NATIONAL SOIL CONSERVATION PROGRAM

RESEARCH COMPONENT

SUMMARY REPORT

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EXECUTIVE SUMMARY

The purpose of the National Soil Conservation Program (NSCP) Research Component was to encourage research related to soil management practices toward the long term productivity of soil. The research sub-program was given a budget of $1.1 million for the two year duration of the program.

The initiation of the process to handle this component began in the fall of 1990. Dr. W. I. Findlay was appointed Scientific Authority for the solicitation of proposals for Soil Conservation Research. Through numerous committee meetings and with the assistance of individuals from the private sector, university, OMAF and Agriculture Canada, areas of concern were consolidated to issues which were subsequently developed into a "Statement of Work: which would be part of the Request for Proposals (RFP). Proposals totalling $4.45 million were submitted for consideration against the $1.1 million available. A rigorous review system, often involving out of province referees, was used with a preplanned evaluation criteria form. Twenty-nine referees were involved in the initial cut prior to committee priorization. Six proposals were selected for contract, three for in-house support and two for contribution agreements. In addition, a literature search on buffer strips was supported.

All of this effort was completed before Dr. Findlay announced his pending retirement in the late spring of 1991. His dedication and thoroughness as Scientific Authority set the stage and paved the way for the smooth running administration of these research projects. A sincere expression of gratitude is extended to him on behalf of myself and all those involved in the initial organization (many of whom have now also retired).

The following pages present a short summary of the proposal selection process (in addition to the above), the statement of work, and the successful recipient. In each case where research was carried out, an Executive Summary (prepared by the awardee) and/or an edited version of the conclusions is provided. This document provides a "snapshot" of the findings related to the projects for which detailed reports are maintained separately.

Respectfully

A. S. Hamill, Ph.D., P. Ag.
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RESEARCH SUB-PROGRAM OF THE NATIONAL SOIL CONSERVATION PROGRAM

BACKGROUND

The overall purpose of the National Soil Conservation Program was to encourage the implementation of appropriate soil resource management practices to maximize societal benefits and sustain the long-term productivity of soil with the framework of environmentally sustainable agriculture.

The Canada-Ontario Agreement on Soil Conservation provided for $11.1 million from both Canada and Ontario in matching funds over a three year period ending March 31, 1993. The Monitoring, Research, and Soil Survey activities under the Canada portion of the agreement had a budget of $1.1 million each.

The Research component of the program was administered for Agriculture Canada by the Harrow Research Station. The key processes of land use, tillage practices and cropping systems that result in changes in soil quality were studied in terms of the sensitivity of soil to degradation, the conditions under which degradation occurs and its impact on productivity. A major task was research into changes in soil organic matter, nutrients, erosion, and pesticide levels related to land use, tillage practices and cropping systems for intensively cultivated land.

Projects were carried out by Agriculture Canada, universities, colleges or other agencies.

RESEARCH AREAS

1. The following areas of research were considered for support:
    (a) the development of soil management systems that protect fragile land and improve the environment, and are economically viable.;
    (b) the development of indicators of degradation or conservation that can be used in monitoring the resource base;
    (c) development of methods to improve the transfer of conservation technology, e.g. "expert systems".

2. Preference was given to projects which were complementary to ongoing Federal and Provincial related research activities in soil and water conservation e.g. Soil and

Water Environmental Enhancement Program (SWEEP), Great Lakes Water Quality Agreement and the Land Stewardship Program.

3. Preference was given to extend existing research projects, as compared to starting new research projects.

4. Preference was given to projects where there was good potential for commercial application of specific research results that had high potential for improvement of soil and environmental quality.

UNIVERSITIES, COLLEGE, AND PRIVATE AGENCY COMPETITION

Within the general guidelines offered above, specific issues were defined by the Implementation Committee in Ontario for Canada's portion of the agreement. Competitions were based on five issues plus one open category subject to the guidelines above. These issues are:

- A) Soil macropore structures resulting from tillage and their effects on solute transport;
- B) Manure management to sustain water quality;
- C) Response of crops to soil quality;
- D) Influence of soil management systems on soil quality (e.g. soil biota);
- E) Methodologies for assessing soil structure (degradation) in a meaningful way;
- F) An open category to accommodate unique ideas about soil quality within the terms of the NSCP program not included in the identified issues above.

One competition was open to Universities, colleges and other agencies in Ontario. It excluded federal research stations and laboratories except where collaborative participation at no additional cost was indicated. This call for research proposals was distributed through Supply and Services Canada (SSC) with statements of work under the following titles:

Statement of Work Title:

Project A: Soil Macropore Structures and Their Effect on solute Transport to Tile Drains

Project B: Manure Management to Sustain Water Quality

Project C: Prediction of Crop Responses to Changes in Soil Quality
Project D: Influence of Soil Management Systems on Soil Quality
Project E: Methodologies for Assessing Soil Structure (Degradation) in a Meaningful Way
Project F: Open Category RFP under the NSCP Research Program

Level of Effort

The suggested level of effort was $50,000.00 annually for two years ($100,000) ending March 31, 1993.

IN-HOUSE COMPETITION

The issues to be addressed by Federal Research Stations under Canada's portion of the agreement follow. This competition is based on five issues plus one open category subject to the guidelines above. These issues are:

A) Soil macropore development as a mechanism for root distribution and solute transport
B) Composting of manure as a means of sustaining water quality;
C) Prediction of crop seedling responses to changes in soil quality;
D) Soil biota as indicators of soil quality;
E) Methodologies for assessing soil organic matter sustainability;
F) An open category to accommodate unique ideas about soil quality within the terms of the NSCP program not included in the identified issues above. The In-house component was more clearly, but not exclusively related to the effects of cover crops compared to the University and private sector. It was considered that the two lists, those in-house and those to the private sector and University, would be complimentary. Further coordination occurred during proposal review. Redundancies, where noted were resolved among qualified proposals in favour of the private sector.

The separate call for proposals for in-house research was held for federal research institutions on issues complimentary to those described above.

For these proposals statements of work were established with the following titles:

Title:

Project G: Soil Macropore Development as a Mechanism for Root Distribution and Solute Transport

Project H: Composting Manure as a means of Sustaining Air and Water Quality

Project I: Prediction of Crop Seedling Responses to Changes in Soil Quality

Project J: Soil Biota as Indicators of Soil Quality

Project K: Methodologies for Assessing Soil Organic Matter Sustainability

Project L: Open Category RFP under the NSCP Research Program

Level of Effort

The suggested level of effort was $40,000.00 annually for two years ($80,000.00) ending March 31, 1993.

DELIVERABLES AND PROPOSAL FORMAT

A detailed list of deliverables was provided to the respondents as well as a format for presenting the proposals.

PROPOSAL REVIEW

Included with the call for proposals was a copy of the "evaluation criteria" (Appendix A) which was to be used by the Proposal Review Committee when the proposals were reviewed. This Committee consisted of a representative from the following groups: Agriculture Canada, Ontario Ministry of Agriculture and Food, University of Guelph, Ontario Soil and Crop Improvement Association and the Scientific Authority (Harrow Research Station representative, as chairman).

RESPONSE TO THE CALL FOR PROPOSALS

An overwhelming response was obtained both from the SSC competition and the in-house call, with 24 and 27 proposals being received in each respectively. The value of 48 proposals deemed appropriate for NSCP funding totalled $4.45 million, a measure of the level of participation by the scientific community.

The proposals were circulated in groups of 4-5 to 29 outside referees who were asked to provide technical evaluations and peer review. The cooperation from soil scientists and other specialists was outstanding. The evaluations by the referees were used by the Proposal Review Committee to generate a short list of the best proposals prior to a meeting for final prioritization.

The following pages present the project titles and a brief summary of the results as presented by the successful bidder.

PART I - RESEARCH CONTRACTS THROUGH SSC

Project A

Title: Soil Macropore Structures and Their Effect on solute Transport to Tile Drains

Purpose:

Recent evidence suggests that contaminants such as phosphorus, pesticides and bacteria are rapidly transported to tile drains by rainfall events shortly after surface application. Such transport most likely occurs through macropores.

Objectives

1. To characterize macropore transport of contaminants to tile drains.
2. To suggest or develop soil management systems which will curtail excessive amounts of such transport.

Scope

This statement of work is quite specific in its requirements. The technical approach to the problem should be well defined, and supported with the laboratory and scientific equipment necessary to perform the soil physical measurements required. Alternatives to natural precipitation events should be considered if field studies are involved. The data collected should be valid for use in extrapolating the results to a number of soils and soil management situations.

Successful Bidder

Environmental Soil Services (Dr. R. G. Kachanoski) - $96,924.00

Effect of Macropores on Contaminant Transport to Tile Drains

Environmental Soil Services;
Dr. R. G. Kachanoski and Dr. I. J. van Wesenbeeck

A series of solute transport experiments were conducted to determine the effect of surface soil boundary conditions, initial soil water content and water application rate on the movement of reactive and non-reactive tracers. Experiments were conducted at four sites in southern Ontario over a range of soil textures, where migration of agricultural chemicals to the water table or tile lines may pose a serious threat to water quality. The selected sites were near Alliston, Brantford, Crediton, and Woodslee where intensive characterization of soil hydraulic and solute transport properties was being conducted under a separate GLWQ study.

Specific objectives of this study were to characterize the macropore transport of reactive and non-reactive chemicals through the root zone in representative Ontario soils and to determine the effect of surface and initial soil boundary conditions on the movement of contaminants through soil macropores. Plot scale tracer experiments were conducted to compare treatments that included simulated tillage incorporation of chemicals into the soil surface, surface spreading (non-incorporation) of chemicals, and varying water application rate and timing. The information collected also provides input into a data base with soil hydraulic, physical and chemical modelling parameters for use in the Great Lakes Water Quality modelling project, the National Soil Conservation Program, and the Soil Quality evaluation modelling projects.

Results indicate that the tillage incorporation of the chemical into the top 10 cm of soil significantly reduced the loss of both reactive and non-reactive tracers from the root zone, and hence would minimize tracer migration to the water table or tile lines. The effect of tillage incorporation was especially significant in the heavier textured soils, but some effect was also measured in the lighter texture soils. Tillage incorporation results in a 500% increase in surface (0-10 cm) absorption of a reactive tracer compared to non-incorporation. The effect of the tillage is to disrupt the macropore continuity and mix the tracer into the finer pores of the soil matrix where it is bypassed by the infiltrating water. Higher soil water content at the time of tracer application also resulted in more loss of tracer from the root zone. This was related to the increase in water filled pores, especially macropores, at the higher water contents.

