The Department of Land Resource Science's building was named the "Richards Building" in 1989 in recognition of the contributions Prof. N.R. (Rick) Richards made to the Department, the Ontario Agricultural College and the University of Guelph. It was during his tenure as Department Head from 1952 to 1961 that the building was conceived and constructed. He was Dean of O.A.C. from 1962 to 1972.

Prof. Richards is shown here with the plaque erected in 1993 to recognize again the naming of the building and his contribution.
1993 Annual Report
Congratulations are extended to the Morwick Scholarship recipient Heather Addy by Jean Smith and Barbara Tate, daughters of Professor Frank Morwick.

Congratulations are extended to Gene Shelp who received the 1993 Excellence in Research and Technology Development Award at the Technology Transfer Conference on November 23rd, 1993. The award was presented by Carl Griffith of the Ontario Ministry of Environment and Energy.
# TABLE OF CONTENTS

## FOREWORD


## PERSONNEL AND INTERESTS

Faculty/Professional Staff ............................................. 3
Clerical/Technical Staff ............................................. 5

## UNDERGRADUATE EDUCATION

Undergraduate Education ............................................. 7
Undergraduate Diploma and Degree Courses Offered During 1993  8
Graduates in Resources Management and Earth Science,
Agronomy and Environmental Soil Science .......................... 9
Undergraduate In-Course Awards .................................... 9
Dean’s Honours Recipients ......................................... 10

## GRADUATE EDUCATION

Graduate Education .................................................. 12
Graduate Students and Advisors - Winter Semester, 1994 13
Graduate Degrees Conferred Spring, Fall 1993 and Winter 1994 15
Graduate Degree Courses Offered During 1993 .................. 16
Graduate Awards November 1993 .................................. 16

## EXTENSION HIGHLIGHTS

................................................................. 18

## RESEARCH

Summary .......................................................... 19
Current Research Projects and Funding Sources ................. 20

## PROJECT REPORTS

1) Land Characterization

A Proton Binding and CD Complexation Model for a Soil Humic Acid ............................................. 27
Modelling Soil Organic Matter Content .......................... 28
Probing the "Capillary Fringe" or "Tension-Saturated Zone" ....................................................... 29
Comparison of KCI and K_2SO_4 Extractants for soil NH_4^+ and NO_3^- ....................................... 30
Soil-Water Content and Potential Measured by Hollow Time Domain Reflectometry Probe ............... 31
Extraction of Biomass C Affected by Soil Homogenization ....................................................... 31
Land Resource Science

The Manciano Sandstone: A Shoreface Deposit of Lower-Middle Miocene "Satellite Basins" of the Thrust-Faulted Foredeep Basin-Flank of the Northern Apennines, Italy .................................................. 32

Pedosedimentary History of Cretaceous Polygenetic Paleosols, Crowsnest Pass, Alberta ............................................................ 33

Boron Adsorption on Soil Clay Fractions ........................................... 34

Sediment Dynamics at the Head of a Subarctic Estuary Affected in Part by Human Activity, Moose River, Northern Ontario ...................... 35

Is it Possible to Cathode-Protect a Weathering Ore Body? .................. 36

Inducing the Breakdown of Apatite .................................................... 37

Soil Genesis and Natural and Anthropogenic Gamma Radioactivity at Pinery Provincial Park ......................................................... 38

Tensile Strength of Aggregates from Three Corn Management Practices ................................................................. 39

Fragmentation of Aggregates from Three Corn Management Practices ...................................................................................... 40

Carbon and Nitrogen Cycling in a Boreal Aspen Forest ........................ 41

Runoff and Sediment Losses as Influenced by Selected Stability and Hydrologic Robustness Parameters ............................................. 42

Compressive and Consolidation Behaviour of Agricultural Soils from the R.M. of Haldimand-Norfolk ...................................................... 44

The Risk of Soil Compaction in the R.M. of Haldimand-Norfolk .......... 46

Use of Digital Image Analysis and GIS to Determine the Relation Between Agricultural Cropping Patterns and Soil Associations in the R.M. of Haldimand-Norfolk ........................................ 47

A Pedotransfer Function for Estimating Preconsolidation Stress and its Application to Agricultural Soils in Southwestern Ontario ........... 48

Soil Compaction along Transmission Line Rights-of-Way and its Effect on Crop Productivity of Selected Soils ................................. 49

Measurement of Unsaturated Hydraulic Conductivity using TDR under a Rainfall Simulator .............................................................. 49

Boron Fractionation in Ontario Soils ..................................................... 51

Heavy Metal Solubility in Sewage Sludge Amended Soils ................. 52
2) Land Management

Variable Rate Technology for N Fertilizer Application ........................................ 53
Field Scale Fertilizer Recommendations and Spatial Variability ............................. 54
Agrogeology Projects in Eastern and Southern Africa: from Ethiopia to Zimbabwe. .................................................. 54
The Exchange of the Greenhouse Gases N$_2$O and CH$_4$ between Natural and Agricultural Sites and the Atmosphere .................................................. 56
Cover Crops for Reducing Leaching of Nitrate in the Fall ........................................ 58
Reduction of Ammonia Using Biological Air Filtration Systems .............................. 59
Allelopathy of Canola Residues: Activity and Identification of Phytotoxins ............ 60
Gradient-Based Measurements of Isoprene Fluxes Above a Forest ........................... 61
Revision of Factsheet on Heat Units and Map for Crop Recommendations ............... 62
Forage Quality as Affected by Weather During Field Drying for Hay ...................... 63
Time and Incorporation of Liquid Dairy Cattle Manure on Soil N Test Values ........... 63
Corn Crop Response to Residual N in the Second and Third Years Following Application of Urea and Liquid Cattle Manure (LCM). ........................................ 65
Soil Nitrate Levels Following Alfalfa Plowdown or Chemical Burndown at Different Times .................................................. 66
Corn Crop Response to Fall vs Spring Applications of Urea and Liquid Cattle Manure .................................................. 67
Does the More Effective Mycorrhizal Symbiosis Found with Reduced Tillage Increase Corn Yield? .................................................. 69

3) Land Inventory & Stewardship

Centre for Land and Water Stewardship .................................................. 71
Preparation of a Conservation Planning Handbook for Rural Non-Farm Landowners .................................................. 72
Preparation of a Landowner Casebook and Factsheets for Carolinian Canada ........... 73
Development of Guidelines for Reforestation Projects in the Great Lakes Basin ........................................ 73
Evaluation of Land Trusts in Ontario ................................................................. 74
Development of a Training Program for MNR, OMAF and Conservation Authority Extension Staff ........................................ 74

PUBLICATIONS, PAPERS PRESENTED, SEMINARS

Titles of Books and Chapters in Books ......................................................... 75
Publications in Refereed Journals ................................................................. 75
Non-Refereed Reports and Publications ....................................................... 77
Seminars and Papers presented ................................................................. 77
Departmental Seminars ................................................................. 79
FOREWORD

The Annual Report provides a glimpse of the exciting developments in teaching, research and extension which have occurred in the Department of Land Resource Science in the past year.

Undergraduate enrollments continue to grow. Students are now enrolled in our new majors in the B.Sc. Environment Program (Natural Resources Management, and Earth and Atmosphere Science) as well as in the B.Sc.Agr. Program (Agronomy, offered jointly with Crop Science).

Research programs have continued to grow with the greatest growth in studies related to diminishing soil degradation and improving air and water quality in agricultural areas.

The two graduate programs (Soil Science and Agrometeorology) have evolved into a single new graduate program, Land and Atmosphere Sciences, with fields of study in Atmosphere Science, Soil Science, Environmental Geology and Land Resources Management. The new program has been approved by the Ontario Council of Graduate Studies and students began registering in the new program in September 1993. Enrollments remain stable. Major adjustments occurred in our Extension program this year as a consequence of termination of funding for Extension by the Ontario Ministry of Agriculture and Food (OMAF). The transfer of technology from research programs to the user continues to be crucial to the success of our research programs and the interaction of researchers with user groups provides direction to the nature of research that is being conducted. As a consequence we have decided to absorb part of the costs of extension in our OMAF-funded research program in order to ensure that technology transfer to user groups is maintained.

Significant adjustments in our faculty compliment occurred in the past year as a consequence of the retirement of Drs. Murray Brown and Murray Miller.

Murray Brown has contributed significantly to our understanding of the influence of climate on agriculture and has shared this understanding with students in undergraduate and graduate programs.

Murray Miller has had a great impact in several areas including soil fertility, water quality and land use planning. He has been an enthusiastic participant in our graduate and undergraduate teaching programs, our research endeavours and provided leadership as Chair of the Department from 1966 to 1971. Both faculty have been committed to extension
Land Resource Science

activities. Drs. Brown and Miller leave the Department enriched by their contributions over many years.

Faculty, staff and students continue to be recognized for achievements in many areas. Highlights include receipt of the O.A.C. Alumnae Distinguished Extension Award by Dr. S.G. Hilts, the Ontario Ministry of Environment Excellence in Research and Technology Development Award by G.S. Shelp, the Sigma XI awards for distinguished Ph.D. and M.Sc. theses by K. Bolton and I. Simpson respectively, the Canadian Soil Society Award for the outstanding poster at the Annual Meeting by D. Veenhof, and the Morwick Scholarship by Heather Addy.

The success that we have achieved, as a Department is a reflection, in part, of the enthusiasm and creativity of students, staff and faculty in the Department. The skills and the attitudes that enable members of the Department to fulfil their roles are, however, strengthened by the support and the constructive criticism that a much larger community provides to the Department. This report is really dedicated to you as a member of that larger community. We value your involvement in our programs and we look forward to continued exchange with you.

In closing I wish to acknowledge the effort of S. Bushen, D. Irvine and J. Rzadki in assembling this report and in encouraging all of us to meet publication deadlines.

[Signature]

B.D. KAY
Professor & Chair
PERSONNEL AND INTERESTS
FACULTY/PROFESSIONAL STAFF

B.D. KAY, B.S.A., M.Sc. (Guelph), Ph.D. (Purdue), Professor and Chairman. Physical-chemical reactions in soils, dynamics of frost heaving, influence of tillage and cropping practices on soil structure. (Ext. 2447-8)*.


D. BERGSTROM, B.Sc., M.Sc. (Alberta), Ph.D. (Guelph). Research Associate. (Ext. 8748).

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

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

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; solute and water transport in soils. (Ext. 3758).


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


C.A. FITZGIBBON, B.A. (McMaster), M.Sc. (Saskatchewan), Teaching Associate and Coordinator of Landscape Architecture Computer Laboratory. Soil science, resources planning and management. (Ext. 4802).

M.J. GOSS, B.Sc. (London), M.Sc. (Birmingham), Ph.D. (Reading), Professor and Chair, Land Stewardship. Impact of current agricultural practices on soil and water resources. Soil-root-shoot relations. (Ext. 2491).

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

P.H. GROENEVELT, M.Sc., Ph.D. (Wageningen), Professor. Soil physics, soil and water conservation and land reclamation. (Ext. 3585).

S.G. HILTS, B.A. (Western Ontario), M.A. (Toronto), Ph.D. (Toronto), Director, Centre for Land and Water Stewardship; Associate Professor. Joint appointment with University School of Rural Planning and Development. Natural resources management, environmental planning, land stewardship. (Ext. 2702).

R.G. KACHANOSKI, B.Sc., M.Sc. (Saskatchewan), Ph.D. (California, Davis), Associate Professor and Coordinator of Extension. Soil physics, soil and water conservation and extension. (Ext. 2498).

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


I.P. MARTINI, Doct. Geol. Sci. (Florence), Ph.D. (McMaster), Professor. Sediments and sedimentary rocks, sedimentology, glacial geology. (Ext. 2488).
R. MCBRIDE, B.Sc., Ph.D. (Guelph), Associate Professor. Soil science and agricultural land use planning. (Ext. 2492).


M.H. MILLER, B.S.A. (Toronto), M.S., Ph.D. (Purdue), Part-Time Professor. Soil fertility and plant nutrition. Mycorrhizal relations. Integrated farming systems research. (Ext. 2482).


E. PERFECT, B.Sc. (Newcastle-upon-Tyne), M.A. (Carleton), Ph.D. (Cornell), Scientist. Effect of cropping systems and ground freezing on soil structure. (Ext. 4276).

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).

V. RASIAH, B.Sc. (Ceylon), M.Sc., Ph.D. (SDSU), Scientist. Land stewardship cropping systems. (Ext. 2476).


C.A. RUSSELL, B.Sc.Ag. (Hons), Ph.D. (Western Australia), Post Doctorate. C & N cycling, N-15 analysis, soil microbial activity, carbon dioxide analysis. (Ext. 2452).


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


D. TRIVERS, B.Sc.(Eng.) (Guelph), Systems Engineer. Ontario Ministry of Agriculture and Food, Agroclimatology Program. (Ext. 2480).

H.P. VAN STRAATEN, Dipl. Geol., Dr. rer. nat (Gottingen, Germany), Scientist. Geology, mineral exploration, agrogeology in East Africa. (Ext. 2454).

R.P. VORONEY, B.Sc. (Calgary), M.Sc., Ph.D. (Saskatchewan), Associate Professor. Soil biological activity, soil management. (Ext. 3057).

C. WAGNER-RIDDLE, B.Sc.(Agr.) (Brazil), M.Sc. (Brazil), Ph.D. (Guelph), Research Associate. Agrometeorology; crop modelling; emission of trace gases from agricultural fields.. (Ext. 2787).


G.J. WALL, B.Sc.(Agr.), M.Sc. (Guelph), Ph.D. (Ohio). Agriculture Canada, Associate Graduate Faculty. (Ext. 2103).

*Extension number (e.g. Ext. 2447) at the University of Guelph. University of Guelph phone number is (519) 824-4120.

FAX No. (519) 824-5730
CLERICAL/TECHNICAL STAFF


P.E. BEIRNES, Administrative Secretary. (Ext. 2448).

L. BISSELL, Clerk. (Ext. 4359).

D. BRENNER, Secretary. Extension. (Ext. 6364).

S. BUSHEN, Secretary. (Ext. 6365).

M. COCHRAN, Secretary. Soil and Water Conservation Information Bureau. (Ext. 2799).


E.F. GAGNON, Assoc. Dipl. Agr. (Guelph), Manager. Analytical Services Laboratory. (Ext. 2494).


L. LIU, B.Sc.Agr. (Hubei, China), M.Sc. (Guelph), Ph.D. candidate (Guelph), Research Associate. Amelioration of acid mine drainage project. (Ext. 2450).

V. MARCILLE-KERSLAKE, B.Sc., M.Sc. (Guelph), Assistant Manager. Analytical Services Laboratory. (Ext. 2494).


J.A. POISSON, B.Sc. (Guelph), Technician. Soil chemistry/biochemistry and Analytical Services Laboratory. (Ext. 2494).

P.J. ROBERTS, Secretary. Undergraduate and graduate programs. (Ext. 2456).

S. SADURA, B.Sc.(Agr.) (Guelph), Teaching and laboratory technician. Information technology. (Ext. 3393).

J.K. SCARROW, Clerk. (Ext. 2455/2661).


L. SHEPHERD, B.A. (Guelph), Technician. Mycorrhizal laboratory. (Ext. 8167).

P. SMITH, B.A. (Guelph), Technician. Land Stewardship. (Ext. 4263).


Land Resource Science


W.G. WILSON, B.Sc. (Guelph), Technician. Soil chemistry, biology and clay mineralogy. (Ext. 8157).


*Extension number (e.g. Ext. 2447) at the University of Guelph. University of Guelph phone number is (519) 824-4120.

FAX No. (519) 824-5730
UNDERGRADUATE EDUCATION

R. Protz

The Earth and Atmosphere Science and Natural Resource Management Majors within the B.Sc.(Env.) are attracting substantial numbers of well qualified students.

The B.Sc.(Agr.) program is in the midst of extensive revision under Vision 95. Currently two majors, Agronomy and Agroecosystem Management are being developed. A concept called course clusters is being proposed within the new B.Sc.(Agr.). Within this plan of course offering, students will be able to take an unspecialized (non-major) B.Sc.(Agr.) degree, by selecting three (core course clusters) from departments of their choice. The new program is being developed to provide a clear academic structure within which the flexibility of course selection will be maximized by future B.Sc.(Agr.) students.
### UNDERGRADUATE EDUCATION

Undergraduate Diploma and Degree Courses Offered During 1993

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
<th>Enrolment</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-310</td>
<td>Land Stewardship and Environmental Management</td>
<td>62</td>
</tr>
<tr>
<td>46-100</td>
<td>Principles of Geology</td>
<td>93</td>
</tr>
<tr>
<td>46-104</td>
<td>Study of the Earth</td>
<td>152</td>
</tr>
<tr>
<td>46-110</td>
<td>Principles of Geology</td>
<td>354</td>
</tr>
<tr>
<td>46-202</td>
<td>Stratigraphy</td>
<td>10</td>
</tr>
<tr>
<td>46-210</td>
<td>Mineralogy</td>
<td>9</td>
</tr>
<tr>
<td>46-215</td>
<td>Glacial Geology</td>
<td>15</td>
</tr>
<tr>
<td>46-216</td>
<td>Glacial Geology</td>
<td>23</td>
</tr>
<tr>
<td>46-306</td>
<td>Groundwater</td>
<td>61</td>
</tr>
<tr>
<td>46-307</td>
<td>Petrography</td>
<td>8</td>
</tr>
<tr>
<td>46-309</td>
<td>United Plates of America</td>
<td>18</td>
</tr>
<tr>
<td>46-310</td>
<td>Fossil Resources</td>
<td>15</td>
</tr>
<tr>
<td>46-319</td>
<td>Environmental Water Chemistry</td>
<td>26</td>
</tr>
<tr>
<td>46-409</td>
<td>Sedimentology</td>
<td>5</td>
</tr>
<tr>
<td>46-411</td>
<td>Topics in Earth Science</td>
<td>4</td>
</tr>
<tr>
<td>46-412</td>
<td>Topics in Earth Science</td>
<td>1</td>
</tr>
<tr>
<td>58-103</td>
<td>United Plates of America</td>
<td>62</td>
</tr>
<tr>
<td>64-203</td>
<td>Meteorology &amp; Climatology</td>
<td>155</td>
</tr>
<tr>
<td>64-305</td>
<td>Microclimatology</td>
<td>19</td>
</tr>
<tr>
<td>64-421</td>
<td>Physical Meteorology</td>
<td>18</td>
</tr>
<tr>
<td>83-410</td>
<td>Soil &amp; Plant Relations</td>
<td>25</td>
</tr>
<tr>
<td>87-012</td>
<td>Principles of Managing Soils</td>
<td>150</td>
</tr>
<tr>
<td>87-022</td>
<td>Land and Water Resources</td>
<td>112</td>
</tr>
<tr>
<td>87-201</td>
<td>Soil Science</td>
<td>325</td>
</tr>
<tr>
<td>87-212</td>
<td>Intro. to Environmental Stewardship</td>
<td>89</td>
</tr>
<tr>
<td>87-250</td>
<td>Problem Solving in Land Resource Science</td>
<td>71</td>
</tr>
<tr>
<td>87-302</td>
<td>Soil Genesis &amp; Classification</td>
<td>27</td>
</tr>
<tr>
<td>87-305</td>
<td>Land Utilization</td>
<td>78</td>
</tr>
<tr>
<td>87-308</td>
<td>Soil &amp; Water Conservation</td>
<td>91</td>
</tr>
<tr>
<td>87-310</td>
<td>Resources Planning and Management</td>
<td>55</td>
</tr>
<tr>
<td>87-350</td>
<td>Land &amp; Water Use in Tropical Countries</td>
<td>33</td>
</tr>
<tr>
<td>87-401</td>
<td>Soil Chemistry</td>
<td>24</td>
</tr>
<tr>
<td>87-402</td>
<td>Soil Physics</td>
<td>26</td>
</tr>
<tr>
<td>87-407</td>
<td>Problems in Land Resource Science</td>
<td>5</td>
</tr>
<tr>
<td>87-409</td>
<td>Soil Management</td>
<td>38</td>
</tr>
<tr>
<td>87-411</td>
<td>Land Resources Field Camp</td>
<td>57</td>
</tr>
<tr>
<td>87-420</td>
<td>Issues in Land Resources</td>
<td>29</td>
</tr>
</tbody>
</table>
GRADUATES IN RESOURCES MANAGEMENT and EARTH SCIENCE
AGRONOMY AND ENVIRONMENTAL SOIL SCIENCE
SPRING, FALL 1993, AND WINTER 1994

SOIL SCIENCE MAJORS

RESOURCES MANAGEMENT MAJORS

* Christine Beadle
Craig Betts
Paul Buzdon
Pierre Chauvin (Co-op)
Philippa Evert
Jon Gingerich (Co-op)
Ray Janssen
David Jones
Debra Kenette (Co-op)
Bubby Kettlewell
Janet Le Camp
Andrew Madery
Tara McCaughhey
James Murray
Aynslie Ogden
Katherine Proctor
Lynn Rowan
Jamie Stanford
Karen Tabe
Gary Telford
Marie van Heukelom
Andrew Vokes
Bronwynne Wilton

EARTH SCIENCE MAJORS

Michelle Hawke
Debra Smith

AGRONOMY MAJORS

Dennis Joosse

**

ENVIRONMENTAL SOIL SCIENCE MAJORS

*

* Soil Science and Environmental Soil Science Majors are Terminated.
** Agronomy Major is a new major in which students are enrolled.

