rodeja
(Univ. of Santiago, Spain)

The Immobilization of Metal-Organic Complexes in Northern Ontario Podzols

Concepts of metal-fulvate translocation as the central process of podzolization are common in the literature. It is believed that the immobilization of these complexes is due to the saturation of fulvate complexing sites by Fe^{3+} and Al^{3+}. However, determinations of critical metal: fulvic acid molar ratios at which precipitation occurs have been hampered by difficulties in measuring accurate molecular weights for fulvic acid.

An experiment was therefore designed to determine critical atomic ratios between Fe^{3+} or Al^{3+} and elemental organic carbon. Aqueous extracts of L-F-H/Al horizon material were prepared, and their chemical compositions determined. Organic carbon ranged from 3500-4500 μmol/litre, and Si in solution ranged from 45-55 μmol/litre. Iron and Al contents were negligible. Known quantities of Fe^{3+} and Al^{3+} were added to 10 ml of extract, while pH was kept constant (pH 4.5) by additions of 0.01M NaOH. Amounts of Fe, Al, and organic C were determined in the resulting supernatants and precipitates after centrifugation.

The precipitation curves for Fe and C for one extract are shown in Fig. 25. The atomic ratio Fe/C at 50% precipitation of the organic matter was 0.09, while critical Al/C and (Fe + Al)/C ratios were 0.06 and 0.07 respectively. The range of ratios calculated at 5%, 50% and 95% precipitation account well for similar ratios determined in tetraborate and pyrophosphate extracts from Northern Ontario podzols (Table 59).

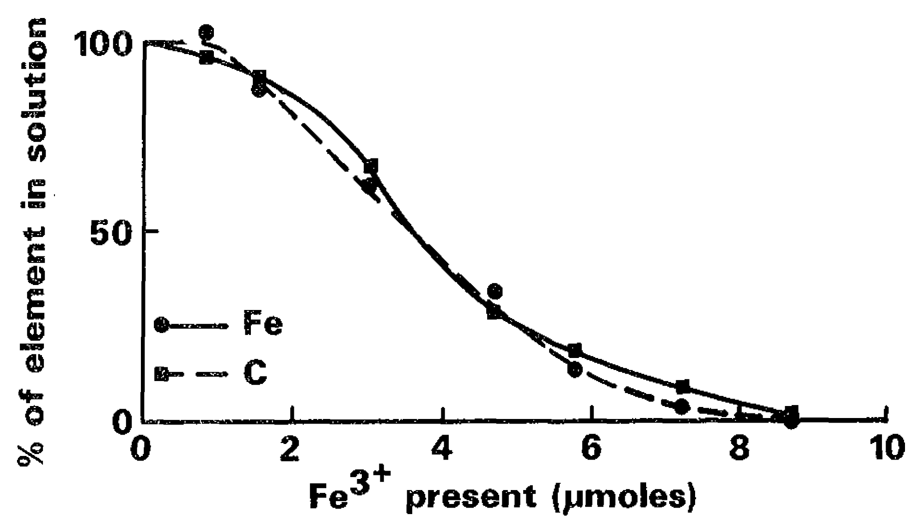


Figure 25: Amounts of Fe and C remaining in solution after additions of Fe^{3+} to soil extract at pH 4.5.

TABLE 59. Metal-Carbon Ratios in Precipitates Compared with Those of Tetraborate and Pyrophosphate Extracts of Northern Ontario Podzols.

Ratio	Fe/C	Al/C	(Fe + Al)/C
At 5% precipitation	0.04	0.02	0.03
At 50% precipitation	0.09	0.06	0.07
At 95% precipitation	0.19	0.16	0.18
Ae (pyrophosphate)	0.01-0.02	0.02-0.06	0.01-0.05
Bf (pyrophosphate)	0.09-0.20	0.09-0.23	0.09-0.26
Bf (tetraborate)	0.04-0.11	0.05-0.13	0.05-0.14

The ionic Fe and Al species reacting with the organic matter were determined from the consumption of OH^- from the NaOH added (Figs. 27 and 28). In water, Fe forms a stable colloidal suspension of $Fe(OH)_3$, while Al forms the $AlOH^{2+}$ ion. Iron reacting with organic matter is in the $Fe(OH)_3$ form above 3.65 μmoles Fe^{3+}, the amount required to cause 50% precipitation. Complexed Al is in the $Al(OH)_2^+$ form throughout.

Figure 26 shows that the addition of Si to the extracts before Al^{3+} addition maintains Al-organic complexes in solution to much higher ratios, depending on Si concentration. From Figure 28, it appears that Si (as H_4SiO_4 at pH 4.5) competes successfully with OH^- in the coordination of Al, since the OH^- consumed is reduced. These effects were not observed in experiments using Fe^{3+}.

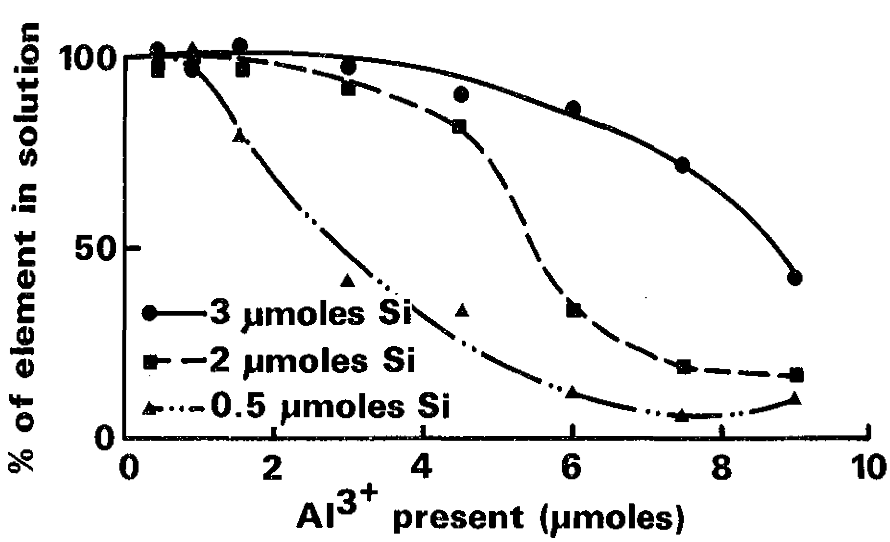


Figure 26: Amounts of Al remaining in solution after additions of Al^{3+} to soil extract + Si at pH 4.5.

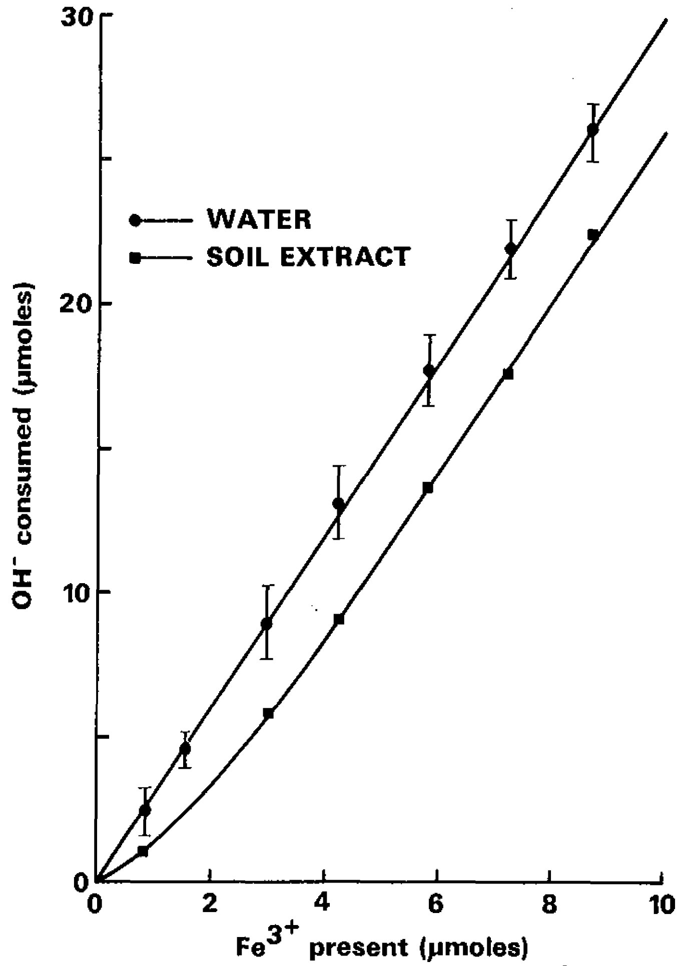


Figure 27: Hydroxyl ions (OH^-) consumed by Fe^{3+} ions added to soil extract or water at pH 4.5.

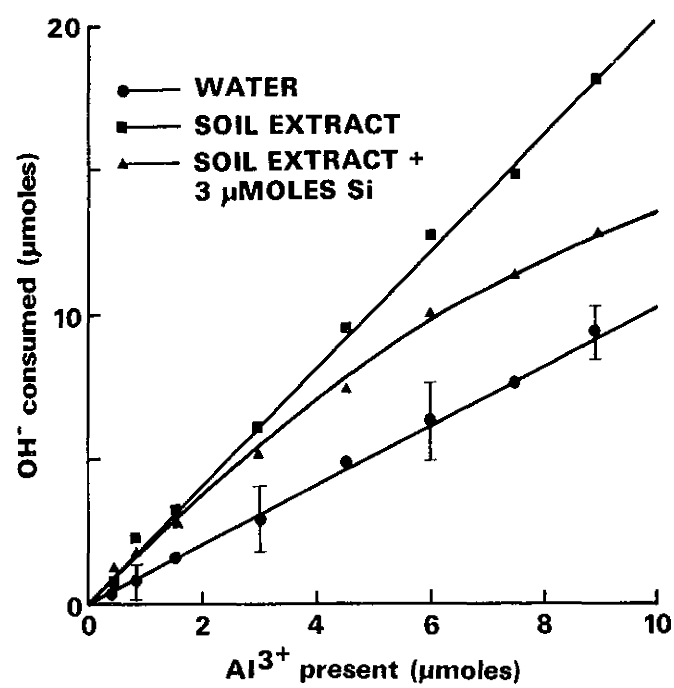


Figure 28: Hydroxyl ions (OH^-) consumed by Al^{3+} ions added to soil extract (± Si) or water at pH 4.5.

The results were confirmed on extracts from two other podzols, and the following conclusions were drawn:

1. Precipitation of organic matter by Al^{3+} or Fe^{3+} accounts for the chemical nature of immobilized metal-organic complexes in some spodic horizons.

2. The involvement of Si in such reactions could account for the lower depth maxima of pyrophosphate-extractable Al than Fe in Ontario podzols and the presence of amorphous aluminosilicates in Bf horizons.

3. Al^{3+} - fulvate and "proto-imogolite" may not be mutually exclusive in soil solutions.

E.P. Manley and L.J. Evans

Podzol Studies in Northeastern Ontario

Podzolic soils occupy over 2,000,000 km^2 in the Boreal and Mixed Forest regions of Ontario. These soils are developed on till or glaciofluvial deposits, with Archaean felsic intrusives and smaller areas of greenschist facies metavolcanics and metasediments dominating the bedrock geology. Mineralogically, quartz and sodic feldspars dominate in the soils, with subordinate amounts of hornblende, micas and chlorite. The climate is continental, with precipitations ranging from 600 to 850 mm/year; 40 to 60% of the precipitation falls as snow, and the soils are frozen from 4 to 7 months of the year. Many of the soils classify as Orthic Humo-Ferric Podzols (Typic Cryorthods).

The pH's of albic horizons range from 3.3 to 4.3, and extensive weathering of pyroxenes and albite can be observed in these horizons. Their clay mineralogy is dominated by a high-charge, beidellitic smectite, although traces of kaolinite were also detected. Calculations of net elemental balance using Zr as an internal standard indicated significant losses of Mg, Ca, Fe and Al from albic horizons, and gains of Fe, and to a lesser extent, Al in spodic horizons. Oxalate-extractable Fe, Al and Si contents in spodic horizons approached 5% in well-developed podzols. Molar ratios of extractable SiO_2:Al_2O_3 averaged 0.7, and the atomic ratio Al:Si approached 2.0 towards the bottom of the spodic horizons. Infrared spectroscopy, T.E.M., and ^{29}Si N.M.R. of spodic fine clay fractions did not indicate the presence of imogolite, but did suggest the presence of Al-rich allophanes. Water -extractable phenolic acid contents ranged from 600-2000 μg/g in LFH layers and from 3-100 μg/g in mineral horizons, with amounts generally decreasing with depth. A positive correlation was observed between phenolic acid content in surface horizons and the morphological expression of podzolisation in these soils.

Soil solutions were extracted by depth from three representative podzol profiles by immiscible displacement with CCl_4. These were analysed for pH, Si, Al, Fe, major cations, SO_4^{2-}, Cl^-, organic carbon and phenolic acids. For all three soils, ionic strength decreased with depth, as did the proportion of organically bound Al and Fe.

Applications of phase diagrams showed that the soil solutions of albic horizons should be in equilibrium with kaolinite, but that spodic horizon solutions plotted within the stability field of imogolite.

Fieldwork in N.E. Ontario showed that podzol development was most pronounced on parent materials with coarse loamy family particle size classes, and that podzolic morphology deteriorated as coarse and very coarse sand contents increased. Podzols were thus more common on morainal material than on aeolian or glaciofluvial outwash sands. It is suggested that increased moisture retention and prolonged contact of soil solutions with mineral surfaces compensate for the relatively slow throughput of water during podzolisation in these continental environments.

L.J. Evans and E.P. Manley

Pleistocene Lacustrine Sediments of the Scarborough Formation, Lake Ontario

The Scarborough Bluffs, east of Toronto, exhibit one of the classical Pleistocene sequences of the Great Lakes. The Scarborough Formation represents a shallowing out deltaic sequence, from distal rythmites at the base, grading upward into sandy, ripple-marked rythmites, grading to the topmost cross-bedded proximal sands (Figure 29). The formation is capped by the Sunnybrook Till which records the advance of an early Wisconsin glacier into the area. The Scarborough Formation represents an early Wisconsin(?) lacustrine phase following the Sangamon interglacial. It is one of four lacustrine phases recorded in the bluffs since the Wisconsin. Within the sediment of the Scarborough there are indications of wind blown sand grains and smectite clays probably associated with reworked Sangamon soil horizons of Ontario.

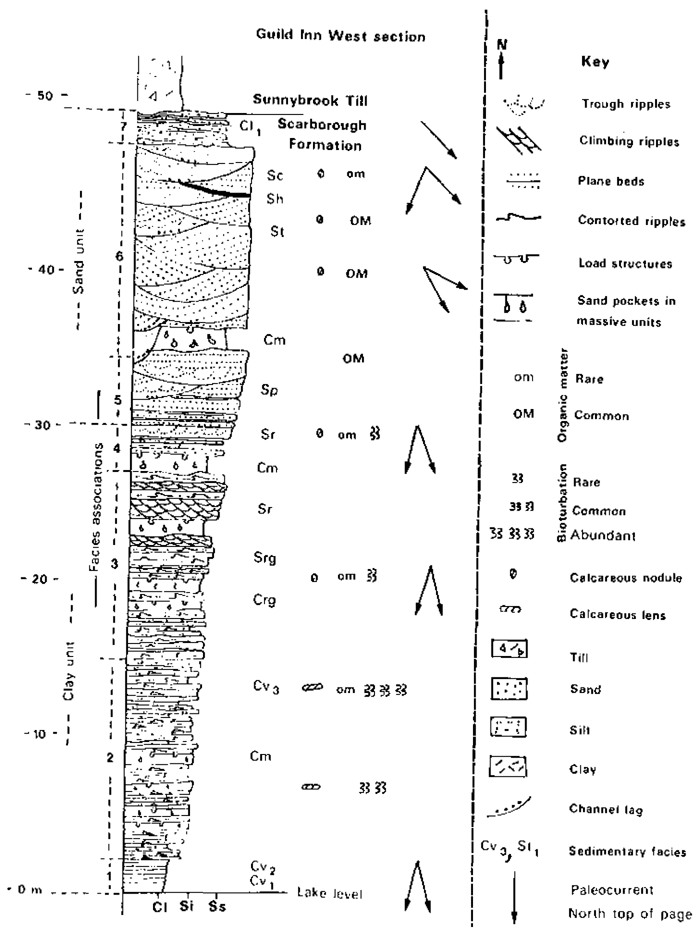


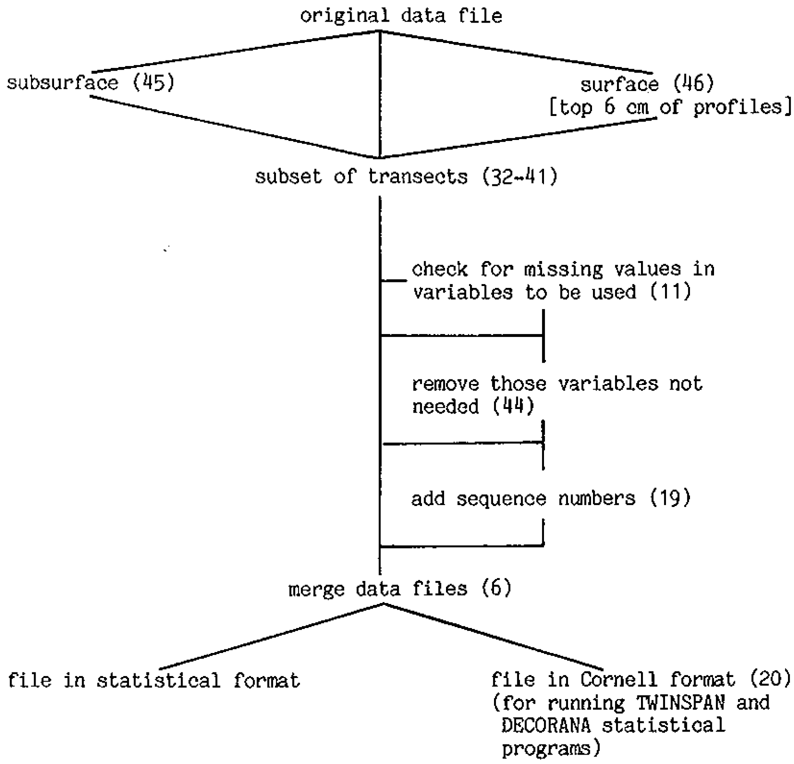
Figure 29: Guild Inn West Section.