Deep transport of both the reactive and non-reactive tracers occurred for all treatments and water application rates indicating that significant preferential flow of contaminants can occur even under unsaturated conditions.

Measurements of hydraulic properties using the Guelph Pressure permeameter and undisturbed core were completed. The measurements indicated significant variability as would be expected at sites with significant macropore flow. However, average values of the hydraulic properties would not have predicted the preferential flow and transport that was observed at the sites. Thus, it is likely that the occurrence of fast transport of surface applied chemicals will have to be predicted by including additional information from a site.

Conclusions

1. Reactive and non-reactive tracer (Sr and Cl) were found at depths well below the mean depth predicted by the amount of applied water, and the soil water content, for all treatments at all the study sites.

2. Incorporation of the tracer into the soil surface by tillage significantly reduced the loss of the tracers (reactive and non-reactive) to the approximate depth of the water table or tile lines. The effect was most noticeable in the clay sites where there were significant cracks, soil structure, and macropores. In these soils, tillage incorporation increased the retention of a reactive tracer in the top 10 cm of soil by over 500%. The effects of tillage were two-fold:

   i) tillage appears to have destroyed pore continuity resulting in less flow of contaminant through the macropores, and

   ii) tillage caused mixing of the tracer into the finer pores of the soil matrix where it was bypassed by macropore flow.

3. Solutes leached under transient conditions generally exhibited greater recovery at the high and low rates compared to the prewetted soils. However, significant amounts of deep transport did occur in the transient treatments for a portion of the solute

mass, especially at the high rate. The bulk of the reactive tracer in the shallow layers is related to the initial sorption of water into the initially dry soil matrix, until steady state 0_v is attained. Solutes are then bypassed as the matrix water content increases, and the flow bypasses the matrix. This effect was noticed most in the clay sites, and least of all in the sandy sites.

4. The above result also indicates that solutes applied to the soil are more likely to reach tile lines or to the water table if the initial soil water content is high at the time of chemical application. Results of the biotracer experiments by the Ausable-Bayfield Conservation Authority showed that transport of bacteria to the tile lines occurred much more rapidly if the soil was near saturation.

5. Retardation of Sr was greatest at the low rates of water application for all of the soils. This shows the importance of retention time for the adsorption and degradation of chemicals in the soil. Tillage incorporation also has the effect increasing retention time of a solute in the soil matrix, thereby allowing it to reach equilibrium adsorption and reducing downward movement of the tracer.

Project B

Title: Manure Management to Sustain Water Quality

Purpose

A major contributor of nitrate-N to groundwater is application of livestock manure, even when applications are consistent with the agricultural code of practice. Application of manure in late summer or fall, frequently on sod prior to fall plowing results in excess concentrations of nitrates in the soil during the fall and spring leaching periods. However, it is usually difficult for farmers to apply manure at a time when crop demand for nitrogen is high. Approaches such as manure composting and use of cover crops have potential to convert the N to an organic form and release it for crop use in the subsequent season.

Objectives

1. To evaluate methods of manure management designed to retain the nitrogen in a non-leachable form during the fall and winter following application.
2. To measure the effectiveness of these approaches as a means for supplying nitrogen to a crop during the subsequent growing season.

Scope

This statement of work is quite specific in its requirements. The technical approach to the problem should be well defined. In light of the short period of funding and the need to produce definitive results within the time frame of this program, the proposal should clearly indicate how the management of manure and the production of a subsequent crop is to be handled. The description of existing or ongoing work which may contribute to a proposal should be given in sufficient detail to permit assessment of the opportunity for success.

Successful Bidders

Ecologistics Limited; Dr. D. R. Cressman - $98,008.00
University of Guelph; Dr. M. J. Goss - $97,953.00

The Evaluation of Three Manure Composting Methods for Nitrogen Conservation Environmental Impact, Crop Growth Response and Operating and Maintenance Costs

Ecologistics Limited;
R. St. Jean - Project Leader

Conclusion

The data collected for the passive aeration, turned pile and forced aeration composts and a control pile of stored manure did not indicate a significant difference in nitrogen volatilization losses between treatments. The losses ranged from 30.1 percent for the passive aeration compost process to 44.4 percent for the control pile of manure. The data did indicate that the three composts and control pile of manure underwent different degrees of stabilization, as indicated by the significant differences in carbon loss. Carbon losses ranged from 18% for the forced aeration compost to 36 percent for the turned pile compost. The data showed a general trend of higher nitrogen losses from the manures which underwent the highest levels of stabilization. The control pile of manure actually showed the highest level of nitrogen volatilization losses, although not statistically significant.

The peat moss cover skin on the passive aeration windrow demonstrated an excellent capacity for nitrogen retention. Nitrogen increased by a factor of 1.87 during the composting process. However, approximately one third of it was in the ammoniacal form and would be very susceptible to loss during handling and spreading of the solid material. It would also require thorough mixing with the compost in order to make effective use of the additional nitrogen. The data indicated that a 50.8 percent reduction in carbon occurred in the cover skin resulting in a concentration of nitrogen to 4.3 percent on a dry matter basis.

It was observed that composting of livestock manures can not be completed under covered conditions without the addition of moisture, to maintain levels above the 45 percent range at which moisture becomes limiting to the biological process. Moisture levels in the finished composts ranged between 21.8 percent for the passive aeration compost to 33.3 percent for the turned pile compost. The three composts and control pile of manure were retained under cover for an 8 to 12 month curing period, irrigated to a 50-60 percent moisture level and mixed to assess their potential for reheating. All materials reheated to active composting temperatures in the 45 to 60EC range, indicating that the rapid biological stabilization activity associated with composting was not complete. The high evaporative capacity of composting manure indicates it has potential as a treatment process for barnyard runoffs and dairy farm milkhouse washwater.

Leachate analysis indicated that the potential for nitrogen loss by leaching was not significantly altered by the composting processes examined. But, the compost with the greatest degree of biological stabilization had the lowest mean nitrogen levels in the leachates, indicating a possible trend. Distilled water leachates contained total Kjeldahl nitrogen (TKN) ranging from a mean of 240 mg/l for the turned pile compost to 399 mg/l for the raw manure used in the composting processes. Differences were not statistically significant, however, composting did result in higher levels of phosphorus in the acetic acid leachates from compost, compared to raw manures. There was no significant difference in phosphorus leaching between treatments in the distilled water leachate.

The crop growth response trials showed a definite trend of more consistent yields from the plots receiving commercial fertilizers compared to all other treatments. However, at least one treatment plot from each of the compost treatments achieved yields equivalent to the fertilizer yields.

There was no significant difference in corn yields between treatments, even at a 75 percent level of confidence. The cold, wet growing season experienced during the plot trial experiment is thought to have confounded the results to some degree, due to the slow rate of nutrient mineralization from organic amendments and potential for denitrification in cold, waterlogged soils.

Corn plants harvested in July for comparison of total plant dry weight and tissue nutrient analysis had higher plant weights for plots receiving compost pre-plant incorporated compared to winter application. Fall harvested grain corn and whole corn plants did not show any significant difference in yields between pre-plant and winter compost applications. Mean grain corn moisture levels were all in the 53 to 55 percent range, indicating that no difference in corn maturity resulted from the various treatments.

The economic comparison indicated that the mechanically mixed forced aeration composting system has the lowest energy requirements at $0.185/tonne of manure composted followed by $0.190/tonne for the passive aeration compost and $0.72/tonne for the turned pile compost. The mechanically mixed forced aeration composting method has no direct labour requirements associated with the process itself. The passive aeration method requires 0.039 hours/tonne followed by the turned pile method with 0.147 hours/tonne. The capital cost estimates indicate that the turned pile and passive aeration composts have similar capital costs of $19,300, for concrete pads and leachate collection and re-distribution systems. The mechanically mixed forced aeration system had the highest capital cost of $80,000, assuming equivalent tonnage capacity.

Manure Management to Sustain Water Quality

University of Guelph;
M. J. Goss, W. E. Curnoe, E. M. Beauchamp, P. S. Smith, B. D. C. Nunn

EXECUTIVE SUMMARY

A field experiment was established at the Winchester Research Station of Kemptville College of Agricultural Technology to investigate the fate of nitrogen from cattle manure applied to land previously under alfalfa residues, and the consequences for the quality of water resources. The objective of the programme was to evaluate the risk of nitrate leaching from fall-applied manure, and evaluate whether this could be alleviated by timely agronomic practices. Specific practices considered were the use of cover crops, incorporation of straw residues and sowing a winter cereal crop.

The following treatments were imposed and test crops planted.

1. Alfalfa ploughed in; grass (Timothy); no manure; corn (check).
2. Alfalfa ploughed in; grass (Timothy); 172 x 10^3 L ha^{-1} liquid cattle manure; corn (manure check).
3. Alfalfa ploughed in; 54 t ha^{-1} composed cattle manure; corn.
4. Alfalfa ploughed in; liquid manure; barley; wheat.
5. Alfalfa ploughed in; liquid manure; oilseed radish cover crop; corn.
6. Alfalfa ploughed in; liquid manure; 3.8 t ha^{-1} straw (dry weight) incorporated; corn.
7. Alfalfa ploughed in; liquid manure; straw; oilseed radish cover crop; corn.
8. Alfalfa ploughed in; liquid manure; winter wheat, corn.
9. Alfalfa ploughed in; winter wheat; corn.
10. Alfalfa ploughed in; barley; wheat.

The liquid cattle manure was injected, and the solid manure applied with a conventional spreader. The soil at this time contained 80 kg ha^{-1} mineral nitrogen. Only 5 kg ha^{-1} of mineral nitrogen was present in the 98 kg N ha^{-1} from the composted cattle manure, but the liquid manure contained 203 kg N ha^{-1} as mineral nitrogen.

The experimental programme involved the sampling of soil, soil water, and plant material to assess the fate of the nitrogen from the manure, the availability of the nitrogen to crops, and the presence of mineral nitrogen, including the mobile nitrate ion, in the soil.