UNDERGRADUATE IN-COURSE AWARDS
November 1993

John A. Archibald Memorial Scholarship
Peter Presant
Resources Management

Robert Harcourt Scholarships
Sharen Layne
Natural Resource Management

Lesley Shaffer
Resources Management

Robert McCann Scholarship
Lesley Shaffer
Resources Management

Foodland Hydro Scholarship
Jackie Fraser
Resources Management

Thomas H. Peters Scholarship
Jackie Fraser
Resources Management

Frank E. Wolff International Scholarship
Shelley Peterson
Resources Management

Helen Thomas
Resources Management

'67 O.A.C. Centennial Award
Jackie Fraser
Resources Management

J. Ross Cavens Memorial Scholarship
Sharon Layne
Resources Management
DEAN'S HONOURS RECIPIENTS

F'93
Bradley Digweed  Earth Atmosphere Science
Julie Hodowick  Earth Atmosphere Science
Gerard Peets  Earth Atmosphere Science
Rebecca Vanderspiegel  Earth Atmosphere Science
Matthew Carlson  Natural Resources Management
Jennifer Fay  Natural Resources Management
Daniel Schuurman  Natural Resources Management
Shelley Peterson  Resources Management
Boua Sengdy  Earth Atmospheric Science
Carol Coffey  Natural Resources Management
Rick Gray  Natural Resources Management
Katherine Borg  Resources Management
Lori Armstrong  Natural Resources Management
Hannah King  Natural Resources Management
Sharon Layne  Natural Resources Management
Katherine Ward  Natural Resources Management
Lesley Shaffer  Resources Management
Heather Kepran  Resources Management
Melissa Murray  Resources Management
Peter Presant  Resources Management
Bryan Rooney  Resources Management
Isabelle Schmelzer  Resources Management
Sandra Shore  Resources Management
Jackie Fraser  Resources Management
Andrew Batchelor  Resources Management
Adriana Holmberg  Resources Management
Bart Hulshof  Resources Management
Pierre Chauvin  Resources Management
Debra Kennette  Resources Management
Aleta Vienneau  Resources Management
Debra Tallan  Resources Management
DEAN'S HONOURS RECIPIENTS

W '93
Shelley Peterson  Resources Management
Colette Rigney  Resources Management
Nancy Marcus  Natural Resources Management
Hannah King  Natural Resources Management
Sharon Layne  Natural Resources Management
Kerstin Scott  Natural Resources Management
Sandra Van Osch  Natural Resources Management
Lisa Parker  Environmental Soil Science
Daniel Clarke  Resources Management
Heather Kepran  Resources Management
Peter Presant  Resources Management
Bryan Rooney  Resources Management
Isabelle Schuelzer  Resources Management
Sandra Shore  Resources Management
Jackie Fraser  Resources Management
Adriana Holmberg  Resources Management
Debra Tallan  Resources Management
GRADUATE EDUCATION

In 1993 the Department of Land Resource Science continued to offer a wide range of opportunities for graduate studies at the M.Sc. and Ph.D. levels. M.Sc. programs were available in Agrometeorology, Soil Science, and in Resources Development (in conjunction with the University School of Rural Planning and Development). Ph.D. programs were available in Agrometeorology and Soil Science. The Department also participated in the interdepartmental groups on Biophysics, Plant Physiology, and Toxicology whereby a student registered in the Department, may enrol and specialize in one of the disciplines. Beginning in 1994, the various graduate programs offered by the Department were consolidated into one graduate program in Land and Atmospheric Science. The four fields of study comprise: (1) Atmospheric Science (2) Soil Science (3) Environmental Earth Science and (4) Land Resources Management. The cross-disciplinary nature of the new program with its strengths in four fields and emphasis on integration of these disciplines is unique in Canada.

Financial assistance in the form of scholarships, research assistantships, and teaching assistantships are available to qualified students. Research facilities available include well equipped laboratories for atmospheric science and agrometeorology, soil chemistry, soil mineralogy, soil physics, soil biology and biochemistry, and plant nutrition. Research instrumentation includes x-ray diffraction, mass spectrometry, liquid and gas chromatographs, an Inductively Coupled Plasma-atomic Emission Spectrometer (ICP-AES), sonic anemometry, gas analyzers, data loggers, and agrometeorological field equipment. Greenhouses, growth chambers and 50 ha of field research plots are available for research projects. A graduate student has the opportunity to work with faculty in one of the many research projects underway in the Department. For further information contact the faculty members in the relevant area of interest or the Graduate Co-ordinator.

Graduate Co-ordinator:
Land and Atmospheric Science
D.E. Eirick
## Graduate Students and Advisors - Winter Semester, 1994

### ATMOSPHERIC SCIENCE

<table>
<thead>
<tr>
<th>M.Sc. Students</th>
<th>Advisor</th>
<th>Ph.D. Students</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admiral, Stuart</td>
<td>T.J. Gillespie</td>
<td>Gordon, Robert</td>
<td>D.M. Brown</td>
</tr>
<tr>
<td>Dias, Goretty</td>
<td>G.W. Thurtell</td>
<td>Lin, Mei</td>
<td>G.W. Thurtell</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lin, Shaojun</td>
<td>T.J. Gillespie</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simpson, Isobel</td>
<td>G.W. Thurtell</td>
</tr>
</tbody>
</table>

### SOIL SCIENCE

<table>
<thead>
<tr>
<th>M.Sc. Students</th>
<th>Advisor</th>
<th>Ph.D. Students</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraser, Stephen</td>
<td>L.J. Evans</td>
<td>Addy, Heather</td>
<td>M.H. Miller</td>
</tr>
<tr>
<td>Gachuiri, Elizabeth</td>
<td>L.J. Evans</td>
<td>Beyaert, Ron</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Gibson, Richard</td>
<td>R.G. Kachanoski</td>
<td>Boucher, Isabelle</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Grunthal, Paul</td>
<td>P.H. Groenevelt</td>
<td>Da Silva, Alvaro</td>
<td>B.D. Kay</td>
</tr>
<tr>
<td>Hosler, Kevin</td>
<td>R.P. Voroney</td>
<td>Dagesse, Daryl</td>
<td>B.D. Kay</td>
</tr>
<tr>
<td>Kadir, Sabaruddin</td>
<td>M.J. Goss</td>
<td>Denholm, Ken</td>
<td>B.D. Kay</td>
</tr>
<tr>
<td>Kettlewell, Busby</td>
<td>R.P. Voroney</td>
<td>Fallow, David</td>
<td>D.E. Elrick</td>
</tr>
<tr>
<td>King, Donald</td>
<td>G.J. Wall</td>
<td>Gavito, Mayra Elena</td>
<td>M.H. Miller</td>
</tr>
<tr>
<td>Langat, Jackson</td>
<td>M.H. Miller</td>
<td>Goorahoo, Dave</td>
<td>R.G. Kachanoski</td>
</tr>
<tr>
<td>Lauzon, John</td>
<td>M.H. Miller</td>
<td>Hamlen, Cathy</td>
<td>R.G. Kachanoski</td>
</tr>
<tr>
<td>Loro, Petra</td>
<td>E.G. Beauchamp</td>
<td>Hou, Junning</td>
<td>L.J. Evans</td>
</tr>
<tr>
<td>MacDonald, Sara</td>
<td>E.G. Beauchamp</td>
<td>McCabe, Don</td>
<td>R. Protz</td>
</tr>
<tr>
<td>Makalew, Anna Maria</td>
<td>P.H. Groenevelt</td>
<td>Parkin, Gary</td>
<td>D.E. Elrick</td>
</tr>
<tr>
<td>O'Brien, Gavin</td>
<td>D.E. Elrick/R.G. Kachanoski</td>
<td>Sweeney, Stewart</td>
<td></td>
</tr>
<tr>
<td>Obbema, Jeff</td>
<td>M.J. Goss</td>
<td>Uribe, Lidieth</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Odell, Brian</td>
<td>P.H. Groenevelt</td>
<td>Vandenbygaart, Bert</td>
<td>R. Protz</td>
</tr>
<tr>
<td>Pringle, Elizabeth</td>
<td>R.G. Kachanoski</td>
<td>von Bertoldi, Peter</td>
<td>R.G. Kachanoski</td>
</tr>
<tr>
<td>Raymond, David</td>
<td>R.P. Voroney</td>
<td>Wanniarachchi, Sudas</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Reid, Keith</td>
<td>E.G. Beauchamp</td>
<td>Wen, Guang</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Schweyer, James</td>
<td>E.G. Beauchamp</td>
<td>Winter, Julien</td>
<td>R.P. Voroney</td>
</tr>
<tr>
<td>Siregar, Adelina</td>
<td>R.P. Voroney</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor, Nigel</td>
<td>E.G. Beauchamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenuta, Mario</td>
<td>E.G. Beauchamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood, Duncan</td>
<td>R. Protz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zhao, Gaoxia</td>
<td>R.P. Voroney</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zwart, Peter</td>
<td>M.H. Miller</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## ENVIRONMENTAL EARTH SCIENCE

<table>
<thead>
<tr>
<th>M.Sc. Students</th>
<th>Advisor</th>
<th>Ph.D. Students</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chirenje, Tait</td>
<td>H.P. van Straaten</td>
<td>Shelp, Gene</td>
<td>W. Chesworth</td>
</tr>
<tr>
<td>Dhammika, Perera</td>
<td>H.P. van Straaten</td>
<td>McCarthy, Paul</td>
<td>I.P. Martini</td>
</tr>
<tr>
<td>Poehlman, Tania</td>
<td>I.P. Martini</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## LAND RESOURCES MANAGEMENT

<table>
<thead>
<tr>
<th>M.Sc. Students</th>
<th>Advisor</th>
<th>Ph.D. Students</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watson, Gary</td>
<td>R.A. McBride</td>
<td>Joosse, Pamela</td>
<td>R.A. McBride</td>
</tr>
<tr>
<td>Wilton, Bronwynne</td>
<td>S.G. Hilts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Graduate Degrees Conferred Spring, Fall 1993 and Winter 1994

<table>
<thead>
<tr>
<th>Student</th>
<th>Degree</th>
<th>Advisor</th>
<th>Title of thesis</th>
<th>Defence Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covert, Jeffrey Alan</td>
<td>M.Sc.</td>
<td>E.G. Beauchamp</td>
<td>Phenolic Acids and Other Phenolic Compounds in Plant Residues as Carbon Sources for Denitrifying Bacteria</td>
<td>August 5, 1993</td>
</tr>
<tr>
<td>Dey, Anton</td>
<td>M.Sc.</td>
<td>E.G. Beauchamp</td>
<td>Soil N for Barley and Potatoes in Ontario</td>
<td>March 26, 1993</td>
</tr>
<tr>
<td>Fallow, David James</td>
<td>M.Sc.</td>
<td>D.E. Elrick</td>
<td>Measurement of Air Entry and Air Exit Soil Water Pressure Heads with a Modified Guelph Pressure Infiltrometer</td>
<td>September 1, 1993</td>
</tr>
<tr>
<td>Goorahoo, Dave</td>
<td>M.Sc.</td>
<td>M.J. Goss</td>
<td>The Use of Whole Farm Nitrogen Budgets to Estimate Nitrate Concentrations in Groundwater for Three Organic Farms in Bruce County</td>
<td>December 9, 1993</td>
</tr>
<tr>
<td>MacKay, Mark Wallace</td>
<td>M.Sc.</td>
<td>I.P. Martini</td>
<td>Grain Shape Analysis of Cold Coastal Sands, Canada</td>
<td>August 30, 1993</td>
</tr>
<tr>
<td>McCabe, Rhonda</td>
<td>M.Sc.</td>
<td>R.P. Voroney</td>
<td>The Effect of Intensive Fertilization and Tillage on the Biodegradation of Oily Wastes</td>
<td>April 21, 1993</td>
</tr>
<tr>
<td>Vanden, Bygaart, Bert J.</td>
<td>M.Sc.</td>
<td>R. Protz</td>
<td>Soil Genesis and Gamma Radioactivity on a Dune Soil Chronosequence, Pinery Provincial Park</td>
<td>December 10, 1993</td>
</tr>
<tr>
<td>van Wesenbeeck, Ian, J.</td>
<td>Ph.D.</td>
<td>R.G. Kachanoski</td>
<td>Horizontal Spatial Scale Dependence of Vertical Solute Transport</td>
<td>February 25, 1993</td>
</tr>
<tr>
<td>Veenhof, Derek</td>
<td>M.Sc.</td>
<td>R.A. McBride</td>
<td>The Compression Characteristics and Susceptibility to Compaction of Soils from the Regional Municipality of Haldimand-Norfolk</td>
<td>July 15, 1993</td>
</tr>
<tr>
<td>Wanniarachchi, Sudas</td>
<td>M.Sc.</td>
<td>R.P. Voroney</td>
<td>Allelopathy of Canola Residues: Activity and Identification of Phytoxins</td>
<td>September 23, 1993</td>
</tr>
<tr>
<td>Younge, Michael Francis</td>
<td>M.Sc.</td>
<td>R.G. Kachanoski</td>
<td>Chloride and Nitrate Transport in a Sandy Soil</td>
<td>January 19, 1993</td>
</tr>
</tbody>
</table>

### Agrometeorology

<table>
<thead>
<tr>
<th>Student</th>
<th>Degree</th>
<th>Advisor</th>
<th>Title of thesis</th>
<th>Defence Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyamchau, Charles Joseph</td>
<td>M.Sc.</td>
<td>T.J. Gillespie</td>
<td>Predicting Maize Yield in a Tropical Environment</td>
<td>August 12, 1993</td>
</tr>
<tr>
<td>Simpson, Isobel</td>
<td>M.Sc.</td>
<td>G.W. Thurtell</td>
<td>Measurement of Methane Fluxes From an Irrigated Rice Paddy Field in the Philippines Using a Tunable Diode Laser</td>
<td>April 29, 1993</td>
</tr>
</tbody>
</table>
Land Resource Science

GRADUATE EDUCATION
GRADUATE DEGREE COURSES OFFERED DURING 1993

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
<th>Enrolment</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-601</td>
<td>Physical Environment of Crops &amp; Forests</td>
<td>11</td>
</tr>
<tr>
<td>64-620</td>
<td>Seminar</td>
<td>3</td>
</tr>
<tr>
<td>87-601</td>
<td>Soil Genesis and Classification</td>
<td>1</td>
</tr>
<tr>
<td>87-610</td>
<td>Soil Physics</td>
<td>7</td>
</tr>
<tr>
<td>87-615</td>
<td>Applied Soil Physics</td>
<td>9</td>
</tr>
<tr>
<td>87-619</td>
<td>Non-Equilibrium Thermodynamics of Porous Materials</td>
<td>2</td>
</tr>
<tr>
<td>87-620</td>
<td>Soil Organic Matter &amp; Biochemistry</td>
<td>17</td>
</tr>
<tr>
<td>87-625</td>
<td>Soil &amp; Water Chemistry</td>
<td>13</td>
</tr>
<tr>
<td>87-631</td>
<td>Advanced Topics in Soil Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>87-655</td>
<td>Principles of Scientific Research</td>
<td>15</td>
</tr>
<tr>
<td>87-660</td>
<td>Special Topics in Soil Science</td>
<td>10</td>
</tr>
<tr>
<td>87-665</td>
<td>Special Topics in Land Use</td>
<td>5</td>
</tr>
<tr>
<td>87-675</td>
<td>Seminar</td>
<td>28</td>
</tr>
</tbody>
</table>

GRADUATE AWARDS NOVEMBER 1993

Soden Fellowship in Agriculture
Pamela Joosse

Mary Edmunds Williams Fellowship
Heather Addy
Isobel Simpson

Commonwealth Scholarship
Sudas Wanniarachchi

Natural Science and Engineering Research Council Fellowship
Isobel Simpson
Stephen Fraser
Gorettty Dias
Bubby Kettlewell

Ontario Graduate Scholarship
Heather Addy

World University Service of Canada
Anna Maria Makalew
Sabaruuddin Kadir

University of Guelph Graduate Fellowship (Open)
Romeo Popa
Cathy Hamlen
Gavin O’Brien
Gene Shelp

University of Guelph Graduate Fellowship (Department)
Gorettty Dias
Isabelle Boucher
David Fallow
Bubby Kettlewell

Visa Scholarship
Shaojun Lin
Romeo Popa

CIDA Scholarship
Elizabeth Gachuiri
Jailani Husain
Charles Lyamchaoi
Mei Lin
Adelina Siregar

N.R. Richards Scholarship
Brian Odell

IDRC Scholarship
Lidieth Uribe
Dhamnika Perera
Anton Dey

Morwick Scholarship
Heather Addy
Waterdown Garden Supplies Graduate Scholarship
David Raymond

Bell Sargent Scholarship
Bronwynne Wilton

Kenneth McAlpine Pretty Scholarship
Keith Reid

Arthur D. Latornell Graduate Scholarship
Isabelle Boucher

Land Resource Science
EXTENSION HIGHLIGHTS

The Department of Land Resource Science is committed to the rapid dissemination of research results through extension activities. Unfortunately, the amount of activity in 1993 was significantly reduced by the cancellation of the Extension and Outreach Program funded by the Ontario Ministry of Agriculture and Food (OMAF). As a result of the cancellation, participation of faculty in extension activities has become much more selective. Faculty continued to transfer technology through written material, up-date sessions with Provincial advisory personnel and talks at Provincial level meetings. However, interaction at the local and regional level was significantly curtailed. Faculty involvement in professional development courses, workshops, etc. for industry, regulatory, policy, and advisory personnel will continue, but on a total cost-recovery basis. Participation in expert committees such as the Ontario Soil Management Research and Services Committee also continued, but the level of involvement was also reduced.

The Department of Land Resource Science recognizes that transfer of technology arising from research to the appropriate user is an integral component of our research program. The relevancy and strength of our research program is dependant upon information flowing from the users to the researchers and vice-versa. The department will continue to respond to the new opportunity resulting from the cancellation of the OMAF extension program through careful consultation with our business and government partners.

The Department was honoured during 1993, when another of its faculty was named 'OAC Alumni Distinguished Extension Professor'. Dr. Stewart Hilts, Director of the Centre for Land and Water Stewardship took the honour this year, for his years of effort dealing directly with rural landowners. Dr. Hilts has promoted the idea of 'private stewardship' as an approach to conservation, both with rural farm and non-farm landowners. Concepts he has developed are now being applied in several other Canadian provinces. For example he travelled to Quebec City to run a workshop on private stewardship programs for conservation, for a group of government staff and non-government organizations from that province.

Activities of the Centre for Land and Water Stewardship include the establishment of an Environmental Communication Network at the University of Guelph; a training program for extension staff of Provincial Government Agencies; and the publication of a book, entitled Creative Conservation. A Handbook for Ontario Land Trusts.

The establishment of the Stewardship Information Bureau at its new offices in the University’s Research Park was another major highlight of the department’s extension effort in 1993.