R. Kelly and I.P. Martini

The Hudson Bay Lowland Information Retrieval System

A system to store, manipulate and retrieve ecological data obtained from the Ontario coasts of Hudson-James Bay has been designed and implemented on a VAX 11/780 minicomputer running under UNIX System at the University of Guelph. The samples treated were obtained from intertidal zones, marshes and few inland sites. The data consists of sediment and soil analyses (grain size, pH, conductivity, concentration of organic matter, calcium carbonate equivalent, calcite/dolomite ratios, organic bound Fe and Al, semiquantitative clay mineralogy, sand mineralogy, concentration of major elements, soil morphology, soil temperature); vegetation species and percentage cover in marshes; concentration of macrobethos (primarily *Macoma balthica*, *Hydrobia minuta*, *Polychaete*, *Oligochaete*) in tidal flats; migratory shorebirds (species, number, activity). The coordinated identifiers of all the information consist of latitude, longitude, and relative distance and elevation from the mean sea level (boundary between the algal flat and the marshes).

Table 60. Data paths.



(45)	subsurf.p	(44)	remove.p
(46	surface.p	(6)	merge.p
(32-41)	"GREP" shell programs	(19)	seqnum.p
(11)	subset.p	(20)	decform.p

The numbers in parentheses refer to programs described in: Salvadori A., Bredin N., Lohr S. and Martini, I.P., 1983, The Hudson Bay Lowland Information Retrieval System, Tech. Report CIS83-3, Dept. Computing and Information Science, University of Guelph. 122 p.

A series of programs allows input of data in specified formats, checking of errors, coding of information, reduction of all the information to location identifiers. The ultimate input consisted of 32 master files, out of which a series of subfiles were derived according to the following procedure for statistical analysis (Table 60).

I.P. Martini, R. Lohr and A. Salvadori

Statistical Analytical Strategy

Ordination, cluster and discriminant analyses were applied to various sets of geological and ecological data from coastal areas of Hudson-James Bay and Lake Ontario according to the strategy indicated in Figure 30. The data consisted of grain size analyses (concentration in the various size, silt and clay classes) mineralogy (light and heavy minerals) chemical analyses (soil analyses and geochemical data), vegetation species cover, concentrations of migrant shorebirds in various environments.

The programs were run on an AMDHAL computer system under CMS and OS. Specific informations on the running of the programs are summarized in Salvadori et al. (1983) where also references to basic programs are given (see report on the Hudson Bay Lowland Information Retrieval System).

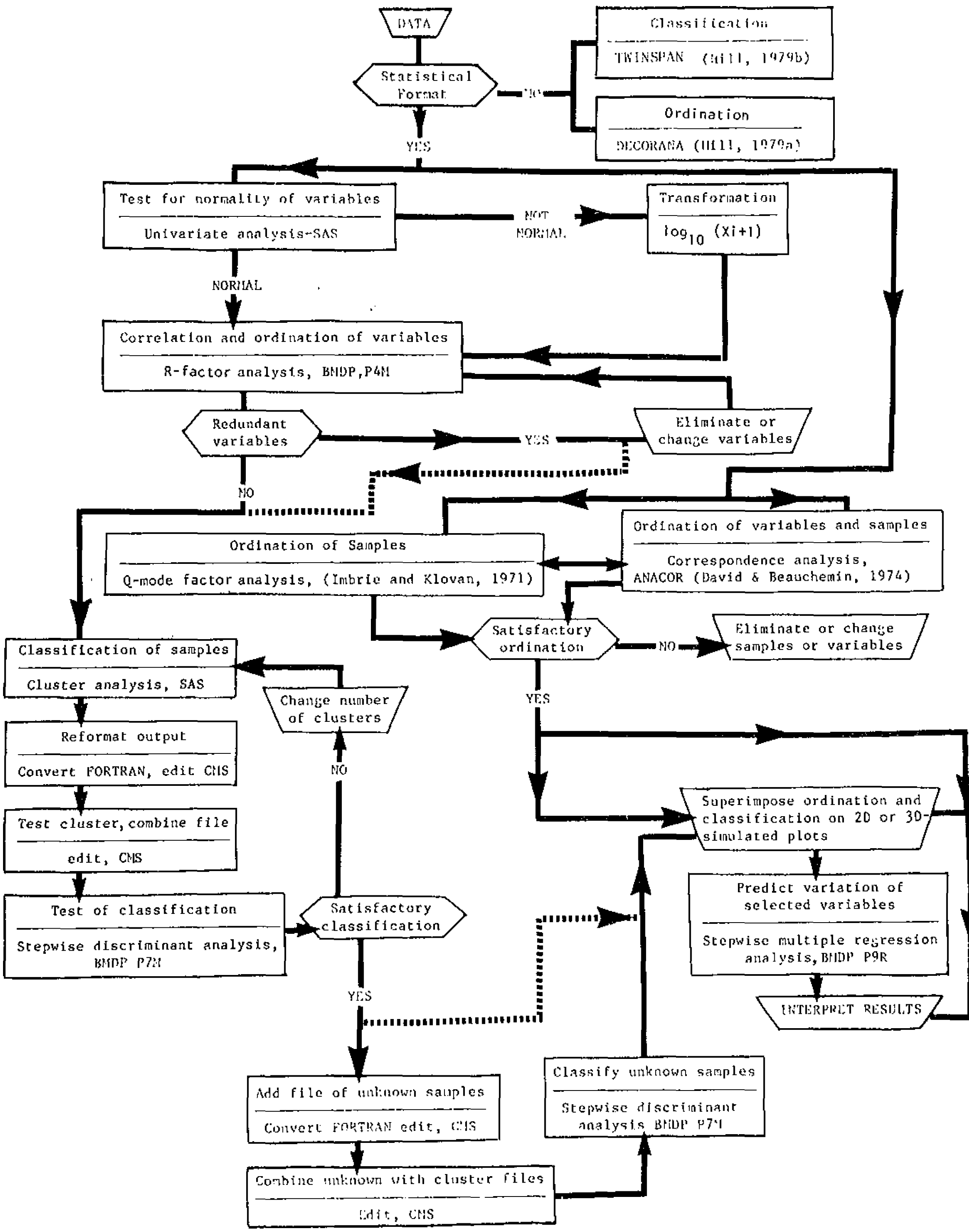


Figure 30: Statistical analytical strategy and computer programs used.

The ordinations of variables (R-Mode) and samples (Q-Mode) were constructed by the methods of principal components with a final varimax rotation of the axes. In the Q-Mode factor analysis a further oblique rotation was implemented to force the axes through extreme samples and to ordinate the samples in relation to the properties of the extreme ones. The number of factors per solution was determined by the number of eigenvalues greater than 1 in the R-Mode factor analysis, and by the pre-established percentage (98%) of variation to be explained by the factors, in the Q-Mode factor analysis.

For the Q-Mode factor analysis, the loadings of the samples on the varimax axes for the two and three factors solutions were normalized and plotted respectively on a scatter diagram and on a triangular diagram. Such a triangular plots were used also to superimpose upon them the boundaries established by cluster analysis, and for showing the fields of samples loading preferentially on the various oblique factors (Fig. 31).

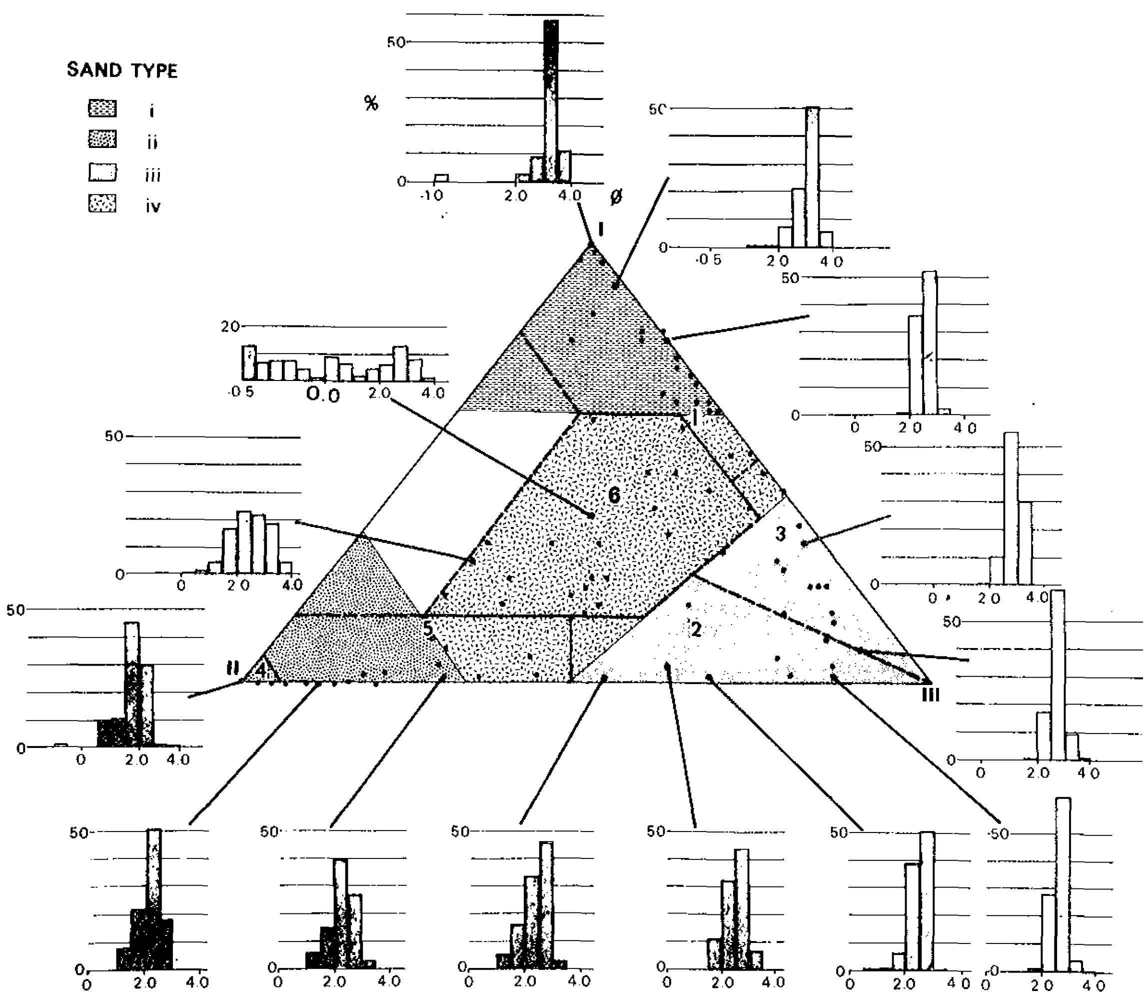


Figure 31: Types of sands (i, ii, iii) are displayed with different patterns on a triangular loading diagram of the three principal Q-Factors (I, II, III). The clusters (1 to 6) determined through cluster and discriminant analyses have been superimposed on the triangular scatter diagram. Their boundaries are indicted by heavy lines. The histograms represent typical grain size distributions (Presqu'ile-Wellington Bay, Lake Ontario).

Correspondence analysis combines the qualities of the R-Mode and Q-Mode factor analyses in finding associations and oppositions between variables and samples. It has the advantage of representing them both on the same factorial axes. Two dimensional and simulated three dimensional plots are provided by the ANACOR program (Fig. 32).

It was found that whereas normality of the variables (usually obtained with the transformation ($\log_{10}(x_i + 1)$) is required when testing hypotheses and it is advisable in the R-Mode and multiple regression analysis, better results are obtained utilizing untransformed data in the Q-Mode factor analysis and correspondence analysis. This is particularly true when variables of the same kind are used, such as the frequencies percent of different grain size classes.

TWINSPAN and DECORANA are programs written with special formatting requirements for biological data.

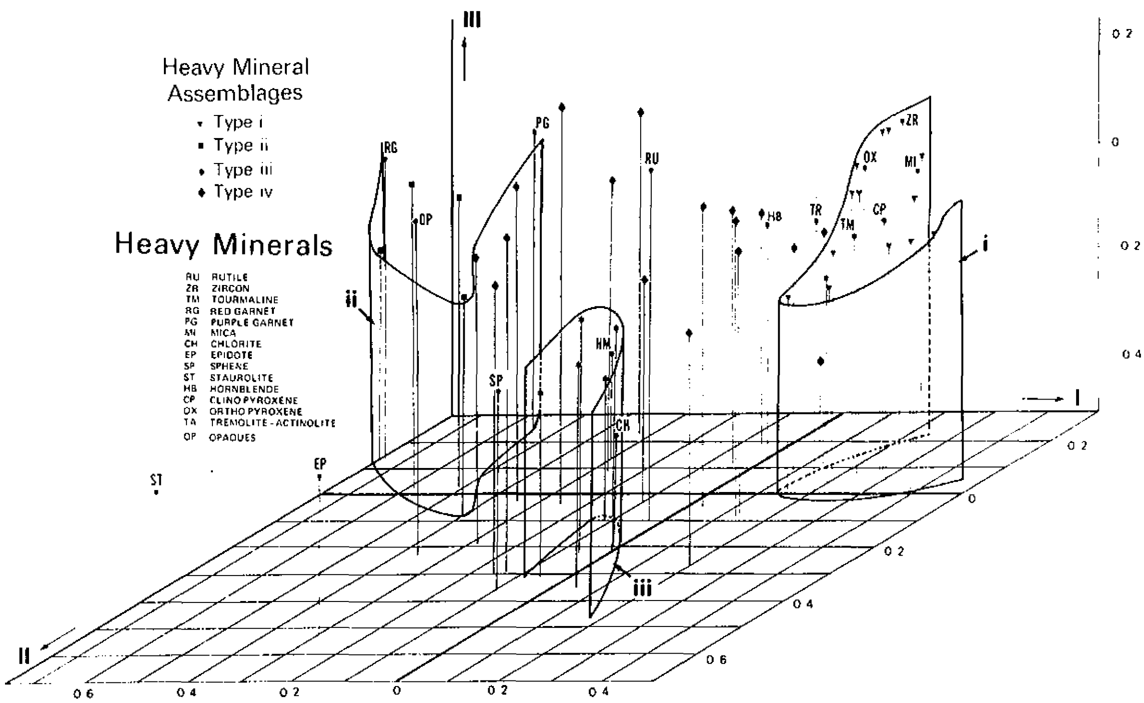


Figure 32: Simulated three dimensional diagram showing the relative loadings of heavy minerals (variables) and samples on the three principal factors (I-III), determined by correspondence analysis. The envelopes indicate the preferred field of occurrence of types of heavy mineral assemblages (Presqu'ile-Wellington Bay, Eastern Lake Ontario).

I.P. Martini and R. Lohr

Sedimentological Analysis of Coastal Sands in the Presqu'ile-Wellington Bay Area, Eastern Lake Ontario

Four major sand deposits have formed along the Canadian shores of Lake Ontario, at Niagara, Hamilton, Toronto, and Presqu'ile-Wellington Bay (Table 61; Fig. 33). They have been interpreted in the past as formed primarily by longshore drift of material obtained from erosion of coastal bluffs and tills exposed in the shallow shelf. Results of our study in the Presqu'ile-Wellington Bay area indicate that some sands deposited in the various coastal embayments of the Wellington and Athol Bay area have local origin.

This implies that for these deposits and others in the Great Lakes, dredged material would not be replenished by long-range longshore drift, rather erosion may occur in adjacent shores.

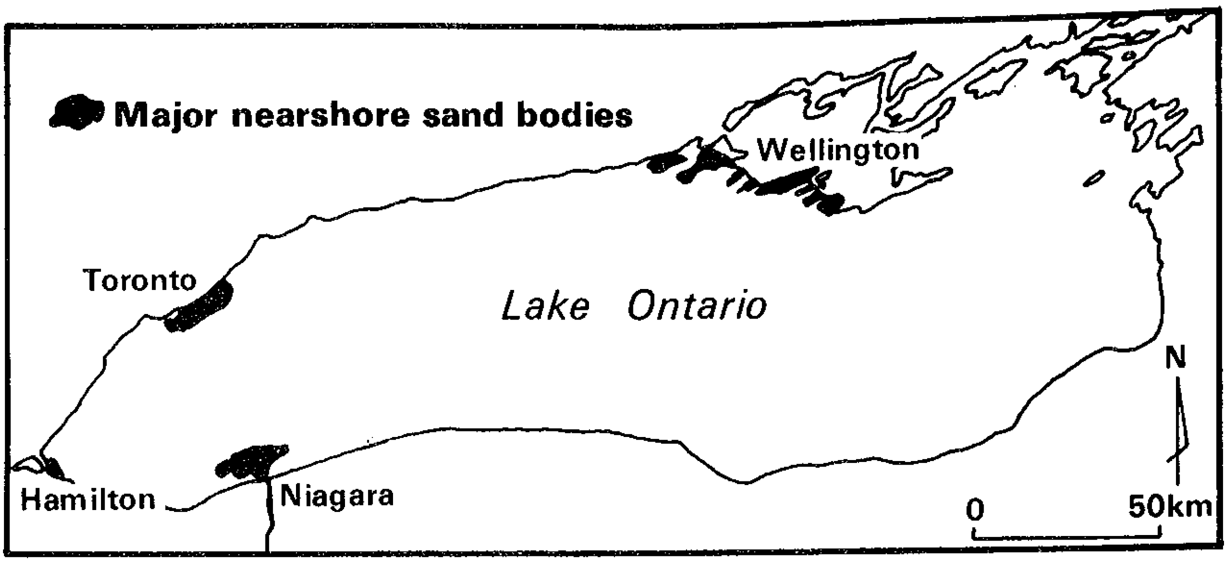


Figure 33: Major sand deposits of Lake Ontario.