The cropping history of the chosen site was known, along with information on crop response to N fertilization. This knowledge was considered essential so that information gained at this site would then be mo;re readily transferable to similar farm systems in other areas of Ontario.

Three periods were identified as crucial for evaluating the agronomic practices. These were the fall, the period of spring runoff, and the main growth stages of the spring sown crop. The results from the field experiment were evaluated for these three periods.

The volumetric water content of the top 100 mm of soil was approximately 0.15 at the time the manure was applied at the end of August. This was ideal for injection, but severely impaired the establishment of the grass. Growth of the winter wheat, oilseed radish, volunteer oats from the incorporated straw, and wild mustard weeds was good in the fall of 1991.

The uptake of mineral nitrogen (y, kg N ha^{-1}) by all crops in the fall was directly related to the dry matter produced (x, t ha^{-1}) according to the equation: $y = 0.43x - 10.2$ ($p < 0.001$). By the end of November almost all the mineral nitrogen applied in the manure could be accounted for in the soil and plants. In unmanured plots there was 55 kg NO_3-N ha^{-1}, 78 kg NO_3-N ha^{-1} in plots that received composted manure, and 134 kg NO_3-N ha^{-1} in plots given liquid manure. All this nitrogen was at risk of leaching.

The winter was cold and the snow cover was ended by heavy rain on January 14, after which the temperature dropped sharply and killed the winter wheat crop.

There was little through drainage in the early spring and all plots contained more mineral nitrogen at planting in May than in November. Two periods of leaching were identified in late spring and early summer. The maximum concentration of nitrate-N recorded in the water draining from the rooting zone for all treatments exceeded the Ontario Drinking Water Objective of 10 mg L^{-1} during one or both periods.

The Ontario soil nitrogen test suggested that the unmanured plots would require some fertilizer nitrogen to obtain the maximum economic yield, but all manured plots contained sufficient nitrogen. When the test was repeated at the time for side-dressing corn, nitrate-N had increased by an average 26% for the treatments where nitrogen was immobilized during the fall.

The growth and yield of the corn, and the grain yield of spring barley were largely unaffected by treatment. The yield of barley was influenced by the lodging that took place preferentially on the manured plots. Although earlier in the season nitrogen uptake by barley was greater on manured plots than on plots that received no manure, there was no significant difference at harvest, probably because of the lodging which made sampling difficult.

Nitrogen released by the ploughing of the alfalfa hay soil provided sufficient nitrogen for the corn crop. The total nitrogen in the control treatment at harvest was 150 kg N ha^{-1}. The crop on land injected with liquid manure contained 225 kg N ha^{-1}, but this was not converted into significantly more harvestable yield. About half of the additional nitrogen was present in the grain, but the remainder was in the harvest residues that will contribute to the organic matter pool of the soil and be remineralized in the future. There was more nitrogen in corn crops grown on land where cover crops were grown in the previous fall compared to that in unmanured controls. However, the increase only occurred after August 20. This indicated that the main period for release of nitrogen from the cover crop residues only took place late in the season. If cereals rather than corn had been the test crop it strongly suggests that most of this nitrogen would have remained in the soil where it would have been at risk of leaching.

Since yields of corn were unaffected by the treatments imposed despite the indications of the soil nitrogen test, it is clear that adjustments are needed when making fertilizer recommendations based on the test to ensure that the nitrogen from crop residues (straw or cover crop) is included. The soil N test, which only takes account of nitrate-N, clearly underestimated the amount of mineral nitrogen available in the soil on all treatments. This was even true for controls where nitrogen from below-ground residues of the alfalfa hay was not adequately assessed. The results indicated that 115 kg N ha^{-1} was an appropriate credit for the underground residues of the alfalfa hay.

The study strongly indicated that applying liquid manure in the fall was potentially hazardous to water resources. The risk from leaching was high in the fall immediately after application, in the following spring, and in the next fall period, especially if cereals were grown in the spring. None of the fall treatments to immobilize nitrogen were adequate to reduce the risk significantly.

Composted cattle manure did not pose a significant hazard in the fall after application, but did so in the fall of the following year.

Project C

Title: Prediction of Crop Responses to Changes in Soil Quality

Purpose

Several components in the Soil Quality Evaluation Project (SQEP) under NSCP involve monitoring or predicting changes in soil characteristics that are known or assumed to affect crop yield. Benchmark sites are to be established to monitor changes in these characteristics. What is missing is a system to integrate these changes in terms of the response of crops.

Objectives

1. To evaluate existing crop productivity models in terms of their suitability for predicting crop response to changes in soil quality.
2. To modify and adapt the most suitable model as required.
3. To prepare and document the model in a form that will permit its use with the soil quality monitoring data.

Scope

This statement of work is quite specific in its requirements. The technical approach to the problem should be well defined with identification and demonstration of knowledge of existing candidate models. With a view to linking this model with the development of a data base, there should be good coordination and liaison with scientists establishing the benchmark sites and conducting the monitoring of soil quality characteristics in the SQEP.

Successful Bidder

University of Guelph; Dr. B. Kay - See Part III.

Project D

Title: Influence of Soil Management Systems on Soil Quality

Purpose:

Several components in the Soil Quality Evaluation Project (SQEP) under NSCP as well as field staff such as the Soil Conservation Advisors are involved in predicting changes in soil characteristics. These characteristics may be described as those which are useful for identifying soil quality degradation or the reversal of soil degradation (soil quality improvement) attributable to tillage/cropping/land use systems.

Objectives

1. To identify soil quality parameters which may be identified with soil management systems and which can be shown to be useful indicators of soil quality for crop production.
2. To describe field/laboratory methodologies which will characterize the chosen parameters.
3. To relate temporal changes in the selected soil quality parameters to tillage, cropping or lang use systems.

Scope

This statement of work is general in its requirements. It might be described as the provision of tools for the Soil Conservation Advisor. It should address specific areas of interest such as microflora, vertebrate/invertebrate populations in soil, level and quality of organic matter, stability of soil structure, soil erosivity or soil pH as examples. It should clearly identify the responsiveness of the parameter to the land use change and the importance of the parameter in soil management sustainability. Two constraints need to be observed. The time frame of the study does not permit establishment of tillage and cropping systems in the field, and the "motherhood" approach to soil quality factors would not expect to yield definitive results. Therefore, it is considered that the proposal will offer an extension to or enrichment of existing and ongoing work.

Successful Bidder

Environmental Soil Services; Dr. R. G. Kachanoski - $47,998.00

Influence of Soil Management Systems on Soil Quality: Potentially Mineralizable Nitrogen

Dr. R. G. Kachanoski and Dr. P. von Bertoldi

EXECUTIVE SUMMARY

The objective of this study was to assess the effects of soil loss and tillage system on the long term nitrogen (N) mineralization potential of a number of Ontario soils. Estimates of potentially mineralizable nitrogen N^{o} (mg N kg^{-1}), mineralization rate constant k (wk^{-1}), and total nitrogen supplying potential N_F (kg N ha^{-1}) were obtained from 22 week incubations of soil samples. The soils selected were the Ap horizons of selected soil landscape positions from the provincial Tillage 2000 project. A total of 104 soil landscape positions, each split into two tillage systems (conservation, conventional), for a total of 208 benchmark locations were analyzed. The landscape positions were selected to cover a range of soil types, textures, past erosion, and tillage treatment. Benchmarks were classified as severely eroded, moderately eroded, or depositional based on their level of ^{137}Cs, a naturally occurring soil tracer.

The value of N_o and N_F were significantly lower by up to 200 kg N ha^{-1} in soil landscapes that were classified as eroded than in the depositional sites. Conservation tillage systems significantly increased the value of N_o and N_F in eroded landscapes compared to conventional tillage systems. Moldboard systems had lower values in eroded landscapes than either minimum or no-till systems. Increased values of N_F were found in depressional areas of conventional tillage systems, which was related to a significant increase in the amount of soil present and not to an increase in N_o.

The data clearly suggest that conservation tillage systems have had a significant remediating effect on the most severely degraded and eroded soil landscapes. Regression analysis of N_o and Ap horizon soil organic matter indicated that the differences between tillage systems increased as the soil organic matter decreased. At a soil organic matter of 7 to 8%, there was no difference in tillage systems. For soils low in organic matter, no-till N_o values were 5x and 3x higher than moldboard and minimum tillage systems respectively.

The large differences in N mineralization potential in different erosion classes, and the significant effects of conservation tillage in remediating the effects of erosion, suggest these types of measurements may be valuable in long term soil quality monitoring programs. In addition, the relationship between the N mineralization potential and the actual field N mineralization rates needs to be examined. The work would have implications for the release of nitrate in the late fall and early spring (periods of high leaching risk), and also on the interpretation of spring soil N tests.

Discussion

Conservation versus Conventional Tillage

At each pair of benchmarks there was a conservation and a conventional tillage system. The average value of N_o was 103.1 and 99.2 (mg N kg^{-1}) for the conservation and conventional tillage systems respectively. This difference is statistically significant at the 0.05 probability level. The magnitude of the difference (i.e. 4%), however, is not particularly large. A small (6%), but statistically significant increase in the mineralization rate constant K in the conservation tillage system, was also found. However, the total N supplying potential N_F was similar in both the conventional and conservation tillage system. The slightly smaller value of N_o in the conventional system was offset by a slightly larger value of the specific mass of the Ap horizon, which combined gave equal values of N_F for the two tillage systems. The average value of soil organic matter was 3.3% in both tillage systems.

The average values for the benchmarks classified as severely eroded (E), moderately eroded (M), and depositional (D) for both the conservation and conventional tillage benchmarks, are also given. Across both tillage systems, separation by erosion class was statistically significant (> 0.01 probability) for both N_o and N_F, with E < M < D. In addition there was a significant interaction of erosion class and tillage system. The values of N_o and N_F were 15% and 18% higher in the severely eroded conservation benchmarks compared to the severely eroded conventional tillage benchmarks. There were no statistical differences in N_o values between tillage systems in the moderately eroded or depositional classes. The value of N_F was 10% higher (significant at 0.05 probability level) in the conventional tillage system in the depressional areas. The value of the mineralization rate constant k was always higher in the conservation system in each of the erosion classes, but the difference was not statistically significant in the moderate erosion class (M).