Further details on the activities of the Centre for Land and Water Stewardship (CLWS) and the Stewardship Information Bureau are found in the section on the CLWS and elsewhere in this Report.
RESEARCH SUMMARY

Research involves learning about ourselves and our environment. It provides new information as a cornerstone for teaching in a University and for society in general. Although curiosity is often the driving force for the research we do, our objectives and goals are usually mission-oriented. Our research generates new knowledge and new ideas which will assist those needing to know more about our land resources and our ability to sustain them for the future.

The total value of grants and contracts supporting research in Land Resource Science in 1992 was approximately 3.53 million. This amount represents a further significant increase over last year. The Ontario Ministry of Agriculture and Food contributed 1.38 million to this funding. Other agencies which contributed funding to Land Resource Science include the following:

- Agriculture Canada
- Canadian International Development Agency
- Canadian Network and Toxicology Centres
- Environment Canada
- Federation of Ontario Naturalists
- Indian Affairs and Northern Development
- Institute for Space and Terrestrial Science
- Laidlaw Foundation
- Natural Sciences and Engineering Research Council
- Ontario Heritage Foundation
- Ontario Ministry of the Environment
- Potash-Phosphate Institute of Canada
- Waterdown Gardens
- University Research Incentive Fund (Ontario Government)

The funding from these agencies indicates the continuing and increasing needs for more knowledge about our land resources. In addition, the funding helps to maintain a dynamic research program at the frontiers of new knowledge.

Progress reports on research projects in 1992 are presented in the following pages. An index of authors are presented at the end of this Report. The reports are grouped as follows:

1. Land characterization
2. Land management
3. Land inventory and stewardship
## CURRENT RESEARCH PROJECTS AND FUNDING SOURCES

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Title of Project</th>
<th>Funding Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beauchamp, E.G.</td>
<td>Denitrification in Soils</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td>Automated Chromatographic System for Trace Gases</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Voroney, R.P.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td>Soil N Test Development</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td>Production of N₂O and NO in Agricultural Soils</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Brookfield, M.E.</td>
<td>Orogenesis and Basin Development</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Chesworth, W.</td>
<td>Geochemistry of Soil Formation</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Chesworth, W.</td>
<td>Amelioration of Acid Mine Drainage by the In-Situ Application of Low-Cost Sphagnum Peat.</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>van Straaten, P.</td>
<td>Phosphate Rock Blends: Developing Local Alternatives, Zimbabwe</td>
<td>I.D.R.C.</td>
</tr>
<tr>
<td>Chesworth, W.</td>
<td>The Utilization of Natural Organic Materials in Amelioration of Acid Mine Drainage (AMD) Associated with Sulphide-Rich Tailings</td>
<td>University of Guelph Research Excellence Fund</td>
</tr>
<tr>
<td>Spiers, G.A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chesworth, W.</td>
<td>Rock Mulching in Ethiopia</td>
<td>I.D.R.C.</td>
</tr>
<tr>
<td>van Straaten, P.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chesworth, W.</td>
<td>Igneous Phosphate Research in Ethiopia</td>
<td>I.D.R.C.</td>
</tr>
<tr>
<td>van Straaten, P.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elrick, D.E.</td>
<td>Transport Phenomena in Natural Porous Media</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Elrick, D.E.</td>
<td>Field Technique for Measuring the Hydraulic Properties of Soils</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Evans, L.J.</td>
<td>The Nature of Soil-Test Extractable Boron</td>
<td>Potash Phosphate Institute</td>
</tr>
<tr>
<td>Evans, L.J.</td>
<td>Modeling Chromium Retention in Soils</td>
<td>N.S.E.R.C.</td>
</tr>
</tbody>
</table>
Evans, L.J.  Retention of Pesticides by Ontario Soils  O.M.A.F.

Evans, L.J.  Metal Mobility in Sewage-Sludge Amended Soils  O.M.A.F.


Evans, L.J.  Research Support for Elizabeth Gachiuri  Kenya/Canada Agric. Research

Gillespie, T.J.  Microclimatic Regulation of Biogenic Volatile Organic Compound Emissions  N.S.E.R.C.


Gillespie, T.J.  Volatile Organic Compound Fluxes from Agricultural Surfaces  Environment Canada N.S.E.R.C.

Gillespie, T.J.  Meteorological and Photochemical Modelling of Ozone Episodes in the Lower Fraser Valley  N.S.E.R.C.

Gillespie, T.J.  Non-Methane Hydrocarbon Emissions from Agricultural Plants  O.M.A.F.


Goss, M.J.  To Identify the Seasonal Variation in Well-Water Contamination and Survey the Health of Farm Families Drinking Water Contaminated with Nitrate or Bacteria  Agriculture Canada

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Project Title</th>
<th>Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groenevelt, P.H.</td>
<td>Movement of Solutes in Frozen Soil under Different Hydrologic Regimes</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Groenevelt, P.H.</td>
<td>Soil Amendments to Reduce Water Erosion</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Preparation of a Landowner Casebook and Factsheets for Carolinian Canada</td>
<td>Ontario Heritage Foundation</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Development of a Training Program for MNR, OMAF and Conservation Authority Extension Staff</td>
<td>M.N.R.</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Watershed Regeneration: Principles and Practices</td>
<td>Laidlaw Foundation</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Conservation Planning for Niagara Escarpment Landowners Project</td>
<td>Ontario Heritage Foundation</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Partners in Protection</td>
<td>Federation of Ontario Naturalists</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Stewardship Information Bureau</td>
<td>Agriculture Canada</td>
</tr>
<tr>
<td>Hiltis, S.G.</td>
<td>Stewardship Enhancement Techniques for Farm-level Soil Conservation</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Kachanoski, R.G.</td>
<td>Impact of Livestock Manure and Fertilizer Application on Nitrate Contamination of Groundwater</td>
<td>O.M.E.</td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td>Stewardship Enhancement Techniques for Farm-level Soil Conservation</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Kachanoski, R.G.</td>
<td>Variable Rate Technology for Fertilizer Nitrogen Application</td>
<td>Agriculture Canada</td>
</tr>
<tr>
<td>Kachanoski, R.G.</td>
<td>Tillage Effects on Transport Processes in Soil</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Kachanoski, R.G.</td>
<td>Crop Productivity and Soil Loss in Variable Topography</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
<td>Sponsor</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Kachenoski, R.G.</td>
<td>Prevention of Nitrate Contamination of Groundwater from Fertilizer</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Kay, B.D.</td>
<td>Role of Environmental Factors and Land Management Practices on Soil Structure</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Kay, B.D.</td>
<td>Influence of Soil Texture and Tillage Practices on the Susceptibility of Legume Nitrogen to Leaching</td>
<td>Agriculture Canada</td>
</tr>
<tr>
<td>Kay, B.D.</td>
<td>Impact of Soil Structure on Plant Growth and Yield</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Kay, B.D.</td>
<td>Soil and Crop Management Practices to Enhance Soil Structural Stability</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>King, K.M.</td>
<td>Surface-Atmosphere Exchange of Greenhouse Gases</td>
<td>Environment Canada</td>
</tr>
<tr>
<td>Martini, I.P.</td>
<td>Support for Students Working in the North Development</td>
<td>Indian Affairs &amp; Northern</td>
</tr>
<tr>
<td>Martini, I.P.</td>
<td>Sedimentology of Non-Glacial Cold Climate Deposits</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>McBride, R.A.</td>
<td>Characterization of Soil Compaction in Ontario and Its Agronomic Importance</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Miller, M.H.</td>
<td>Soil Disturbance Effects on VA Mycorrhizal Symbiosis and Shoot/Root Growth of Maize</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Miller, M.H.</td>
<td>Fertilization of Hybrid Poplar</td>
<td>Forestry Canada</td>
</tr>
<tr>
<td>Miller, M.H.</td>
<td>Fluorescence Microscope with Camera to Study Soil Micro-Organisms</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Voroney, R.P.</td>
<td>Research Support for J. Langat</td>
<td>Kenya/Canada Agric. Research Training</td>
</tr>
<tr>
<td>Miller, M.H.</td>
<td>Role of Indigenous VA-Mycorrhizal Fungi in Sustainable Crop Productions</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Kay, B.D.</td>
<td>Role of Indigenous VA-Mycorrhizal Fungi in Sustainable Crop Productions</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
<td>Institution</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Miller, M.H.</td>
<td>Nitrogen and Phosphorus Management in No-till Corn Production</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>A Comprehensive Image Analysis System for Studies of Soil Processes</td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>Radar Imagery for an Agricultural Monitoring System</td>
<td>Institute for Space &amp; Terrestrial Science</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>Ground Based Radiometer for Water Resources Assessment</td>
<td>Institute for Space &amp; Terrestrial Science</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>Soil Biota as an Indicator of Soil Quality and its Contribution to Soil Structure</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>Image Analyses for the Study of Soil Processes</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Protz, R.</td>
<td>Radar Imagery for an Agricultural Monitoring System</td>
<td>O.M.A.F.</td>
</tr>
<tr>
<td>Robinson, D.M.</td>
<td>Farming for Maximum Efficiency and Environmental Sustainability</td>
<td>Agriculture Canada</td>
</tr>
<tr>
<td>Spiers, G.A.</td>
<td>Evaluation of Soil Sampling and Analysis</td>
<td>Environment Canada</td>
</tr>
<tr>
<td>Spiers, G.A.</td>
<td>Development for Trace Element Content of Grains and Oil Seeds</td>
<td>Canadian Network of Toxicology Centres</td>
</tr>
<tr>
<td>Thurtell, G.W.</td>
<td>Efflux of Trace Greenhouse Gases from Agricultural Sites into the Atmosphere</td>
<td>O.M.E.</td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td></td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>King, K.M.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thurtell, G.W.</td>
<td>Greenhouse Gas Production in Field Soils</td>
<td>Agriculture Canada</td>
</tr>
<tr>
<td>Beauchamp, E.G.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thurtell, G.W.</td>
<td>Flux Measurements of Greenhouse Trace Gases</td>
<td>Environment Canada</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N.S.E.R.C.</td>
</tr>
<tr>
<td>Thurtell, G.W.</td>
<td>Purchase of Instrumentation for Trace Gas Measurements</td>
<td>Environment Canada</td>
</tr>
<tr>
<td>Thurtell, G.W.</td>
<td>The Design of IR Diode Laser Spectrometers and their Application to Gas Concentration and Flux Measurements</td>
<td>N.S.E.R.C.</td>
</tr>
</tbody>
</table>
Thurtell, G.W. Detailed Measurements of Trace Gas Fluxes from Small Plots Agriculture Canada


Thurtell, G.W., Gillespie, T.J. Flux of Greenhouse Gases between Land Surfaces and the Atmosphere O.M.A.F.


Voroney, R.P. Effects of Management on Nitrogen Mineralization of a Fall Rye Rotation Crop Simon Fraser University

Voroney, R.P. Composting Research Waterdown Gardens

Voroney, R.P. Costa Rica Bean Mulch I.D.R.C.

Voroney, R.P. Canada-Costa Rica Project Agriculture Canada C.I.D.A.

Voroney, R.P., Kachanoksi, R.G., Otten, L. Measurement of Maturity Parameters in M.S.W. Composts O.M.E.

Voroney, R.P. Allelopathy of Crop Residue O.M.A.F.

Voroney, R.P. Application of Organic Wastes to Agricultural Land O.M.A.F.

Voroney, R.P. Potential for C Sequestration as Soil Organic Matter by Agriculture in Ontario O.M.A.F.
Professor Evans down in the dump looking for toxic metals
Land
Characterization
A PROTON BINDING AND CD COMPLEXATION MODEL FOR A SOIL HUMIC ACID

K.A. Bolton, S. Sjöberg† and L.J. Evans
† Department of Inorganic Chemistry, University of Umeå, Sweden

Perhaps the most poorly understood aspect of metal retention in soils is that of the complexation of metals with humic materials. The purpose of this study was to determine the extent of Cd complexation with a soil humic acid. Potentiometric titration data was obtained and a quasi-particle discrete multi-ligand model was used to determine both proton dissociation and Cd complexation constants. All constants were determined from experimental titration data using the optimization procedure in the computer program FITEQ (Table 1). Experimental data was modelled using the computer program SOLGASWATER by plotting -log[H⁺], pH, against Z_A which was defined as the average number of OH⁻ reacted per mole of HA (Fig. 1). The best fit to the experimental data was given by a proton binding model incorporating two diprotic acids. Potentiometric titrations in the presence of Cd were best described by a model involving the formation of four inner-sphere complexes. This study has shown that Cd forms relatively strong complexes with soil humic acids and that organic matter can influence the fate of Cd in the soil environment.

Table 1. Proton dissociation constants and Cd complexation constants, -logβ ± 3α.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Value (± error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>([H_2A]^+) = 0.7455 mM</td>
<td>-4.00 ± 0.02</td>
</tr>
<tr>
<td>([H_2B]^-) = 0.3326 mM</td>
<td>-9.32 ± 0.03</td>
</tr>
<tr>
<td>(\text{H}_2\text{A} \rightleftharpoons \text{H}^+ + \text{HA}^-)</td>
<td>-7.43 ± 0.24</td>
</tr>
<tr>
<td>(\text{H}_2\text{B} \rightleftharpoons \text{H}^+ + \text{HB}^-)</td>
<td>-16.66 ± 0.31</td>
</tr>
<tr>
<td>(\text{H}_2\text{A} + \text{Cd}^{2+} \rightleftharpoons \text{H}^+ + \text{CdHA}^-)</td>
<td>-1.31 ± 0.10</td>
</tr>
<tr>
<td>(\text{H}_2\text{A} + \text{Cd}^{2+} \rightleftharpoons 2\text{H}^+ + \text{CdA}^-)</td>
<td>-5.88 ± 0.06</td>
</tr>
<tr>
<td>(\text{H}_2\text{B} + \text{Cd}^{2+} \rightleftharpoons 2\text{H}^+ + \text{CdB}^-)</td>
<td>-12.15 ± 0.17</td>
</tr>
<tr>
<td>(\text{H}_2\text{B} + \text{Cd}^{2+} + \text{H}_2\text{O} \rightleftharpoons 3\text{H}^+ + \text{Cd(OH)}_2^-)</td>
<td>-21.10 ± 0.16</td>
</tr>
</tbody>
</table>

Figure 1. Experimental data and model lines (Table 1) for humic acid titrations in the presence of 1.25 and 0.125 mM Cd
In the 1984 LRS Progress Report, we (Brunsting and Groenevelt) presented a model for the prediction of the organic matter content in soil. The model contains several gain functions and several loss functions. The model was developed from thirty years of observations on the runoff plots on Hydrology Hill. We provided predictions of the future organic matter content under different scenarios. These scenarios lead to either increasing, stable or decreasing organic matter (OM) contents. A graph was presented that contains the complete picture of the historical (1952-1983) OM contents and the predicted values for future years (1984-2050).

During the past ten years (1983-1992) the measurements of the OM content on those runoff plots have continued. During those years the management has been deliberately beneficial to the soil and was intended to lead to increased OM contents. According to the model the OM content, under such beneficial management, can indeed rise, but will do so only very slowly. The calculations prescribed in the model are progressively carried out from one year to the next, according to:

\[ \Delta OM = \sum_i G_i - \sum_j L_j^{(1)} \]

where \( \Delta OM \) is the change in stable organic matter content, expressed in kg OM ha\(^{-1}\) year\(^{-1}\); \( G_i \) is the ith Gain Function [kg OM ha\(^{-1}\) year\(^{-1}\)]; and \( L_j \) is the jth Loss Function [kg OM ha\(^{-1}\) year\(^{-1}\)].

The three loss functions, oxidation, erosion, and enrichment of organic matter in the sediment have been calculated precisely as in 1984. The same method was also used to calculate the first two gain functions, viz. the addition of root material and the addition of above ground plant material. New gain functions were established for the additions of the following soil amendments: polyvinyl alcohol (PVA), latex, sugar lime, and cellopol (starch).

The complete results of the calculations for plot #2, together with the measured values at different points in time during the period 1983-1992 are presented in Figure 1.

![Figure 1. Organic matter over time on Plot #2 of Hydrology Hill](image-url)
PROBING THE "CAPILLARY FRINGE" OR "TENSION-SATURATED ZONE"

J. Husain and P. H. Groenevelt

Porous media with a narrow range of pore diameters, or consisting of well-sorted (same diameter) particles, show a clearly defined capillary fringe (i.e., a saturated zone above the phreatic level). Upon decreasing the water potential below atmospheric pressure, these media show a clearly detectable negative water pressure (the "bubbling pressure" or the "air-entry pressure"), where suddenly a rather large amount of water is released.

Two things are usually taken for granted. First that this "tension-saturated zone" the porous medium upon decreasing the water potential, stays saturated. Also that the hydraulic conductivity remains at the value of the saturated hydraulic conductivity. A consequence of this mindset is that the differential soil water capacity, \( C \), is zero and therefore the diffusivity, \( D \), the ratio of the hydraulic conductivity and the capacity is infinitely large.

The validity (non-validity) of this concept can be elegantly demonstrated by a simple experiment using the Guelph Tension Infiltrometer.

The experiment:

For several (say four) different values of water tension in the infiltrometer, \( H \), (\( H \) has a negative value), the flow rate out of the infiltrometer is measured.

The values of the saturated hydraulic conductivity and the matric flux potential are then calculated from pairs of data sets, using the equation that was developed by Reynolds and Elrick (1990) for the Guelph Pressure Infiltrometer:

\[
Q_s = \frac{d}{d}(K_f H + \phi_m) + \pi a^2 K_p
\]

in which \( H \), the hydraulic head, has a positive value.

Subsequently, one can calculate separately, for a certain value of the set tension, the corresponding value of the "tension" hydraulic conductivity and the "tension matric flux potential".

The validity (non-validity) of the above mentioned concept can now be shown by testing the equation. If this equation holds, the concept is valid. If one finds that the calculated "tension matric flux potential" is smaller than the matric flux potential plus the product of the saturated hydraulic conductivity and the matric flux potential, then the concept fails. One must then come to the conclusion that the hydraulic conductivity in the tension saturated zone is slowly decreasing with decreasing water potential, and that the capacity near saturation is not zero but finite. So the diffusivity at saturation is not infinitely large, but finite. This latter conclusion was the result of the experiments with Caledon sand, as shown in the following schematic diagram:
COMPARISON OF KCl AND K₂SO₄ EXTRACTANTS FOR SOIL NH₄⁺ AND NO₃⁻


Often in studies of C and N transformations, it is necessary to obtain estimates of extractable C and mineral N (NH₄⁺, NO₃⁻, and NO₂⁻). Routinely, automated analysis of extractable C in soil extracts is done by UV-persulfate digestion using a Technicon AAI system (Alfa-Laval Braun-Luebbe, Mississauga, ON) following Technicon Industrial Method No. 455-76/W/A. Routine automated analysis of mineral N in soil extracts is done by the Berthelot reaction (NH₄⁺ determination) and the azo-dye method (NO₃⁻ and NO₂⁻ determinations) using an instrument such as the Traacs 800 Analyzer (Alfa-Laval Braun and Luebbe, Mississauga, ON) following Tel and Heseltine (1990, Commun. Soil Sci. Plant Anal. 21: 1681-1688).

Unfortunately, 2M KCl, the generally accepted extractant for mineral N, interferes with the determination of extractable C by the UV-persulfate digestion method. Accordingly, 0.5 M K₂SO₄ is used as a soil extractant for determination of extractable mineral N and C. Estimates of soil NH₄⁺ and NO₃⁻ contents in 2 M KCl and 0.5 M K₂SO₄ extracts were compared.

Fifteen soil samples were collected from four soils planted to corn (Zea mays L.) in southern Ontario with varying fertilizer application rates and sampling depths. The soil horizons, sampled (Ap and B), were from a Fox sandy loam, Brady sandy loam, Conestogo silt loam, and Brookston clay loam. All soil samples were air-dried and passed through a 2 mm sieve prior to analysis.

Soil samples were extracted in triplicate, with 2 M KCl or 0.5 M K₂SO₄ in a 2:1 (extract volume: soil weight) ratio, shaken for 30 min., and filtered through Whatman #42 paper. Extracts were stored at 5°C until analysis for extractable C, NH₄⁺, and NO₃⁻.