Table 61. Sand and gravel volumes

	Deposit	Surface Area*, m^2	Average Thickness**, m	Volume, m^3
1.	Niagara	3.8×10^7	3.2	1.2×10^8
2.	Hamilton	3.0×10^7	7.0	2.1×10^8
3.	Toronto	5.7×10^7	3.8	2.2×10^8
4.	Presqu'ile/ Wellington	9.7×10^7	4.8	4.7×10^8

* % sand + gravel > 50% in surface samples ** based on jetting to refusal

The evidences for our interpretation include new information about the Pleistocene Geology of the Prince Edward and surrounding counties in eastern Ontario, the statistical analysis of grain size data from offshore deposits (Figure 34) and the distribution of characteristic heavy minerals and ratios between purple and red garnet (Figure 35). Different glacial lobes carried tills and glacio-fluvial sand on to specific areas of the Lake Ontario shelf and shores areas.

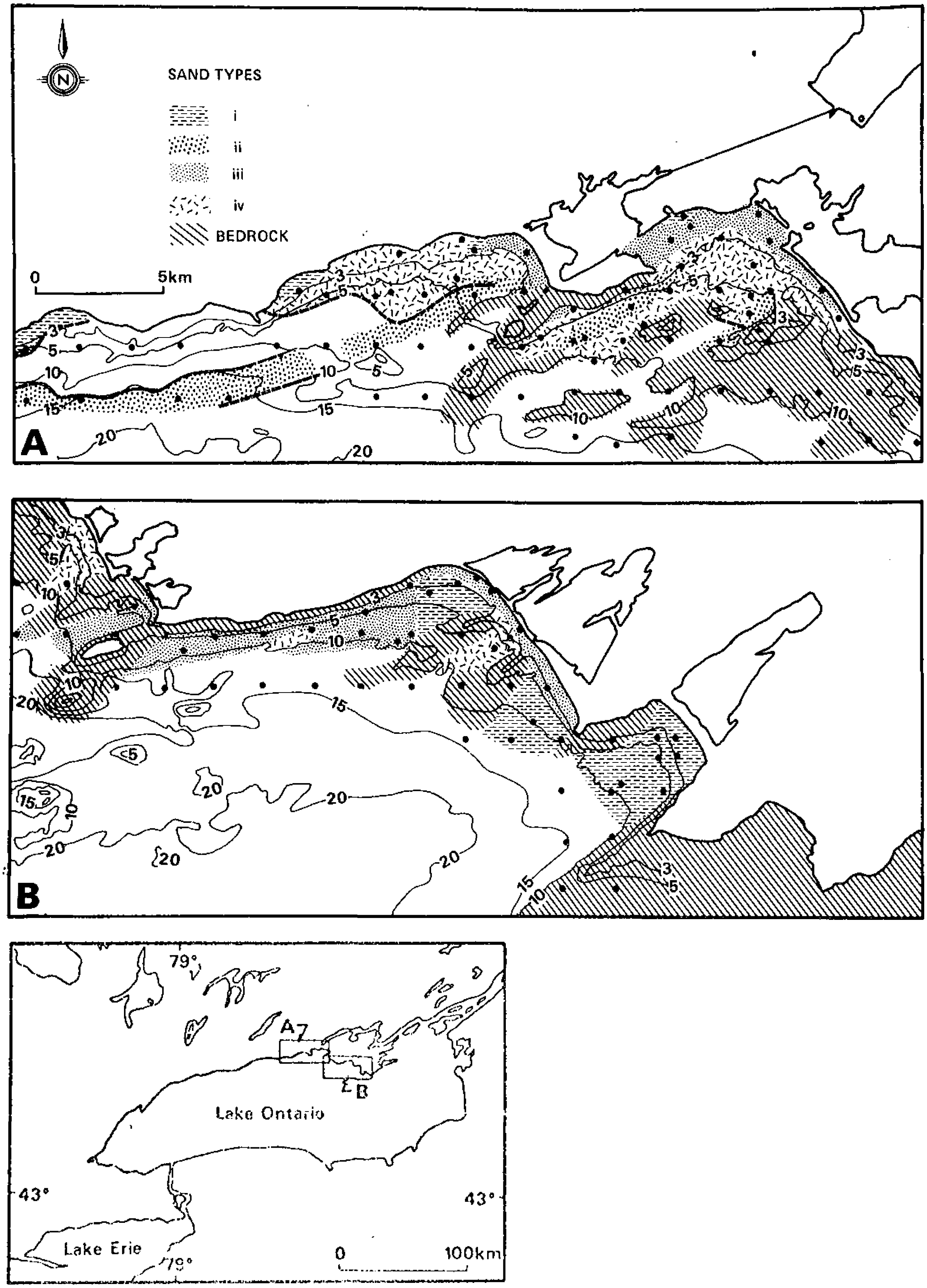


Figure 34: Areal distribution of sand types (see report on Statistical Analytical Strategy).

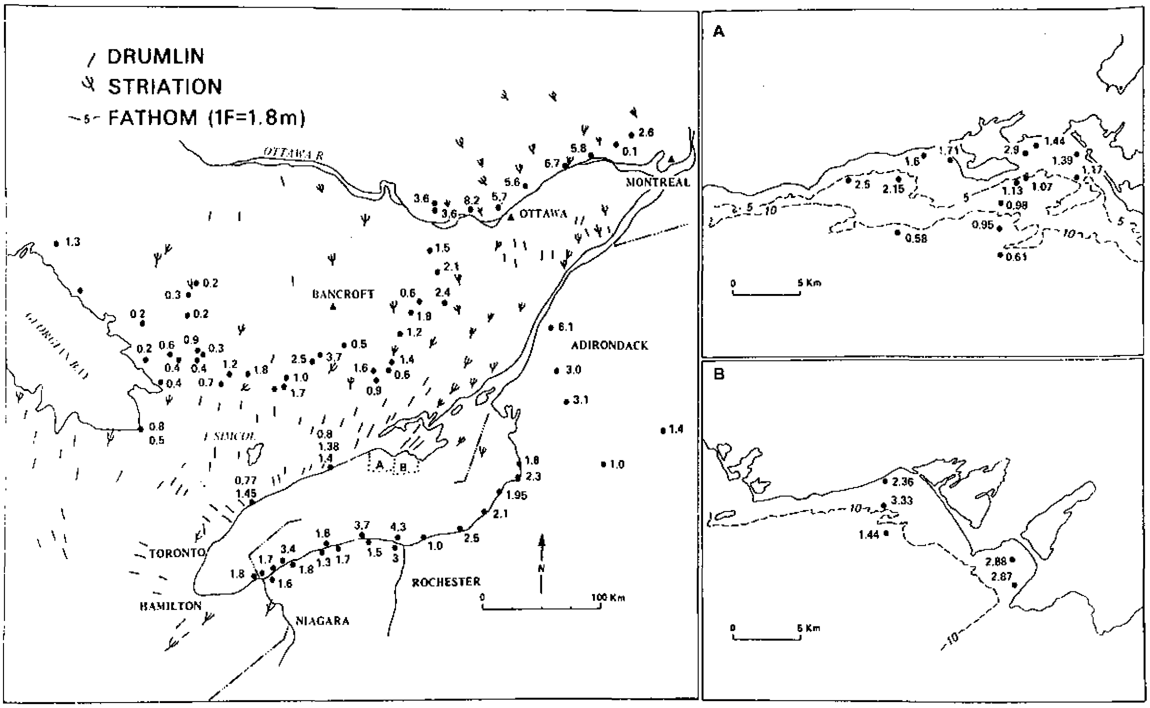


Figure 35: Distribution of the purple to red Garnet ratios in the Lake Ontario area.

I.P. Martini and J.K.P. Kwong

Depositional Characteristics of the Whirlpool Sandstone, Lower Silurian, Ontario

The Whirlpool Sandstone (Lower Silurian) has been extensively quarried as building stone in the Milton-Inglewood area, Ontario (Figure 36). It has been used under the trade name of "Credit Valley Sandstone" in many Government and University buildings in Southern Ontario. The economics of the industry and the depletion of the easily accessible reserves require that only shallow (3-5 m) buried sandstone be extracted which shows good splitability ('reed' of the quarryman) and does not require sawing.

It was found that good reed is presented not only by plane beds, but also by large scale shallow cross-beds and swales. Sandstone with these types of sedimentary features is usually formed in large streams, coastal bars and shelf sheets (Figure 37). These sandstones may be locally reworked by small sand dunes or disected by channels generating medium scale, steep cross-beds (kurls) forming unworkable, waste stone.

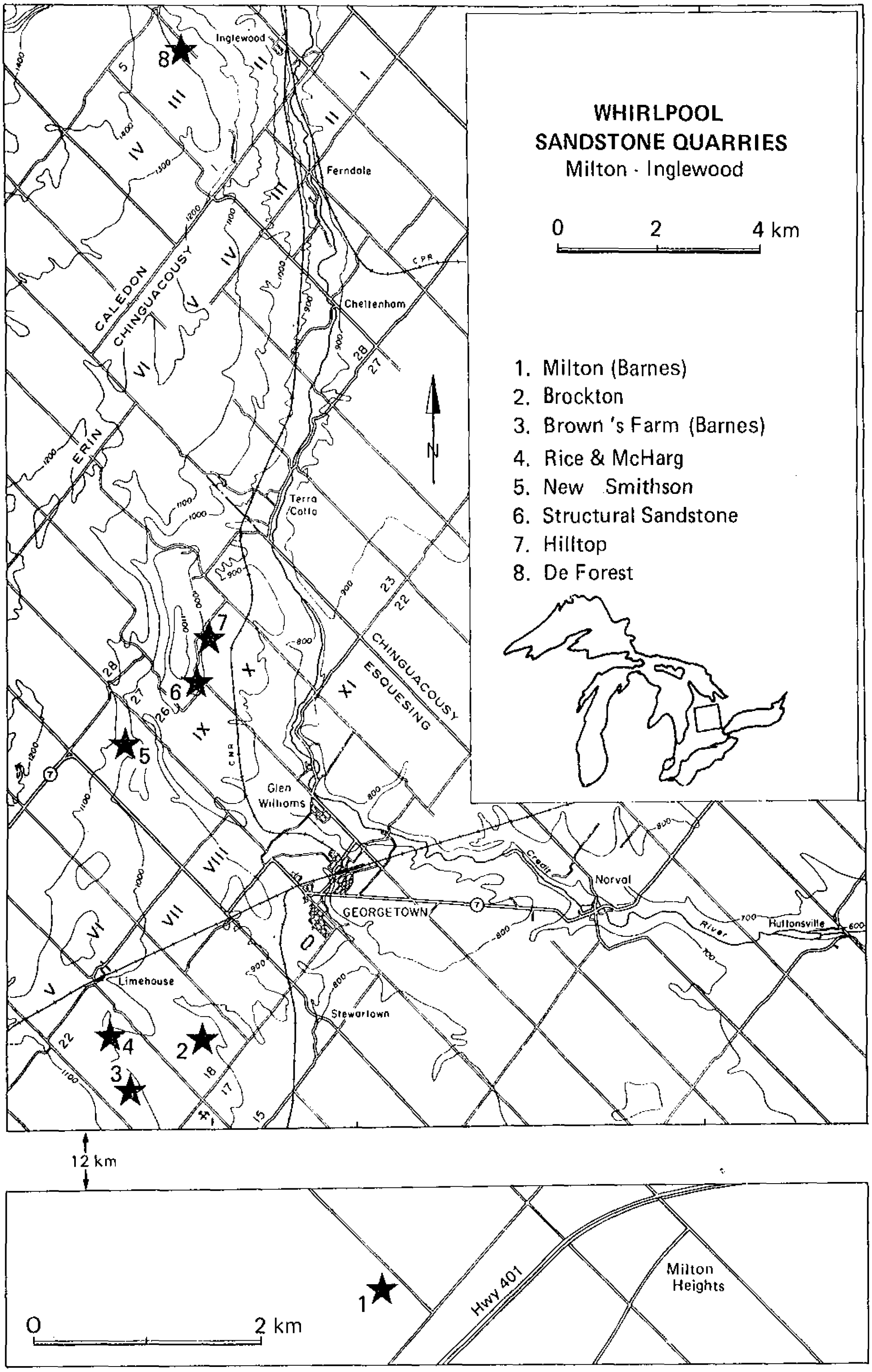


Figure 36: Location of quarries studied in the Milton-Inglewood area.

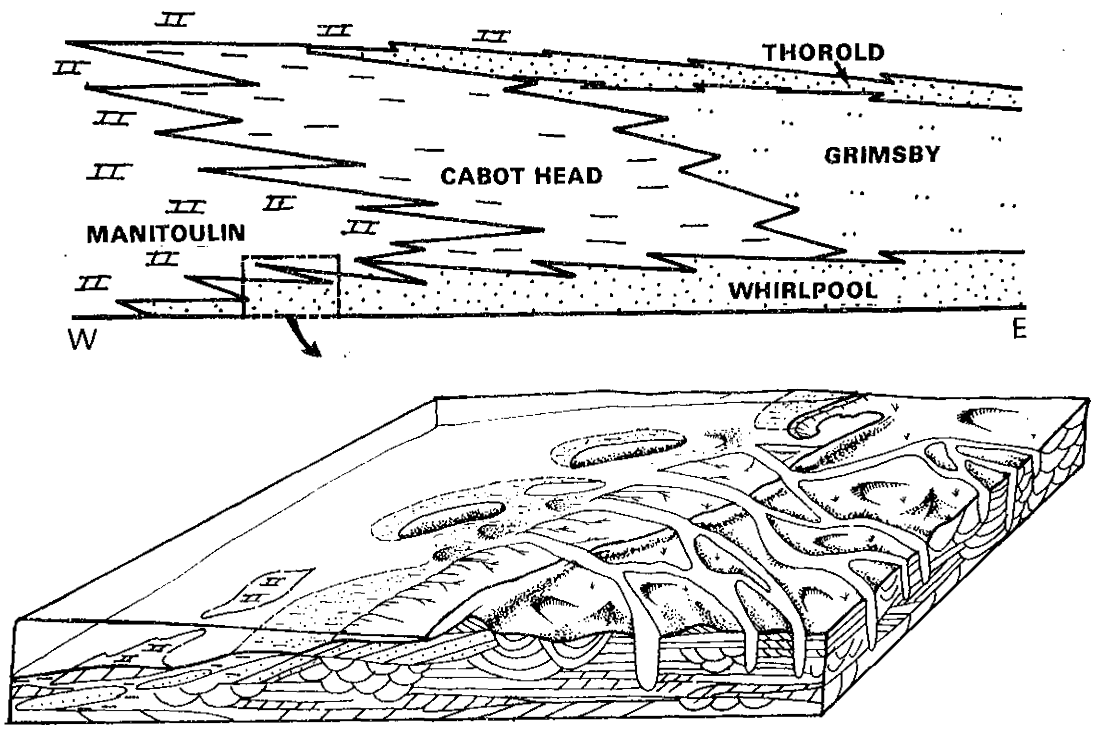


Figure 37: Environmental model for the Whirlpool Sandstone. Regional cross-section and model are not to scale.

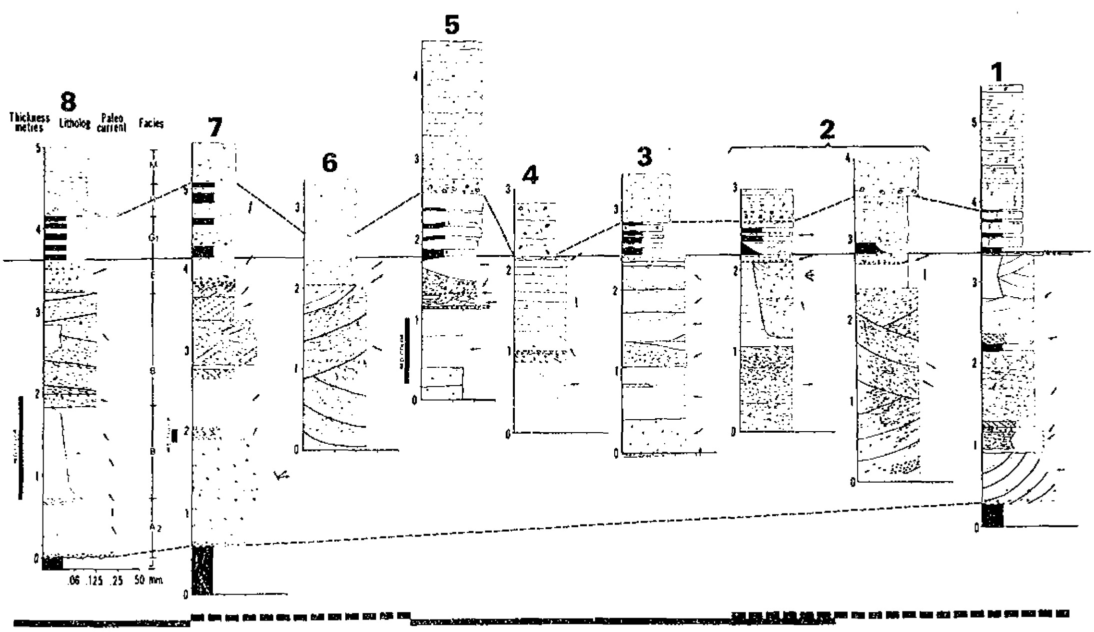


Figure 38: Stratigraphic cross-section of Quarries studied.
Cross-beds, ripple marks, wave ripples, convolute lamination, plane beds, burrows, calcareous, fossiliferous, mineralized, vugs, clay pebbles, shale.
Prospective zones with plane bedded beds.
— — — Zones with abundant cross-beds.

The regional sedimentological analysis of the Whirlpool Sandstone indicates that the best area for extracting stone is the Limehouse-New Smithson quarry region, although small kurls may interrupt the continuity of the extractable zones (Figure 38).