The data suggest that the effect of conservation tillage was to increase both the potential rate of N mineralization and the potential amount of organic N available for mineralization in severely eroded benchmarks. The increase in N_F in the depressional benchmarks of the conventional systems is attributable to a statistically significant increase (0.05 probability) in the amount of soil in the Ap horizon, probably from increased erosion and tillage translocation of soil. Thus, it appears that the conservation tillage systems had a remediating effect on the most degraded areas within the fields.

The value of soil organic matter was also significantly affected by erosion class with E < M < D. However, no significant differences between tillage systems were not found. This suggests that the 4 to 5 yrs of conservation tillage has changed a smaller, active portion of the organic matter in the soil, but the larger, more resistant portion of the organic fraction has not changed measurably.

<u>Paired Tillage Comparisons</u>

A summary of the measured mineralization parameters for the different paired tillage comparisons and erosion classes was presented. For every tillage comparison the values of N_o and N_F were significantly different in the erosion classes, with E < M < D. The values of the mineralization constant k had an opposite trend with E > M > D. The erosion classes also had significantly different soil properties consistent with the occurrence of soil redistribution. For example, the $\%CaCO_3$ was considerably higher in the severely eroded sites suggesting the incorporation of parent material (C_k horizon) into the surface Ap horizon. Soil organic matter, solum depth, and relative yield also follow expected relationships with the erosion classes. A detailed summary of the relationships of the soil properties and erosion class has been given by Kachanoski et al. (1992).

For the severely eroded (E) benchmarks, the values of N_o and N_F were significantly (> 0.05 probability) greater in the MIN and NT systems compared to the MB system. There was no significant difference in these variables in the paired NT and MIN eroded benchmarks. Moderate erosion (M) benchmarks generally had values between the E and D erosion classes, with no measurable differences between tillage systems. The values of the mineralization constant k were generally higher in the conservation tillage system for each paired comparison, but the differences were not as large and statistically significant as the other mineralization parameters.

The paired tillage comparisons indicate that the effect of conservation tillage is to reduce the variability in N mineralization parameters between eroded and non-eroded sites within a field. The N mineralization potential in the eroded sites increases in conservation tillage relative to conventional tillage, and the opposite effect occurs in the depositional areas. The results are consistent with the process of redistribution of carbon rich topsoil from eroded to depositional areas.

The remediating influence of conservation tillage on the N mineralization potential is encouraging, as is the decrease in variability between locations in the field. In the provincial Partners In Nitrogen project (OMAF, Univ. of Guelph, Fertilizer Inst. of Ont.), which was field testing the new Ontario soil N test for corn, a major problem was the variability of the soil test and the variable response of corn within a field to applied N fertilizer (Kachanoski and Beauchamp, Final PINS report, Dept. Land Resource Science, Univ. of Guelph, 1993). Other studies have suggested that the variability in N fertility within a field is a major obstacle to meeting groundwater quality objectives (Van Noordwijk and Wadman, 1992). Adding N fertilizer to meet the average N requirements for the field, when there is high variability within the field, resulted in areas with high excessive N for leaching as nitrate.

The differences in total N supplying potential N_F in the erosion classes are very large, in some cases exceeding 200 kg N ha^{-1}. This difference is larger than the amount of fertilizer N normally applied to corn in Ontario. The differences in N_F values could easily account for the observed variations in the spring soil N test. If a correlation exists between the spatial pattern of N_F and the pattern of the N test or of crop response to applied N fertilizer, then the potential for mapping this variability exists. Of particular interest is the rate of change of the soil N test in the early spring period, and the relationship between the test taken at time of planting versus the test taken at time of sidedress. Since the soil N test measures only the amount of nitrate-N in the soil, the rate of change of the test is directly related to the rate of N mineralization occurring in the field.

The values for N mineralization parameters must be interpreted as potential values, and no the values for mineralization which would be occurring in the field. For example, the increase in N_o in the eroded locations under conservation tillage could be related to an actual decrease in the field N mineralization, resulting in a larger reserve of material left over. The decrease could be related to a number of factors such as physical stabilization of labile substrate in soil aggregates, which are not destroyed by tillage. In any case, the measurements carried out in this study indicate that some qualitative and quantitative change in the soil organic fraction has occurred under conservation tillage, and this change was more prevalent in eroded areas. The implications of the measured changes need to be investigated.

As mentioned earlier, the values of total soil organic carbon did not show any significant differences between tillage treatments. However, the value of organic matter did change significantly from field to field, and these changes were correlated to changes in N mineralization. Regression of N_o versus % organic matter OM, for each of the tillage treatments (MB, MIN, NT) resulted in:

MB; $N_o = 24.7 + 21.4$ OM; $r = 0.60$
MIN; $N_o = 84.56 + 11.5$ OM; $r = 0.66$
NT; $N_o = 138.2 + 7.1$ OM; $r = 0.50$

As indicated, the correlations with organic matter were all significant (0.01 probability). The regression intercepts and slopes changed significantly with tillage system. The regressions indicate that the effect of tillage system increases as the soil organic matter decreases. The intercept is the value of N_o that would be expected if the soil organic matter was close to zero, and the value for NT is 5x higher than MB. At a soil organic matter of 7 to 8% the values of N_o for MB, MIN and NT are essentially equal. This again indicates that the major influence of conservation tillage is in the soils which are more degraded (i.e. high erosion, low organic matter).

Project E

Title: Methodologies for Assessing Soil Structure (Degradation) in a Meaningful Way

Purpose

A component in the Soil Quality Evaluation Project (SQEP) under NSCP will seek to develop methods to measure soil structure in order to estimate the status of soil structure and changes in soil structure which may be identified with soil conservation practices.

Objectives

1. To identify a method(s) for measuring soil structural changes which may be related to soil management systems and which can be shown to be useful for characterizing changes in soil quality.
2. To relate these measurements of structural changes to soil chemical and physical properties.

Scope

This statement of work is quite specific in its requirements. The technical approach to the problem may be based on the concept of "non-limiting water range" (NLWR) which is being examined in the soil quality monitoring program to assess soil structural changes. Very limited information is available on the influence of inherent soil properties on the sensitivity of this parameter to soil management. The proposal must clearly indicate how the work will augment the Soil Structure Assessment and Prediction Study (STAPS) without overlapping other proposed work responsibilities or funding allocations under the current Canada/Ontario Agreement.

Successful Bidder

University of Guelph; Dr. B. Kay - See Part III

Project F

Title: Open Category RFP under the NSCP Research Program

Purpose

The research program under NSCP is inviting unique proposals for research on soil quality issues which have not been identified in the foregoing five. They should be confined to the areas of work set out on page 1 of this guideline and subject to the preferences identified there. It is fully expected that any submission will be a serious contribution to our understanding of the conservation of soil quality, its measurement or extension to the agricultural community.

Objectives

1. Please state the objectives of the proposed study clearly.

Scope

Although the expected scope of the work is undefined here, the scope of the work in the proposal should be clearly stated. The proposal should fall within the guidelines given above, observing the two year time frame, and the suggested level of effort. On farm demonstrations are discouraged in favour of more technically sophisticated studies which relate to our understanding of sustainable and/or restorable soil quality.

NOTE: Any proposed work on Buffer Strips, for which a literature review is being commissioned as an initial step, should be deferred until the literature review has been completed.

Successful Bidders

Beak Consultants Limited; Dr. R. Walker and Dr. R. Tossel - $97,575.00

Buffer Strip Review - Sole Sourced Contribution

Soil and Water Conservation Information Bureau; D. Robinson - $14,830.00

The Effect of Soil Quality on Field Scale Runoff under Conventional and Conservation Tillage Systems

Beak Consultants Limited;
Dr. R. Walker and Dr. R. Tossel

SUMMARY AND CONCLUSION

A summary of the main results of monitoring and analyses conducted for the NSCP study are presented below. Conclusions are based on interpretation of significant trends and differences in the aforementioned data sets.

Agronomy

No significant differences were noted for crop type or yield when comparing test microbasins to control. There were also no significant differences observed with respect to applications of fertilizers and pesticides, including metolachlor. The only difference between test and control microbasins involved surface crop residue. As expected, pre-plant and post-harvest residue counts in the test (no-till) microbasins were significantly higher than in the control (conventional tillage). The higher surface residues are incorporated into the soil surface resulting in an overall improvement of soil quality (higher organic matter content, moisture retention capacity, etc.). In theory, this affects soil microbial populations and subsequently affects microbial degradation of agrochemicals such as metolachlor.

Soil Monitoring

The physical and chemical properties of the soils of the test and control microbasins differed in a number of respects. The soils of the test microbasins (KTB1 and KTB2) exhibited the expected characteristics of soil under conservation management (no-till) when examined in comparison to the soils from the control microbasins (KCB1 and KCB2). These characteristics include:

- higher organic matter, both at the surface (0-5 cm) and at depth (25-30 cm)
- higher soil moisture retention, indicating smaller pore size distribution,

- greater soil moisture content throughout all seasons
- lower bulk density at surface and at depth, and
- generally lower soil pH (surface and sub-surface).

There were further differences evident in the chemistries of test and control soils, including lower levels of calcium in the test soils, which is also expected for no-till soils.

These general soil conditions for the test areas, especially elevated organic matter, provide an environment with a higher capacity for supporting soil micro-organisms than do the soil conditions found in the control areas. The test soils are therefore likely to have higher populations and activity levels of microbes. These micro-organisms, acting as decomposers, can in turn enhance the rate of degradation of agrochemicals such as metolachlor. Analyses of the soils from the Kettle Creek study area support the contention that metolachlor is degraded more readily in the test soils. Levels of metolachlor in soil samples from the test microbasins were much lower than those for control soil samples for almost every period of sampling. The difference in soil metolachlor concentration is most prominent during the periods closely following the application of the herbicide.

Groundwater

The main results from groundwater monitoring are as follows:

- average linear velocity of groundwater samples from all microbasins, as expected for an agricultural area.
- nitrate and phosphorous were detected in groundwater samples from all microbasins, as expected for an agricultural area.
- levels of nitrate, soluble reactive phosphorous (SRP), and metolachlor are much lower in groundwater than in surface water.
- the chemical parameters addressed herein show no significant temporal or spatial trends within individual microbasins, and
- no significant differences in groundwater chemistry, including metolachlor concentration, exist between test and control microbasins.

