AGRICULTURAL SOIL QUALITY CRITERIA FOR CANADA

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ABSTRACT

The concept of soil quality has evolved from an expression of productivity to an assessment of environmental sustainability. It now includes elements of health and time as well as biological production. This paper tracks the evolution from an agricultural context and defines specific, discrete components which can be managed separately within the environmental framework. A brief outline of agricultural soil suitability identifies some of the critical soil qualities such as the ability to supply nutrients and moisture and how we presently assess them. A discussion of emerging issues touches on the requirements to link various data sources and disciplines, the need for standardization and coordination, the need to establish and monitor sensitive environmental indicators and the challenge of puttin a "value" on quality so that it can become an integral part of economic asssessments and development planning.

5.1 INTRODUCTION

Soil quality per se is an abstract term which requires a description or context before it assumes specific meaning. For an assessment of soil quality one needs to know the purpose or use, the critical parameters by which it will be measured, and a rating standard to asses excellence (Pettapiece 1986). The term "soil quality" may be used for a variety of purposes including forestry, waste management or reclamation. Within an agricultural context, a number of terms and procedures such as rating index (cf Storie 1936), capability (CLI 1964) and land evaluation (cf Stewart 1968) have been used to describe soil quality. More recently, there has

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been a shift to emphasize a sustainability aspect (FAO 1976, Acton 1992) and a holistic ecological perspective (Dover and Talbot 1987, Lourance 1990).

The concept of sustainability, which has long been implicit in many assessments, is now a principal pillar of most definitions of soil quality and has been broadened to include the financial side of land use (Committee on Sustainable Agriculture, 1992). When one adds in the fact that the majority of soil quality considerations also include landscape, hydrology and particularly climatic components it is easy to see why there has been some confusion about this topic. In the past, with industries and disciplines relatively isolated and with a somewhat restricted number of people working on the issue, communication was not a major concern. That is no longer true today. Soil quality is now a major environmental issue that touches on an increasing variety of disciplines and jurisdictions and ranges in application from individual farms to international arenas. The need to integrate and cooperate has never been greater.

The number and usage of terms to describe soil quality is confusing at best and at worst can actually create problems and obstruct progress. The concept of soil quality and particularly the environmental perspective is critical to our future land use planning and management and needs to be clearly defined. The purpose of this presentation is to: (a) review the history and definition of (agricultural) soil quality, (b) place (agricultural) soil quality in a broad environmental perspective, (c) discuss the present criteria used to assess agricultural soil quality, and (d) consider emerging issues and concerns impinging on soil quality considerations.

5.2 BACKGROUND

Agricultural rating systems are actually assessments of soil quality for a specified purpose. They started in the early part of this century in a very qualitive Good-Fair-Poor style. However, by the mid 1930's there were a number of systems which provided some specific structure. Most were based on yield predictions with very little attempt at defining processes or interrelationships. These deductive approaches were gradually replaced by systems which were based on some assesment of inferred response or inductive approaches. Both approaches were somewhat quantitative and were used by some as a relative (index) rating and by others, particularly those using the ratings to support land assessment for taxation purposes, in an absolute sense. Some used classes, others used multiplicative or additive procedures (Huddleston 1984).

While productivity was still a major consideration, the 50's and 60's saw the introduction of capability and suitability concepts (CLI 1965, Klingebiel 1958). These used a class format with a limiting factor approach and, even though based on more and better information, appeared less precise and therefore often gave the impression of being less reliable. However, the simple straight forward concepts were very useful for comparing land use options and they were quickly adopted by the planning community. Although the scope of interpretations was expanding, agricultural assessments still did not consider the environment or the idea of change.

In the decade of the 70's computer technology was introduced and process modelling began. Later, land evaluation (FAO 1976, Smit et al. 1984) added an economic component to soil quality assessments but the emphasis was still mainly on agricultural development. However, sustainability was becaming an underlying assumption and the concept of soil quality now included elements of time and "health". It was not simply the kind and amount of production but also would it stay healthy enough to maintain the production. Degradation and conservation became topical issues and the need for monitoring was introduced.