Martini, I. Peter and Salas, C. 1983. Depositional Characteristics of the Whirlpool Sandstone, Lower Silurian, Ontario; Ontario Geological Survey Open File Report 5363, 124 p., 5 tables, numerous figures and photos.

I.P. Martini and C. Salas

Symposia and Congress

In 1982-83 the editing of the Proceedings of the Symposium on Hudson-James Bay has been completed. The proceedings have been published in two volumes by Le Naturaliste Canadien (Table 1).

In August 1983, the International Congress of Sedimentology was held in Hamilton, Ontario. This was the first time such a congress was held in America. Several people from Guelph were involved in organizing the field excursions (22 of them), in editing the Guidebooks, and in leading some of the field trips. Papers by several people in the Department (Brookfield, Chesworth, Evans, Martini) were read at the conference and two Symposia on Aeolian environments and weathering were chaired, respectively, by Brookfield and Evans.

A limited number of Guidebooks are still available from the Department of Geology, McMaster University, Hamilton, Ontario (Table 63).

I.P. Martini

Table 62. Table of Contents of Hudson-James Bay Symposium Proceedings.

Recherches sur la baie d'Hudson et la baie James/Scientific Studies on Hudson and James Bay

TABLE DES MATIÈRES/TABLE OF CONTENTS

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Table 63. List of Guidebooks for Field Excursions.

Eleventh Congress
Onzième Congrès
McMaster University
Hamilton, Ontario
Canada 1982

PUBLISHED GUIDEBOOKS (Main Authors in Brackets)

Excursion 1: Lower Cambrian Bioherms and Sandstones, Southern Labrador.
(N.P. James and R.N. Hiscott)

Excursion 2: Anatomy and Evolution of a Lower Paleozoic Continental Margin, Western Newfoundland.
(N.P. James and R.K. Stevens)

Excursion 4: From Sabkha to Coal Swamp - The Carboniferous Sediments of Nova Scotia and Southern New Brunswick.
(P.J. McCabe and P.E. Schenk)

Excursion 5: Early Paleozoic Continental Embankment and Juxtaposed Micro-Continent, Nova Scotia.
(P.E. Schenk and T.E. Lane)

Excursion 6: Beach and Nearshore Depositional Environments of The Bay of Fundy and Southern Gulf of St. Lawrence.
(R.W. Dalrymple, C.L. Amos and S.B. McCann)

Excursion 7: Paleozoic Continental Margin Sedimentation in The Quebec Appalachians.
(R. Hesse, G.V. Middleton and B.R. Rust)

Excursion 9: Coastal Sediments and Geomorphology of the Lower Great Lakes, Southern Ontario.
(R.G.D. Davidson - Arnott, B. Greenwood, J.P. Coakley and A.J. Leman)

Excursion 10: Weathering, Soil Formation and Land Use in South and Central Ontario.
(W. Chesworth and L.J. Evans)

Excursion 11: Late Quaternary Sedimentary Environments of a Glaciated Area, Southern Ontario.
(P.F. Karrow, A.V. Jopling and I.P. Martini)

Excursion 12: Lower Paleozoic Carbonate Rocks and Paleoenvironments of Southern Ontario.
(D.R. Kobluk and M.E. Brookfield)

Excursion 13: Depositional Environments and Tectonic Setting of the Early Proterozoic Huronian Supergroup.
(G.M. Young)

Excursion 14: Precambrian Sediments and Environmental Aspects.
(J.R. Kramer and Nels Conroy)

Excursion 16: Precambrian Geology of the Cobalt Area, Northern Ontario.
(J.A. Donaldson)

Excursion 17: Sedimentary Facies: Products of Sedimentary Environments in a Cross Section of the Classic Appalachian Mountains and adjoining Appalachian Basin in New York and Ontario.
(G.M. Friedman, J.E. Sanders and I.P. Martini)

Excursion 19: Comparative Sedimentology of Paleozoic Clastic Wedges in the Central Appalachians, U.S.A.
(A.M. Thompson and W.D. Sevon)

Excursion 20: Glacial and Postglacial Sediments, Banff-Jasper Area, Alberta.
(D.N. Proudfoot, R.W. May, N.W. Rutter and J. Shaw)

Excursion 21: Clastic Units of the Front Ranges, Foothills and Plains in the area Between Field, B.C., and Drumheller, Alberta.
(R.G. Walker and R.A. Rahmani)

Excursion 22: Athabasca Oil Sands, Sedimentology and Development Technology.
(G.D. Mossop, P.D. Flack, S.G. Pemberton and J.C. Hopkins)

Excursion 27: Upper Miette Reef Complex, Jasper National Park, Alberta.
(E.W. Mountjoy and O.G. Burrowes)

Excursion 28: Upper Devonian Stratigraphy and Sedimentology, Southern Alberta Rocky Mountains.
(H.H.J. Geldsetzer and E.W. Mountjoy, G.E. Tebbutt and O.G. Burrowes)

Excursion 30: Late Quaternary Sedimentary Environments, Southwestern British Columbia.
(J.J. Clague and J.L. Luternauer)

GRADUATE EDUCATION

Table 64: Graduate students and supervisors - Winter Semester, 1983.

M.Sc. Students	Supervisor	Ph.D. Students	Supervisor
Soil Science Program			
Allen, N.	B.D. Kay	Abboud, S.	T.E. Bates
Ball, B.	M.H. Miller	Cobbina, J.	M.H. Miller
Barry, D.	M.H. Miller	Davenport, J.	R.L. Thomas
Battiston, L.	M.H. Miller	El-Asswad, R.	P. Groenevelt
Brasche-Villeneuve, D.	E.G. Beauchamp	Gaied, O.	T.E. Bates
Chan, C.	W. Chesworth	Gajem, Y.	D.E. Elrick
Charlton, D.	S. Hilts	Reynolds, D.	D.E. Elrick
Donald, R.	B.D. Kay	Richards, J.	T.E. Bates
Evans, D.	E.G. Beauchamp	Shipitalo, M.	R. Protz
Farrell, B.	E.G. Beauchamp	Yanuka, M.	D.E. Elrick
Grant, C.	B.D. Kay		
Kelly, R.	I.P. Martini		
Lee, D.	D.E. Elrick		
Lopez, P.	E.E. Mackintosh		
Lowden, D.	I.P. Martini		
Manley, P.	L.J. Evans		
Okoye, C.A.	D.M. Brown		
Santos, A.	J.W. Ketcheson		
Sevean, G.	R.L. Thomas		
Shipitalo, S.E.	W. Chesworth		
Singh, Y.	E.G. Beauchamp		
Siwale, G.	M.H. Miller		
Uhlig, P.	R. Protz		
van Roestel, J.	J.W. Ketcheson		
Zebarth, B.	R.W. Sheard		
Agrometeorology Program			
Adams, R.	T.J. Gillespie	Amiro, B.	T.J. Gillespie
Barr, A.	K.M. King	Berard, R.	D.M. Brown
Heikinheimo, M.	G.W. Thurtell	Brown, R.	T.J. Gillespie
Place, R.	D.M. Brown	Graham, M.	G.W. Thurtell
		Leclerc, M.	G.W. Thurtell

Table 65: Graduate degrees conferred October 1982, February and May 1983.

Student	Degree	Supervisor	Thesis Title
		Soil Science Program	
R. Garrett	M.Sc.	E.E. Mackintosh	The development and use of soil potential ratings in land use planning - a case study within the Niagara Region.
R.A. McBride	Ph.D.	E.E. Mackintosh	Agronomic and engineering soil interpretations from water retention data
A.N. Montgomery	M.Sc.	E.E. Mackintosh	Water movement in selected fine textured soils in the region of Haldimand-Norfolk, Southern Ontario
A. Nunez-Barrios	M.Sc.	M.H. Miller	Soil-Plant-Water status and growth, development and Yield of Maize (*Zea mays* L.)
I. O'Halloran	M.Sc.	M.H. Miller	Phosphorus absorption by corn (*Zea mays* L.) in relation to tillage
D. Schulman	M.Sc.	W. Chesworth	The soil solution chemistry of a calcareous soil horizon
M. Stypa	M.Sc.	M.H. Miller	The relationships between corn (*Zea mays* L.) yield and root growth under field conditions.
		Agrometeorology Program	
B. Amiro	Ph.D.	T.J. Gillespie	Studies of ozone flux and leaf temperature in *Phaseolus vulgaris*
M. Leclerc	M.Sc.	G.W. Thurtell	Development and testing of two mathematical models to predict evaporation to surface wetness.

UNDERGRADUATE EDUCATION

Table 66: Diploma and undergraduate courses presented during 1982/83.

Course Number	Course	Enrollment*
	Diploma	
87-010	Principles of Soil Science	221
87-011	Soil Management for Crop Production	185
87-020	Land Resources and Environmental Quality	50
	Degree	
46-100	Principles of Geology (Fall and Winter)	81
46-104	Study of the Earth	17
46-202	Stratigraphy	1
46-203	Paleontology	17
46-205	Glacial Geology	23
46-210	Mineralogy	27
46-250	Remote Sensing	17
46-306	Hydrogeology	42
46-307	Petrography	15
46-310	Geochemistry and Geology of Fossil Fuels	12
46-404	Geology of Canada	24
46-405	Field Geology	11
46-408	Geochemistry of Weathering	19
46-409	Sedimentology	21
46-411	Topics in Earth Science	19
46-412	Special Topics	16
64-203	Meteorology and Climatology	51
64-204	Meteorology and Climatology	23
64-302	Agrometeorology	25
64-305	Microclimatology	16
64-406	Micrometeorology	9
64-416	Intermediate Meteorology	5
87-200	Soil Science	474
87-201	Soil in Planned Environments	42
87-250	Problem Solving in Land Resource Science	37
87-302	Soil Genesis and Classification	57
87-305	Land Utilization	41
87-308	Soil and Water Conservation	25
87-310	Resources Planning and Management	12
87-311	Resources Field Camp	17
87-350	Land and Water Use in Tropical Countries	19
87-401	Soil Chemistry	20
87-402	Soil Physics	36
87-405	Soil Management	103
87-406	Problems in Land Resource Science I	9
87-407	Problems in Land Resource Science II	7
87-410	Soil Plant Relationships	36
87-412	Current Resources Management Issues	17
87-415	Decision Making in Resources Management	18

* Actual number writing final

Table 67: Graduates in Soil Science, Resources Management and Earth Science 1982/83.

Soil Science Majors

Jeffrey Baldock
Thomas Buckland
Sophia Cho-Wing
Carol Anne Gallagher
Shawn Kennedy
Katherine Killinger
Bill MacDonald
Chee Teo

Resource Management Majors

Thomas Bergen
Michael Bock
Colleen Drew
Murray Eby
Sandra Eising
Margaret Evans
Robert Fuller
Donna Healey
Harold Hofmeyr
Kyle McLean
Peter Newdick
Sylke Noesch
Dale Rivers
Mark Sauve
Margaret Schmidt
Gregory Shields
Karen Stewart
Rosemary Stokman
Barbara Strachan
Javier Valencia
Peter Wehr
Patricia Wills
John Wright
Ingrid Wypkema

Earth Science Majors

Shelley Gerrard
Timothy Gregorini
Ralph Krueger
Andrew Laycock
David Murray
Steven Sadura
Jim Sibley
Gene Shelp
William Skinner

Geology Minors

Lynne Holloway
Ian MacKenzie
Peter Mordaunt

ACTIVE RESEARCH PROJECTS

(Names underlined are L.R.S. faculty or professional staff)

Agrometeorology

Meteorological aspects of integrated pest control. T.J. Gillespie, J.C. Sutton (Env. Biology). Ontario Ministry of Agriculture and Food, Ontario Ministry of the Environment.

Estimation of surface wetness duration from weather data. T.J. Gillespie. Natural Science and Engineering Research Council.

Assessment of the potential for increasing yields of field corn with irrigation. D.M. Brown. Ontario Ministry of Agriculture and Food.

Characteristics of droughts and their effects on field crop yields in Southern Ontario. D.M. Brown, H.D. Ayers (Engineering). Atmospheric Environment Service and Ontario Ministry of Agriculture and Food.

Observation, compilation and analysis of current and past weather records. D.M. Brown, T.J. Gillespie, K.M. King. Ontario Ministry of Agriculture and Food.

Effects of CO_2 enrichment and water stress on maize. K.M. King and D.H. Greer (DSIR, Palmerston North, N.Z.). Atmospheric Environment Service, Ontario Ministry of Agriculture and Food, DSIR.

Soil-plant-water relationships. G.W. Thurtell. Agriculture Canada.

Turbulent transport processes above terrestrial surfaces and within plant canopies. G.W. Thurtell. Atmospheric Environment Serivce.

Plant-water relationships and canopy diffusion. G.W. Thurtell. Natural Sciences and Engineering Research Council.

Development of an electronic weather-monitoring device for pest management. T.J. Gillespie and G.E. Kidd. Ontario Ministry of Agriculture and Food.

Geology

Phenolic acids and podzolisation. L.J. Evans. Natural Sciences and Engineering Research Council.

Geology and archeology of the Middle Liri Valley, Lazio, Italy. I.P. Martini and others. Natural Sciences and Engineering Research Council.

Geomorphology and sedimentology of the Ontario Coast of Hudson/James Bay. I.P. Martini.
Natural Sciences and Engineering Research Council.

Sedimentology and weathering of pleistocene and modern lacustrine and fluvial sediments. I.P. Martini.
Natural Sciences and Engineering Research Council.

Geomorphology sedimentological and pedological studies in the coastal zone of the Hudson Bay Lowlands. I.P. Martini and R. Protz.
C.S.W., Fisheries and Environment.

Evolution of recent and ancient sand seas; presently of El Gran Desierto, Mexico. M.E. Brookfield.
Natural Sciences and Engineering Research Council.

Palaeoenvironments of the Middle Ordovician carbonates of Southern Ontario. M.E. Brookfield.
Natural Sciences and Engineering Research Council.

Radiometric dating of rocks across the Indus Sutre zone, India and Pakistan. M.E. Brookfield (coordinator) with Universities of Toronto, McMaster, Dalhousie and Lahore (Pakistan) and Wadia Institute of Himalayan Geology (India).
Funded from various sources by the participants. Brookfield - Natural Sciences and Engineering Research Council.

Geochemistry of weathering. W. Chesworth.
Natural Sciences and Engineering Research Council.

Investigation of the fundamental chemistry and mineralogy associated with podzolization. W. Chesworth and S.E. Shipitalo.
Atomic Energy of Canada.

Soil Science

Resources Inventory, Planning and Development

Pilot study of biophysical information used in rural land use planning. S.G. Hilts.
Ontario Ministry of Agriculture and Food.

A land evaluation model for Ontario. B. Smit (Department of Geography), D.M. Brown, S.G. Hilts, E.E. Mackintosh, M.H. Miller, R.S. Rodd, (Centre for Resources Development), T. Phillips and J. Schildroth (School of Agricultural Economics and Extension Education).
Agriculture Canada and Ontario Ministry of Agricuture and Food.

Predictive soil mapping in Northern Ontario. L.J. Evans and B.H. Cameron.
Ontario Ministry of Natural Resources.

Clay mineralogy of Ontario soils. L.J. Evans.
Ontario Ministry of Agriculture and Food.

The relationship of soil organic matter to the physical properties of soil. R.L. Thomas.
Ontario Ministry of Agriculture and Food.

Agronomic and engineering interpretations from water retention data. R.A. McBride and E.E. Mackintosh.
Natural Sciences and Engineering Research Council.

The use of soil potential ratings in land use planning. R.E. Garrett and E.E. Mackintosh.
Central Mortgage and Housing.

Agricultural rehabilitation of aggregate lands. E.E. Mackintosh, E.J. Mozuraitis and W.E.J. Worthy.
Ontario Ministry of Natural Resources, Industrial Minerals.

Water movement in selected fine textured soils in the region of Haldimand-Norfolk. A.N. Montgomery and E.E. Mackintosh.
Ontario Ministry of Agriculture and Food.

Interpretation of soil survey information for specialty crop production. Pedro Lopez and E.E. Mackintosh.
Ontario Ministry of Agriculture and Food.

Development of the methodology for examining the macro- and micro-morphology of soil and the relation of plant roots to this morphology. R. Protz and M. Shipitalo.
Natural Sciences and Engineering Research Council

Micropedologic characterization of the major soil types in Ontario. R. Protz.
Ontario Ministry of Agriculture and Food.

Remote sensing for soil survey, land use inventories and crop yield prediction in Southern Ontario. R. Protz and S. Nolan.
Ontario Ministry of Agriculture and Food.

Soil criteria and class limits for soil classification. R. Protz and P. Uhlig.
Ontario Ministry of Agriculture and Food.

Survey of woodlots and forest industry of Wellington County. S.G. Hilts.

Survey of environmentally sensitive areas on Manitoulin Island. S.G. Hilts.
Federation of Ontario Naturalists.

Preparation of master plan for Misery Bay Provincial Nature Reserve.. S.G. Hilts.
McLean Foundation.

Pilot study of biophysical information used in rural land use planning. S.G. Hilts.
Ontario Ministry of Agriculture and Food.

Soil Physics

Water and chemical transport in soils. D.E. Elrick.
Ontario Ministry of Agriculture and Food.

Transport phenomena in natural porous media. D.E. Elrick.
Natural Sciences and Engineering Research Council.

In-situ determination of the saturated hydraulic conductivity of soils. D.E. Elrick.
Agriculture Canada.

Soil compaction problems in Ontario. P.H. Groenevelt.
Research Board, University of Guelph.

Quantitative characterization of heat, water and solute transport in freezing soils. B.D. Kay.
Natural Sciences and Engineering Research Council.

Effect of freezing and thawing on soil physical properties. B.D. Kay, P.H. Groenevelt and C. Grant.
Ontario Ministry of Agriculture and Food.

Development of methodology to characterize some physical properties of soils under different tillage treatments. B.D. Kay, P.H. Groenevelt and C. Grant.
Ontario Ministry of Agriculture and Food.