Surface Water

Surface water flow in the four study microbasins was quite variable over the NSCP study period. General findings concerning flow include the following:

- KTB1 consistently produced the lowest flow of all four microbasins
- KTB2 usually produced the highest flow of all four microbasins, and
- KCB1 and KCB2 produced similar flows throughout the period of study.

Overall, further examination of flow data during periods of adequate precipitation is required to accurately assess any differences between test and control microbasins with respect to flow. Flow during the NSCP study was too infrequent for a thorough assessment.

Analyses of surface runoff samples collected from the four Kettle Creek microbasins during the study period reveal several differences in water quality between the test and control microbasins. The two main conclusions with respect to concentrations of water quality parameters are:

- surface runoff nitrate concentrations were lower in the test microbasins, and
- surface runoff metolachlor concentrations were also lower in the test microbasins.

Microbasin water quality loads were also computed for six primary water quality parameters. The main findings are as follows:

- soil sorbed water quality indicators total suspended solids (TSS), total phosphorous (TP) and total Kjeldahl nitrogen (TKN) showed no consistent differences between test and control microbasins
- SRP and nitrate (dissolved water quality indicators) showed no clear differences between test and control (although indications are that nitrate may tend to be lower in the test microbasins), and
- in all cases, unit area metolachlor loads were lower in the test microbasin.

Overall, both soil and water quality analysis appears to indicate that the conservation tillage implemented in the test microbasins is having a positive effect on environmental quality with respect to residues of the herbicide metolachlor. The main reason for the improvement is theorized to be the enrichment of soil organic matter and subsequent increase in populations of microorganisms (relying on organic matter to thrive) that act to degrade metolachlor and other compounds in the soil. Lower levels of soil metolachlor translate to lower water borne metolachlor delivered by runoff.

Recommendations for further study include:

- continuation of current studies to provide a larger and more conclusive data base with respect to surface water flow, and
- monitoring of degradation products of metolachlor in soil and water to better understand the fate of the herbicide in agricultural systems.

Literature Review Pertaining to Buffer Strips

Soil and Water Conservation Information Bureau;
D. Robinson

EXECUTIVE SUMMARY

Buffer strips historically have been used for the improvement of surface water runoff from logging and surface mine operations. Most recently they have been promoted in the U.S. and now Ontario for feedlot and cropland runoff.

Buffer stirps are bands of planted or indigenous vegetation situated downslope from cropland or animal production facilities to provide localized erosion protection and filter nutrients, sediment and other pollutants from agricultural runoff before they reach receiving waters. Buffer strips are also known as vegetative filter strips, grass filters, grass strips, riparian plantings and combinations thereof.

The two major removal mechanisms at work in vegetative filter strips are deposition and infiltration. As runoff enters the filter strip, its flow is retarded byu the increased surface roughness and resistance of the vegetation. The decrease in velocity results in a decrease in the sediment transport capacity of the flow. If the resultant transport capacity is less than the inflow sediment load, sediment is deposited at the interface between the filter and the upslope area. The deposition wedge is typically 30-50 cm wide and occurs immediately upslope of the filter. Once this deposition zone fills up, the deposition front moves downslope in 50 cm intervals until the buffer strip is completely full. Sediment-bound pollutants are also deposited.

Soluble nutrients and some fine particles enter the soil profile with runoff infiltrating into the buffer strip. After entering the soil profile they can be removed by a combination of chemical, physical and biological processes. Mobile water soluble nutrients such as nitrate may leach through the soil profile.

Other mechanisms presumed to be at work are filtration of suspended solids, adsorption to plant and soil surfaces and absorption of soluble pollutants by plants. However, these mechanisms are not well understood at this time.

Research in the U.S. has shown that both tree and grass buffer strips can effectively remove coarse sediments if the runoff flow is shallow and uniform. Buffer strips are less efficient at removal of the small particle sizes. Buffer strips do remove sediment-bound nutrients but with a slightly less efficiency than sediment.

Removal of soluble nutrients by buffer strips is highly variable. The concentration can actually increase due to the re-release of previously trapped nutrients as flow passes through the buffer strip.

There is very little information currently available with respect to the abilities of buffer strips to remove pesticides or pathogens from runoff water. Sediment-bound pesticides and pathogens are likely deposited to some extent but could be re-released at a later time. Some pathogens and pesticide would be removed with infiltrating water. More research is needed in this area.

Buffer strips have been credited with stabilizing streambanks and reducing in-channel erosion. Tillage implements are kept away from the watercourse edge, heavy equipment off the banks and vegetation roots stabilize the soil.

The buffer strip width required depends on many site, vegetation and climatic factors. In general terms, the width required increases as:

- slope of the land above the filter strip increases
- cross-slope of the buffer strip increases
- drainage area increases
- particle size of the soil upslope decreases
- infiltration of the soil upslope decreases
- velocity/volume of runoff increases

There are currently no simple design models available. According to James Krider, the National Environmental Engineer with the United States Department of Agriculture in Washington, D.C. a national handbook with design recommendations for site-specific conditions is in draft form and should be available later this year. The design criteria only consider sediment and surface flow. This may offer some guidance to extension personnel in Ontario.

There has not been any research to date on recommended species for buffer strips for Ontario conditions. Species recommended for grassed waterways could serve as a guide for grass buffer strips. There has not been any research yet on the most appropriate species selection for riparian tree plantings.

Since runoff must cross the buffer strip as sheet flow in order to be most effective, in-field buffer strips or grasses waterways may be more appropriate in hilly areas where water tends to concentrate in natural drainageways prior to crossing the buffer strip.

No research to date has examined the effectiveness of buffer strips during the winter and early spring when vegetation is dormant. Runoff from snowmelt and winter/spring rains is very significant in Ontario.

Maintenance of a dense vegetation is essential to the long-term performance of the buffer strip. Mowing, fertilization and possibly herbicide application are necessary. Using the buffer strips as turn lanes or traffic lanes or for grazing livestock destroys the vegetation. Leaving a plough furrow parallel to the edge of the buffer strip results in water concentrating and flowing along the buffer strip edge and then crossing as concentrated flow at a low point. Furrows can be removed following ploughing with a light disking. There is also a tendency for the strips to get narrower each year due to ploughing of the edge of the strip. This should be avoided.

More research is needed in several key areas in order to utilize buffer strips effectively in Ontario.

1. How can they be used effectively in the upland areas of the province where flow tends to concentrate in natural drainageways prior to entering watercourses?

2. How effective are buffer strips during the winter and early spring when vegetation is dormant?
3. What is the ability of limited-width buffer strips in removing fine particles? This is of particular importance in the lowland areas of the province with heavy clay soils such as Essex, Lambton and Haldimand Counties.
4. Most experiments have been short-term. What is the long-term effectiveness of buffer strips? What is the fate of organic material trapped in the filter? Are nutrients re-released into runoff flows? What impact do buffer strips have on subsurface water quality due to increased infiltration of runoff water and associated pollutants?
5. Simple design criteria which consider particle size, nitrogen, phosphorus, pathogens and pesticides under various site-specific conditions such as topography and soil texture are needed in order to utilize buffer strips effectively.
6. What is the effectiveness of buffer strips with respect to the removal of pathogens (if they are a problem) and pesticides?
7. What tree and herbaceous species are most suitable for vegetative filter strips here in Ontario?

PART II - IN-HOUSE RESEARCH

Project G

Title: **Soil Macropore Development as a Mechanism for Root Distribution and Solute Transport**

Purpose

Conventional wisdom has held that an advantage of using deep rooted crops, either as a main crop or soil improving crop, has been the development of deep root channels which improve drainage and offer new root channels for the growth of following crops. Soil drying creates extensive cracking in soils such as Brookston clay. It is not well understood how these factors may be related.

Objectives

1. To characterize macropore development under the influence of crops with different root development capabilities.
2. To relate macropore development to development of the subsequent crop and to solute transport.
3. To suggest or develop soil management systems which will curtail excessive amounts of adverse transport while retaining advantages of enhanced root development.

Scope

This statement of work offers large scope for innovative approaches to the problem. The requirements may be met by practical field observation, by innovative technical evaluation where suitable existing facilities are available, by more theoretical modelling approaches, or by any combination of these. The technical approach to the problem should be well defined with clear definition of the chosen approach. The foreseeable difficulties which put a successful conclusion at risk should be recognized and potential solutions suggested.

Successful Bidder

London Research Centre; Dr. B. T. Bowman - $80,000.00

Rainfall simulator - Grid Lysimeter System for Preferential Solute Transport Studies Using Large, Intact Soil Blocks

London Research Centre;
Dr. B. T. Bowman

EXECUTIVE SUMMARY

During recent years, there has been increasing interest in preferential water flow through soils and the resulting potential for rapid transport of pesticides, nutrients and other solutes to tile drains and groundwater. A technique has been developed to study in detail and under controlled conditions, the preferential flow of water and solutes in large, intact soil blocks, isolated at field sites and transported to the laboratory. The soil blocks, 46-cm (18") on each side (145 kg, 320 lb) were carefully cut with a flat shovel, then encased on the vertical sides with a polyurethane foam shell (inside a plywood box) to stabilize it during transport and later experimentation. The blocks were cut at least 46 cm deep to ensure that the A/B horizon interlayer was included. Unstable, preferential water flow (and solute movement) often occurs across dissimilar interlayer boundaries in soil profiles. A boiler plate was jacked under the block to isolate it, then the entire assembly was carefully lifted onto a truck and transported back to the laboratory.

In the laboratory, the block assembly was turned on its side, the base plate was removed, the base of the soil block was cleaned and an aluminum plate (60 x 60 x 2 cm) grid solution collector (containing a 10 x 10 grid of shallow, 2.38-cm square collector funnels) was sealed to the base of the polyurethane foam shell. The assembly was turned upright onto a portable dolly, then wheeled under a precision rainfall simulator, capable of uniformly delivering water to the soil surface over a 5 to 80 mm hr^{-1} range. A grid of collector tubes below the collector plate was used to determine flow patterns of water and applied tracers. Much of the experimental data collected in this study were used to test the various components of the apparatus, as well as to characterize tracer movement through the soil blocks. Volumetric moisture content was continuously monitored at four depths in the soil block (2.5, 25, 33 40 cm) using horizontally-inserted side-by-side pairs of Time Domain Reflectometry (TDR) probes. The probes at 25 and 33 cm were on opposite sides of the A/B horizon boundary.