The fine and medium textured soils (Brookston and Conestogo) were found to have more extractable NH₄⁺ with KCl compared to K₂SO₄(Fig.1). Mulvaney et al. (1992, Commun. Soil Sci. Plant Anal. 23: 1805-1813) found that 0.5 M K₂SO₄ extracts recover nearly 100% of recently added ¹⁵ΝH₄⁺ to soil as determined by Kjeldahl digestion. Therefore, KCl and K₂SO₄ may have different extraction efficiencies for exchangeable NH₄⁺. Extraction efficiency for NH₄⁺ may be related to K⁺ concentration (2 M of K⁺ in 2 M KCl vs 1 M of K⁺ in 0.5 M K₂SO₄) and/or the different ionic strengths of the extractants. Calculation of the amount of NH₄⁺ exchanged with 2 M KCl and 0.5 M K₂SO₄ based on the activity of K⁺ and NH₄⁺ in solution, indicated that K₂SO₄ should extract 0.86 times that of KCl. The concentrations of nitrate extracted did not differ with extractant because NO₃⁻ is present in the soil solution and not held on exchange sites for soils in southern Ontario. Extraction of NH₄⁺ with K₂SO₄ in heavy to medium textured soils is cautioned when precise estimates of NH₄⁺ are required.

![Figure 1: 0.5 M K₂SO₄ and 2 M KCl Extractable Soil NH₄⁺ of four soils from Southern Ontario (n=3)](image-url)
SOIL-WATER CONTENT AND POTENTIAL MEASURED BY HOLLOW TIME DOMAIN REFLECTOMETRY PROBE

N. Baumgartner, G.W. Parkin, D.E. Eirick

A new soil probe used in conjunction with time domain reflectometry (TDR), tensiometry, and solution extraction devices and designed to allow simultaneous in situ measurement of soil-water content, matric potential, and solute concentration has been designed. Hollow stainless steel electrodes with a porous stainless steel tip serve as TDR wave guides in a standard two parallel probe configuration. The porous tip allows water inside the hollow rods to equilibrate with the soil-water in an unsaturated or saturated system. A pressure transducer system is used to measure the soil matric potential around the porous tip. A vacuum pump can be used to withdraw soil solution through the perm-eable porous tip. Comparison between measurements of soil-water content obtained by a two solid wires TDR probe and the new probe gave encouraging results. Favorable agreement was obtained between measurements of the soil matric potential and depth to an artificial water table.

EXTRACTION OF BIOMASS C AFFECTED BY SOIL HOMOGENIZATION

M. Tenuta, J.P. Winter, R. P. Voroney and E. Beauchamp

Previous research found fumigation-extractable biomass C in aggregates of various sizes (<0.25 to > 19.5 mm in diameter) to decrease with increasing aggregate size. We suspected that a reduction in efficiency of extraction of biomass C may have been associated with increasing aggregate size. Therefore, mechanical disruption of large aggregates during extraction of biomass C was tested to see whether extraction efficiency would increase.

Soil aggregates 9-19 mm in diameter were separated by hand sieving a surface horizon sample of a Conestogo silt loam. This soil had been planted to bromegrass at the Elora Research Station. Extractable biomass C was determined by fumigation-extraction. In addition, aggregates plus extracting solution were homogenized for 5 seconds with a Brinkman tissue (PT 10-35) homogenizer fitted with a saw tooth probe generator (PT 20S-T). The homogenization treatments were 0, 3.8, 4.3, 4.9, and 5.5 on the machine power level dial and were replicated 5 times. With increasing power level, homogenization would result in greater mechanical shearing and sonification of soil.

Extractable organic C in extracts was determined with a Technicon Autoanalyzer II system (Alfa-Laval Braun-Luebbe, Mississauga, ON) following Technicon Industrial Methods No. 455-76W/A. Extractable C from the non-fumigated, chloroform fumigated. The difference between these treatments were referred to as control, fumigated, and extractable biomass C, respectively.

Extractable C increased for fumigated samples compared to control samples (Fig. 1 on previous page). Extractable biomass C increased by 30% with homogenization at power levels ≥ 4.8 compared to un-homogenized soil. Gregorich et al. found that sonification released readily decomposable C sequestered within micro-aggregates.

In this experiment, homogenization improved the extraction of microbial biomass C located within aggregates. For highly structured and fine-texture soils, we suggest that homogenization should be used to increase the efficiency of extraction of microbial biomass C.
Land Characterization

THE MANCIANO SANDSTONE: A SHOREFACE DEPOSIT OF LOWER-MIDDLE MIocene "SATELLITE BASINS" OF THE THRUST-FAULTED FOREDEEP BASIN-FLANK OF THE NORTHERN APENNINES, ITALY.

I. P. Martini (Univ. of Guelph), A. Rau (C.N.R., Dip. Scienze della Terra, Universita' di Pisa, Italy).

In Southern Tuscany, Italy, there are several isolated deposits which are remnants of tectonically disrupted sedimentary "satellite basins" (secondary basins formed on still-moving thrust faulted sheets). In some places outcrops are good enough for detailed sedimentological analysis, but the scattered nature and approximate dating of some the bodies make regional paleogeographic interpretation difficult. Yet these deposits relate in some way to the formation and filling of foredeep basins of the Northern Apennines and provide information on the hydrology of the ancient seas (Thetis) which were narrowing as the African and Indian plates were closing against the European and Asian crustal plates. Because of this, one of the best exposed sandstone bodies, the Lower-Middle Miocene Manciano Sandstone, has been analyzed in details to gather as much information as possible from local sedimentological analysis, and to pose some basic paleogeographic questions which, admittedly, will require a more regional analysis to be fully answered.

The 180 m thick Manciano Sandstone is a medium to very coarse, washed, lithic sandstone, with thin interlayers of sandy conglomerates. It is characterized mostly by trough-cross beds alternating with planar beds which in places form accretionary surfaces of 1-2 metre thick bars, and minor ripple cross-laminations. In the lower part of the section a 20 m thick section shows unidirectional cross-beds with "tidal bundle" structure.

The sandstone contains layers with abundant oysters, echinoid (Scutella) some balanids, reworked foraminifera and bryozoa. It is locally intensely bioturbated with a Cruziana-Skolithos mixed ichnofauna. The trace fossils occurs in a few assemblages.

1. One contains predominantly Macharonicnthus segregatus, small Ohioomorpha and Skolithos linearis typical of a shoreface to foreshore paleoenvironments.

2. A second assemblage is implanted in slightly finer sandstone, still cross-bedded, with much higher degree of bioturbation. The typical trace fossils consists of Bergaueria ?perata, Skolithos linearis, Conichnus conicus, Planolites beverleyensis. This is a typical lower shoreface assemblage.

3. A third assemblage is characterized by J-shaped opportunistic Arenicolites and Thalassinoides suevicus and Planolites beverleyensis. It occurs in intensely bioturbated sandstones retaining ghosts of storm/washover layers probably formed in sheltered back-bar/ridge areas.

4. A fourth assemblage consists of a firm ground Glossifungites ichnofacies with Arenicolites and Skolithos linearis. This occurs on a surface over which a widespread colony of large oysters was implanted.

5. Finally several units have broken oyster shells and calcareous pebbles bored by lithofaghi organisms, indicating a nearshore coastal setting.

The assemblages of sedimentary structures, body and trace fossils and their vertical repetitive occurrences indicate that the Manciano Sandstone is a barred shoreface deposit with recognizable clear distinctions between bar flank, top and back-bar settings. Whereas the shore was wave dominated. Currents were modified also by tides as indicated by the presence of "tidal bundle" structures in part of the section. This in turn confirms the fact that the relatively narrow foredeep basins forming in between the advancing tectonic front of the Apennines and the Adria foreland (approximately located where is now the Adriatic Sea) was open to large oceans, such as the enlarging Atlantic Ocean to the west and the closing Thetis to the east.
PEDOSEDIMENTARY HISTORY OF CRETACEOUS POLYGENETIC PALEOSOLS, CROWSNEST PASS, ALBERTA

P.J. McCarthy and I.P. Martini

Micromorphological analysis of Cretaceous paleosols from the vicinity of Crowsnest Pass, southwestern Alberta, has resulted in the identification of complex polygenetic paleosol successions from which are interpreted local pedosedimentary histories.

The paleosol-bearing successions commonly fine upward from a sharp-based, medium to fine-grained, greenish-grey sandstone to dark greyish-red or variegated red and green mudstone, overlain by green or grey mudstone. Thick mud-dominated floodplain sections commonly contain repetitive, quasi-regular alternations of red, green and variegated mudstone interspersed with occasional splay sandstones.

At least two levels of sedimentary cyclicity are identified. Small-scale cycles (20-50 cm thick) occur within individual colour units. They are related to depositional events in which synsedimentary cumulative pedogenesis occurred. Larger scale cycles (1-3 m), identified by both grain size and colour changes, reflect major changes in floodplain stability and hydrological conditions at a site. Analysis of micromorphologic assemblages indicates that at least three phases of pedogenesis may have been superimposed upon these sedimentary cycles to form complex polygenetic paleosols.

Dark reddish brown, microlaminated, iron-rich clay coatings were deposited during an early phase of pedogenesis under humid temperate, well-drained conditions. Subsequent disruption resulted in the incorporation of some of these coatings into the matrix as papules and intercalations.

A second phase of pale yellow, weakly laminated, iron-depleted and aluminum-enriched clay coatings occurs overlying the dark reddish coatings. In some places the dark reddish coatings have a gradual transition to the pale yellow coatings. This is interpreted as evidence that the pale yellow coatings represent a subsequent phase of illuviation of deferrated clay coatings under conditions of increasing hydromorphy.

A final phase of translocation of silty clay coatings interbedded with thin Fe-Mn oxide coatings commonly occurs, suggesting a change to predominantly waterlogged, but fluctuating, drainage conditions.

The paleosols provide an important record of local environmental changes which is particularly useful for the interpretation of ancient continental sequences where faunal and floral evidence of paleoenvironmental change may be lacking.
Land Characterization

BORON ADSORPTION ON SOIL CLAY FRACTIONS

J. Hou and L. J. Evans

The effects of ionic strength on B retention by soil clay fractions provides a means of assessing the mechanisms of bonding of B to surface hydroxyl groups found in minerals. Soil clay fractions (<2 μm) were separated by sedimentation from two soils: a Humic Gleysol (Cane series) and an Orthic Humic Gleysol (Welland series). Boron adsorption on the clay fractions as a function of pH was conducted in a batch system at various ionic strengths from 0.01M to 0.50 M LiCl.

Boron adsorption on the two clay fractions as a function of pH and ionic strength is shown in Figure 1. For the clay fraction from the Cane soil (Fig. 1b), B adsorption increased from an initial pH of 4.5 and exhibited an adsorption maxima between pH 6.8 to 8. The extent of adsorption then decreased as the pH continued to increase. Changes in ionic strength of about one and a half orders of magnitude, from 0.01 M to 0.5 M LiCl, affected B adsorption over the entire experimental pH range. Boron adsorption decreased with increasing ionic strength below pH 7, while increasing with increasing ionic strength above pH 7.8.

A similar adsorption pattern was observed on the clay fraction from the Welland soil (Fig. 1a) with the extent of B adsorption also dependent on ionic strength. The effects of ionic strength on the B adsorption maxima was similar for both soil clay fractions probably because of the similar clay mineralogies.

The observed effects of ionic strength on B retention by the soil clay fractions suggests that B is relatively weakly bound to clay mineral edges through the formation of outer-sphere complexes. At low pH’s, clay mineral edges are positively charged. Also, the electrical potential in the plane of adsorption decreases with increasing ionic strength because more Cl− ions are accumulating near the positively charged surface. As a result, B adsorption is reduced due to anionic competition. At high pH’s, clay mineral edges are negatively charged. Also, the electrical potential in the plane of adsorption increases with increasing ionic strength because more Li+ accumulates near the negatively charged edge, thus increasing B adsorption.

Figure 1: Boron Adsorption on Clay Fractions at Different Ionic Strength and pH: (a) Welland Soil Clay; (b) Cane Soil Clay
SEDIMENT DYNAMICS AT THE HEAD OF A SUBARCTIC ESTUARY AFFECTED IN PART BY HUMAN ACTIVITY, MOOSE RIVER, NORTHERN ONTARIO.

T. Poehlman and I.P. Martini

This research deals with the hydrodynamics and sedimentary regime in the upper mesotidal reaches of the subarctic estuary of the Moose River. The Moose River drains part of the vast peatlands of the Hudson Bay Lowlands as it follows its northeast course and empties into the southwest corner of James Bay. The towns of Moosonee and Moose Factory, situated along its banks about 15 km from the mouth, rely on the river for transportation, tourism, and gravel excavation. Both natural processes and human activity are changing this system. For example, navigation is being made increasingly difficult as the river's depth is being reduced in some reaches.

Measurements and observations were made during the winter (ice thickness and flow under the ice), spring (ice breakup and sediment movement) and the summer of 1993. The summer field season included determining the morphology through echosounding, hydrology (depth, velocity, direction, bedload, suspended load, salinity, conductivity, and temperature), and sediment distribution (bottom sampling), at 30 tidal stations throughout 8 full tidal cycles.

Special attention was given to the evolution of a large sand bar forming in front of Moosonee. The surficial features and internal structure of this bar were described through observation and shallow cores, Sedimentary structures observed on and within the bar were then compared with those found in ancient bars preserved in bank exposures.

We assessed the impacts of human activity such as gravel excavation, vehicular, boat, and pedestrian traffic, dredging to maintain deep, navigable channels, loading of banks, shoreline protection, and channelling of drainage waters from the towns. This study should foster a better understanding on the behaviour of subarctic estuarine systems affected by human activity, and provide some basic information for land use planning.
IS IT POSSIBLE TO CATHODE-PROTECT A WEATHERING ORE BODY?

W. Chesworth and G. Shelp

If the answer to the above question is yes, then it may be possible to devise a walk-away solution to the acid mine drainage (AMD) problem. Consider the situation at the Sherman mine in northern Ontario (Fig. 1). Oxygenated water passing through the sulphide-graphite vein acquires acidity by the following summary (and simplified) reaction:

$$4 \text{FeS}_2 + 15 \text{O}_2 + 14 \text{H}_2\text{O} = 4 \text{Fe(OH)}_3 + 16 \text{H}^+ + 8 \text{SO}_4^{2-}$$

Consequently the water in South Pit has a pH around 3. Now if the sulphide-graphite vein could be electrically connected to a more electropositive metal immersed in the water of the pit, a galvanic battery would be produced in which the vein would be the cathode. During the winter of 1993-4 we set up a cell of this kind using scrap iron as the sacrificial anode. It generated an average EMF for 9 months of 0-4 volts, and a current of approximately 50mA. The anode lost 0.392 kgm. weight (compared with 0.081 kgm loss for a control). In other words the technique is feasible.

More substantial support comes from the experimental work that forms part of Gene Shelp's Ph.D. thesis requirement. Experimental cells, constructed as analogue models of the South Pit at Sherman Mine, and also using scrap-iron as the anode, have succeeded in bringing the pH of AMD up to an environmentally acceptable 5.6.

For his work on this project Gene Shelp received the $1000 Environmental Research and Technology Award for 1993, of the Ontario Ministry of the Environment and Energy another first for Guelph.

---

Fig. 1 Cross section of the South Pit, Sherman Mine. BIF signifies banded iron formation. The vertical scale is in metres above sea level.

Fig. 2 Making an electrical connection with the sulphide vein using the thermite process.
INDUCING THE BREAKDOWN OF APATITE

W. Chesworth and P. van Straaten

In its simplest form, the phosphorus providing reaction which forms the basis of the use of apatite as a fertilizer or fertilizer raw material is:

\[
\text{Apatite} + \text{acid} = \text{Calcium ions} + \text{P-species}
\]

The key to manipulating the reaction and causing apatite to yield P to growing crops is the law of mass action:

An increase in the thermodynamic activity of species in solution on the left hand side of the reaction, or a decrease in thermodynamic activity of species on the right hand side, induces the mineral to break down.

In effect, such manipulations alter the stability field of apatite (See Figure). In a soil with a near neutral pH, apatite will not have a high solubility (point A on the diagram). To render the apatite more soluble the system can either be moved up the solution curve A to B on the diagram, (i.e. by acidification), or it can be moved from A to C by reducing the activity of Ca\(^{2+}\).

In work done by us or by our students at Guelph (largely funded by IDRC), we have been successful in devising cheap, alternative ways of acidifying the system, either by mixing the apatite with a more soluble calcium phosphate (Chesworth and van Straaten, 1993) or by using bacteria, indigenous to Tanzania to break down the apatite (Milne, M.Sc. thesis 1994). In laboratory experiments Marcille-Kerslake (1991) showed the effectiveness of natural zeolites and NH\(_4\)^+ exchanged zeolites in breaking down apatite. Using NH\(_4\)^+ charged zeolites proved to be more effective in acting as a Ca-sink than untreated zeolites, which contained some inherent calcium.

In other words either increasing H\(^+\) or lowering the Ca activity are ways to induce the breakdown of apatite. However, the increase of H\(^+\) to induce apatite dissolution is a direction fraught with some danger. After all, the acidifying effect of the common industrial fertilizers has been one of the ways that farm-soils have been degraded in the past.
SOIL GENESIS AND NATURAL AND ANTHROPOGENIC GAMMA RADIOACTIVITY AT PINERY PROVINCIAL PARK

B. VandenBygaart, R. Protz, and W. Stafford

Pinery Provincial Park lies on a series of dune ridges representing a chronosequence. Soil profiles were intensively sampled in fine depth increments at six positions along the sequence, ranging in age from about 100 years before present (y.B.P.) to 4700 y.B.P. The soils graded from an Orthic Regosol near the shore to an Eluviated Dystric Brunisol 2.3 km inland. Chronofunctions were formulated and showed the progression of soil weathering and development with soil age (Fig. 1). Gamma radioactivity was also shown to be related to soil genesis. $^{40}$K tended to increase in relative concentration in the upper solum likely due to carbonate mineral weathering and removal. $^{226}$Ra and $^{232}$Th tended to accumulate in the B horizons possibly associated with sorption onto Fe-oxyhydroxide and clay surfaces. However, more $^{226}$Ra was retained in the solum relative to $^{226}$Ra due to the greater immobility of $^{232}$Th. Chronofunctions were also formulated relating gamma radioisotope properties within soil horizons to the ages of the soils (Fig. 2). Due to its non-specific adsorption and possible fixation with clay minerals and organic matter, anthropogenic $^{137}$Cs remained in the top few centimetres of each of the profiles with one exception. This profile has been accumulating fresh sand from a dune blowout and thus the $^{137}$Cs could be used as a recent stratigraphic marker in the dune sands of the Pinery (Fig. 3).

Figure 1: A Chronofunction Calculated in the Pinery Soils

Figure 2: A Chronofunction of Natural Gamma Radioisotopes in the Pinery Soils

Figure 3: Cs-137 at Pinery 1 and Atmospheric Fallout
TENSILE STRENGTH OF AGGREGATES FROM THREE CORN MANAGEMENT PRACTICES

E. Perfect, B.D. Kay, and J.A. Ferguson

Corn (Zea mays L.) is a major cash crop in Ontario. However, continuous corn production using conventional corn management practices can cause a deterioration in soil structure. Structural deterioration is associated with increased erosion and reduced yields. Alternative management practices such as minimum tillage and underseeding with red clover (Trifolium pratense L.) have been shown to improve soil structure. Parameters are needed to quantify the changes in soil structure brought about by alternative management practices.

One measure of soil structure is aggregate tensile strength. Aggregate tensile strength varies with water content and inherent soil properties. For a given water content and soil type, the aggregate tensile strength also depends upon management practices such as tillage and cropping history. This dependency is most pronounced for air-dry aggregates.

We investigated the influence of three corn management practices (in place for 4-yr) on the tensile strength of air-dry aggregates from a loam soil at the Elora Research Station. The practices were conventional-till, conventional-till underseeded with red clover, and minimum-till underseeded with red clover. Conventional-till consisted of spring moldboard plowing followed by three passes with a cultivator. Minimum-till was two light spring diskings. The red clover was established annually.

Soil was sampled from the 0-15 cm depth of each management practice in the spring of 1992, and air-dried in the laboratory. The air-dried soil was sieved into five size fractions, ranging from 0.8-1.6 to 19.1-31.5 mm. Forty aggregates from each size fraction were crushed individually between parallel flat plates. The measured force at fracture was then used to calculate the dry aggregate tensile strength(s).