Soil Plant Relations

Modifying soil plant environment to maximize yield potential of maize. M.H. Miller, G.K. Walker, M. Tollenaar, G.W. Thurtell and D.M. Brown.
Natural Sciences and Engineering Research Council.

Reactions at the soil-root interface and their significance in plant nutrition. M.H. Miller.
Natural Sciences and Engineering Research Council.

Soil factors limiting corn yield in Ontario. M.H. Miller and W.A. Mitchell.
Natural Sciences and Engineering Research Council and Ontario Ministry of Agriculture and Food.

Potential corn yields in Ontario. M.H. Miller and W.A. Mitchell.
Sylvite Sales Inc.

Denitrification in soils. E.G. Beauchamp.
Natural Sciences and Engineering Research Council.

Nitrapyrin with fall applied N for winter wheat. E.G. Beauchamp.
Dow Chemical Co.

Manure systems (nitrogen volatilization). D.P. Stonehouse, J.B. Robinson, D. Burton, E.G. Beauchamp.
Ontario Ministry of Agriculture and Food (Agricultural Energy Management Resource Centre).

Availability of manure nitrogen. E.G. Beauchamp.
Ontario Ministry of Agriculture and Food.

Use of nitrification inhibitors with preplant N and time of N fertilizer application on winter wheat. E.G. Beauchamp, L.A. Hunt (Crop Science) and J. Sutton (Environmental Biology).
Ontario Ministry of Agriculture and Food.

Fertilizer use in the production of grass for esthetic purposes. R.W. Sheard.
Ontario Ministry of Agriculture and Food, Canadian Industries Ltd. Ontario Turf Research Foundation, American Cyanamid-Canada Ltd.

Forage systems as nitrogen sources in crop production. R.W. Sheard.
Ontario Ministry of Agriculture and Food. Natural Sciences and Engineering Research Council.

Interaction of soil drainage, species and plant nutrition. R.W. Sheard.
Ontario Ministry of Agriculture and Food.

Time of application and placement of phosphorus and potassium for grasses, legumes and mixtures. R.W. Sheard.
Ontario Ministry of Agriculture and Food, Phosphate-Potash Insitute, Potash Corp. Saskatchewan.

Tillage and crop rotation effects on soil structure, erodability, and productivity under intensive corn cultivation. B.D. Kay, J.W. Ketcheson, K.M. King, R. Protz, R.L. Thomas, T.B. Daynard (Crop Science), W.T. Dickinson (Engineering), J.H.A. Lee (Engineering), D.P. Stonehouse (Agricultural Economics and Extension Education.
Natural Science and Engineering Research Council and Ontario Ministry of Agriculture and Food.

Management of soil physical conditions under intensive corn cultivation. D.E. Elrick, B.D. Kay, J.W. Ketcheson, R. Protz, R.L. Thomas, P.H. Groenevelt, T.B. Daynard (Crop Science), W.T. Dickinson (Engineering), J.H.A. Lee (Engineering), D.P. Stonehouse (Agricultural Economics and Extension Education.)
National Science and Engineering Research Council and Ontario Ministry of Agriculture and Food.

Effects of tillage practices on soil properties and on growth and yield of corn. J.W. Ketcheson, T.J. Vyn, T.B. Daynard (Crop Science) and J.H.A. Lee (Engineering).
Ontario Ministry of Agriculture and Food, Imperial Oil Ltd., West-Central Soil and Crop Improvement Association.

Characterization, identification, degradation, and availability of phosphorus from organic phosphorus compounds in soil. R.L. Thomas.
Natural Sciences and Engineering Research Council.

A study of the organic constituents in stable soil microaggregates. R.L. Thomas.
Natural Sciences and Engineering Research Council.

Response of corn to nitrogen on Ontario soils. E.G. Beauchamp.
Ontario Ministry of Agriculture and Food.

Effects of tillage practices on soil properties and on growth and yield of corn. J.W. Ketcheson, T.J. Vyn, T.B. Daynard (Crop Science) and J.H.A. Lee (Engineering).
Ontario Ministry of Agriculture and Food, Imperial Oil Ltd.

Nitrogen requirements for whole-plant corn silage grown at high plant densities. E.G. Beauchamp.
Ontario Ministry of Agriculture and Food.

Phosphorus and potassium requirements for alfalfa production. R.W. Sheard.
Ontario Ministry of Agriculture and Food.

Soil factors limiting corn yield in Ontario. M.H. Miller.
Ontario Ministry of Agriculture and Food.

Effect of soil structure and tilth on crop growth. J.W. Ketcheson and B.D. Kay.
Ontario Ministry of Agriculture and Food.

Effects of crop sequence on soil structure, stability, and productivity. J.W. Ketcheson and T.J. Vyn.
Ontario Ministry of Agriculture and Food.

Soil management for turfgrass production. R.W. Sheard.
Ontario Ministry of Agriculture and Food.

Waste Disposal and Pollution Control

Use of sewage sludge on agricultural land with emphasis on plant availability of heavy metals. T.E. Bates and S. Abboud.
Ontario Ministry of Agriculture and Food

Agriculture and Water Quality

Phosphorus and pesticide contribution to the Holland River.

R.L. Thomas, M.H. Miller, T.H. Lane.
Ontario Ministry of the Environment.

CONFERENCES, SEMINARS, VISITING SCIENTISTS

Departmental Seminars

C.S. Baldwin, Ridgetown College of Agricultural Technology, Ridgetown. Soil erosion in Southern Ontario.

T.E. Bates, Dept. of Land Resource Science, Univ. of Guelph. Sewage sludge disposal in Ontario.

G. Catroux, Laboratoire de Microbiologie des Sols, Institut National de la Recherche Agronomique, Dijon, France. Soil nitrogen research in I.N.R.A., Dijon.

J. Cihlar, Canada Centre for Remote Sensing, Ottawa. Advances and innovations in remote sensing.

A.R. Dexter, The Waite Agricultural Research Institute, University of Adelaide, Australia. The mechanical properties of top soil and its relation to root development.

V.C. Farmer, Macaulay Soil Research Institute, Aberdeen, Scotland. A new look at podzolization.

D. Johnson, Dept. of Geology, James Cook University, Australia. Sheet-washing and development of the red mudstone plain of the Glascoyne Delta, Australia.

W. Jolley, Department of Geology, Brock University. Zeolite-bearing metamorphic rocks.

B.D. Kay, Dept. of Land Resource Science, Univ. of Guelph. Tillage and crop rotation research: an overview and developments in understanding soil structure.

K.M. King, Dept. of Land Resource Science, Univ. of Guelph. Effects of increasing atmospheric CO_2 on crop production.

J. Kwong, Dept. of Land Resource Science, Univ. of Guelph. Engineering geology of "residual soils" and their relationship to slope stability problems in Hong Kong.

E.E. Mackintosh, Dept. of Land Resource Science, Univ. of Guelph. Southwestern Ontario transmission system expansion - impact on agriculture.

E.W. Manning, Lands Directorate, Environment Canada. Changing agricultural land use in Canada: data base and research requirements.

R. Protz, Dept. of Land Resource Science, Univ. of Guelph. Soils of the Hudson Bay - James Bay Lowlands.

M. Schnitzer, Chemistry and Biology Research Institute, Agriculture Canada, Ottawa. Developments in the understanding of soil organic matter (jointly with Sigma-XI).

R.W. Sheard, Dept. of Land Resource Science, Univ. of Guelph. A new approach to soil test calibration - computer interaction.

J. Stone, Agriculture Canada, Harrow, Ontario. Soybean root growth.

P. Stonehouse, Dept. of Agricultural Economics, University of Guelph. Tillage and crop rotation research: an economic analysis of alternatives in tillage and cropping sequences.

S.K. Tandon, Department of Geology, University of Delhi, India. Calcrete (pedogenetic and non-pedogenetic), paleosols (floodplain and loessic) in Himalayan late orogenic deposits.

E. Taylor, Dept. of Land Resource Science, Univ. of Guelph. Soil interpretations for forest land management in Southern Ontario.

G.J. Wall, Agriculture Canada, Guelph. Predicting soil erosion in Ontario.

Seminars and Presented Papers

Amiro, B., T.J. Gillespie and G.W. Thurtell. 1982. An ozone flux-uptake relationship for foliar injury on white beans. 14th Air Pollution Workshop, Riverside, California, April 1982. (Poster session).

Beauchamp, E.G. 1982. Efficient use of manure for crop production. Manure Management Symposium, Toronto.

Blackburn, W., J. Proctor, T. Gillespie and B. MacNeil. 1982. A model to estimate discharge of Venturia maequalis. Canadian Meteorology. Ocean. Society, Ottawa, May 1982.

Chesworth, W. 1982. Soil: a geochemist's view. International . Congress of Sedimentology, Hamilton, Ontario.

Glooschenko, W.A. and I.P. Martini. 1983 Wetlands of the Attawapiskat River Mouth, James Bay, Ontario, Canada. Annual Wetland Conference, U.S.A.

Kelly, R. and I.P. Martini. 1982 Pleistocene lacustrine sediments of the Scarborough Formation, Lake Ontario. Workshop on Coastal Erosion and Sedimentation of the Great Lakes, Burlington.

Ketcheson, J.W., P.H. Groenevelt, B.D. Kay and C.D. Grant. 1982. Effect of tillage and stover management on soil temperature. Ninth Conference of the International Soil Tillage Research Organization, Yugoslavia.

King, K.M. and D.H. Greer. 1982 Effects of long-term elevated CO_2 and water stress on maize physiology. New Zealand. Plant Physics Society. Dunedin August 1982.

Lane, T.H. and T.E. Bates. 1982. Sampling and chemical analysis of manure. Manure Management Conference, Toronto.

Martini, I.P. and D.F. Grinham. Hydrology and sediment dispersal in Akimiski Strait, James Bay. International Congress of Sedimentology, Hamilton.

Martini, I.P. and E.M. Wightman. The geology of Roman land use in the Lower Liri Valley, Italy. International Congress of Sedimentology, Hamilton.

Martini,I.P. Processes of primary and secondary migration of petroleum. Annual Meeting of the Ontario Petroleum Institute, Toronto.

Martini, I.P. and J. Kwong. Resource potential of Lake Ontario nearshore deposits. Workshop on Coastal Erosion and Sedimentation of the Great Lakes, Burlington.

Vyn, T.J., T.B. Daynard and J.W. Ketcheson. 1982. Effect of reduced tillage systems on soil physical properties and maize grain yield in Ontario. pp. 156-161 in Proceedings of the Ninth International Soil Tillage Research Organization Conference, Dsijek, Yugoslavia.

Non-Refereed Journals, Reports, Conference Papers and Abstracts

Amiro, B.D. and T.J. Gillespie. 1982. Ozone concentrations, Meteorological conditions, and injury to White Bean at Arkell, Ontario, during the 1982 growing season. Report to Environment . Canada for D.S.S. Contract No. 01Se.KM147-2-0180, 38 pp.

Beauchamp, E.G. 1982. Efficient Use of Manure for Crop Production. Manure Management Seminar, Toronto, February 3.

Brown, D. and Greg A. Brown. 1982. Simulation of forage yield for crop insurance purposes in Ontario. Presented at 1982 Annual Meeting of American Soc. of Agronomy. Anaheim, California (A.S.A. 1982 Agronomy Abstracts, p. 11).

Chesworth, W. and Evans, L.J. 1982. Weathering, soil formation and land use in south and central Ontario. Field Excursion Guide Book 10A. Eleventh International Congress on Sedimentology, McMaster University, August 22-27, pp. 66.

Elrick, D.E. 1982. Etudes sur l'eau du sol dans les regions arides du Senegal. CT Rapport No. 1963. Agence Internationale de l'Energie Atomic, Vienne.

Elrick, D.E. 1982. Soil physics review: A review of the soil physics research activities within MARDI (Malaysian Agricultural Research and Development Institute). Serdang, Selangor, Malaysia.

Foster, N.W., E.G. Beauchamp and C.T. Corke. 1982. Importance of chemical reactions and microbial activity in immobilizing urea nitrogen in jack pine humus. Annual Meeting, American Society of Agronomy, Anaheim, California. December 3.

Hilts, S.G. 1982. Natural Areas of Provincial Significance. Seasons 22(2): 7-8.

Hilts, S.G. (ed.) 1982. Sanctuaries. Newsletter of the Nature Reserves Committee, Federation of Ontario Naturalists.

Hilts, S.G. and Fitzgibbon, J.F. 1982. Environmentally Sensitive Areas in the Guelph Urban Fringe. School of Rural Planning and Development, University of Guelph.

Hilts, S.G. and Kirk, D. 1982. Evaluation and Priority Ranking of Selected Natural Areas in the Bruce Peninsula. Report to the Federation of Ontario Naturalists Nature Reserves Committee.

Hilts, S.G. and C. Kruspe. 1982. A citizen's guide to issues surrounding the establishment of a new national park in the Bruce Peninsula. School of Rural Planning and Development, University of Guelph.

Hilts, S.G., C. Kruspe, and J. Port. 1982. The uniqueness of the Bruce Peninsula. School of Rural Planning and Development, University of Guelph.

Kay, B.D. and P.H. Groenevelt. 1983. Development of a model to describe subsurface transport of solutes as a consequence of freezing conditions. Report to Inland Waters Directorate, Environment Canada.

Mackintosh, E.E. and E.J. Mozuraitis. 1982. Agricutlure and the Aggregate Industry. Ontario Ministry of Natural Resources, Inudstrial Mineral Background Paper 3, 44 pp.

Mackintosh, E.E., E.J. Mozuraitis, W. Worthy and J.W. Ketcheson. 1982. Rehabilitation of Mined Sand and Gravel Lands to an Agricultural After-Use in Ontario. Final Research Report. Prepared for Industrial Minerals Branch, Ontario Ministry of Natural Resources, 260 pp.

Shipitalo, M.J. and R. Protz. 1982. Micromorphological Characterization of Void Arrangement in Soils. Soil Science Soc. of Amer. Nov. 28-Dec. 3, Anaheim, California. Agronomy Abstracts, p. 239.

Uhlig, P.W.C. and R. Protz. 1982. Identification and Analysis of Soil Variability Using Ordination and Clustering Methods. Soil Science Soc. of Amer. Nov. 28-Dec. 3, Anaheim, California. Agronomy Abstracts, p. 241.

Vyn, T.J. and T.B. Daynard. 1982. Conservation tillage and associated ground residue cover for erosion control with corn production. Final report to Ministry of Environment (Experience '82). 14 pp.

Vyn, T.J. 1983. Progress in tillage research at the University of Guelph. pp. E1-E3 in Soil Management Day Proceedings, Southwestern Ontario Farmer's Week.

Vyn, T.J., T.B. Daynard and J.W. Ketcheson. 1982. Feasibility of alternative tillage practices for reducing soil erosion in Ontario corn production. American Society of Agronomy Annual Meeting. Dec. 1, 1982. Anaheim, Calif.

Walker, G.K. 1982. Evaporation and transpiration components of evapotranspiration. Am. Soc. Agron. Annual Meetings, Anaheim, Ca. (Agron. Abst. p. 19).

Walker, G.K. 1983. Energy limited evaporation from soil beneath crop canopies. 16th Conf. on Agriculture and Forest Meteorology, Am. Met. Soc. Biennial Meetings, Fort Collins, Co.

Refereed Journals and Chapters in Books

Beauchamp, E.G. 1982. Fixed ammonium and potassium release from two soils. Community Soil Science Plant Analysis. 13: 927-944.

Brown, D.M. 1983. Chapter 2 in Effects of Climatic Variability on Agriculture and of Agricultural Activities on Climate. World Meteorologic Organization CAGM Report. No. 17, 36 pp.

Chesworth, W., Jean Dejou and Pierre Larroque. 1982. Donnees nouvelles sur l'evolution superficielle de nature fersiallitique subie par les basaltes Patiens du bassin d'Aurillac (Cantal) cas du profil de St. Etienne-de-Carlat, et consequences paleoclimatiques. Pedologie (in press).

Chesworth, W. 1983. Phase relationships in the system SiO_2-Al_2O_3-H_2O, applicable to weathered materials of the earth. Kelkar Mem. Volume, Indian Society of Earth Science. 1-6.

Chesworth, W., Felipe Macias, David Acquaye and Edmond Thompson. 1983. Geology and the Food Supply: Bread from Stones. Episodes. 1983. 1: 3-7.

Elrick, D.E., M.J.L. Robin and K.B. Laryea. 1983. Hydrodynamic dispersion during absorption of water by soil: 1. Model moisture profiles. Journal Hydrology. (accepted for publication 3 September, 1982).

Evans, L.J. 1982. Dating methods of Pleistocene deposits and their problems. VIII. Paleosols. Geoscience Canada. 9: 155-160.

Friesen, D.K., A.S.R. Juo and M.H. Miller. 1982. Residual value of lime and leaching of calcium in a kaolinitic ultrasol in the high rainfall tropics. Soil Science Society Of America Journal. 46: 1184-1189.

Kay, B.D. and P.H. Groenevelt. 1983. The Redistribution of Solutes in Freezing Soil: Exclusion of Solutes. Proceedings Fourth Int. Conference on Permafrost. Fairbanks, Alaska (in press).

Laryea, K.B., D.E. Elrick and M.J.L. Robin. 1982. Hydrodynamic dispersion involving cationic adsorption during unsaturated, transient water flow in soil. Soil Science Society Of America Journal.46: 667-671.

Loebel, K., E.G. Beauchamp and S. Lowe. 1982. Soil modification and plant growth on a calcareous subsoil material treated with a partially composted "sludge leaf" mixture. Reclamation Revegetation.1: 283-293.

Major, D.M., D.M. Brown, A. Bootsma, G. Dupuis, N.A. Fairey, E.A. Grant, D.G. Green, R.I. Hamilton, J. Langille, L.G. Senmor, G.C. Smeltzer and R.P. White. 1983. An evaluation of the corn heat unit system for the short-season growing regions across Canada. Canadian Journal Plant Science.63: 121-130.