The next major change, coming mainly in the 80's, was inclusion of the holistic ecological concept. Soils were now considered part of a larger environmental system and added to soil quality was the idea of a filter in that system (Larson and Pierce 1992). For example, water was now seen not only in terms of plant growth but also something that passed through or over the soil connecting it with other parts of the environment. Not only was the production system becoming more inclusive, but the concepts about what it should be were constantly evolving.

It is interesting to consider some of the scientific and institutional responses to the evolving concepts of soil quality and the emerging environmental awareness although cause and effect are often difficult to establish. For example, the 70's saw the development of land evaluation concepts but it is not clear whether it was a response to the multiple land use needs of planning or because the introduction of computers made it possible. Today, society is clearly responding to global environmental concerns and the idea of sustainability such as expressed in the "Brundtland report" (The World Commission on Environment and Development 1987). This in turn directs governments. We have recently had the National Soil Conservation Program and Federal-Provincial (agricultural) reports on environmental sustainability (1990) and now the Green Plan (Government of Canada 1990).

What then is an acceptable definition of soil quality?

5.3 DEFINITION OF (AGRICULTURAL) SOIL QUALITY

There are a number of definitions which capture our present concept of what we think soil quality should be. Leopold (1949) provided an early holistic concept which has been interpreted by Anderson and Gregorich (1984) as " the sustaining capability of a soil to accept, store and recycle water, nutrients and energy". More recently Larson and Pierce (1992) have suggested that "soil quality is the capacity of a soil to function within the ecosystem boundaries and interact positively with the environment external to that ecosystem". That is, the management of a soil within a particular set of environmetal conditions, an ecosystem, cannot be judged without consideration of its impact on adjoining ecosystems. Others have specifically included profitability but that seems superfluous in addition to sustainablity. In all cases there is an implication of inherent soil capability and sustainability. Also, one understands that biological production is involved and that sustainability refers to both economic and environmental considerations. While the term 'soil' is used, the context indicates a broad concept which includes landscape and climatic attributes. There are situations where one may wish to specify soil or climatic quality for a particular use but in the general context it seems preferable to use 'land' as an explicit integration of the main contributing factors.

According to the FAO (1976) definition, "land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific use". Suitability is understood to include the aspects of biological production and sustainability and the definition emphasizes the need to specify a use or objective, an important point for clarity of communication. This is quite generic but can be adapted for any use or level of detail and would seem to be a good starting point. As quality also implies a "degree of excellence" it is clear that critical values for one purpose could be quite different from those for some other use. For example, a salinity level which is acceptable for barley might be limiting for onions or, topographic parameters which might be limiting for cultivation might be quite acceptable for grazing.

The previous discussions have noted a shift in the concept of soil quality from something that was almost synonymous with productivity to a much broader concept which includes sustainability and hence time and health aspects as well as an ecological perspective. Figure 1 is an attempt to illustrate the place of soil quality in the present context. The box in the middle defines the real geographic entity that we can analyse and monitor. This figure also "defines" the various components and identifies the linkages which must be developed to make the whole system function.