The mean gravimetric water content (w) at sampling was 17.0%. The w after air drying was 2.2%. There was no significant effect of management practice on w, either before or after air drying.

Differences in s due to corn management practices were most pronounced in the smallest size fraction. The absolute strength of this fraction was higher, and the spread of strengths was narrower, for conventional-till corn compared to minimum-till corn under-seeded with red clover. The mean s decreased with increasing size fraction for all of the management practices. There were only small differences in s between management practices for the largest fraction. These results suggest that cultivation and traffic-induced compaction affect the basic smaller structural units of a soil rather than the larger aggregation units.
Parameters are needed to quantify changes in soil structure produced by alternative corn (Zea mays L.) management practices. Aggregate size distribution (ASD) is a commonly used parameter. However, the use of ASD is questionable when comparing tillage practices. This is because the energy input under conventional-till is much greater than under minimum-till. Ideally, the ASD's of these practices should be compared under conditions of equal energy input.

We measured ASD's resulting from the fragmentation of air-dry clods (19.1–31.5 mm in length) collected from three corn management practices (conventional-till, conventional-till underseeded with red clover, Trifolium pratense L., and minimum-till underseeded with red clover), and crushed at five specific energy levels: 0.005, 0.01, 0.02 0.04 and 0.08 J/g. The management practices were described in detail in our previous report. Eight clods from each practice were crushed individually between a pair of flat parallel plates at each specific energy level.

Fragments from the eight clods were pooled after crushing and placed on the top sieve of a nest of sieves (sized 16, 8, 4, 2, 1 and 0.5 mm) and shaken for 6 seconds. The mass of material retained on each sieve was then recorded. The cumulative number of aggregates (N[X ≥ x]), was calculated from the masses assuming cubic geometry and constant bulk density. Normalized aggregate length, \( x_1 \), was taken as the mean of the upper and lower sieve openings divided by the mean of the two largest sieve openings.

Typical aggregate-number size distributions resulting from fragmentation of individual clods are shown in Figure 1. The ASD for conventional-till (not shown) was similar to that for conventional-till underseeded with red clover. Taking the slopes of the lines in Figure 1 in the range \( \log(x_1) < 0 \) gives the fractal dimension, \( D \). The \( D \) is a measure of the spread of aggregate sizes. The larger the value of \( D \), the greater the spread of aggregate sizes.

The specific energy input, and its interaction with management practice, had no significant effect on the calculated values of \( D \). In contrast, management practice was highly significant.

The mean \( D \) ranged from 2.03 for conventional-till underseeded with red clover to 2.40 for minimum-till underseeded with red clover. The mean for minimum-till underseeded with red clover was significantly higher than the other means. There was no significant difference between the means for conventional-till and conventional-till corn underseeded with red clover.

The above results indicate minimum-till produces a wider range of aggregate sizes than conventional-till when compared under conditions of equal energy input.

Fig. 1. Aggregate number-size distributions, \( \log\{N[X \geq x]\} \) versus \( \log\{x_1\} \), for specific energy inputs of 0.005, 0.01, 0.02, 0.04 and 0.08 J/g: (A) conventional-till corn underseeded with red clover, and (B) minimum-till corn underseeded with red clover.
CARBON AND NITROGEN CYCLING IN A BOREAL ASPEN FOREST

C.A. Russell, I. Boucher and R.P. Voroney

The objective of this research is to quantify the seasonal carbon and nitrogen dynamics in a boreal forest. An aspen forest located within Prince Albert National Park, Saskatchewan, has been selected as the research site. This research project is a sub programme of the Boreal Ecosystem Atmosphere Study (BOREAS), an international study that is attempting to quantify the exchange of trace gases, energy and water between the boreal biome and the atmosphere.

Several methods for measuring soil respiration (CO₂ evolution) in the field and laboratory were assessed and we have chosen to use a closed chamber design combined with a portable infrared gas (CO₂) analyzer. This system allows measurement of soil CO₂ flux at several locations within the landscape.

The technique was tested at the research site in October 1993. Measurements of the flux of CO₂ from the soil showed that it was quite uniform throughout the landscape. Furthermore, these measurements approximated independent estimates obtained using eddy correlation techniques.

Intensive measurements will be made at the site throughout the spring, summer and fall 1994 and 1995 to determine the seasonal relationships between the factors which control soil biological activity (temperature and soil/litter water content, organic C and inorganic N availability) and the biological processes which contribute to gaseous emissions (decomposition, nitrification and denitrification). The spatial and temporal dynamics of microbial biomass C and N in forest litter and soil will also be measured. Soil profile temperatures and moisture contents will be monitored continuously.
RUNOFF AND SEDIMENT LOSSES AS INFLUENCED BY SELECTED STABILITY AND HYDROLOGIC ROBUSTNESS PARAMETERS

V. Rasiah and B.D. Kay

The objective of this study was to investigate the relative importance of wet aggregate stability (WAS), dispersible clay (DC), time to ponding (TP), and surface cover (SC) created by variations in cropping and tillage systems on runoff (RO) and sediment load (SL).

Ninety-six rainfall simulations, using a portable rainfall simulator during the 1991 and 1992 growing seasons, were undertaken in a cropping and tillage system experiment established on a silt loam soil in 1988 at Elora Research Station. The cropping treatments were continuous conventional corn, continuous minimally tilled corn, forage phase of corn-forage rotations, and the conventional corn following forages of corn-forage rotations.

Cropping and tillage systems had significant influence on runoff, sediment load, time to ponding, surface cover, wet aggregate stability and dispersible clay in 1991. However, in 1992, the influence on some of the variables was not significant at P = 0.05. For the data pooled for 2 years the influence was significant for all the variables, exclusive of time to runoff (TRO).

Simple linear correlation analysis indicated that runoff was linearly negatively correlated to wet aggregate stability, surface cover, time to ponding, time to runoff, and the soil water content, \( \theta \), at simulation (Table 1). Significant positive correlations existed between (i) runoff and sediment load (ii) time to ponding and surface cover or wet aggregate stability, and (iii) time to runoff and surface cover or wet aggregate stability. These analyses indicate that both runoff and sediment load were correlated to stability (WAS and DC) and hydrologic robustness (time to ponding and time to runoff) parameters and surface cover.

Table 1: The correlation matrix for the variables, RO, SL, SC, WAS, DC, TP, TRO, and \( \theta \)

<table>
<thead>
<tr>
<th>Variable</th>
<th>RO</th>
<th>SL</th>
<th>SC</th>
<th>WAS</th>
<th>DC</th>
<th>TP</th>
<th>TRO</th>
<th>( \theta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO</td>
<td>0.79**</td>
<td>-0.47**</td>
<td>-0.32*</td>
<td>0.14ns</td>
<td>-0.52**</td>
<td>-0.43**</td>
<td>-0.21*</td>
<td></td>
</tr>
<tr>
<td>SL</td>
<td>-0.52**</td>
<td>-0.29*</td>
<td>0.18ns</td>
<td>-0.46**</td>
<td>-0.38**</td>
<td>-0.09ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>0.21*</td>
<td>0.23*</td>
<td>0.48**</td>
<td>0.23*</td>
<td>-0.32**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAS</td>
<td>-0.23*</td>
<td>0.27*</td>
<td>0.24*</td>
<td>-0.27*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>-0.15ns</td>
<td>0.18ns</td>
<td>0.48**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP</td>
<td></td>
<td>0.69**</td>
<td>0.28**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRO</td>
<td></td>
<td></td>
<td>0.41**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correlation coefficients followed by '***' and '**' indicate the relation was significant at P = 0.01 and = 0.05, respectively, and those followed by ns indicate the relation was not significant at P = 0.05.
When time to ponding was regressed, using a stepwise variable selection procedure, with surface cover, dispersible clay, wet aggregate stability, and water content at simulation and the interaction terms involving the latter three variables, the following equation was obtained:

$$ TP = -27.68 - 2.30 \text{ WAS} + 0.19 \text{ WAS} \theta + 0.93 \text{ SC} $$  \hspace{1cm} \text{[1]}

$$ (R^2 = 0.53, \ P = 0.01) $$

The cumulative effect of time to ponding, time to runoff, surface cover, wet aggregate stability, dispersible clay, antecedent water content, and the interaction terms involving the latter three on runoff and sediment load was explored. Using the stepwise variable selection procedure, the following equations were obtained:

$$ RO = 38.38 + 2.73 \text{ DC} - 1.09 \theta - 0.05 \text{ TP} - 0.16 \text{ SC} $$  \hspace{1cm} \text{[2]}

$$ (R^2 = 0.48, \ P = 0.01) $$

$$ SL = 32.01 + 1.97 \text{ DC} - 0.77 \theta - 0.04 \text{ TP} - 0.19 \text{ SC} $$  \hspace{1cm} \text{[3]}

$$ (R^2 = 0.46, \ P = 0.01) $$

The changes in stability and hydrologic robustness induced by forages were responsible for reductions in runoff and sediment load during forage phases. However, when conventionally-tilled corn was reintroduced the residual beneficial effects of forages on sediment load seems to have persisted, at least for one season. The beneficial effects on runoff seems to be less persistent. The results indicate that dispersible clay was a more important stability parameter than wet aggregate stability in determining runoff and sediment load when several variables, particularly time to ponding and surface cover, were involved.
Land Characterization

COMPRESSIVE AND CONSOLIDATION BEHAVIOUR OF AGRICULTURAL SOILS FROM THE R.M. OF HALDIMAND-NORFOLK

D.W. Veenhof and R.A. McBride

Compression of Structurally Intact Soils

Static, uniaxial compression lines for 285 soil cores (saturated and unsaturated) were measured as part of a larger N.S.C.P. study funded by Agriculture Canada ("Soil Compaction Risk Assessment for Corn Production in the R.M. of Haldimand-Norfolk"). Fitted non-linear regression coefficients \( r^2 > 0.990 \) were used to calculate the "compression index", or slope of the "virgin compression line" (VCL), and the preconsolidation stress for each structurally intact soil sample (Fig. 1). Using data on the amounts of clay and organic matter, degree of saturation and initial void ratio, a regression equation was formulated that allowed prediction of the compression index and the preconsolidation stress of the soils used in this study.

Compression data are shown in Figure 1 for the sandy clay loam Colwood Ap horizon (7-15 cm depth) that are very typical for most of the soils investigated in this study. The compressive behaviour of this topsoil under saturated and unsaturated conditions shows that the compression index increases with increasing initial total soil porosity and the degree of saturation has only a limited influence on the relative positions of the compression lines. Overall, the compression index showed a strong correlation with the initial void ratio, the initial water content and the previous stress history for both plastic and non-plastic soil types in this region of Ontario. An important conclusion drawn from this study is that the initial void ratio has a much greater influence on the configuration of the compression line of structurally intact soils than previously believed. The compression data also showed that the preconsolidation stress of the soils investigated was curvilinearly correlated to a "degree of compactness" index. The index \( D_x \) is simply the quotient of the initial void ratio \( e_0 \) in situ and a reference void ratio determined by static uniaxial compression to 0.2 MPa. This index was also found to be sensitive to changes in soil strength with variation in soil water content (i.e. strength increases with desaturation). A threshold index value of \( D_x = 1.3 \), representing a somewhat arbitrary division between soils that are susceptible to significant degrees of soil compaction from those that are not, was determined based on the relationship between \( D_x \), the measured preconsolidation stress and the soil water content at the plastic limit.

Comparison of Stress-strain Relationships (Remoulded vs. Structured)

A comparison of virgin compression lines (saturated, structurally intact) with their remoulded counterparts for the Haldimand-Norfolk soils indicated that the soil horizon depth (i.e. overburden pressure), the degree of past mechanical disturbance (i.e., tillage), the mode of soil deposition and soil plasticity are all important determinants of the consolidation behaviour of agricultural soils. The graphs shown in Figure 2 are from the same profile of the Kelvin soil series (loam textured till) and illustrate the full range of possible mechanical behaviour. In a well aggregated soil, the NCL (normal consolidation line) would be expected to plot below the VCL under saturated conditions (i.e., at lower void ratios for a given stress load) due to the structural bonds (organic and mineral) that would impart added soil strength to the structurally intact soil; bonds that would be disrupted during compression. This is true only in the case of the upper portion of the Kelvin series plow layer (Fig. 2a). At the base of the Ap horizon and in the upper B horizon, this relative displacement between the two compression lines is lost (Fig. 2b), indicating a more overconsolidated
condition in situ and the likelihood of increased orientation of phyllosilicates due perhaps to high vertical stresses from wheel loading and/or shear from soil engaging implements or rotating tires/tracks. It is therefore possible to segregate the soils of the R.M. of Haldimand-Norfolk into three categories based on the relative positions of these stress-strain functions under saturated conditions.

Furthermore, the study results suggest that this relationship between the VCL and NCL for a given soil is a more sensitive measure of the degree of soil overconsolidation than the more traditional preconsolidation stress variable.

Figure 1: Saturated and unsaturated compression lines in e(logσ) co-ordinates for a structurally intact, sandy clay loam Colwood soil (7.5 - 15 cm depth).

Figure 2: Compression lines (structurally intact and remoulded) measured under saturated conditions for the Kelvin soil series profile sampled at three depths a) 0 - 7.5 cm, b) 7.5 - 15 cm, and c) 15 - 30 cm.
Land Characterization

THE RISK OF SOIL COMPACTION IN THE R.M. OF HALDIMAND-NORFOLK

D.W. Veenhof and R.A. McBride

An evaluation of a soil water balance simulation model (SWATRE) was conducted for some of the major soil associations and landscapes where corn was grown in the Regional Municipality of Haldimand-Norfolk during the 1991 cropping season. The SWATRE model requires soil physical properties and crop characteristics along with climatic data as input in order to estimate soil water content profiles on a daily time step. Soil input data included a combination of measured and predicted soil water retention curves in conjunction with measured values of field-saturated hydraulic conductivity ($K_s$). The predicted soil water characteristic curves were validated with actual water retention data measured from structurally intact cores. Overall, the SWATRE model adequately simulated the soil water content and soil water extraction and replenishment patterns for the texturally disparate sites located in this regional municipality and under the climatic and cropping conditions found in this part of Ontario.

The SWATRE model was used in conjunction with a "degree of compactness" index ($D_v$) and climatic data for a 32 year period (1960-1991) to calculate probability distributions of exceeding a compaction susceptibility threshold value of $D_v$ equal to 1.3. Six sites representative of major soil associations in the regional municipality were modelled at four depths (7.5, 12.5, 22.5 and 32.5 cm). The $D_v$ index was calculated for each site from the daily soil water contents modelled from April 1 to November 30 for each of 32 years in order to determine the probability distributions. Probability distributions for a loam textured plow layer at two depths are shown in Figure 1.

The results from this stochastic analysis suggest that the soils which are the most susceptible to a significant loss of total soil porosity are the medium-textured soils (i.e., clay content of 20 to 35% kg kg$^{-1}$) that are imperfectly to poorly drained. The fine textured soil (clay content > 39% kg kg$^{-1}$) that was modelled in this way was found to be susceptible to compaction at only the 7.5 cm depth, while the lower depths were already sufficiently overconsolidated that they did not show any significant vulnerability to further compaction at any point during the growing or harvesting season. A coarse-textured (non-plastic) soil that was sampled from a no-till cropping system showed susceptibility to compaction only at the 22.5 and 32.5 cm depths, while the plow layer (7.5 and 12.5 cm) showed sufficient structural strength that it was not susceptible to any significant porosity loss at the 0.2 MPa stress load that was assumed throughout this analysis.

Figure 1: Probability distributions for exceeding a compaction susceptibility threshold of $D_v = 1.3$ for the loam Kelvin Ap horizon at two depths a) 7.5 cm and b) 12.5 cm.
USE OF DIGITAL IMAGE ANALYSIS AND GIS TO DETERMINE THE RELATION BETWEEN AGRICULTURAL CROPPING PATTERNS AND SOIL ASSOCIATIONS IN THE R.M. OF HALDIMAND-NORFOLK

M.L. Bober, D. Wood and R.A. McBride

Current information was required for the N.S.C.P. research/monitoring project on the distribution of agricultural crops (primarily corn and other row crops) in relation to the major soil associations mapped in the R.M. of Haldimand-Norfolk. Existing agricultural land use mapping was outdated (early 1980’s) and was based on farm systems rather than field-level crop classification. Landsat 5 Thematic Mapper imagery was obtained for this region for two dates during the middle of the growing season when the study area was relatively free of cloud cover (1 August 1990 and 3 July 1991). Visual assessments of land areas cropped in corn during the 1990 crop year were made in the field in the spring of 1991 (i.e., corn stover on plowed and unplowed fields). A more comprehensive survey of crop cover for the 1991 crop year was carried out in the summer of 1991 by ground inspection. Three large blocks were delineated within the regional municipality where the location and type of common field crops were noted on orthophoto base maps. This information served as "training areas" for digital image analysis with EASI-PACE and allowed statistical confidence levels to be calculated.

The 1991 crop cover results showed that the total area of the major crop groups (hectares) within three of the larger local municipalities as classified from the satellite imagery corresponded well to total areas obtained from the 1991 Census of Agriculture (Table 1). Field level verification of the 1991 crop classification further showed that the major row crop groups were correctly identified at between 82% (soybeans) and 100% (tobacco) of the time. Corn was identified correctly 88% of the time.

The generalized soil map (scale 1:100,000) for the regional municipality was not yet available in digital form from Agriculture Canada, so the map was digitized on the ARC/INFO geographical information system and imported into the SPANS GIS. This scale of soil mapping was chosen over the more detailed 1:25,000 inventory available for the region since the effective scale of Landsat 5 imagery (30 m x 30 m pixels) is about 1:50,000. Overlay analysis of the crop cover and soil association spatial information was carried out with SPANS. This analysis assisted in identifying soils that are the most susceptible to traffic-induced soil compaction during planting and harvesting periods given a) their present use for row crop production (including monoculturing), and b) the soil compression behaviour and soil compaction risk assessment test results for these soil associations (Table 1).

Table 1. SPANS cross-tabulation results of map unit areas (hectares) from an overlay of crop cover and the generalized soil inventory for the R.M. of Haldimand-Norfolk.

<table>
<thead>
<tr>
<th>SOIL ASSOCIATION</th>
<th>CORRESPONDING SOIL SERIES NAMES</th>
<th>TOWNSHIP OF NORFOLK</th>
<th>TOWNSHIP OF DELHI</th>
<th>CITY OF NANTICKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy loam sands with wind-modified surfaces</td>
<td>Flat, Brady, Gritney, Wantford, Normandale, St. Williams, Lovelands</td>
<td>2175</td>
<td>3375</td>
<td>1233</td>
</tr>
<tr>
<td>Sandy loam sands at least 100 cm thick, often duned</td>
<td>Plainfield, Wasingham, Waterline</td>
<td>4121</td>
<td>1984</td>
<td>152</td>
</tr>
<tr>
<td>Gravelly sands of fumar or till derivation, or 40 to 100 cm of sand or loam sediments over gravelly sands</td>
<td>Burford, Wiscowin, Scotia, Oakland, Verona</td>
<td>41</td>
<td>756</td>
<td>541</td>
</tr>
<tr>
<td>LANDSAT TM CLASSIFIED IMAGE AREA TOTAL FOR CORN:</td>
<td></td>
<td>9769</td>
<td>8205</td>
<td>10334</td>
</tr>
<tr>
<td>CORN AREA AS % OF MUNICIPALITY AREA THAT IS CLEARED AND AVAILABLE FOR AGRICULTURE:</td>
<td></td>
<td>33.0%</td>
<td>22.2%</td>
<td>20.8%</td>
</tr>
<tr>
<td>1991 CENSUS AREA TOTAL FOR CORN:</td>
<td></td>
<td>5853</td>
<td>6739</td>
<td>10595</td>
</tr>
</tbody>
</table>
A PEDOTRANSFER FUNCTION FOR ESTIMATING PRECONSOLIDATION STRESS AND ITS APPLICATION TO AGRICULTURAL SOILS IN SOUTHWESTERN ONTARIO

R.A. McBride and P.J. Joosse

The hypothesis was tested and corroborated in the laboratory that the compressive behaviour (static, uniaxial) of structured subsoils in the Regional Municipality of Haldimand-Norfolk can be predicted reasonably well from the consolidation behaviour of those same soils when in a remoulded (slurred) condition, and hence from their Atterberg consistency limits. The exception to this are soils that are sufficiently overconsolidated that their void ratio in the field translates into a liquidity index at saturation of less than about 0.25. In view of this finding, a soil survey interpretive procedure (or "pedotransfer function") was developed with the purpose of assisting in characterizing the degree of overconsolidation of subsoils without the need for an extensive and costly soil compression testing program. This pedotransfer function estimates a "first approximation preconsolidation stress" from dry bulk densities (void ratios) measured in situ and from other soil properties needed to estimate the "normal consolidation line" (NCL).