Miller, M.H., J.B. Robinson, D.R. Coote, A.C. Spires and D.W. Draper. 1982. Agriculture and water quality in the Canadian Great Lakes Basin III. Phosphorus Journal Environment Quality. 11: 487-493.

Miller, M.H. 1983. Soil limitations to crop productivity in Canada. Canadian Journal Plant Science 63: 23-32.

Mukammal, E.I., H.H. Neumann and T.J. Gillespie. 1982. Meteorological conditions associated with ozone in southwestern Ontario, Canada. Atmosphere Environment.16: 2095-2106.

Pedro, M.J., and T.J. Gillespie. 1982. Estimating dew duration. I. Utilizing micrometeorolgical data. Agricultural Meteorology. 25: 283-296.

Pedro, M.J., and T.J. Gillespie. 1982. Estimating dew duration. II. Utilizing standard weather data. Agricultural Meteorology. 25: 297-310.

Protz, R. 1982. Development of Gleysolic soils in the Hudson Bay and James Bay Coastal Zone, Ontario. Le Naturaliste Canadien. 109: 491-500.

Protz, R. 1982. Development of podzolic soils in the Hudson Bay and James Bay Lowlands. Le Naturaliste Canadien. 109: 501-510.

Robin, M.J.L., K.B. Laryea and D.E. Elrick. 1983. Hydrodynamic dispersion during absorption of water by soil: 2. Immobile water model. Journal Hydrology. (accepted for publication on 3 September, 1982).

Sheard, R.W. 1982. Supplement to Proceedings. IV Research Conference International Turfgrass Society.

Sheppard, S.C. and T.E. Bates. 1982. Selection of a soil extraction and a multiple regression model to predict plant available manganese. Community Soil Science and Plant Analysis. 13: 1095-1113.

Walker, G.K. 1983. Measurement of evaporation from soil beneath crop canopies. Canadian Journal Soil Science. 63: 137-141.

Yeomans, J.C. and E.G. Beauchamp. 1982. Acetylene as a possible substrate in the denitrification process. Canadian Journal Soil Science. 62: 139-144.

Yeomans, J.C. and E.G. Beauchamp. 1982. Sulfur in acetylene inhibition of nitrous oxide reduction by soil microorganisms. Soil Science Society of America Journal. 46: 75-77.

Book Reviews

Brown, D.M. 1983. Review of World Survey of Climatology, 9. Climates of Southern and Western Asia. K. Takahashi and H. Arakawa (Editors). Publisher: Elsevier Scientific Publication Company, Amsterdam, 1981. Dynamics of Atmospheres and Oceans, 7.

Chesworth, W. 1981. Applied Soil Trace Elements by Davies, Geochemistry Cosmochim. Acta. 45: 595.

Chesworth, W. 1981. The Soil Resource by Jenny, Geochemistry Cosmochim. Acta. 45: 2519.

Chesworth, W. 1981. Pedology by Fitzpatrick, Geochemistry Cosmochim. Acta. 45: 2519.

Chesworth, W. 1982. Chemistry of Soil Constituents by Greenland and Hayes, Geochemistry Cosmochim. Acta. 46: 834.

Chesworth, W. 1982. Chemistry of Soil Processes by Greenland and Hayes, Geochemistry Cosmochim. Acta. 46: 834.

Soon, Y.K. and T.E. Bates. 1982. Land disposal of sewage sludge - a summary of research from 1972 to 1981. 167 pages. Environment Canada and Ontario Ministry of the Environment.

Information for Industry Personnel (I.F.I.P.) and Extension Personnel (I.F.E.P.)

Bates, T.E., T.H. Lane and R. Frank. Revised 1982. Use of stabilized sewage sludge on agricultural land.

Ketcheson, J.W., T.J. Vyn and T.B. Daynard. 1982. Tillage practices for residue management and erosion control. Agdex III/156, O.M.A.F. factsheet, 4 pp.

Vyn, T.J., T.B. Daynard, J.W. Ketcheson and J.H.A. Lee. 1982. Progress in tillage research. IFIP Agdex 516. April, 1982, 9 pp.

Vyn, T.J., T.B. Daynard, J.W. Ketcheson and J.H.A. Lee. 1983. Tillage for crop production on Ontario soils: Principles. Agdex 100/516, O.M.A.F. factsheet, 4 pp.

Vyn, T.J., T.B. Daynard, J.W. Ketcheson and J.H. Lee. 1983. Tillage for crop production on Ontario soils: Practices. Agdex 100/516, O.M.A.F. factsheet, 4 pp.

Radio Tapes and Television

Bates T.E. - CKNX TV Wingham - soil testing.

Bates T.E. - radio tape on heavy metals - local and national distribution.

Gillespie, T.J. - radio tape for CKLA - ozone and agriculture. October 1982.

Vyn, T.J. - CKNX TV Wingham - Implements and management systems for conservation tillage.

4th Year Resources Management Projects

In the spring of 1982, six final projects were submitted by the graduating Resources Management class. These include:

A Study of the Gozier Nature Reserve - report to the Federation of Ontario Naturalists for property management purposes.

Investigation of Computer Facilities for Resource Mapping - report to the Department of Land Resource Science.

The Ontario Mystery of Planning - simulation game being developed for use in Ontario High Schools.

Access Issues and Environmentally Sensitive Areas - report to the Halton County Planning Board.

Marshall Township: A Simulation Game - land use game being used in university teaching.

Gravel Pit Rehabilitation: A Case Study.

ontario
institute
of pedology

INTRODUCTION

The Ontario Institute of Pedology has responsibility for coordinating activities in soil resource inventories and research in soil genesis, morphology, classification, characterization and interpretation of Ontario soils. Because of its affiliation and working relationship with the Department of Land Resource Science, the Institute is pleased once again to present its 1982 Progress Report in conjunction with that of the Department.

In addition to on-going support from the cooperating agencies, namely Agriculture Canada, Ontario Ministry Agriculture and Food and University of Guelph, during the past year, continued support was received by means of contract funds from the Ontario Ministry of Natural Resources. At the same time, the cooperation of personnel from agencies including Northern Region and Ontario Tree Improvement and Forest Biomass Institute, Ministry of Natural Resources; Great Lakes Forest Research Centre, Canadian Forestry Service; and Land Directorate, Environment Canada, has assisted these programs and is much appreciated. Contract funds also were received in 1982 from Ontario Hydro for upgrading soil survey information along proposed Hydro transmission corridors in Southwestern Ontario.

A brief description of the projects carried on by the Ontario Institute of Pedology and some of the results are presented in the following pages. We hope that you find the information of value and we welcome your enquiries or comments relative to the program of the Institute.

PERSONNEL

Ontario Ministry of Agriculture and Food

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Professional

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J.E. GILLESPIE, B.S.A. (Guelph), M.S.A. (Toronto), Pedologist. Temporary contract position. (Ext. 330)

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G.J. WALL, B.Sc. (Agr.), M.Sc. (Guelph), Ph.D. (Ohio State), Pedologist, (Ext. 331) (824-4120, Ext. 2103)

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SOIL RESOURCE INVENTORY

Field Mapping

Field mapping continued in the Regional Municipality of Niagara, and commenced in Elgin County during 1982. Approximately 33% of the total area of the Niagara region has now been remapped at a scale of 1:25,000. One preliminary soils map (West Lincoln Township) has been published and another (Lincoln and Grimsby Townships) is now in preparation and is soon to be released. Preliminary field work has been carried out in Elgin county for the purpose of establishing the field legend with anticipation of commencing the regular field mapping in 1983.

Map and Report Preparation

The final soil maps for the Regional Municipality of Haldimand-Norfolk have now been completed and cartographic preparation and digitizing is under way in the Land Resource Research Institute, Ottawa. The first draft of the soils report for the region is now in preparation.

The final soil maps for the Regional Municipality of Ottawa-Carleton are now being prepared and final cartography is to commence in the spring of 1983. After additional field sampling in the region in 1982, all the available analytical information was synthesized by computer means in preparation for writing the final draft of the soils report.

The first draft soils report for Brant county is now complete. The final soil maps are in preparation and it is anticipated that these will be completed in 1983.

The final soil map and report for Middlesex county are in preparation.

The soil maps for Peterborough county have been digitized and printed and copies are available from the Communication Branch, Ontario Ministry of Agriculture and Food. Various types of interpretive maps have now been generated for the area (i.e. agriculture capability, soil erosion potential, and soil suitability for white beans. The final manuscript for Peterborough county has been submitted for printing.

The compilation of the soils information for regions of Northern Ontario is progressing steadily. The soil maps for Timmins, Noranda-Rouyn and Thunder Bay have now been printed and are available from the Communications Branch, Ontario Ministry of Agriculture and Food. The respective soil reports are presently in their second draft stage and will require minor editing prior to printing. In addition, the map manuscripts for various other regions in Northern Ontario (Figure 1; Table 1) are now in cartographic preparation and will be available preparation and will be available commencing in 1983. All these latter maps will be published with an extended soils legend rather than a complete soils report.

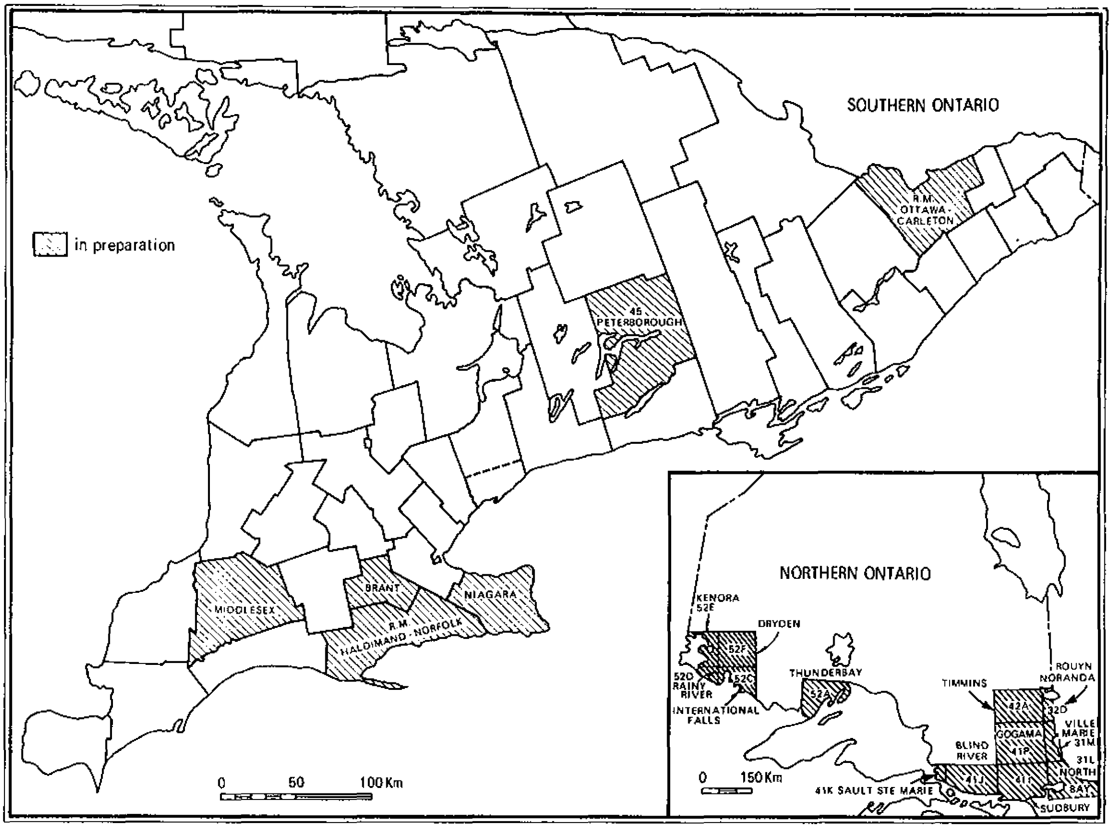

Figure 1. Ontario soil maps and reports in preparation (1980).

TABLE 1. STATUS OF MAPPING PROJECTS

Projects	Scale	Status in 1982	Anticipated Publication Date
Peterborough County	1:63,360	Soils map digitized and printed. Soils report in printing.	1983
Middlesex County	1:50,000	Map compilation, soils report in preparation.	1984
Brant County	1:25,000	Map compiliation, report editing.	1984
R.M. Ottawa-Carleton	1:50,000	Preliminary soil maps (3) available. Final soil maps in preparation. Report in preparation.	1984
R.M. Niagara	1:25,000	Inventory program continuing. Preliminary soil maps (1) available.	1986/87

Elgin County	1:50,000	Field legend completed. Inventory program to start in 1983.	1987/88
Thunder Bay Map Sheet (52A)	1:50,000 1:250,000	Soil maps printed. Report editing.	1984
Sault Ste. Marie Blind River Map Sheets (41J, 41K)	1:50,000 1:250,000	Soil maps in cartography, Extended legends completed.	1983
Sudbury Map Sheet (41I)	1:50,000	Soil maps in cartography. Extended legends completed.	1983
Cochrane-Kapuskasing Map Sheets (42H, 42G)	1:50,000 1:250,000	Soil maps in cartography. Extended legends in preparation.	1984
Kenora, Dryden Map Sheets (52E, 52F)	1:50,000 1:250,000	Soil maps in cartography. Extended legends completed.	1984
Fort Frances, Rainy River Map Sheets (52C, 52D)	1:50,000 1:250,000	Soil maps in cartography. Extended legends completed.	1984
Timmins-Noranda Rouyn Map Sheet (42A)	1:50,000 1:250,000	Soils map printed. Report in progress.	1984
Ville Marie Map Sheet (31M)	1:50,000 1:250,000	soil report in preparation.	1985
North Bay Map Sheet (31L)	1:50,000 1:250,000	Extended legend in preparation.	1985
Gogama Map sheet (41P)	1:50,000 1:250,000	Extended legend in preparation.	1985

Upgrading of Existing Soils Information

In the 1981 progress report, reference was made to the "Southwestern Ontario Hydro Transmission System: Impact on Agriculture". On request from the Ontario Ministry of Agriculture and Food, the Ontario Institute of Pedology undertook an extensive upgrading program of the existing soils information for those areas covered by the M3 study area (Figure 2). This work was carried out under contract with Ontario Hydro, with the Institute coordinating and supervising the work performed by several companies.

From the upgraded soils maps, interpretations were made for agriculture capability for common field crops and for numerous horticultural crops. By year end, this part of the program was nearly completed.

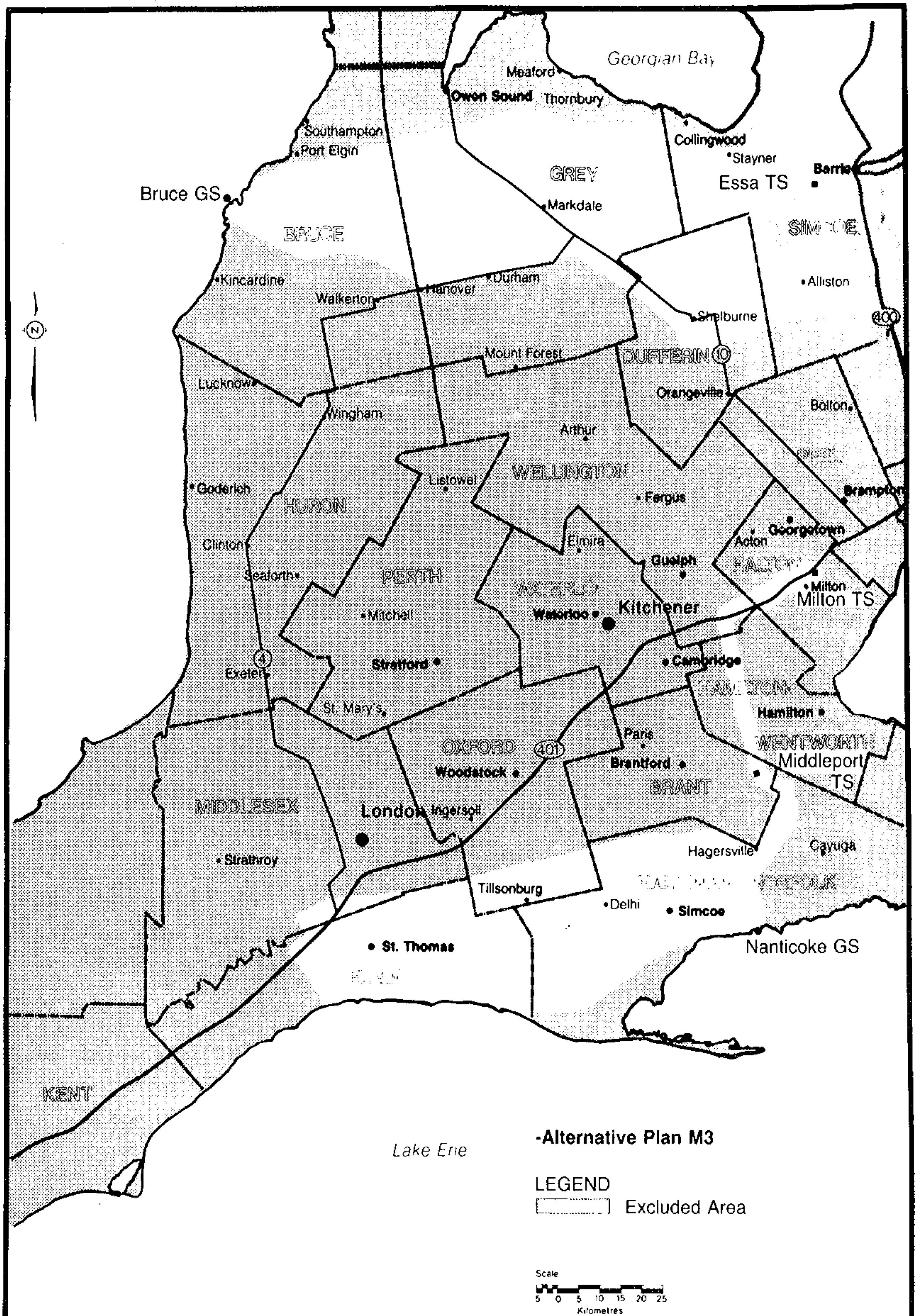

Figure 2: M3 study area.