A tensiometer was horizontally inserted beside each TDR probe-set to monitor, in real-time, the matric potential (soil water tension).

Initial tracer tests were conducted using the bromide ion (Br^-) as a conservative, non-reactive tracer, applied to the surface of an Embro slit loam soil block that has been in alfalfa for several years. Alfalfa roots, as well as numerous earthworm channels, had penetrated the full depth of the soil block. Under steady-state rainfall inputs and independent of the input rate (from 5.6 to 19.2 mm hr^{-1}), initial traces of Br^- ion were quickly detected in the outflow from the block within 0.5 hr after the pulse had been applied to the soil surface. At saturation input rates (19.2 mm hr^{-1}), the peak concentration of the Br^- pulse in the effluent occurred 1.25 hr after initial Br^- introduction after collecting 5 L (< 1/7 pore vol.). At 5.6 mm hr^{-1} input, the Br^- peak was delayed until 16 hr, after collecting 11.3 (< 1/3 pore vol.). Approximately 85% of the water in the soil block was "bypassed" by the Br^- tracer. The distribution of water flow in the solution collector confirmed that extensive preferential flow of water and solute occurred in these tracer experiments.

This grid lysimeter apparatus will be used to characterize preferential water and solute movement in soil and is part of a larger collaborative effort which is investigating the same phenomena at larger scales at the same field sites where the soil blocks were obtained.

Concluding Remarks

Elucidation of the mechanisms controlling the preferential movement of water and solutes through soil require extensive and careful experimentation on intact soil samples that are large enough to be representative of true field conditions. Detailed and accurate measurements through space and time of the water and solute storage and transmission properties of the soil must be both known and controllable. The grid lysimeter system and the sample collection, containment and storage techniques described in this report are an attempt to satisfy these requirements.

Future Directions

This study has focused on the careful validation of the various components of the grid lysimeter system to accurately characterize preferential water and solute transport in intact soil blocks. We are quite confident that the current setup could be scaled up to accommodate considerably deeper intact soil profiles (perhaps up to 1 m) with modest strengthening of the support structures. This would permit realistic groundtruthing of various solute transport models to tile drain depths, and to further investigate the behaviour of solute transport across heterogeneous soil interlayer boundaries. The grid lysimeter system is also well suited to examine stop-and-go (intermittent) flow phenomena in soils, which may well prove to be more relevant than much of the steady-state flow experiments which have been traditionally used to characterize solute behaviour in soil profiles.

Project H

Title: Composting Manure as a Means of Sustaining Air and Water Quality

Purpose

A major contributor of nitrate-N to groundwater is application of livestock manure, even when applications are consistent with the agricultural code of practice. Application of manure in late summer or fall, frequently on sod prior to fall plowing results in excess concentrations of nitrates in the soil during the fall and spring leaching periods. However, it is usually difficult for farmers to apply manure at a time when crop demand for nitrogen is high. Approaches such as manure composting and use of cover crops have potential to convert the N to an organic form and release it for crop use in the subsequent season. Aeration of liquid manure and conventional turning of manure piles offer questionable advantages as both a means of conserving N and reducing odours. Dr. S. Mathur's work at LRRC, Ottawa, is suggested as a basis for examining manure handling technology at the farm level.

Objectives

1. To evaluate composting as a way to manage manure on the farm which will tend to convert or retain nitrogen in a non-leachable form while reducing losses of gaseous components associated with N losses or odour control during processing.
2. To demonstrate the ability of the system to deliver nitrogen to the soil in a form resistant to leaching during the fall and winter months following application; which will act as an effective source of N during the ensuing growing season.
3. To estimate the potential for losses of nitrogen in the field following application. These may involve estimates of biological fixation, rates of nitrification or mineralization, leaching losses and the rate of crop growth in systems which may include different kinds of soil incorporation.

Scope

The technical approach to the problem should be well defined. In light of the short period of funding and the need to produce definitive results within the time frame of this program, the proposal should clearly indicate how the management of manure and the production of a subsequent crop is to be handled. The description of existing or ongoing work which may contribute to a proposal should be given in sufficient detail to permit assessment of the opportunity for success.

Insufficient funds to support submitted proposals.

Project I

Title: Prediction of Crop Seedling Responses to Changes in Soil Quality

Purpose

Several components in the Soil Quality Evaluation Project (SQEP) under NSCP involve monitoring or predicting changes in soil characteristics that are known or assumed to affect crop yield. Benchmark sites are to be established to monitor changes in these characteristics. Recent work has been conducted which indicates the potential of cover crops to affect the wet aggregate stability and biomass of clayey soils. What is missing is an attempt to rank these changes in terms of the response of crops, either in terms of seedling performance or crop yield.

Objectives

1. To evaluate changes in soil quality caused by use of cover crops and to relate these changes in soil quality to crop performance.
2. To attempt to characterize differences in soil quality in terms of stress on either crops or micro-organisms (aeration, carbon supply, N cycling).

Scope

The requirement is to attempt to establish threshold values of soil quality related to crop performance. Soil degradation, as opposed to soil quality improvement, can be envisaged as a treatment, but there may be more information to be obtained from attempts to improve soil quality. The use of cover crops, especially the practice of intercropping e.g. annual rye grass in corn, may be an important practice if it can be shown that the perceived improvement in soil quality resulting from this practice can be demonstrated to have a favourable effect on the following crop. Caution is advised in the choice of variety or hybrid as a test crop because the response to the experimental conditions could be confounded with the mechanics of crop adaptability (susceptibility or tolerance) to stress.

Insufficient funds to support submitted proposals.

Project J

Title: Soil Biota as Indicators of Soil Quality

Purpose

Several components in the Soil Quality Evaluation Project (SQEP) under NSCP as well as field staff such as the Soil Conservation Advisors are involved in predicting changes in soil characteristics. These characteristics may be described as those which are useful for identifying soil quality degradation or the reversal of soil degradation (soil quality improvement) attributable to tillage/cropping/land use systems. The community structure of soil microflora and fauna may well be a suitable indicator of soil quality.

Objectives

1. To identify biological indices which may be identified with soil management systems and which can be shown to be useful indicators of soil quality for crop production.
2. To describe field/laboratory methodologies which will characterize the chosen indices which might serve as field measurement tools for Soil Conservation Advisors.
3. To relate temporal changes in the selected soil quality indices to tillage, cropping or land use systems.

Scope

This statement of work is general in its requirements. It might be described as the provision of tools for the Soil Conservation Advisor. It should address specific areas of interest such as microflora, vertebrate/invertebrate populations in soil related to the level and quality of organic matter, stability of soil structure, soil compaction or soil pH as examples. It should clearly identify the responsiveness of the parameter to the land use change and the importance of the parameter in soil management sustainability. Two constraints need to be observed. The time frame of the study does not permit establishment of tillage and cropping systems in the field, and the "motherhood" approach to describing soil quality factors would not be expected to yield definitive results. Therefore it is considered that the proposal will offer an extension to or enrichment of existing, ongoing work.

Successful Bidder

London Research Centre; Dr. A. D. Tomlin - $76,600.00

Response of earthworms, soil biota, and soil structure to agricultural practices in corn, soybean, and cereal rotations

London Research Centre;
Dr. A. D. Tomlin, Dr. C. M. Tu, J. J. Miller and J. DaFonseca

Summary

The comparative effects of herbicide treatments, crop rotations and weed control practice on soil fauna, microflora, and soil microfabric features (e.g. soil particle size and shape) were measured in a multifactorial experimental design. Because of the extensive availability of nutrients in earthworm casts both at the surface and within the burrows, agronomic techniques enhancing or reducing earthworm populations have significant consequences for processes involving soil microflora and soil microfauna colonizing the burrows and for infiltration rates for air and water into soil.

Herbicide treatments reduced earthworm and some mite populations as much as machine cultivation for weed control. Continuous soybean rotations reduced abundance of earthworms, mites and springtails compared to rotations containing cereals and continuous corn rotations. Most of the faunal and microfloral increases can be ascribed to increases in available soil organic matter.

Image analysis is a powerful tool which allows the physical associations of minerals, aggregates, organic matter and biotic components of soil to be measured in situ. Statistical analysis of image analyzed microfabric scenes taken from the resin impregnated soil blocks revealed differences in particle size (area) for both the herbicide and hand-hoed plots but not for the non-weeded control in all three crops. The particle shape parameter showed a similar result, except that there was no significant difference for herbicide treatment. This could be due to the 'homogenizing' effect of the weeds (or at least their roots) on soil physical structure. Using impregnated blocks, image analysis and spatial mapping of elements in earthworm faecal pellets in earthworm burrows it is possible to trace micro-scale interactions occurring in earthworm burrows, and compare cropping and tillage treatments on these interactions.

As a consequence of this research predictions can be made on the effect of tillage practices and weed control methods on populations of earthworms and mites with some confidence. Image analysis techniques of soil microfabric and fine soil structure were developed and measurements were made on the microfabric response to cropping, tillage and weed control methods and segregation of these differences with high statistical confidence was accomplished.

Future research

It now necessary to separate (tease apart) the contribution of agronomic practices from faunal/biotic contributions to soil microfabric. As a result of this research a method of accomplishing this goal by tracking identifiable microfabric-scale pedofeatures in the various treatments, and subjecting those features to fluorescence imaging and statistical analysis to establish their spatial distributions is now available. The imaging method is now feasible using fluorescence microscopy that incorporates an ultra-sensitive colour video camera and image analysis software. Further work could emphasize the relationship between fauna, soil structure, and plant roots in response to tillage treatments and weed control methods, for example.

Project K

Title: Methodologies for Assessing Soil Organic Matter Sustainability

Purpose

A component in the Soil Quality Evaluation Project (SQEP) under NSCP will seek to develop methods to measure the status of soil degradation. A factor thought to relate to soil structure and soil quality, frequently attributed to soil conservation practices, is soil organic matter (OM). The addition of crop residues from either main crop, cover crop or manures is commonly recommended as a practice for sustaining or improving the OM status of soil. In the cycling of carbon involving photosynthesis, respiration and microbial fixation of carbon there may be a pattern which would define the probable status of soil organic matter in conjunction with the level of microbial activity associated with carbon enrichment or depletion of the soil.