Preliminary testing of this simple function was carried out by assembling the necessary data on soil physical properties for all soil horizons characterized by the Ontario Centre for Soil Resource Evaluation (O.C.S.R.-E.; formerly the Ontario Institute of Pedology) for soil series mapped during the course of the last five county-level soil inventory upgrades in southwestern Ontario and that met the minimum data requirements (i.e., 210 soil horizons).

It was concluded that the solum (A and B) horizons of agricultural soils in southwestern Ontario are in a less compacted condition than the C horizon subsoils. If a tillage- or traffic-induced compaction problem existed, then it might have been expected to show up in higher estimated preconsolidation stresses in the B horizon, but this was not the case. Furthermore, many of the soils of finer-particle size are quite overconsolidated, whereas the coarser soil groups are much less so. The soil horizons with the greatest estimated preconsolidation stress values (mean > 150 kPa) tended to be glaciolacustrine C horizons that belonged to the fine clayey or very fine clayey particle-size classes and which had low organic carbon contents. Therefore, we might expect the coarser soils to exhibit compressive behaviour in the field very much like normally consolidated soils (i.e., very little prestress history in evidence) with a high degree of vulnerability to soil compaction from wheel loading. Fortunately, the amelioration of subsoil compaction by subsoiling is more easily achieved in these soils. The clay-rich soils, however, are not likely to be as vulnerable to the loss of total soil porosity with normal wheel loadings of 0.1 - 0.2 MPa at the soil surface, but may undergo other forms of soil structural degradation (shear, plastic deformation) that can be equally or more limiting to root growth.
SOIL COMPACTION ALONG TRANSMISSION LINE RIGHTS-OF-WAY AND ITS EFFECT ON CROP PRODUCTIVITY OF SELECTED SOILS

K.J. McKague (Ecologistics Ltd.), R.A. McBride (Univ. of Guelph), S. Rimmer (Ontario Hydro) and W.S. Scott (Ontario Hydro)

A total of 28 field locations were selected along the recently constructed Bruce Nuclear Generating Station-Longwood Transformer Station and Nanticoke Generating Station-Longwood Transformer Station transmission lines in southwestern Ontario. The locations represented a variety of soil types. Paired benchmark sites (on and off access) were monitored to determine the degree of soil compaction occurring along the right-of-way during the construction phase, as well as the effectiveness of the remedial measures (i.e., deep ripping or subsoiling) used by Ontario Hydro. Soil penetration resistance, moisture content, dry bulk density and other soil characteristics were measured at benchmark sites i) prior to construction activity, ii) immediately following transmission line construction, iii) following site remediation work, and iv) one year later when the construction access area was returned to agricultural production. The yields of the crops being grown on the benchmarks in years 1 and 2 after remediation (corn, soybeans, small grains, forage, etc.) were also measured by hand harvesting.

Crop yield data were analyzed statistically to determine if significant yield differences existed between the trafficked and untrafficked benchmark sites. Soils data were used to help explain the crop response observed. All soils underwent considerable compaction on the access roads, but the yield responses were very dependent on the textural group. Coarse-textured soils with some residual post-remediation compaction often showed a significant yield enhancement on the right-of-way due to improved moisture supplying capacity and a widening of the Non-limiting Water Range. The medium-textured soils showed the greatest crop yield response to mechanical site restoration. Fine-textured soils, even when protected by a temporary gravel access pad, were very sensitive to structural damage caused by wheel traffic by construction-class equipment. The physical properties of these clay-rich soils were often successfully restored to pre-construction values, but without necessarily eliminating severe crop yield deflation on the heavily trafficked areas. Guidelines were developed for determining compensation levels and for minimizing the impact of transmission line construction on affected agricultural land.

MEASUREMENT OF UNSATURATED HYDRAULIC CONDUCTIVITY USING TDR UNDER A RAINFALL SIMULATOR

G.W. Parkin, D.E. Erlick, R.G. Kachanoski, R.G. Gibson

Tillage practices may have a profound influence on the amount of rainfall which infiltrates surface soils. The measurement of unsaturated hydraulic conductivity (K) of soil may provide insight as to the impact of different management practices on soil-water status. We present a technique to estimate the hydraulic conductivity of surface soil based on Time Domain Reflectometry (TDR) measurements of transient soil water content beneath a rainfall
Land Characterization

Simulation device.

The theory of infiltration of water into an initially dry, ideal (homogeneous, isotropic, rigid, and nonswelling) soil shows that measurement of transient average soil water content in a fixed depth of soil beneath the soil surface gives an estimate of the volume flux density of water across the soil surface. An unsaturated soil under a constant rate of rainfall less than the saturated hydraulic conductivity will eventually acquire a fixed water content less than saturation. The time required to approach this equilibrium water content \( \theta_e \) depends on the ability of the soil to conduct water and the rainfall rate. At the equilibrium water content gravity is the only driving force for water flow. According to Darcy’s Law, the flux density of water under this condition is equivalent to \( K(\theta_e) \), the hydraulic conductivity of the soil at the equilibrium water content. The combination of TDR-based measurements of the flux density of water across the soil surface and \( \theta_e \) gives an estimate of the unsaturated hydraulic conductivity.

The experimental site was at the Agriculture Canada research station near Delhi, Ontario. The soil is well-drained with a loamy sand to sand texture. The rainfall simulation experiments were conducted in a corn field subdivided into conventional (spring moldboard plow plus secondary discing) and no till (disturbance by planter only) plots.

A total of 96 individual measurements of \( K(\theta_e) \) were obtained by using TDR under a rainfall simulator (single nozzle sprinkler) (Fig. 1). There is a wide scatter in measurements; however, the anticipated trend of a decrease in \( K \) with \( \theta_e \) is clear. The wide scatter in data points renders a critical data analysis rather dubious.

Intermittent ponding of water on the surface of conventionally tilled soil was probably due to a thin surface crust of low infiltrability. The effect of the surface crust was not detected by the TDR measurements. Crop residue and microtopography may have forced redistribution of water at the soil surface resulting in an increased scatter of \( K(\theta_e) \) measurements.

Fig. 1. An estimate of the unsaturated hydraulic conductivity of field soils using TDR-based measurements of soil volumetric water content.
BORON FRACTIONATION IN ONTARIO SOILS

J. Hou, L.J. Evans and G.A. Spiers

A chemical fractionation separately and sequentially on twenty-four Ontario soils with various physical and chemical properties. The scheme fractionated soil B into five fractions - a readily soluble fraction, which included both soluble and non-specifically adsorbed B (0.01 M CaCl₂); a specifically adsorbed fraction (0.05 M KH₂PO₄); an oxide bound fraction (0.20 M acidic NH₄-oxalate); an organically bound fraction (0.02 M HNO₃-30% H₂O₂); and a residual fraction (HNO₃-HCl-HF).

The major proportion of the soil B was found to exist in the residual fraction (87%), followed by 8.6% in organically bound forms and 2.3% associated with various oxides and oxyhydroxides. The readily soluble and specifically adsorbed B fractions generally accounted for less than 2% of the total soil B.

The distribution of B fractions from the sequential extraction procedure for five selected soils is shown in Figure 1. Readily soluble and specifically adsorbed B fractions in poorly and well drained sandy soils were greater than those in poorly and well drained clay soils (Fig. 1). On the other hand, readily soluble and specifically adsorbed B were barely detectable in the well drained clay soil. Larger amounts of organically bound B were found in poorly-drained soils as compared to well-drained soil. Soils with high organic C contents had larger amounts of organically bound B. The residual- or occluded-B fraction was the dominant B fraction, with most of the B presumably found within the crystalline structures of minerals, such as tourmaline or clay mica.

A highly significant linear correlation coefficient of 0.972 was found between the sum of the five B fractions and the total soil B content measured independently. Readily soluble B was positively correlated with pH and cation exchange capacity, while negatively correlated with contents of DCB-extracted Al. Specifically adsorbed B was only correlated with the DCB-extracted Fe content. Organically bound B was correlated with the content of both clay and organic C.

The scheme presented here should be useful for examining the forms of B in soils, both native and as soil amendments. It should also be useful in determining the effects of soil management practices on soil B status. Furthermore, the scheme will be useful for the development of an improved soil B extraction for assessing the plant requirements for B.

Figure 1: Distribution of B Fractions from the Sequential Extraction in Selected Soils of Different Texture, Drainage Class and Organic C Content

51
HEAVY METAL SOLUBILITY IN SEWAGE SLUDGE AMENDED SOILS

L. J. Evans, G.A. Spiers and G. Zhao

The long term benefits of applications of sewage sludges to land as an alternative source for plant nutrients are frequently limited by potentially toxic contents of heavy metals. While upper limits for metal contents in amended soils have been defined in both North America and Europe, there has been little attention paid to the fate of the metals if soil management practices are changed and the solubility and hence the mobility of the metals increased.

This study investigated the role of changes in pH and additions of chloride ions on the content of soluble Cd, Co, Cr, Cu, Pb, Ni, V and Zn in soils from Elora Research Station to which sewage sludge had been applied between 1972-1980. The mobility of the metals was investigated by a series of laboratory experiments in which the pH of the soils was adjusted by addition of appropriate amounts of acid or base to give a range in pH’s from 3.5 to 8. The mobility of the metals was investigated in the presence of two different background electrolytes - LiCl, containing the complexant Cl⁻ ion, and LiClO₄ containing the non-complexant ClO₄⁻ ion.

The soil used for the trials was a Conestogo loam (Gleyed Melanic Brunisol; Aquic Eutrochrept). To these plots were applied three different sludges - a Ca-sludge, a Al-sludge and a Fe-sludge. Only the results of the Al-sludge application at a rate of four times the lowest application will be discussed. The contents of DTPA-extractable metals in the soil from this treatment were 0.16 mg kg⁻¹ for Co, 1.75 for Cd, 0.1 for Cr, 8.8 for Pb, 67.5 for Zn, 26.8 for Cu and 1.0 for Ni.

The contents of soluble metals ranged from less than 1 μmol L⁻¹ for V to 500 μmol L⁻¹ for Zn (See Figure). For all the metals, contents were greater in the presence of Cl⁻ ions and increased markedly as the pH decreased below about pH 5.

Contents of V, Cr, Cu and Pb increased at pH’s above 7. As all metal contents were undersaturated with respect to hydroxide or carbonate precipitates, the changes in their contents were probably related to desorption from variable charge sites on mineral and/or humic surfaces.

Although current guidelines for the application of sewage sludge to agricultural land emphasize the metal content of the sludge and the soil, in addition to soil pH, other soil properties are known to influence the retention and mobility of toxic elements.

Results from this study will be of value in providing information on the soil chemistry of toxic elements to aid in the development of useful, and scientifically sound, guidelines for the application of industrial and municipal wastes onto land. The results will also aid in the development of strategies for the remediation of soils contaminated by heavy metals.
Land
Management
VARIABLE RATE TECHNOLOGY FOR N FERTILIZER APPLICATION

R. G. Kachanoski

Recent studies have indicated significant within field variability of fertilizer N requirements. Technology has also been developed for variably applying fertilizer within fields. However, procedures for obtaining the map which determines how the fertilizer should be varied are not defined and have not been evaluated. The overall objective of the study is to determine the feasibility of using variable rate technology for N fertilizer application, to maximize economic crop response while minimizing environmental impacts on water quality. Specific objectives include (1) To assess different methods of obtaining the field map for variable application of N fertilizer; (2) Determine the economic benefits of variable application of N fertilizers; and (3) Determine the change in potential nitrate loading to the groundwater from variably applying N fertilizer within a field compared to constant application.

Two main sites (S1, S2) were established in the spring of 1993 in Huron Co. near Londesboron, Ontario on the farm of Bruce Shillinglaw. Each site consisted of 4 adjacent blocks of no-till planted corn. Each block consisted of 2 treatments: (1) Fertilizer added (F) @ 160 kg N/ha, and (2) No fertilizer N added (NF). Each treatment was 8 rows of corn with 75 cm row spacing and a length of approximately 325 m. Spatial patterns of yield with fertilizer added and yield with no fertilizer were obtained from detailed hand harvesting (approx. 250 m hand yield samples per field). Yield patterns were also obtained using a commercial on-the-go yield sensor attached to a combine. Soil cores were taken in a dense grid from each field to obtain the spatial pattern of the soil N test. Extensive soil sampling to a 90 cm depth was also carried out in the fall period to obtain the spatial patterns of residual mineral soil N, and the subsequent loss of N by leaching. Soil water solution samplers were also installed at selected landscape positions in the fertilized and non-fertilized treatments to monitor the quality of leaching water. All of the instrumentation and sampling was referenced to a detailed elevation map of the site obtained from a laser theodolite survey of each site.

First year results indicate significant within field variability of soil N test (ie Coeff. Variation = 52%), yield with fertilizer applied, and the crop response to applied fertilizer (ie. yield with fertilizer minus yield with no fertilizer). Increases in yield from applied fertilizer N varied from essentially zero to over 3500 kg grain/ha. Fertilizer N requirements within the field varied from 0 to 170 kg N/ha. The variability was not random and was significantly correlated to topography. A single map of yield with fertilizer added would not be enough information for fertilizer recommendations. The yield gain from adding fertilizer N is required. Areas within the field with the highest yields were also the areas that did not require any fertilizer N. The measurements are being used to obtain the map for varying fertilizer requirements this coming growing season.

The yield measurements with the on-the-go yield sensor were highly correlated (r=0.92) to hand sampled yields. The sensor did an excellent job in mapping out yield variations. The only problem encountered with the sensor was a minimum yield requirement of approximately 1.8 t/ha for the sensor to work. The yield measurements from the sensor were accurate enough to detect the yield decreases every 10 m from the hand sampling locations. In 1994 fertilizer N will be applied variably and evenly to compare the economic and environmental benefits of this technology.
FIELD SCALE FERTILIZER RECOMMENDATIONS AND SPATIAL VARIABILITY

R. G. Kachanoski and G. L. Fairchild

Fertilizer is usually applied at a single constant rate across a field. However, soil fertility may vary considerably within a field. Soil test calibrations (i.e. recommended fertilizer versus soil test) are usually obtained from sites with low spatial variability of soil test values (e.g. small plots). These calibrations are then assumed to be valid for large fields with variable soil fertility. The effects of variable soil fertility on the relationship between average crop yield, average soil test, and fertilizer applied evenly to a field has not been examined. This study developed stochastic equations to describe the average field yield gain from the application of a constant rate of fertilizer, in fields with variable soil fertility. The equations were solved numerically for the case of nitrogen fertilizer on corn.

The results indicate that since the relationships between yield response, soil test, and applied fertilizer are non-linear, a single soil test calibration cannot exist for fields with different spatial variability. A family of calibration curves exist which depend not only on the mean soil test value, but also on the variability of soil test within a field. Soil test calibrations obtained from sites with low variability (e.g. small plots) will not hold for sites with higher variability (e.g. farm fields). In addition, calibrations obtained from sites with low variability will under predict the optimum fertilizer rate for maximum economic yield for sites with high variability of soil test. The results do not invalidate soil test calibration relationships. In fact, because of the spatial scaling problem, it is more important than ever to have accurate calibrations. The challenge is to combine these calibrations with additional knowledge about the spatial distribution and field scale variability of soil test values.

AGROGEOLOGY PROJECTS IN EASTERN AND SOUTHERN AFRICA: FROM ETHIOPIA TO ZIMBABWE.

P. van Straaten, A. Woldeab, A. Yematawork, S. Abera, R. Fernandes and W. Chesworth

Agrogeology is the application of geology to agriculture. Over the past 9 years agrogeologists from L. R. S. have worked with counterparts in Eastern and Southern Africa to improve the chemical and physical nature of soils by utilizing locally available geological resources. Three projects with L. R. S. participants are currently being supported by the International Development Research Centre (IDRC): in Eastern and Southern Africa.

Two projects in Ethiopia deal with rock phosphates and with soil moisture conservation using rock mulches respectively; research in Zimbabwe involves the development of alternative rock phosphate modification techniques.

Ethiopia

The projects in Ethiopia involve researchers from the Ethiopian Institute of Geological Surveys and the Institute of Agricultural Research and agrogeologists from L.R.S. In 1993, experimental plots using rock mulch were set up at two research sites, Melkassa and Zway. As in previous years, the mulched plots performed much better than the unmulched plots in the arid rift valley. Best results over a period of three years were achieved with volcanic scoria and pumice mulches with average yield increases of 125 - 193% over the control. Temperature measurements were
carried out at all mulched and unmulched plots at four different depths over a 14 hour period on March 24, 1993. The results show clear temperature differences, with unmulched plots reaching 48°C at a depth of 5cm as compared to 29°C in plots mulched with pumice and scoria.

Zimbabwe

The project in Zimbabwe involves researchers from the Institute of Mining Research (IMR), University of Zimbabwe, the Ministry of Agriculture, the Zimbabwean phosphate industry and agrogeologists from LRS. The project aims at producing low cost, adapted fertilizers for peasant farmers in communal areas using locally available geological resources. The project will develop agglomerated phosphate blends using Dorowa rock phosphate concentrates from the existing Dorowa phosphate mine, as well as fine-grained apatite from tailings which are currently being discarded, and flue dust that is lost from the stack during the drying process.

The process envisaged involves agglomeration of these geological resources with locally produced triple superphosphate (TSP) and is based on equilibrium data of the four component system CaO-P₂O₅-CO₂-H₂O and the breakdown of apatite (see Chesworth and van Straaten, Annual Reports 1992 and 1991). The first blended phosphates were successfully tested on a bench scale using a disc pelletizer, and a blender-compactor.

Dissolution experiments with Dorowa rock phosphate (DRP) and monocalcium phosphate (MCP) were conducted and the dissolution products and residues as well as physical and chemical changes on apatite surfaces studied by SEM and XRD. Initial results indicate that the predicted reaction of TSP hydrolysis-induced acidification takes place in the investigated products. There was clear evidence of the development of new phases in the blended material.

The field work in Zimbabwe included some much needed consultations with communal farmers. This participatory research in the early phases of the project was organized in cooperation with the Extension Service of the Ministry of Agriculture. The local farmers selected for consultation included elders, opinion leaders, master farmers and less skilled farmers in four wards of Buhera district. The consultations revealed that the farmers were interested mainly in upgrading their existing methods of improving soil productivity. Specifically to improve the existing and traditional techniques and inputs in manure composting. Consultations will continue throughout the duration of the project to ensure sustained participation of farmers in the application of the research.
THE EXCHANGE OF THE GREENHOUSE GASES N₂O AND CH₄ BETWEEN NATURAL AND AGRICULTURAL SITES AND THE ATMOSPHERE


Significant uncertainties exist concerning global sources and sinks of the greenhouse gases N₂O and CH₄. Unambiguous direct measurements of the exchange of these gases from agricultural and natural systems with the atmosphere are very important to enhancing our understanding of the global warming phenomena in several areas: rationalizing global budgets of greenhouse gases; developing resource management strategies; and contributing to global warming modelling efforts; and to the debate surrounding policy and the regulation of human activity leading to the emission of these gases.

A new method developed in the Department of Land Science several years ago has proven to be a powerful tool for the characterization of the exchange of greenhouse gases between the biosphere and the atmosphere and for studying those processes that control the emission. The method couples tunable diode laser (TDL) spectroscopy with traditional micrometeorological methods to directly measure the flux over a surface of interest.

Elora Research
Since its inception the method has been used extensively to measure the flux of CH₄ and N₂O from various ecosystems. One notable example is the study of N₂O flux from agricultural plots, being carried out at the Elora Research Station since the summer of 1991. The flux of nitrous oxide is being measured over bare soil, manured bare soil, alfalfa, and blue grass. Measurements over the past year have shown some interesting results. N₂O was highest over the non crop plots at spring thaw, and drying and wetting cycles initiated flux from these plots but not from the cropped plots. Ploughing of the alfalfa last fall resulted in a significant increase in the emission of N₂O. Overall, the emissions from the grass surface were very small and at times the grass was a sink for N₂O.