Soil Map Reprinting

The following "out-of-print" soil maps were reprinted using photographic techniques.

- Essex county
- Prince Edward county
- Simcoe County

The maps for Bruce County are in the process of being reprinted and will be available during 1983.

Soil Data Handling

The use of computers as an aid to soil survey has escalated rapidly in recent years. With this capability of analysing and compiling field as well as lab data, the volume of soils information collected also has increased.

In the past years, the Institute relied heavily on CANSIS for data handling and map generating capabilities. Due to high costs, editing capabilities, slow turn-around time, etc., the Institute is now relying on the computer facilities provided by the University of Guelph for its day-to-day computer operations. Financial assistance for this service is provided through Agriculture Canada and OMAF Program 67.

For more information regarding the various computer files now in use by the Institute, one is referred to Tables 2 and 3.

Table 2: Existing O.I.P. Soil Data Files.

File Name	Description	Variables	Output	Accessibility	Comments
Niagara Haldimand-Norfolk Ottawa-Carleton Elgin County, Pluarg	Laboratory analysis for soil inventory samples.	Location, series code, horizonation, horizon thickness, % sand, silt, clay; % O.M., pH, % Ca CO_3, Texture	Listings, charts graphs of available attributes, modal soil unit concepts.	CMS/SAS	Niagara - 5100 samples Haldimand-Norfolk - 4000 samples, Ottawa-Carleton-1900 samples Elgin County - 2000 samples, pluarg - 600 samples.
Soil Erodibility	"K" values for various soil series	Particle size, texture, soil series, "K" values	as above	CMS/SAS	1500 samples on record
Soil Legends	Legends for Niagara, Elgin, Middlesex, Ottawa-Carleton	Soil codes, textures drainage, mode of deposition, special notes.	Charts and tables	CMS/script	--
Soil Reports	Reports for Haldimand-Norfolk, Brant.		Report	CMS/script	--
Soil Watertables	Watertable, rain gauge, and soil temperature files for Haldimand-Norfolk and Niagara.	47 semi-monthly watertable records, 35 locations for precipitation recordings, 4 soil temperature sites.	Graphs	CMS/SAS	--
Forest Soil Inventories		Soil physical and chemical variables, forest productivity information.	Tables and charts	CMS/SAS	400 samples on record
Forest Ecological Classification	250 detailed profile descriptions from the Clay Belt area of northern Ontario; 774 additional sites with limited amount of soils data.	Detailed site information, soil profile, chemical and physical attributes, texture, moisture regime, depth to carbonates, depth of organic matter, etc.	Profile descriptions, tables, charts	CMS/SAS	Approx. 2000 samples on record

Table 3: Existing CANSIS Files.

Soil Data File (Detailed file)	Modal site information and analysis.	Detailed soil, site, physical, chemical and mineralogical properties	Profile descriptions special request reports	Interactive accessiblity not available, must put in written request to CANSIS.	Data entered at the completion of a survey.
Soil Names File	A catalogue of all soil names currently used in Canada	soil name, soil code, classification, credibility, mode of deposition, particle size, mineralogy, depth, reaction, calcareousness, soil temperature, soil moisture and location.	Print out of combinations of the variables listed.	Interactive on radid accessed on the Datapack Network	1030 names for Ontario File. Information Lacking for many of variables.
Performance Management File	Files containing crop performance data as well as soils data	Crop yields, quality, growth development, management, weather, experimental design, soils, location.	Summaries and reports.	Interactive	
Cartographic File	Digitized soil maps	Variables as appear on the original soils map.	Interpretive and derivitive maps, unique symbol display, map display with symbol, spatial display, turn-around documents.	Requests sent to CANSIS for specific	19 maps have been digitized, 75 maps are partially completed, 78 maps awaiting digitization.
Land potential	Nation wide crop information.	Soil, climate, capability, biomass production, potential yields for various crops.	Summaries, reports, maps.	Interactive radid file.	
Ontario Daily File	Abreviated detail file for collection of field and laboratory data	Location attributes, parent material, site attributes, pH, o.m., $CaCO_3$, profile descriptions, particle size analysis.	Tables, summaries, charts, graphs	Interactive radid file.	
Special Project File	Subfiles of the soil data file, performance reports, summaries, management file and a series of maps (vegetation, wildlife, biophysical and cartographic files.)				

Computer Assisted Data Management for Soil Surveys in Ontario

The 1982 field season saw the use of computer facilities become an integral part of soil survey data handling, both as a calculative tool and as a data base interface mechanism. Small problems that had been caught during the first year of operation (1981) were corrected and new ideas that further utilized the machines power were implemented. The ability to access and quickly summarize large amounts of data should make the pedologists' task of providing more interpretations for an expanded user group somewhat easier. As well, planning during ongoing surveys is facilitated by having information gathered to date readily accessible.

The data collected in 1982 consisted of physical and chemical analysis provided by the Soil Characterization Laboratory. A simple program performed any calculations necessary, generated hard copy print-outs of results and updated ongoing data files.

The introduction in the 1983 field season of a free-standing micro-computer for data calculation and data base control should significantly reduce computer costs of the Institute in the long run. A further benefit is the more user-friendly environments characteristic of micro-computers which should allow the pedologists at the unit to manipulate their own data bases, rather than relying on a computer resource person.

J.W. Greuel

Generalized Soil Landscape Map for Ontario

Existing soil survey, physiographic, geological and agricultural information was utilized to delineate soil landscape units having general similarities in soil texture, genetic materials, soil development, surface form and slope gradient on a 1:250,000 base map. Each delineation was identified by a unique number which characterized the mapping unit in terms of parent material origin and texture, underlying bedrock, slope and landform, and Great Soil Group. Maps and legends have been completed to the manuscript stage for the southern portion of Ontario, and have been commenced for Northern Ontario.

The intention is to have the map and legend information computerized to enable the generation of single factor derivative or interpretive maps on a provincial scale.

C. Acton, R. Harkes

Forest Ecosystem Classification Program

Site Region 3E/Clay Belt

The forest ecosystem classification (FEC) program continued on its fourth year in the Clay Belt area of Northern Ontario. The field season was spent primarily on the mapping component of the program. Pretyped polygons were ground truthed using the more objective transect methods being introduced in soil survey. Each interval sample point was allocated to an Operational Group, Vegetation Type and Soil Type using the Keys developed the previous year. Towards the objective of developing a map unit typology, 116 polygons were tentatively classified into 19 map unit types using cluster analyses (TWINSPAN). Further polygon sampling will be done in 1983 to increase our sample and thus improve the map unit typology. Some preliminary air photo interpretation keys have also been developed for testing in the 1983 field season. The mapping program will also concentrate on areas of greatest concern to the Ministry of Natural Resources and forest companies.

The Ontario Institute of Pedology and the Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources (Geoffrey Pierpoint) co-hosted the 1982 Northeastern Forest Soils Conference in Cochrane from August 27-29. The NEFSC is held annually and is hosted by a northeastern state or eastern province. The focus of the 1982 conference was on the FEC program as it serves forest management needs in the Clay Belt. The conference was attended by about 80 enthusiastic delegates.

In the fall the first FEC course was given to 25 O.M.N.R. professionals and forest technical staff. By the end of the four day training session, the participants became very proficient with using the Operational Group keys below and started to develop an initial

initial appreciation of the value of the classification system in forest land management planning. During the 1983 field season a number of training sessions are planned with both company and Ministry staff. A waterproof field guide of the Clay Belt classification system will be published for the 1983 field season. Copies of the guide may be obtained from:

Ontario Tree Improvement and
Forest Biomass Institute
Ontario Ministry of Natural Resources
Maple, Ontario
LOJ 1EO

The FEC program is a cooperative research program involving:

R. Keith Jones (Project Leader)	Land Resource Research Institute Agriculture Canada Ontario Institute of Pedology Guelph, Ontario
Geoffrey Pierpoint	Ontario Tree Improvement and Forest Biomass Institute Ontario Ministry of Natural Resources Maple, Ontario
Greg Wickware	Lands Directorate Environment Canada Burlington, Ontario
John Jeglum	Great Lakes Forest Research Centre Canadian Forestry Service Environment Canada Sault Ste. Marie, Ontario
Rob Arnup	Northern Region Ontario Ministry of Natural Resources Timmins, Ontario

R.K. Jones

Soil Interpretations and Soil Training Program for Forest Land Management in Southern Ontario

The 1982 program consisted of the preparation of: interpretative reports for each of Huronia and Lindsay Districts (see current publications); interpretative forest soil research in Chatham, Alymer and Cambridge Districts (see Figure 3); forest soil extension tours and related activities in Chatham, Alymer, Cambridge, Niagara, Huronia and Owen Sound Districts; a Forest Soil Training Session in Cambridge District; a forest soil-silvicultural session in Huronia District, and the preparation of manuals and an "on site" table (see Table 4) to accompany the extension and training programs.

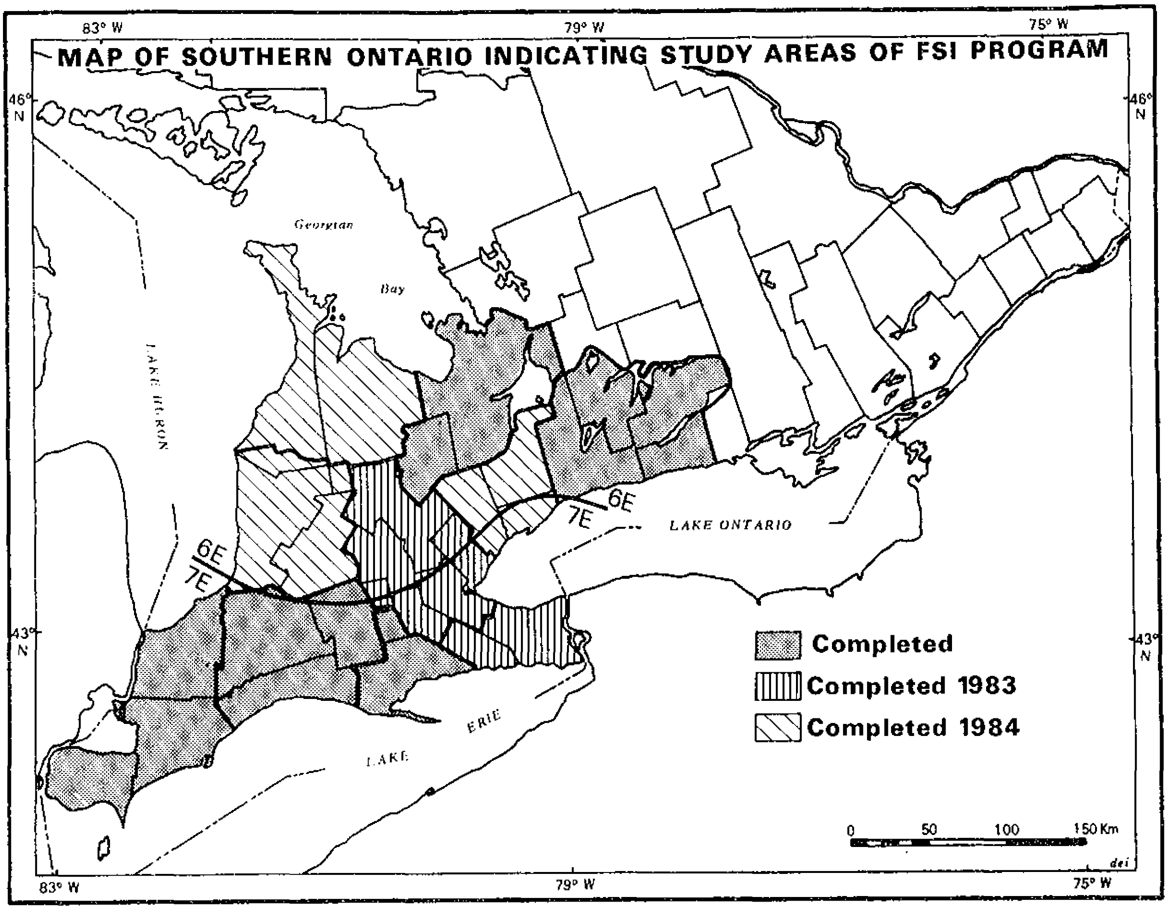

Figure 3: FSI Program Study Areas.

Plans for the 1983 program include: the completion of the soil interpretion for forestry component of the Haldimand-Norfolk soil survey report; conducting interpretative forest soil research in Niagara and Cambridge Districts; presenting soils and silvicultural workshops in Wingham and Huronia Districts; coordinating forest soil extension tours throughout Southern Ontario; and continuing with the compilation and analysis of the detailed soils and forest data sets towards establishing a final integrated, interpretative, framework.

As in the previous year of the program, the assistance and support of the O.M.N.R. staff is greatfully acknowledged.

This table provides productivity ratings for Sugar Maple in Site Region 6E (see Figure 3) within a soil framework. The rows of the table are groupings of soil textures ranging from coarse to fine, while the columns are soil moisture regime classes ranging from dry to moist. Within this framework each texture/moisture regime combination has been rated for its observed or extrapolated productivity. The range of productivity for each commercial species has been sub-divided into five classes, where class 1 is the most productive and class 5 is the least productive (see numbers within each box).

Table 4: Tree to Soil Suitability Table.

	SOIL MOISTURE REGIME Mh						
	DRY	FRESH			MOIST		
Textures	Mod. Dry 0	Mod. Fresh 1	Fesh 2	Very Fresh 3	Mod. Moist 4	Moist 5	Very Moist 6
Very coarse and Course Sands; Loamy Very Coarse and Coarse Sands	5	4	3	3+	3	3	4
Medium Sand; Loamy Medium Sand	3	3+	2	2	3	3	3
Fine Sand; Loamy Fine Sand; Silty Fine Sand		3	3+	1	3	3	3
Sandy Loam; Very Fine Sand; Loamy Very Fine Sand; Silty Very Fine Sand			2	1	2	3+	3+
Loam; Silt Loam; Sandy Clay Loam; Structured Silty Clay and Clay (aggregates <10 mm)			2	2	2	2	
Silt; Silty Clay Loam; Clay Loam; Sandy Clay; Structured Silty Clay and Clay (aggregates >10 mm)			1	1	2	4	
Structureless Silty Clay and Clay				2+	2+	2	

+ denotes upper range of site class

Variability Among Pedons in Selected Soil Physical and Chemical Properties in Southern Ontario

The validity attached to soil survey maps and the interpretations made from the accompanying soils data are dependent on the accuracy in characterizing the variability which exists within a standard sampling unit (pedon) and between several pedons of the same soil series. In an earlier study, 5 replicate samples were found to be required for statistically reliable evaluation of given soil properties for a pedon in order to achieve satisfactory levels of accuracy at the 95% confidence level. The study results have lead to a recommended method of pedon sampling for use by the Ontario Institute of Pedology that stresses the need for composite sampling of morphologically similar horizons.

Research is continuing with the same soil materials to establish the number of pedons that should be characterized to obtain satisfactory estimates of the variability of soil physical and chemical properties within a region. Replicate samples (6) for seven of the major soil series in Southern Ontario have been taken. Laboratory evaluation for particle size, organic matter, pH, and calcium carbonate equivalent is underway. Statistical evaluation of the data will provide pedologists with guidelines for the number of soil samples required to obtain satisfactory estimates of soil properties. This information will lead to a greater understanding of the reliability that can be placed on soil interpretations based on soil physical and chemical properties reported in soil resource inventory publications.

G.J. Wall

Identification of Land Factors Affecting Crop Signatures in Remotely Sensed Spectral Data

A method was developed to characterize the influence of certain land factors, such as erosion and slope, on crop signatures using remotely sensed spectral data.

Crops and crop conditions were documented in the field and located on colour and colour infrared aerial photography, airborne multi-spectral scanner imagery, and Landsat imagery; taken on May 26 and July 20, 1982.

Using soil maps, field data, and the aerial photography, digital image analyses were performed on airborne and Landsat-3 spectral data to obtain reflectance "signatures" in the visible and infrared region for various crop conditions.

A range of signatures for seven major crops were established and the influence of the various land factors were characterized.

A partial classification of the July Landsat imagery was made to map the major land factor influences and uniform crop signatures in the test area.

Further study will proceed in this area. The objectives are to separate land factor influences from early crop signatures using image enhancement techniques, to map soil variability, and improve the accuracy of yield estimates at early stages of crop growth.

R. Protz and S. Nolan

The Application of Numerical Techniques to Studies in Soil Classification in the Hudsons and James Bay Lowlands

Several characteristics of the data sets associated with reconnaissance soil survey projects result in difficulties in analysis and interpretation. Data sets tend to be large and multivariate. The exploratory nature of reconnaissance survey often uncovers unexpected phenomena which may not neccessarily fit preconceived ideas. Methods are required to reduce data set size to allow for efficient analysis. Considering these and other features several methods developed in the field of ecology have been shown to be well suited to the study of taxonomic group structure in large, multivariate soil data sets.

The Hudson and James Bay project was a five year, multi-disciplinary reconnaissance survey of lowlands area within Ontario. A major portion of that study was the collection of representative soil profiles. The goal of this portion of the study is to develop classification of the soils in the area.

One hundred and seven profiles were selected from the total data set to assess the usefulness of these techniques for soils. Particle-size analysis, chemical and morphological characteristics as well as information concerning vegetal features, climate, age and topography will be used in the analysis and interpretation.

To this point methods have been developed and implemented for the coding of non-numerical data (such as morphological descriptions) to numerical form. All other data to be used in the analysis have been edited and prepared for the computer. In addition, all soil profiles have been described and classified according to the Canadian System of Soil Classification. Preliminary descriptive statistics and initial grouping analyses have been completed.