Objectives

1. To identify a method(s) for measuring or estimating soil OM levels which may be related to soil management systems and which can be shown to be useful for characterizing changes in soil quality.
2. To relate these estimates of OM change to changes in soil chemical and physical properties.

Scope

This statement of work is very general in its requirements. The technical approach to the problem may involve a modelling exercise based on a close review of the literature as input for prediction of the OM status of the soil. Alternatively, data from current research which involves production of cover crops, use of livestock manures, green manures or crop residues may suggest a balance sheet approach. The direct measure of soil carbon levels alone is not considered here to be a useful predictor of sustainability. Current techniques for estimating microbial biomass may be useful. It is assumed that factors such as aeration of C/N ratios will be considered. The ultimate focus of the task should be prediction of sustainability of OM levels in soil.

Successful Bidder

Delhi Research Station; R. Beyaert - $99,600.00

Crop Residue Decomposition and Organic Matter Dynamics in Alternative Management Systems on Coarse Textured Soils

Delhi Research Station;
R. Beyaert

Crop residues provide the primary organic source of energy and nutrients affecting soil biological, chemical and physical processes, including organic matter formation. Gains in soil organic matter through plant deposition are offset by losses through decomposition by the soil microflora and leaching of soluble compounds. Changes in crop management affect the soil organic matter in two ways: by altering the annual input of organic matter into the soil and by altering the rate at which organic matter decomposes or is lost. This study examined the effects of management, namely cropping sequence and tillage, on above-ground plant biomass production, on certain agronomic indices such as crop yield and on the rate of decomposition of crop residues and the proportion stabilized in soil organic matter during the first two years of decomposition.

A field study was established to examine the effects of soil management on the organic inputs and losses in a coarse-textured soil cropped to tobacco-fall rye, continuous corn and soybean-winter wheat cropping systems managed under both conventional and conservation tillage practices. In general, harvestable yields of soybeans, tobacco and corn were higher in 1991 than in 1992 with the reverse being observed for the two cereal crops. With the exception of tobacco in both 1991 and 1992 and corn grain in 1992, harvested yields of crops grown under conservation tillage were not significantly different than the yields of crops managed under conventional tillage practices.

The total weight of above-ground non-harvested crop residues differed among crops, cropping systems and tillage practices. In general, total residue weights for the various crops paralleled differences in crop yield for the same crops. Yields of non-harvested biomass were greatest for the continuous corn system and least for the tobacco-fall rye rotation with the soybean-winter wheat rotation being lower than the corn system but higher than the tobacco-fall rye rotation. Crop residue weights of the cereal crops were lower in 1991 than 1992 whereas residue weights of the other crops were higher in 1992 than in 1991. Residue inputs of fall rye were no significantly different when managed under the two different tillage practices in either of the two years of the study, however, wheat residues were significantly lower under conservation tillage practices than under conventional tillage practices in 1991. Tillage practices did not affect the weight of corn residues in 1991 but conventional tillage resulted in higher residue weights in 1992. Similarly, residue weights were higher when soybean was managed under conventional tillage than when managed under conservation tillage in 1992 but resulted in similar residue weights in 1991. The weight of tobacco residues returned to the soil were significantly higher when the crop was managed under conventional tillage in 1991 but tobacco residue weights were similar for both tillage systems in 1992.

The field study also examined the effects of management on the rate of mineralization of crop residues. ^{14}C, ^{15}N-labelled residues from each of the crops were either incorporated to simulate conventional tillage or surface applied to simulate conservation tillage within square steel microplots in the field. Root decomposition was followed within separate microplots from above ground crop residues. All crop residues followed the characteristic rapid decomposition within the first year with a subsequent slowdown of the rate of decomposition in the second year of the study. For all crops, surface applied residues were mineralized to a lesser extent in the short term than incorporated residues but approached similar decomposition rates by the end of the second year of the study. Tobacco residues decomposed at a slower rate than wheat, rye or corn residues which all mineralized more slowly than soybean residues. Roots decomposed more slowly than crop residues incorporated into the soil, however, had a similar decomposition rate to surface applied residues. Less residue nitrogen was available to the subsequent crop when residues were surface applied rather than incorporated into the soil probably due to greater amount of immobilization of nitrogen during the decomposition of the residues.

Similar amounts of residual carbon and nitrogen remained within the soil following a two year decomposition period, however differences in the amounts and position of residual carbon and nitrogen were detected between the tillage practices. No-tillage practices resulted in a stratification of the decomposition products near the soil surface whereas conventional tillage practices uniformly mixed these decomposition products within the plow layer. While no difference in the total amount of carbon and nitrogen within the soil could be detected during the two year period of the study, this stratification of residual decomposition products detected with the use of tracers suggests that the organic matter levels of soils managed under no-tillage practices will increase at the soil surface where they can be of greater use to prevent soil erosion and improve soil quality. However, as a result of the decomposition of organic materials at the soil surface organic matter levels will be reduced deeper in the soil profile under no-tillage practices. In contrast, mixing of crop residues within the plow layer causes a faster decomposition rate in the short term and results in a more uniform organic matter content within the soil profile in the depth of tillage.

Project L

Title: Open Category RFP under the NSCP Research Program

Purpose

The research program under NSCP is inviting unique proposals for research on soil quality issues which have not been identified in the foregoing five. They should be confined to the areas of work set out in the background of this guideline and subject to the preferences identified there. It is fully expected that any submission will be a serious contribution to our understanding of the conservation of soil quality, its measurement or extension to the agricultural community.

Objectives

1. Please state the objectives of the proposed study clearly.

Scope

Although the expected scope of the work is undefined here, the scope of the work in the proposal should be clearly stated. The proposal should fall within the guidelines given above, observing the two year time frame, and the suggested level of effort. On farm demonstrations are discouraged in favour of more technically sophisticated studies which relate to our understanding of sustainable and/or restorable soil quality.

Insufficient funds to support submitted proposals.

PART III - CONTRIBUTION

Contribution agreements were supported to continue two ongoing research projects which were deemed extremely important to understanding soil structure and erosiion modelling.

University of Guelph;
Dr. R. G. Kachanoski - $76,528.00

University of Guelph;
Dr. B. D. Kay - $83,472.00

The Relationship between Landscape Position, Tillage Practices, and Soil Loss: Model Development

University of Guelph;
D. A. Lobb and Dr. R. G. Kachanoski

EXECUTIVE SUMMARY

In 1987, the University of Guelph initiated a soil erosion study, Management of Farm Field Variability I. Soil Erosion Processes on Shoulder Slope Landscape Positions (SWEEP/TED), at two field sites in southwestern Ontario, one in Brant County and the second in Middlesex County. The study measured tillage translocation and tillage erosion on convex upper slope landscape positions. The estimated rate of soil loss resulting from net downslope translocation was in excess of 6.5 kg m^{-2} yr^{-1} at the Brant County field site and in excess of 4.5 kg m^{-2} yr^{-1} at the Middlesex County field site. Subsequent examination of that data recognized that tillage erosion was responsible for at least 70% of the total soil lost on the upper slope landscape positions based on estimates of total soil loss using resident ^{137}Cs.

A second study, Soil Loss by Tillage Erosion: The Effects of Tillage Implement, Slope Gradient, and Tillage Direction on Soil Translocation by Tillage (SWEEP/TED), by the University of Guelph from 1990 to 1991 at two field sites in Huron County was conducted to determine the effect of tillage implement type on the magnitude of tillage translocation and tillage erosion under a range of slope gradients in topographically complex landscapes. All four tillage implements, the chisel plough, mouldboard plough, tandem disc and field cultivator, were found to be erosive, causing soil loss on upper slope landscape positions and soil accumulation in lower slope landscape positions.

The objective of this, the third study conducted by the University of Guelph, study was to define the relationship between tillage erosion and landscape position in the form of a model based on the data collected in the Huron County study.

In the proposed model, tillage erosion was calculated as the net translocation at specified points in the landscape, the difference between the soil translocated into a point and the soil translocated out from that point during a single tillage operation. Tillage translocation was

related to slope gradient and slope curvature by a simple linear function. The translocation in to and out from a point was calculated from forward and backward differences in topographic conditions. Therefore, the model predicted soil redistribution from forward tillage translocation along two-dimensional landscape profiles.

The proposed tillage erosion model was calibrated using experimental data from the Huron County study Soil Loss by Tillage Erosion: The Effects of Tillage Implement, Slope Gradient, and Tillage Direction on Soil Translocation by Tillage (SWEEP/TED).

The proposed tillage erosion model was validated using data collected during two preceding studies, Management of Farm Field Variability I. Quantification of Soil Loss in Complex Topography (SWEEP/TED) conducted in Brant County and Soil Loss by Tillage Erosion: The Effects of Tillage Implement, Slope Gradient, and Tillage Direction on Soil Translocation by Tillage (SWEEP/TED) conducted in Huron County. Resident ^{137}Cs radioactivity was used to estimate soil redistribution within the landscapes of the field sites. These estimates of soil loss and accumulation were compared to those predicted by the tillage erosion model based on the topography of the field sites.

The proposed tillage erosion model provided a reasonably accurate prediction of soil redistribution at the Brant County field site when compared to the estimated using resident ^{137}Cs radioactivity. The tillage erosion model provided a relatively poor prediction of soil redistribution at the Huron County field site when compared to that estimated using resident ^{137}Cs radioactivity. There is some indication that the poor prediction for the Huron County site was due in part to the model's simplicity (not able to predict the effect of curvature asymmetry on tillage erosion - a problem which would be greater at this site than the Brant County site because of smaller scale of the ridge). Soil losses, based on the ^{137}Cs data, were situated on the convex upper slope landscape positions, but they were greater in severity on the should slope position of the steeper of the ridge's two slope faces. Although the model correctly predicted the general pattern of soil losses and accumulations, the model underpredicted the magnitude, or severity, of soil losses at both field sites. Too few data of soil accumulation estimates were available to make a similar inference about soil accumulation. Several possible reasons for this underprediction of soil loss were identified: 1) the tillage implements and the tillage sequence used to predict the soil redistribution may have been less intensive than those responsible; 2) inaccuracies associated with the use of resident ^{137}Cs may have caused overestimation of soil redistribution (the problem associated with point measurements resulting in apparent losses on backslope positions, as well, the current level resident ^{137}Cs for a non-eroded site may be much less than the assumed 2500 Bq m^{-2} in Huron County); 3) wind and water erosion may have caused soil redistribution in addition to that caused by tillage erosion (the redistribution pattern is inconsistent with that of soil erosion by overland water flow).