Wetlands Studies
Another notable example is our participation in the study of methane emissions over a wetland area located near Lake Kinosheo on the Hudson Bay lowlands. This measurement program was carried out during the Canadian Northern Wetlands Study (NOWES), a cooperative project with the Atmospheric Environment Service. The results of this study were key to the assessment of the rates of CH₄ exchange with the atmosphere from these wetlands.

TDL micrometeorological approaches have been applied to the study of the impact of reservoir creation on global warming, through our involvement in the Experimental Lakes Area Reservoir Project (ELARP). One of the major objectives of the ELARP is to quantify the emission of methane from a wetland ecosystem before and after flooding. To accomplish this a wetland area near Kenora, Ontario will be intensively studied for two years prior to flooding and at least three years after flooding; detailed measurements of CH₄ and CO₂ will be made from the vegetated area and the existing central pond of the wetland.

The Boreal Ecosystem - Atmosphere Study
The Boreal Ecosystem-Atmosphere Study (BOREAS) is an international, interdisciplinary scientific study which has the goal of improving our understanding of the interactions between the boreal forest biome and the atmosphere in order to clarify their roles in global change. Measurements of CH₄ + N₂O over a Boreal forest ecosystem near Prince Albert, Saskatchewan are being taken as part of this study.

Other studies that we have been involved in include: the
measurement of \( \text{CH}_4 \) emissions from rice paddies in the Philippines; \( \text{CH}_4 \) and \( \text{N}_2\text{O} \) flux over maize near Kearney Nebraska; \( \text{N}_2\text{O} \) flux over a fully developed wheat crop near Watkinsville, Georgia. All these efforts will ultimately contribute to the development of better land use management practices. In the case of agricultural systems this work should lead to the more efficient use of fertilizers, and lower emissions of greenhouse gases. And in the case of natural systems towards a better understanding and use of these valuable resources.
COVER CROPS FOR REDUCING LEACHING OF NITRATE IN THE FALL

M. J. Goss, J. A. Ferguson, W. Curnoe and P. S. Smith

Cover crops have been advocated for improving soil structure and the prevention of erosion. The potential of cover crops for preventing nitrate leaching in the fall has also been considered. Here the aim is to immobilize within the plant, nitrogen that is at risk of leaching in the fall and early spring. Uptake of nitrogen by non-leguminous cover crops can reduce the mineral-nitrogen content of the soil significantly in the fall compared with leaving the soil bare. In addition, cover crops can reduce leaching by increasing the water loss by evaporation relative to uncropped land. The magnitude of this effect depends on climatic conditions.

Two experiments have investigated the amount of nitrogen removed by cover crops. The first experiment aimed at comparing nitrogen uptake by different cover crops in the fall after liquid cattle manure was injected into the topsoil. The cover crops were either sown (eg. - oilseed radish - Raphanus sativus L. var. oleifera - , winter wheat - Hordeum vulgare L.) or were volunteers from previous crops (eg. - oats - Avena sativa) or were the principal weed that established after cultivation (eg. - mustard -Brassica juncea-). The second experiment concentrated on the effectiveness of spring oats as a cover crop when sown in late summer.

In the first study we found a good correlation between the amount of nitrogen immobilized in the plant (y kg N ha⁻¹) and the dry matter (x t ha⁻¹) produced in the fall (Fig. 1), given by:

\[ y = 43x - 10.2 \]

\( (r^2 = 0.987, \ p < 0.001) \).

The results of the first experiment together with other observations (Meisinger et al. 1991; Landmon, 1990) suggested that a key aspect of growing a fall cover crop to prevent nitrate leaching was the dry matter production. The second experiment tested this by measuring the uptake of nitrogen by spring oats sown in early August, at four densities: normal seeding rate (250 seeds per metre²), two times (500 seeds per metre²) and four times (1000 seeds per metre²) the normal rate. The soil was fertilized with 200 kg N ha⁻¹ prior to seeding.

Plants were harvested, and soil nitrate-N determined in late October a linear relationship was obtained between dry matter production and the nitrogen uptake (Fig 2). The dry matter production was closely related to seeding rate. As the seeding rate increased the amount of extractable nitrate in the soil also increased, while the amount of fertilizer that could not be accounted for in the soil or crop decreased with seeding rate (Fig. 3).

Figure 1. Uptake of nitrogen by winter wheat, spring oats, wild mustard, and oilseed radish cover crops grown in southeastern Ontario.

Figure 2. Effect of seeding rate on nitrogen uptake by spring oats grown as a fall cover crop.
These results show that nitrogen removal in the fall by cover crops is primarily dependent on the dry matter produced. They also suggest that the mineralization-immobilization turnover is directly affected by plant density. Another aspect of the adoption of cover crops to reduce nitrate leaching is the remineralization of nitrogen from the residues. We will continue to study this in further work.

REDUCTION OF AMMONIA USING BIOLOGICAL AIR FILTRATION SYSTEMS

B. Kettlewell, P. van Straaten and P. Voroney

Ammonia gas is one of the major air pollutants originating from agricultural activity. Biological air filtration, a relatively inexpensive pollution control technology is widely used in livestock farming and agriculture related industries in Europe.

The research carried out at LRS included studies of various packing materials with large surface areas and high cation exchange capacities. Mineral and peat based media were tested on their adsorption capacity of waste gas compounds and for suitability as microbial habitats.

Specifically, lava rock, wood bark compost, composted yard wood scraps, clinoptilolite-rich volcanic tuffs, vermiculite, and peat. Some of the materials were inoculated with nitrifying microorganisms.

Analyses of column media included NH₄⁺, NO₃⁻, and NO₂⁻, pH, moisture, electrical conductivity and cation exchange capacity.

During a preliminary trial period of 56 days (average loading rate 76.5 ppm NH₃) the inoculated bark compost/clinoptilolite mix exhibited a 100% ammonia reduction for the first 36 days and > 95% reduction for the following 20 days. A sterile bark compost/clinoptilolite mix with a loading rate averaging 71 ppm NH₃ maintained a 100% reduction for only 23 days and ammonia reduction dropped to 67% by day 45. This indicates that microbial activity is necessary for a sustained high rate removal of ammonia.

The inoculated bark compost/clinoptilolite mix performed better than sterile bark compost/clinoptilolite mixes indicating that nitrifying bacteria were probably responsible for sustained rates of ammonia removal from the air stream.

Inoculated clinoptilolite-rich volcanic tuffs maintained a 100% ammonia reduction for more than 80 days, and proved to be superior in terms of NH₃ removal than any other media.

Differences in nitrate and nitrite levels throughout the columns suggests that microbial activity and population dynamics may vary with distance from the air inlet.

In addition, we studied the feasibility and effectiveness of containing the filtration system within a barn. A small prototype biofilter 1.15 m diameter x 1.25 m high with a packing bed of 1.0 m was constructed and installed in a poultry room holding 300 laying hens at the Arkell Research Station. Ammonia levels in the room averaged around 12 ppm. The existing ventilation system was
not changed, the air flow through the filter was kept below 50 cfm. The experiment ran for 68 days and reduction rates of ammonia from the incoming air were in excess of 95%.

ALLELOPATHY OF CANOLA RESIDUES: ACTIVITY AND IDENTIFICATION OF PHYTOXINS

S. D. Wanniarachchi and R. P. Voroney

Plant material in the form of crop residues, cover crops and organic amendments is continually being added to the soil; therefore, plant debris in all stages of decomposition are always present in field soils. During the decomposition process, various organic compounds are produced and become involved in many biological interactions. These organic compounds exhibit a wide range of properties and their direct and indirect biological consequences are many and varied. Some of these compounds may have toxic or stimulatory effects on plants and microbes.

Field and laboratory experiments were conducted to investigate the allelopathy of canola (Brassica napus L.) residues during their decomposition in soil. A two-year rotation field experiment was conducted at the Elora Research Station to study the effects of over-wintered and partially decomposed canola, corn and soybean residues on the growth and yield of conventional till and no-till planted corn. Early corn growth was not affected by either canola or any other residues used. Canola and soybean residues had no detrimental effect on corn yield, irrespective of the tillage method adopted. However, corn no-till planted into corn residues on the surface had significantly lower plant density, grain and stover yield compared with control, suggesting a possible phytotoxic effect of corn residues. Phytotoxins, as measured by the presence of volatile fatty acids (VFAs) and total phenolic compounds (PCs), were not found in field soils.

Canola root, stem and leaf residues inoculated with soil, were incubated for 8 weeks in a laboratory study. Water extracts of residues obtained prior to and during incubation were significantly toxic to the seedling growth of barley, corn and winter wheat crops bioassayed, with leaf and root residue extracts causing the greatest and least inhibition, respectively. Leaf residues produced very high levels of VFAs during the initial incubation period compared to root and stem residues. Acetic acid was the most common and propionic, butyric and isobutyric acids were found only in leaf residue extracts. Leaf residue extracts had the highest amounts of PCs and phenolic acids followed by stem and root residue extracts. Phenolic acids in residue extracts were identified by HPLC and protocatechuic, p-hydroxybenzoic, vanillic, salicylic, caffeic, syringic, p-coumaric, ferulic and sinapic acids were found in residue extracts. No direct relationships between toxicity and amount of VFAs, PCs or phenolic acids were established. However, toxicity of extracts appeared to be most related to the presence of total phenolic compounds (PCs) in extracts and this was most evident with leaf residues.

Canola root and stem residues were mixed with soil and incubated at three different temperatures (5, 15 and 25°C) in a second incubation. Canola root and stem residues were phytotoxic to the seedling growth of corn and spring wheat crops bioassayed, with no significant difference in toxicity between root and stem residues. Temperature during incubation had no significant impact on toxicity produced, however, it had a significant overall effect on amounts of VFAs and PCs found. Phenolics in residue extracts decreased by nearly 90% when residues were mixed
with soil, and it is assumed that phenolics were adsorbed to the soil. No relationships were observed between toxicity and the amounts of VFAs and PCs. Synergistic effects of phenolics and acetic acid with unidentified toxins of plant and/or microbial origin may have caused the observed toxicity.

Canola residues had high levels of VFAs and PCs prior to the decomposition, however, the toxicity of canola residues to following crops may depend on the amount of toxins which remain in the residues after leaching in the field and the degree of decomposition residues have undergone prior to the sowing of the following crop. In summary, results of these experiments suggest that the allelopathy of canola residues is complex in nature, and cannot be fully explained without further experimentation on several aspects such as identification of other toxins involved, activity and persistence of toxins in soil, and effects of various soil properties on toxicity produced.

**GRADIENT-BASED MEASUREMENTS OF ISOPRENE FLUXES ABOVE A FOREST**


Volatile organic compounds (VOCs) emitted by vegetation are involved in ground-level ozone formation. Therefore, knowledge of source strengths of these VOC emissions, relative to sources from human activity, is essential to assess strategies for curtailing tropospheric ozone in the Windsor-Quebec corridor.

Total canopy emission of isoprene (C₅H₈), which is released by several common tree species and participates strongly in the formation of ozone in the presence of NOₓ, was estimated by a flux-gradient technique.

Isoprene samples were collected in stainless steel canisters over half-hour periods at the 25 m and 35 m levels above a mainly deciduous forest of canopy height ≈ 20 m at Borden, Ontario. Exchange coefficients (K) for the 25-35 m layer were computed from micrometeorological data taken on the same tower, and the isoprene flux (Fᵢ) was calculated from:

\[ Fᵢ = K (Clₑ₂₅₄ - Clₚ₃₅₄) \]

CI is the isoprene concentration.

A strong diurnal trend was observed in the data, with no detectable emissions in the dark and maximum mid-day emissions near 0.6 µg m⁻² s⁻¹ (See Figure).

This experiment was designed primarily to develop the field techniques required to measure VOC emissions. It was the first step in a larger scheme to provide VOC inventory data for both forest and agricultural species in Ontario.

Such data is required to formulate effective control strategies for low-level ozone.

![Isoprene Emission from Gradient Data](image)

*Isoprene Emission from Gradient Data September 1 and 2 (the sec. line), 1993.*
The map based on the accumulated heat units for the frost-free growing season, and used since 1964 for cultivar recommendations for the warm-season crops grown in Ontario, has been revised. The new heat unit map is based on daily temperatures for the 1961 to 1990 period. It shows the average accumulated crop heat units (CHU) for the frost-free season. Included in the Factsheet, with the new map is a table that illustrates the year to year variability in accumulated CHU.

Farmers who wish to choose less risk than one year in two (50% probability) of harvesting a mature crop should select cultivars requiring fewer CHU than the average for the area of their farm as indicated on the map. The number of heat units to subtract from the average CHU to determine specific probability or risk levels vary from 80 for a risk of one year in three to 280 for a risk of one year in 20.

All corn hybrids will now be rated with the accumulated CHU to the date on which they reach 32% kernel moisture. Soybean varieties will be rated with the CHU required to have 95% of the pods turned brown. Crop specific recommendation pamphlets will provide detailed information on these changes.
FORAGE QUALITY AS AFFECTED BY WEATHER DURING FIELD DRYING FOR HAY

D.M. Brown, A.G. Barr, D.M. Smith and J.E. Johnston

The model developed to estimate forage quality (SimForQ) at cutting and to simulate dry matter losses and changes in quality during field drying has been tested for sensitivity and validated using hay samples collected in 1991 and 1992.

The model simulates changes in acid detergent fibre, neutral detergent fibre and crude protein by post-cutting plant respiration, leaching, microbial activity and tedding leaf loss. Hourly climate inputs to drive the model include air temperature, humidity, rainfall, wind speed and solar or net radiation.

The model was tested for its sensitivity to initial forage quality, modelled forage moisture content and the crude protein susceptibility factor, using samples collected from hay swaths of 90% alfalfa and 10% timothy in a field at Elora Research Station (R.S.), for a June, 1992 cutting and prolonged drying period. The ability of the model to estimate changes in forage quality during ideal and prolonged drying conditions was tested using seven drying periods at Elora R.S. and two drying periods at New Liskeard. The herbage mixtures, stage at cutting and weather conditions varied considerably among the test drying periods.

Very little change in quality or loss of dry-matter was calculated or simulated in three rain-free drying periods. In four prolonged drying periods, simulated plant respiration and leaching accounted for 70% and 5% of the calculated dry-matter loss of 234 g kg\(^{-1}\). The loss of crude protein (57 g kg\(^{-1}\)) was simulated fairly well when crude protein was assumed to be half as susceptible to loss by respiration and leaching as other cell contents. A crude initial estimate of microbial respiration was added to the model in order to eliminate the discrepancy between calculated and simulated dry-matter losses.

Application of the SimForQ model indicated that it was very sensitive to the forage moisture content during the drying period. It was also found that the original drying subroutine, based on daily climate data was not adequate to correctly estimate that moisture content. Therefore, a new drying subroutine was developed and based on hourly climate data. This subroutine was calibrated and tested using twice-daily measured moisture contents of hay swaths from several cuttings at Elora R.S. and New Liskeard. The new hay drying (HayDry) model proved to be very satisfactory as the drying subroutine in SimForQ.

TIME AND INCORPORATION OF LIQUID DAIRY CATTLE MANURE ON SOIL N TEST VALUES

E. Dickson & E.G. Beauchamp

A corn trial was conducted in 1992-93 to determine how time and application and incorporation of liquid dairy cattle manure (LCM) affect soil N test values for corn. LCM was applied on September 23, and November 18, 1992, at a rate of 300 kg N ha\(^{-1}\) and either left on the surface or incorporated by moldboard or chisel plow-ing. Another LCM treatment (300 kg N ha\(^{-1}\)) was applied on May 13, 1993, and incorporated the same day by moldboard plowing. The plots that were not plowed in the fall were done so in the spring. Other plots received NH\(_4\)NO\(_3\) at rates of 50, 100, 150 and 200 kg N ha\(^{-1}\) that was incorporated during final seed bed preparations. There were four replications of each treatment.
Land Management

The first set of soil samples from 0-15, 15-30 and 30-60 cm were taken from the check plots only, just prior to LCM application, on September 20. A second set from the same three depths were taken on November 24 from the check plots and those plots which had received LCM. Beginning on April 26 and at 2-week intervals until the end of July, soil samples (0-30 cm) were taken from the fall- and spring-treated plots with LCM as well as those that received N fertilizer treatments. Although both NH₄⁺ and NO₃⁻ were analyzed, only NO₃⁻ data are presented here for several key dates.

The NO₃⁻ levels were generally higher on April 26 with the later LCM application in the fall, especially when incorporated by moldboard or chisel plowing (Table 1). Although the spring application of LCM produced a higher yield than most of the other fall applications of LCM, the NO₃⁻ level tended to be lower than with the fertilizer-N levels. The most economic rate of N (MERN) level determined with yield response data to spring-applied NH₄NO₃ and a quadratic model was found to be 106 kg N ha⁻¹ at a price ratio of 5. By June 16, the NO₃⁻ level for the spring application of LCM was higher than for the fall application treatments reflecting losses of N probably due to leaching, denitrification and NH₃ volatilization. Fall-applied LCM left on the surface tended to result in the lowest NO₃⁻ levels by June 16. This result was probably due to ammonia losses following application. The results so far suggest that the soil N test will not adequately reflect available N with a spring application of LCM.

Table: Soil nitrate and grain yield data with LCM applied in the fall and spring with different incorporation treatments.

<table>
<thead>
<tr>
<th>Source</th>
<th>Application Time</th>
<th>Tillage</th>
<th>Nov. 24</th>
<th>Apr. 26</th>
<th>May 20</th>
<th>June 16</th>
<th>Grain Yield</th>
<th>(t ha⁻¹, 15.5 % H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>check</td>
<td>check</td>
<td>check</td>
<td>24 a</td>
<td>38 b</td>
<td>50 e</td>
<td>65 ef</td>
<td>5.60 b</td>
<td></td>
</tr>
<tr>
<td>LCM(300)⁴</td>
<td>Sept 23</td>
<td>none</td>
<td>32 a</td>
<td>41 b</td>
<td>50 de</td>
<td>59 f</td>
<td>6.22 ab</td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>Sept 23</td>
<td>moldboard</td>
<td>36 a</td>
<td>41 b</td>
<td>62 cde</td>
<td>81 ef</td>
<td>6.27 ab</td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>Sept 23</td>
<td>chisel</td>
<td>31 a</td>
<td>45 b</td>
<td>55 cde</td>
<td>76 ef</td>
<td>6.47 ab</td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>Nov 18</td>
<td>none</td>
<td>46 b</td>
<td>66 cde</td>
<td>76 ef</td>
<td>6.86 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>Nov 18</td>
<td>moldboard</td>
<td>52 ab</td>
<td>77 bcd</td>
<td>94 ef</td>
<td>6.48 ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>Nov 18</td>
<td>chisel</td>
<td>61 a</td>
<td>85 bcd</td>
<td>100 ef</td>
<td>6.78 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCM(300)</td>
<td>May 13</td>
<td>moldboard</td>
<td>85 bcd</td>
<td>140 cd</td>
<td>7.10 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄NO₃(50)</td>
<td>May 17</td>
<td>cultivated</td>
<td>89 bc</td>
<td>106 de</td>
<td>6.77 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄NO₃(100)</td>
<td>May 17</td>
<td>cultivated</td>
<td>103 b</td>
<td>151 c</td>
<td>6.91 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄NO₃(150)</td>
<td>May 17</td>
<td>cultivated</td>
<td>155 a</td>
<td>200 b</td>
<td>7.09 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄NO₃(200)</td>
<td>May 17</td>
<td>cultivated</td>
<td>156 a</td>
<td>248 a</td>
<td>6.95 a</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data within columns followed by the same letter are not significantly different (P = 0.05). ⁴ Numbers in parentheses indicate kg N ha⁻¹ applied.
CORN CROP RESPONSE TO RESIDUAL N IN THE SECOND AND THIRD YEARS FOLLOWING APPLICATION OF UREA AND LIQUID CATTLE MANURE (LCM).