Further analyses to be employed include Cluster, Ordination and Multidiscriminant analyses. These and related techniques employ sorting strategies which group soil individuals on the basis of the similarity of shared character variables. These techniques represent a significant departure from traditional procedures for classifying soils as they do not utilize a priori, genetic weightings for specific soil features used in determining group membership.

In order to evaluate the efficiency of the various methods used, comparisons will be made between the numerical and traditional techniques of soil classification. Advantages and disadvantages of the various methods will be evaluated in the hope of providing logical alternatives to data set management and analysis of multivariate soils data.

P. Uhlig and R. Protz

Agronomic and Engineering Soil Interpretations from Water Retention Data

An interpretive system, based on the prediction of spatial and temporal variations in the soil water regime from limited soil physical and hydrological data, has been developed to provide the necessary land quality/output information for land evaluation in Ontario. The potentials and constraints on the agronomic and engineering performance (productivity) of land which are attributable to the moisture regime are emphasized to assist land planners in resolving conflicts between agricultural and urban-related land uses.

A water retention model estimates (s.e.e. $< 2.2\%$ g/g) the boundary desorption curve from saturation to pF 4.2 for mineral soils <u>in situ</u> using available soil physical data (Figure 4). The total porosity (structural parameter) and clay content (adsorptive parameter) define the position of the moisture characteristic in logarithmic coordinates and the silt content its configuration. Model validation shows that the state and quantity of water retained by field soils near equilibrium is dependent on the position of the phreatic surface.

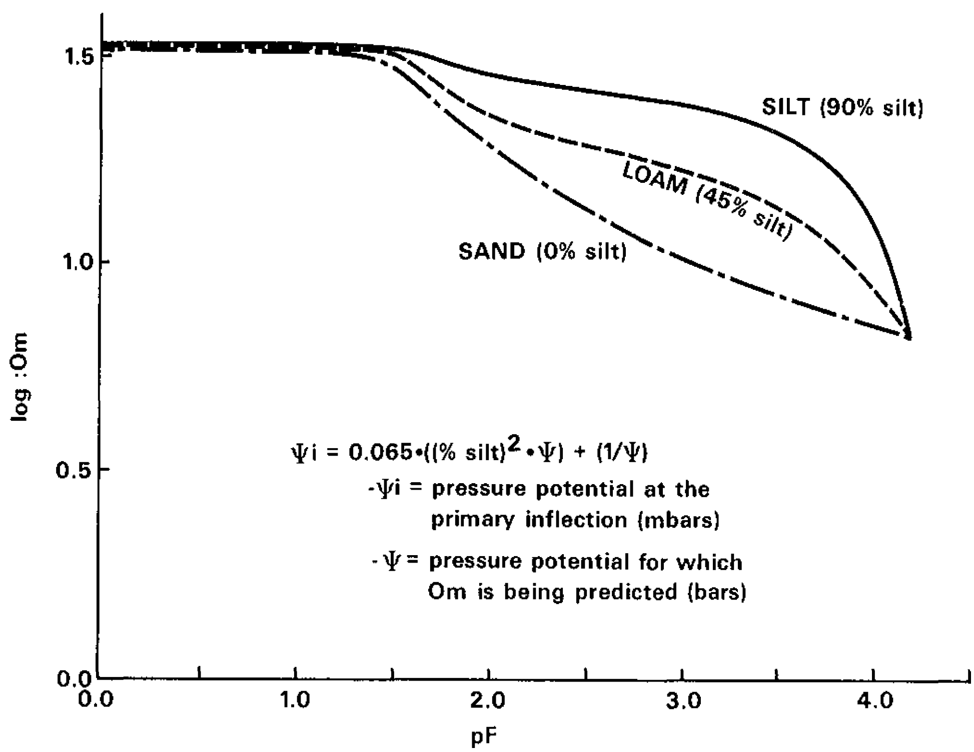

Figure 4: Plots of estimated moisture characteristics for sand, silt and loam soils.

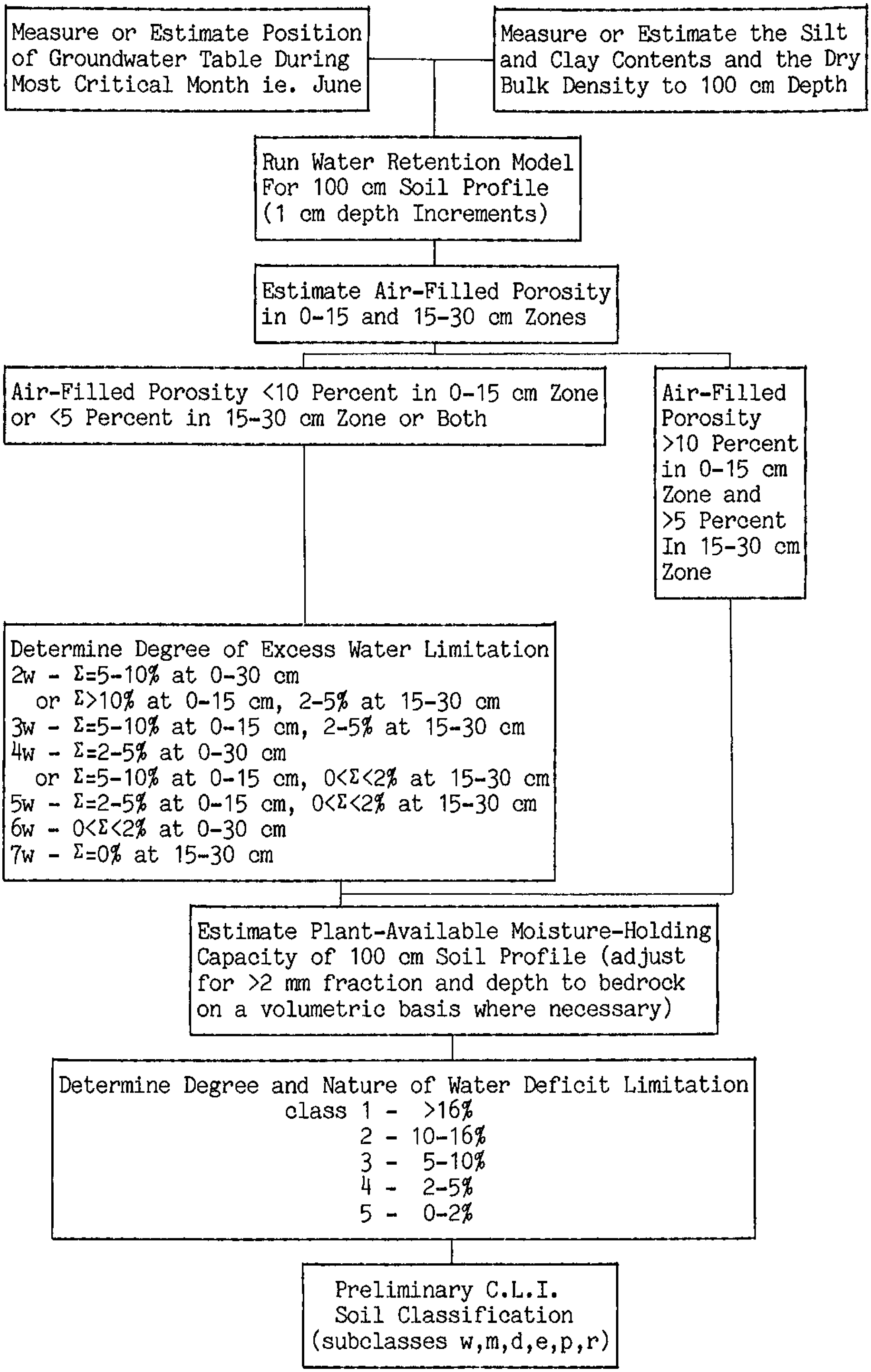

Figure 5. Flow chart for the interpretation of C.L.I. agriculture capability of Ontario soils.

As an interpretive tool, the desorption model enables the user to evaluate many soil qualities which limit agricultural land productivity through their influence on excess or deficit soil moisture availability. Since many of these are designated as subclasses in the Canada Land Inventory system, regional guidelines for Ontario have been established for the assessment of C.L.I. agricultural capability based on class intervals of predicted plant-available moisture and air-filled porosity (Figure 5). Simple land productivity regression models are used to generate crop performance indices for the arable C.L.I. land classes under variable climatic conditions. Many of the observed crop yield responses to soil degradation can be at least partially explained by predicted changes in the suitability of the soil water regime for plant growth.

Soil suitability for specific urban-related land uses is interpreted from predicted engineering soil properties. Unsaturated hydraulic conductivity and specific surface are estimated directly from the moisture characteristic. Soil mechanical behaviour (strength, compressibility, shrink-swell potential) under different moisture conditions is inferred from soil consistence. The plastic consistency limits are found to occur at characteristic pressure potentials. Significant variations in engineering performance are delimited within or among soils similarly classified in the unified system.

R.A. McBride and E.E. Mackintosh

Water Movement in Fine Textured Soils in the Region of Haldimand-Norfolk

In situ measured infiltration rates and hydraulic conductivity rates in structured clay soils are radically different from those predicted by mathematical models. Comparison of laboratory measurements of infiltration and hydraulic conductivity (on small undisturbed soil cores) with *in situ* field measurements indicates that core size has a direct bearing on the magnitude of both the infiltration rate and the saturated hydraulic conductivity. Methylene blue dye was used to assess the effect of different kinds of soil structure on water movement under field conditions, and as well, to assess the role of root channels and soil faunal activity.

Vertical infiltration rates measured in the field far exceed those derived from models or from undisturbed cores in the lab. This is due in part to the difference in initial moisture content, but a number of other factors including structure, roots and earthworms are also important. Traditional concepts of wetting fronts and piston type flow are shown to be non-applicable in highly structured clay soils.

Among the most important conclusions to be drawn from the field work are the following:

i) There appears to be a direct relationship between structural grades and kinds (in the absence of roots and soil/fauna) and the ability to transmit water.

ii) Individual root channels, mammal burrows or earthworm channels may conduct water rapidly in either vertical or horizontal directions regardless of structure.

iii) In horizons where the overall saturated hydraulic conductivity is low (i.e. 2 to 3 cm/day) surges in the rate of water movement along individual channels may be as great as 16 to 17 m/day.

iv) Cultivation in fine clay soils can lead to significant changes in sequence of structure, rooting patterns and soil faunal activity which affect both the pattern and rate of water movement through the soil.

v) The use of undisturbed soil cores to estimate saturated hydraulic conductivity in heavy textured soils is probably misleading if core diameters are not wide enough to contain a sufficient representation of major conducting channels.

vi) Field apparatuses that depend on detection of an advancing wetting front in order to estimate saturated hydraulic conductivity will probably yield erroneous results since water movement tends to occur along a few, select voids rather than along a continuous front.

A.N. Montgomery and E.E. Mackintosh

Rehabilitation of Extracted Sand and Gravel Lands to an Agricultural After-Use

The increased competition and pressures on rural lands in the past decade has made the general public more aware of the need for wise management and stewartship of our agricultural lands. Thus, rationalizing the competing demands between high quality aggregate lands and high quality agricultural lands will become increasingly important in the future.

Until recently it has been difficult to obtain an accurate estimate of the area of prime agriculture lands that were underlain by commercial deposits of sand and gravel. The Aggregate Resources Inventory Program (ARIP), sponsored by the Ontario Geological Survey, Ministry of Natural Resources, now makes this comparison possible.

The program rates all deposits as being of primary, secondary or tertiary economic importance to the sand and gravel industry. An ARIP report is published by township and includes a 1:50,000 scale map showing the distribution of the deposits. To obtain a measure of overlap between prime aggregate and agriculture lands, ARIP maps were simply overlain onto the 1:50,000 scale soil capability for agriculture maps and the area of coincidence measured (Table 5). The information has been recorded by township, but is summarized here according to Ministry of Natural Resources Districts as hectares of prime agriculture lands (Soil capability for Agriculture Classes 1-3) overlying primary, secondary and tertiary aggregate deposits.

Table 5. The Area of Prime Agriculture Lands Overlying Primary, Secondary and Tertiary Aggregate Deposits in Southern Ontario.

O.M.N.R. District	Type of Aggregate Deposits					
	Primary		Secondary		Tertiary	
	Hectare*	Percent**	Hectare	Percent	Hectare	Percent
Aylmer	6,812.6	1.0	21,259.6	3.2	53,000.2	8.0
Brockville	30.2	0.1	3,161.6	2.9	12,204.9	11.2
Cambridge	31,449.2	6.2	23,355.1	4.6	69,314.2	13.7
Carlton Place	167.3	0.1	2,248.3	1.3	9,891.5	5.6
Chatham	3,343.0	0.5	3,182.3	0.5	63,592.1	9.8
Cornwall	0.0	0.0	3,795.4	1.1	21,007.1	6.3
Huronia	11,388.8	3.5	12,307.4	3.8	92,194.8	28.7
Lindsay	3,018.7	0.9	20,797.3	6.0	49,693.1	14.4
Maple	11,693.6	4.4	16,368.0	6.1	26,624.0	9.7
Napanee	210.6	0.1	4,148.2	1.5	7,000.2	2.4
Niagara	1,083.6	0.4	2,418.6	1.0	11,595.3	4.8
Owen Sound	14,267.7	3.7	17,512.8	4.5	20,171.2	5.2
Simcoe	3,662.3	2.3	941.2	0.6	30,950.7	19.5
Tweed	183.8	0.5	1,984.8	5.9	211.0	0.6
Wingham	4,331.3	0.8	33,321.1	5.8	19,449.3	3.4
TOTAL	91,678.5	-	167,269.9	-	485,582.9	-

* The total area in hectares of aggregate deposit underlying classes 1-3 lands by O.M.N.R. District.

** The percent of the total area of Soil Capability Classes 1-3 within each O.M.N.R. District that is underlain by different types of aggregate deposits.

The most economically viable land to extract for sand and gravel are the primary deposits. Many large scale commercial operations are located in primary deposits, and to a lesser extent secondary deposits, whereas smaller operations and wayside pits are often found in secondary and tertiary deposits. The main area for concern between the two industries will obviously focus on lands designated as primary aggregate reserves and as well some secondary deposits. This overlap will inevitably lead to conflict which can be reduced and/or avoided by the implementation of sound rehabilitation programs. Although there are large areas of tertiary deposits it is doubtful if significant amounts of extraction will occur on these lands; hence, the potential for conflict with agriculture should be minimal.

To assess the state of the art in agricultural rehabilitation of extracted sand and gravel lands, a study was carried out in 1980 to inventory and evaluate 63 reclaimed sites located throughout southern

Ontario. This study was used as the basis for establishing a series of recommendations for rehabilitating extracted sand and gravel land back to an agricultural after-use (Mackintosh, E.E. and E.J. Mozuraitis. 1982. Agricultural and the Aggregate Industry, O.M.N.R., Industrial Mineral Background Paper).

Most examples of site restoration to an agriculture after-use in southern Ontario are small in size; indeed, approximately 70 percent are less than three hectares in area and only two sites include more than ten hectares. A complete range of agricultural crops are grown on the properties including grain corn, soybeans, tobacco, coarse grains, forages (grasses and legumes), and tree fruits (apples and sour cherries).

To obtain some measure of the success of the restoration programs, the rehabilitated soil capability class was compared to the pre-extraction capability class obtained from the 1:50,000, C.L.I. maps. Because the majority of sites are less than three hectares in size, there is potential for considerable error in this analysis. The minimum area shown on the original county soil surveys which are the basis for the 1:50,000 C.L.I. maps is about ten hectares which means that many of the rehabilitated sites could be a higher or lower capability class than shown. In spite of these limitations, if one uses pre- and post-extractive soil capability class as the criterion for success, 60-70 per cent of the sites studied can be considered as successful in their rehabilitation programs. Considering the lack of guidelines available to the industry on rehabilitation to agriculture, the success rate is remarkably good and presents an optimistic outlook for rehabilitation programs in the future.

Common problems encountered on many reclaimed sites included: mixing of topsoil/subsoil; lack of adequate topsoil; poor drainage; soil compaction; and excessive stoniness.

Using the O.M.N.R. rehabilitation claim reports for the Cambridge Distict the cost of rehabilitation to agriculture ranged from $1,712.21 to $13,710.68 per hectare. On a metric tonnage basis, the average cost of the successfully rehabilitated sites was 4.6¢ per tonne which is well within the 8¢ per tonne security deposit prescribed by M.N.R. These costs included all necessary earth moving, trimming, grass seeding and mulching, and the initial planting of grass and legumes, together with chemicals and fertilizers.

E.E. Mackintosh, W. Worthy and E.J. Mozuraitis

The Development and Use of Soil Potential Ratings in Land Use Planning — A Case Study within the Niagara Region

The soil potential rating (SPR) system is a relatively new interpretive system which was developed by the Soil Conservation Service in the United States. The system is represented by classes that indicate the relative quality or suitability of a soil for a particular use compared with other soils in a given area. It was developed as an extension of the traditional capability/suitability interpretive methods, but incorporates the costs of corrective measures to overcome soil limitations and increase production. It also establishes costs for any continuing limitations remaining after all economically feasible corrective measures have been implemented.

A soil potential rating system was developed for the production of indigenous and hybrid grapes in the Niagara Region. The classes were numerically derived by establishing a soil potential index (SPI) for each soil mapping unit in the study area. Each SPI was derived from indices of soil performance, cost of corrective measures, and costs established for continuing limitations.

The utility of the system as an aid in land use planning was tested by interviewing twenty-two potential users. The participant's occupations covered regional land use planners, local farmers, professors of land use planning and governmental agricultural representatives.

The outcome of the interviews was generally positive. Some concern was expressed by regional planners that the SPR system was too detailed for their level of planning.

As a result of the interviews several suggestions were made regarding improvements that could be made to soil interpretive systems in general. These included: providing an easily comprehended user package that explains how the interpretive system works; adding information on economically feasible corrective measures; providing cost data on remedial measures; and estimating the yield increases that could be expected with the implementation of prescribed corrective measures.

R.E. Garrett and E.E. Mackintosh

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