For a first attempt at modelling tillage erosion in complex landscapes, the performance of the proposed model was considered very good. Clearly, there are limitations to the complexity and consequently predictive capabilities of the model due to the lack of experimental data for calibration procedures, particularly tillage depths. AT the time the study was initiated, the number of parameters involved and the complexity of the relationships was not fully appreciated. This was exploratory research, and therefore presuming that a model could be developed on such a data set was very ambitious.

The fact that the proposed tillage erosion model predicts greater rates of soil loss on convex upper slope landscape positions where severe soil loss occurs, and soil accumulation in concave lower slope landscape positions where soil accumulation is observed, indicates that this model is more appropriate than water erosion models for predicting soil erosion in topographically complex landscapes. Consequently, it can be presumed that the proposed tillage erosion model is more appropriate than water erosion models for basing soil conservation decisions relating to soil degradation and soil productivity. Comprehensive soil erosion models including submodels for erosion by wind, water and tillage may provide the best prediction of soil redistribution in topographically complex landscapes.

Methodologies for Assessing Soil Structure and for Predicting Crop Response to Changes in Soil Quality

University of Guelph
B. D. Kay, A. da Silva, K. Denholm, N. Eshraghi, E. Perfect and V. Rasiah

EXECUTIVE SUMMARY

The objectives of this study were:

(a) to identify a method(s) for measuring soil structural changes which may be related to soil management systems and which can be shown to be useful for characterizing changes in soil quality across a range of soil conditions and

(b) to evaluate existing crop productivity in terms of their suitability for predicting crop response to changes in soil quality.

The budget associated with the contract was directed to field and laboratory studies related to objective (a) and the collection of field data to be used in the evaluation of crop productivity models [obj. (b)]. The research related to objective (b) has been part of the work plan of an Agriculture Canada Research Branch staff person and the salary expenditures associated with this part of the project have not been charged to the contract.

The field studies for the project were located on the farm of Mr. Don Lobb, Huron County. This site was one of the T-2000 sites investigated during the Ontario Land Stewardship program and is one of the longest running field scale side-by-side comparisons of zero and conventional tillage in Ontario. The comparison is maintained as a strip about 0.5 km in length which traverses soils with clay contents ranging from 7 to 35%. The site was maintained in corn production in 1991 and 1992. (The study has been extended to 1993 and supported by funds from alternative sources). Thirty-six locations (soils) were identified on each transect (tillage treatment) for detailed studies on soil structure.

Soil structure can be defined in terms of structural form and structural stability. Structural form relates to the arrangement or "architecture" of solid and void spaces whereas structural

stability refers to the resistance of structural form to deformation (including fragmentation) when stress is applied. Structural form can progressively change subsequent to a change in soil or crop management practices through changes in the level of stress applied to a soil or by changing the population of soil organisms (e.g. earthworms). Structural form will also change if the stress remains constant but stability changes. Management practices can cause changes in stability by causing changes in the level of stabilizing materials (primarily organic in origin) in soils. Methodologies to assess both structural stability and structural form were assessed in this study. Pedotransfer functions were developed, where possible, in order to describe the contribution of inherent soil properties to the magnitude of the different parameters that were measured.

Parameters which were used to describe structural stability related to the resistance of soil to deformation by two types of stress: moving water and mechanical stress causing fragmentation. Stability parameters related to moving water were assessed at two different scales: that of aggregates > 0.25 mm, and that of clay-sized particles (< 0.002 mm). The resistance to mechanical stress was assessed using tensile strength and the distribution of aggregate sizes created by tillage.

Preliminary studies using rainfall simulation techniques indicated that the amount of runoff and the amount of sediment in the runoff arising from a rainfall event were related to dispersible clay and time to ponding; and that these parameters became more important as the extent of surface cover by crop residues decreased. Time to ponding is related to infiltration characteristics and was found to be strongly dependent on wet aggregate stability. Stability parameters at the scale of aggregates and at the scale of dispersible clay both appeared, therefore, to be important in describing runoff and sediment load in the runoff. Studies were therefore initiated to assess both characteristics in more detail.

A turbidimetric technique was developed to expedite characterization of dispersible clay across the range of soils on the study site. The technique involved developing a standard curve (turbidity as a function of concentration of dispersible clay) which can be described as a function of inherent soil characteristics (clay and organic matter content), and then characterizing the dispersibility of clay. Variation in the characteristics of the standard curve with soil properties appeared to be due to the concentration range in which the standard curve was determined and the mean weight diameter of the dispersed clay fraction. A single curvilinear standard curve was found to be applicable to all of the soils on the study site since the curvilinear representation incorporated the influence of both concentration and mean weight diameter. The dispersible clay content was found to increase with increasing clay content, increasing water content and decreasing organic matter content; the variation in dispersible clay content with tillage appeared to be due primarily to the influence of tillage in reducing the organic matter content.

Wet aggregate stability was found to increase with clay, water and organic matter content. The reduction in stability with tillage appeared to be related to the reduction in organic matter content with tillage.

The response of soil to mechanical stress was assessed by considering tensile strength measurements and the dry aggregate size distribution created in seedbed by tillage. Tensile strength increased with increasing clay content, wet aggregate stability and decreasing organic matter content. Aggregate size distributions were assessed using different approaches. A description of the distribution by fractal theory was found to be most accurate. The analyses indicated that the number of aggregates in the largest size fraction increased with increasing clay content, wet aggregate stability and decreasing organic matter content. A comparison of tensile strength and aggregate size distribution characteristics showed a highly significant correlation indicating increasing fragmentation with decreasing tensile strength. The analyses suggest that one parameter could be predicted from the other and that, for a given application of stress through tillage, either parameter could be predicted from inherent soil characteristics.

Parameters that were used to describe structural form included both static and dynamic parameters. Bulk densities and relative bulk densities were measured. The concept of least limiting water range (LLWR) was used to describe the combined effects of structural form on aeration, resistance to penetration and available water and represented measurements under "static" conditions. Structural form was characterized under dynamic conditions using infiltration measurements. Once again the sensitivity of these parameters to inherent soil properties and to management was determined.

Bulk density was found to vary with clay and organic matter contents and was higher on the no till than the conventional till treatment. The relative bulk densities were determined by dividing the observed bulk density of each soil by the bulk density determined after compacting each soil with a compressive stress of 200 kPa. The bulk density after compaction was also found to vary with clay and organic matter content. The relative bulk density was however constant across all soils for a given tillage treatment and was 11% higher on the no till treatment. This type of analysis has not been done before and obviously has important implications for all laboratory studies in which bulk density and inherent soil properties are variables.

Values of LLWR were determined by establishing the functional dependence of the water release curve (potential versus water content) and the soil resistance curve (resistance to penetration versus water content) on bulk density, clay and organic matter content. Limiting values were then assigned, using generally accepted criteria in the literature, for aeration (10% air filled porosity), field capacity (0.01 MPa), permanent wilting point (1.5 MPa) and resistance to penetration (2.0 MPa) to these functions in order to define the LLWR for each soil. Analyses showed a wide variation in LLWR with clay and organic matter content for a given tillage treatment. Correlation of LLWR with plant growth parameters indicated a strong correlation between LLWR and plant population. Analyses are still underway relating soil water content and LLWR to leaf extension during the growing seasons.

Infiltration was measured in the non-trafficked inter-rows on all 36 locations under both tillage treatments. The field saturated hydraulic conductivity, K_{fs}, was found to be higher under the no-till treatment than under conventional till and may reflect greater continuity in macrospores in the no-till treatment. A statistically significant, but poor, correlation existed between K_{fs} and inherent soil properties.

Data were collected that could be utilized in evaluating plant growth models. Climatic records were obtained from a weather station maintained on the site. Additional information on plant response parameters (yields, root distributions) were also recorded.

Adaptation of current crop productivity models is being undertaken by Mr. Ken Denholm, Agriculture Canada Research Branch, Guelph as part of this project. This activity has not progressed as rapidly as originally anticipated. However, once the models are developed a complete data set is available to assess the models in terms of their ability to predict yield response on soils of different structure and under the dramatically different climatic conditions that existed in 1991 and 1992.

APPENDIX A

Evaluation Criteria

Proposals were evaluated in accordance with the following criteria. Bidders were advised to address these criteria in sufficient depth in their proposals.

	Maximum Points (%)
A) TECHNICAL PROPOSAL 1) Scope and Objectives (10 points) - understanding of the problem - conformance to NSCP program criteria 2) Design (15 points) - scientific merit - conceptual framework, sampling and analyses, data management 3) Impacts (10 points) - consideration of scientific, environmental, social and economic impacts, recognition of technology transfer 4) Understanding of Related Problems (context; 5 points) - knowledge of related problems, links with scientific, professional and farming communities	40
B) TECHNICAL QUALIFICATIONS 1) Management Team (10 points) - relevant experience and involvement of senior personnel 2) Key Personnel (15 points) - Scientific, and agronomic qualifications with demonstrated research capabilities of both the researcher and research establishment applicable to soil conservation 3) Team Organization (5 points) - line of control, role of associates and proposed sub-contractors	30
C) RESOURCES 1) Human resource needs planned and flexible	15
D) CONTRACT MANAGEMENT 1) Financial Capability, Terms and Conditions (10 points) - sufficient to ensure support facilities for life of contract - levels of conformance, sub-contract confirmation, general conditions 2) Control Procedures (5 points) - work plan and schedule - control of progress, costs and subcontracts, as applicable	15
TOTAL POINTS	100

The results of the proposal evaluation according to the above criteria was the prime tool in the overall evaluation; any proposal that received less than 70% of the total points was excluded from further consideration. However, price, level of effort and the method of payment was also considered in the overall evaluation to determine the best value to the Crown. The Crown reserved the right to enter into negotiations concerning price and level of effort.

In accordance with Treasury Board Policy on contracting-out science and technology, proposals received from suitable industrial sources was given precedence over proposals from Universities and other non-profit organizations. This in no way precluded the use of Universities and other non-profit organizations as subcontractors on any project.