E.G. Beuchamp

At the Elora Research Station in 1988, 1989, and 1990 field trials were commenced and included the following treatments: control; 50, 100 and 150 kg urea-N ha\(^{-1}\); 100, 200, 300 kg LCM-N ha\(^{-1}\) applied in the spring before planting. Bromegrass was grown for the previous two years but received only 50 kg N ha\(^{-1}\) annually. Thus response of a corn crop to the highest rates of urea and LCM resulted in a doubling of grain yields compared with the control treatment in year 1 of each trial.

Corn grain yield responses to residual N were determined in years 2 and 3 of each trial. One-half of each plot was left untreated whereas the other half received 150 kg fertilizer N ha\(^{-1}\) each year. All plots were fertilized with P and K in excess of soil test requirements to ensure response only to N. The N-fertilized half of each plot provided a "maximum" potential yield to compare with the yield from the unfertilized half. The average maximum yields were 9.10 ha\(^{-1}\) (year 2) and 7.81 t ha\(^{-1}\) (year 3). The ratio (percentage) of yield without N fertilization to that with N fertilization provided a comparison of residual N from the urea- and LCM- treated plots, and the control plots in years 2 and 3.

The grain yield percentages averaged over the 3 trials are presented in the figure. In year 2, it is evident that there was considerable residual N from urea and especially LCM. The residual N effect continued into year 3 but to a lesser extent. With the exception of urea in year 3, the residual N effect tended to increase with increasing N rates. The average control plot grain yields were 3.51 and 3.08 t ha\(^{-1}\) in years 2 and 3, respectively. There were no indications that grain yields from the N-fertilized half of the plots were affected by residual LCM or urea.
A soil N test for corn has been developed that is particularly useful following nonleguminous crops. The time of incorporation of a forage leguminous crop has an unknown effect on the soil NO$_3$ levels at corn planting so that interpretation of the N test is difficult. A trial was conducted at the Elora Research Station in 1992-93 comparing NO$_3$ production following moldboard incorporation or chemical burn down (CBD) of alfalfa in late summer (Sept. 2), mid fall (Oct. 20) and spring (May 6). The alfalfa was planted in 1987 and was harvested 2 or 3 times annually until 1992. The alfalfa population was 30 plants m$^{-2}$ in 1992 which is less than half the recommended replacement population (65 plants m$^{-2}$).

The soil NO$_3$ levels (0-30 cm) for the plowdown treatment only are presented here inasmuch as they are similar to the chemical burn down/no till treatment (See Figure). Plow-down of alfalfa in early September increased soil NO$_3$ level by mid fall so that substantial NO$_3$ was available for loss over the winter months. Nitrate levels increased linearly from late April to early June with the late summer and mid fall plowdown treatments. From early June to the end of July, NO$_3$ levels for the mid fall treatment levelled off whereas those for the late summer plowdown treatment decreased. These trends probably reflect a balance between NO$_3$ release from the soil plus incorporated alfalfa and corn crop uptake. It is evident that the supply of available N with the mid fall plowdown treatment was greater than that for the late summer plowdown treatment. The spring plow-down treatment produced lower levels of NO$_3$ although in a similar pattern as the other treatments. The availability of N for the spring plowdown treatment was similar to that for the mid fall plowdown treatment as reflected in the corn grain yields (Table 1). The same yield trends were observed with the CBD/no till treatment.
Table 1. Corn grain yields following different dates of plowdown and chemical burn down/no till treatments.

<table>
<thead>
<tr>
<th>Treatment Time</th>
<th>Plowdown</th>
<th>CBD/no till</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kg ha⁻¹; 15.5% H₂O)</td>
<td></td>
</tr>
<tr>
<td>late summer (Sept. 2)</td>
<td>6401</td>
<td>6484</td>
</tr>
<tr>
<td>mid fall (Oct. 20)</td>
<td>6706</td>
<td>6933</td>
</tr>
<tr>
<td>Spring (May 6)</td>
<td>6763</td>
<td>6989</td>
</tr>
</tbody>
</table>

It is evident from results so far that spring plowdown will supply as much available N as mid fall plowdown of alfalfa. The release of available N with the spring plowdown is slower than that for the midfall plowdown and would not be reflected adequately with the soil N test. Late summer plowdown resulted in a higher potential for NO₃ loss over winter and lower corn grain yields (P=0.06) the following year. Thus it appears that plowdown or CBD would be more satisfactory later in the fall. It appears to be satisfactory to plowdown or chemically burnedown alfalfa in the spring ignoring our current inability to interpret the soil N test with such a treatment.

CORN CROP RESPONSE TO FALL VS SPRING APPLICATIONS OF UREA AND LIQUID CATTLE MANURE

E.G. Beauchamp

Field trials were conducted at the Elora Research Station in 1988, 1989 and 1990 to compare the response of corn to fall applications of urea and liquid cattle manure (LCM)(incorporated and not incorporated) with spring preplant applications. Low rates of N (50 kg urea-N ha⁻¹ and 100 kg LCM-N ha⁻¹) were applied so that the effects of time of application and incorporation could be measured in a "responsive" part of the "crop response to N" curve. It has been observed that the N in LCM is about one-half as available as fertilizer N. Bromegrass (50 kg N ha⁻¹ y⁻¹) was grown for the previous two years to create highly responsive trial sites. The applications in the previous fall were done on Oct. 14 (1988), Oct. 19 (1989) and Oct. 16 (1990). The plots were moldboard plowed immediately or left unplowed depending on treatment. In the spring (pre-plant) LCM and urea were applied May 15 (1988 and 1989) and May 8 (1990) and the plots were moldboard plowed immediately.

Corn (cv Pioneer 3902) was planted (60,600 plants ha⁻¹) 3 days following LCM and urea applications. Grain was harvested in mid October. Soil samples (10 cores plot⁻¹) were taken several times during late May or early June for NH₄ and NO₃ determinations.

Grain yield responses to urea and LCM applied in the fall were similar except in 1989 when the LCM treatments resulted in significantly lower yields (Table 1). There is no obvious explanation for this result in 1989, although it is perhaps noteworthy that the LCM used was extraordinarily high in total N and ammonium from a temporary change in manure management. Although there was some tendency for yields to be higher with the spring preplant than fall appli-
Land Management

cations each year, differences were not significant. Incorporation of either LCM or urea in the fall had no influence on yields. It is surprising that responses to the fall-applied N treatments were relatively high because it is commonly believed, that as often shown in other trials, N losses during the winter are substantial. The NO$_3^-$ concentration (0-30 cm) with preplant applications of urea and LCM was slightly higher than with fall applications. Both fall and preplant applications resulted in significantly higher NO$_3^-$ levels than with the control treatment.

Thus, although substantial quantities of applied N were retained during the winter period and became available for the next crop, the mode of this retention requires investigation. The availability of the fall-applied N appeared to be considerably greater in this study than is commonly assumed.

Table 1: Corn grain yields with urea and LCM applied in the fall or preplant.

<table>
<thead>
<tr>
<th>Source</th>
<th>N Rate (kg ha$^{-1}$)</th>
<th>Application Time</th>
<th>Incorporation</th>
<th>Grain Yield 1988</th>
<th>Grain Yield 1989</th>
<th>Grain Yield 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.99</td>
<td>4.35</td>
<td>4.68</td>
</tr>
<tr>
<td>urea</td>
<td>50</td>
<td>fall</td>
<td>no</td>
<td>5.49</td>
<td>5.84</td>
<td>6.74</td>
</tr>
<tr>
<td>urea</td>
<td>50</td>
<td>fall</td>
<td>yes</td>
<td>5.06</td>
<td>6.03</td>
<td>6.77</td>
</tr>
<tr>
<td>urea</td>
<td>50</td>
<td>preplant</td>
<td>yes</td>
<td>6.43</td>
<td>6.34</td>
<td>6.58</td>
</tr>
<tr>
<td>LCM</td>
<td>100</td>
<td>fall</td>
<td>no</td>
<td>5.29</td>
<td>4.55</td>
<td>6.02</td>
</tr>
<tr>
<td>LCM</td>
<td>100</td>
<td>fall</td>
<td>yes</td>
<td>6.71</td>
<td>4.80</td>
<td>5.96</td>
</tr>
<tr>
<td>LCM</td>
<td>100</td>
<td>preplant</td>
<td>yes</td>
<td>6.37</td>
<td>6.24</td>
<td>6.67</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td></td>
<td></td>
<td></td>
<td>1.48</td>
<td>0.75</td>
<td>1.01</td>
</tr>
</tbody>
</table>


DOES THE MORE EFFECTIVE MYCORRHIZAL SYMBIOSIS FOUND WITH REDUCED TILLAGE INCREASE CORN YIELD?

T. P. McGonigle and M. H. Miller

We have previously established that early-season P uptake by corn is greater under reduced tillage due to increased effectiveness of the mycorrhizal symbiosis. Here we present results of a recent experiment we conducted at Elora Research Station to determine if this stimulation of early-season P uptake is translated into greater yields. A range of soil P levels were established by fertilizing plots in an initially P infertile area (NaHCO₃-extractable test of 3 ppm) with rates of 0, 25, 50 and 100 kg P ha⁻¹ in the spring of 1991. The recommended rate based on soil test was 50 kg P ha⁻¹. Prior to the 1991 growth season the entire experimental area was plowed, disced, and cultivated.

Plots were given one of five tillage treatments: (i) CT, a conventional tillage treatment consisting of fall moldboard plow followed by spring discing and cultivating, (ii) CT-roto, which consists of CT plus one pass with a tractor-mounted rototiller, (iii) NT, which was no-till combined with the Guelph no-till planter, (iv) X-slot, a no-till treatment using the so-called cross-slot or T-slot planter developed in New Zealand, and (v) NTHP, a no-till treatment hand-planted using cork borers. These tillage treatments can be arranged in decreasing order of intensity of soil disturbance as follows: CT-roto > CT > NT > X-slot > NTHP. Tillage treatments were imposed following both the 1991 and 1992 growing seasons, and all plots were planted with corn in each of the three years 1991-1993.

The clear trend among tillage treatments was for increased early-season P absorption in association with reduced soil disturbance, a result that is consistent with our previous field experiments (Table 1). Significantly greater levels of mycorrhizal development were found in roots from the NTHP treatment compared to the CT-roto and CT treatments, at both the 3-leaf and 5-leaf stages. Plants in the NT plots had restricted growth at the 5-leaf stage, only reaching a dry mass of between 72% and 82% of that in the other tillage treatments (Table 1). The cause of the restricted growth in the NT treatment is not known; it does not appear to be due to P deficiency, as shown by the higher dry mass at lower shoot P concentration in the CT-roto treatment (Table 1). Restricted dry matter production during early growth under NT was also found in our two previous field experiments in this project.

The greater P absorption in the NTHP treatment compared to the CT-roto and CT treatments at the 5-leaf stage was not translated into higher yield at any of the soil P levels (Fig. 1). The yield in the CT treatment was significantly greater than that in the NT treatment at the two highest rates of applied P. This suggests that plants in the NT and possibly other reduced tillage treatments are held back by some unknown factor which prevents them from responding to the greater early-season P absorption. In short, it seems that plants under reduced tillage have restricted growth in spite of the greater P absorption from the less disturbed soil. In systems where the cause or causes for the reduced growth of NT compared to CT can be overcome, it may be possible to harness the stimulation of early-season P uptake under reduced tillage, and achieve desirable yields with reduced P application.
Table 1. Shoot dry mass, shoot P concentration, and shoot P content at the 5-leaf stage in 1993. Main effects means followed by different letters (a,b,c,d) are significantly (P=0.05) different; n=16.

<table>
<thead>
<tr>
<th>Tillage treatment</th>
<th>Shoot dry mass (mg plant⁻¹)</th>
<th>Shoot [P] (mg g⁻¹)</th>
<th>Shoot P content (μg plant⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT-roto</td>
<td>267 bc</td>
<td>2.78 a</td>
<td>761 ab</td>
</tr>
<tr>
<td>CT</td>
<td>289 c</td>
<td>2.96 ab</td>
<td>891 bc</td>
</tr>
<tr>
<td>NT</td>
<td>211 a</td>
<td>3.31 bc</td>
<td>711 a</td>
</tr>
<tr>
<td>X-slot</td>
<td>256 b</td>
<td>3.57 d</td>
<td>945 cd</td>
</tr>
<tr>
<td>NTHP</td>
<td>294 c</td>
<td>3.49 cd</td>
<td>1049 d</td>
</tr>
</tbody>
</table>

Fig. 1. Final yield of shelled grain at 15.5% moisture content in 1993. The vertical bar indicates the least significant difference (P=0.05) among tillage means; n=4.
Land Inventory & Stewardship
CENTRE FOR LAND AND WATER STEWARDSHIP

Dr. S. Hilts, Director
Dr. M. Goss, Chair in Land Stewardship
Mr. D. Robinson, Manager, Stewardship Information Bureau

The Centre for Land and Water Stewardship currently includes three main program areas:
- the research on nutrient management carried out by the Chair in land stewardship,
- the extension activities on private stewardship for conservation carried out by the Director,
- and the extension programs offered by the Stewardship Information Bureau.

During 1993, research on nutrient management continued, based in part on the results of the Farm Groundwater Quality Survey completed during the year. The major focus of this research is on the development of nutrient budgets for individual farms, using nitrogen as the key element for modelling. Through examination of such nutrient budgets, the extent of groundwater contamination can be predicted, and then evaluated in the field, giving a knowledge base for improved nutrient management recommendations.

Several key extension activities are being developed in the natural resources management area, including a new training program for extension staff of government agencies, a casebook and factsheet series for the Carolinian Canada program, and a set of ecological principles and guidelines for reforestation projects. Major effort is being placed on the development of a 'Conservation Planning Handbook' for rural non-farm landowners, to serve as a parallel to the Environmental Farm Plan for farmers.

The former Soil and Water Conservation Information Bureau became the 'Stewardship Information Bureau', winning a four-year contract under the Green Plan program of Agriculture Canada. To provide a more publically accessible location, the Information Bureau moved to the University's Research Park, on Stone Road in Guelph. It is developing an 'Innovation Network' of farmers, government extension staff, and researchers, it provides state-of-the-art information on land and water stewardship to the farming sector.

The Bureau produces a newsletter called "Innovations," is involved in a program to develop a coordinated set of factsheets among Ontario government Ministries, and is spearheading a farm-level project to optimize economic and environmental benefits in farming.

A key effort of the Director of the Centre during 1993 involved arranging and running a major University Symposium on Restructuring. With financial support from Dr. Donald McQueen Shaver, this symposium brought four outstanding speakers to Guelph, and attracted an audience of 400 to kick-off the University's own restructuring process.

Finally, the Centre is currently providing leadership for the development of an Environmental Communications Network on the campus. A newsletter has been initiated, an inaugural meeting was held, and a Directory of Environmental Expertise at Guelph is now in preparation.

One of several highlights during the year was the naming of Professor Stewart Hilts, Director of the Centre as the 'OAC Alumni Distinguished Extension Professor'.

See also descriptions elsewhere in this Annual Report describing research and publications by S.G. Hilts and M. Goss.
**Land Inventory**

**PREPARATION OF A CONSERVATION PLANNING HANDBOOK FOR RURAL NON-FARM LANDOWNERS**

*S. Hilts, P. Mitchell, S. Shore, P. Chauvin, and B. Wilton*

During the 1993 year, further testing and development of a Conservation Planning Handbook was undertaken. Amalgamating information from a wide variety of sources, this handbook aims to provide a framework for rural non-farm landowners to use in managing their land, in the same way that the Environmental Farm Plan provides a framework for farmers.

Ten brief property inventories have been conducted, on a group of rural properties selected from two case study areas - the Hamilton region, and in Grey County. Visits are being conducted with each, and the input of these landowners is being used to prepare the final contents of the manual. Extensive literature review has also been conducted to provide information on the specific components of the manual.

The handbook is being organized around eleven basic 'ecosystem elements' which can be used to describe the rural landscape.

- The Homestead
- Agricultural Fields
- Streams
- Ponds
- Woodlands
- Wetlands
- Old Fields and Meadows
- Fencerows and Shelterbelts
- Wildlife
- The Surrounding Landscape
- Paths, Trails and Roads

For each of these elements, a series of possible management options will be presented, in simple graphic form. The handbook is being modelled after the Australian Whole Farm Planning Handbook, and is supported by the Ontario Heritage Foundation's Niagara Escarpment Program.
PREPARATION OF A LANDOWNER CASEBOOK AND FACTSHEETS FOR CAROLINIAN CANADA

S. Hilts, P. Mitchell, S. Shore, and B. Wilton

Over the past ten years, several related research and extension projects have been carried out involving landowners of significant natural areas in the Carolinian Canada region. This work has involved development of the 'private stewardship' approach to conservation. A major effort the past year has been a review of this work at the landowner level. A series of six factsheets is in the final production stage, providing further practical information for landowners on managing forested areas.

In addition, a series of in-depth interviews were conducted with both selected landowners and government agencies participating in the program. This enabled documentation of the impact of past extension efforts on landowners, and of the extent of follow-up activities by agencies. In this context, the concept of the 'lead agency' was evaluated. Results are being summarized in a Carolinian Canada Landowner Casebook, with financial support from the Ontario Heritage Foundation's Carolinian Canada Program.

DEVELOPMENT OF GUIDELINES FOR REFORESTATION PROJECTS IN THE GREAT LAKES BASIN

S. Hilts, P. Mitchell and C. Plosz

There is currently widespread public interest in tree-planting, as a practical step citizens, including school children, can take to help 'green' the environment. However, many tree-planting projects are planned on an individual, ad hoc basis. With support from the Laidlaw Foundation, a set of practical principles and guidelines are being developed for local community groups. Based on an extensive literature review, these guidelines will complement available information on how to plant and care for trees, by providing some of the broader principles to take into account during the design of reforestation projects. A major workshop to review the draft guidelines is being organized for March, 1994.
EVALUATION OF LAND TRUSTS IN ONTARIO

S. Hilts, P. Mitchell, and A. Anderson

Continuing several years work, a study of the potential role of Land Trusts as conservation organizations is now taking a national perspective. Land Trusts organizations from across Canada are being contacted with a short questionnaire, and a detailed interview by phone. Information on the origin, size, types of programs, and focus of interest is being compiled, to provide a basis for evaluation. Initial information will appear in a Directory of Canadian Land Trusts.

One special focus of this research is the use of Land Trusts to protect agricultural land. Information on cases from Ontario, New Brunswick, Saskatchewan, and British Columbia is being compiled on this question.

Major effort is going into examination of legal questions related to Land Trust operations, with the cooperation of an interested group of lawyers. A book, entitled Creative Conservation: A Handbook for Ontario Land Trusts, has been published, and a workshop for Land Trust organizations in Ontario was held in Toronto in November, 1993. Support comes from the Environmental Partners Fund through the Federation of Ontario Naturalists, and from the Ontario Ministry of Agriculture and food, through the University’s Program 40.

DEVELOPMENT OF A TRAINING PROGRAM FOR MNR, OMAF AND CONSERVATION AUTHORITY EXTENSION STAFF

S. Hilts and P. Mitchell

At the request of the Sustainable Forestry Branch of the Ministry of Natural Resources, the Centre for Land and Water Stewardship has developed a major new training program for the extension staff of MNR, the Ministry of Agriculture and Food, and Conservation Authorities. The program brings staff together for an intensive week of discussions, practical cases, and information. The focus is on integrating the work of all extension staff in these agencies, providing a 'holistic' approach to rural land stewardship.

Four pilot programs were held during 1993, at Midhurst, Kemptville, New Liskeard and Port Burwell. Input from the participants is being used to modify and expand the Training Manual, 'Ecological Land Stewardship' which is now in the final stages of production. Evaluations of all training events were very positive, with many staff members of different agencies meeting one another, and becoming aware of perspectives held by staff of other Ministries for the first time.
Publications
Papers Presented
Seminars
TITLES OF BOOKS AND CHAPTERS IN BOOKS


PUBLICATIONS IN REFEREED JOURNALS


NON-REFEREED REPORTS AND PUBLICATIONS


SEMINARS AND PAPERS PRESENTED


DEPARTMENTAL SEMINARS


Campbell, Lindsay, C. Department of Agronomy and Horticultural Science, University of Sydney, Australia. Color Pictorial Decision Support System for Diagnosis of Nutrient Deficiencies. December 10th, 1993.

L.R.S. Family Album