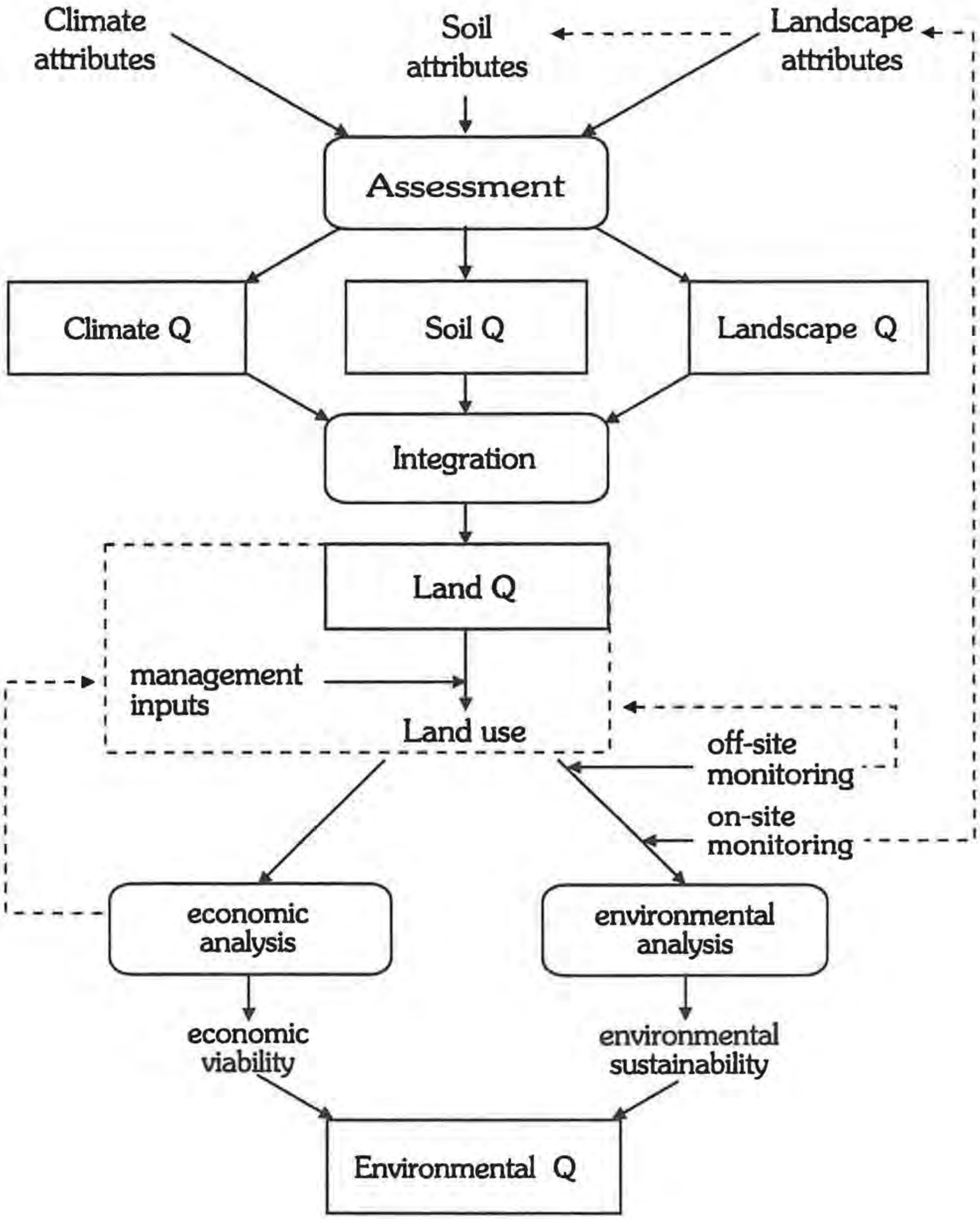

Figure 1. Components of environmental quality

It is difficult to deal with the whole package of "environmental quality" at one time or by one discipline. The next section will deal in more detail with the restricted scope of soil or land quality for agricultural purposes.

5.4 AGRICULTURAL SOIL QUALITY

Agricultural soil quality as used here is identical with suitability for agricultural purposes. Indeed, even the term 'agricultural' is too broad for most discussions of soil quality which must at least specify arable vs nonarable. Therefore, this discussion does not cover the complete range of the soil quality definition but it is a definable sub-component which is basic to nearly all other socioeconomic and environmental assessments and evaluations. Our long term view is that we must deal with processes and that understanding and modelling them is the most effective approach for assessing and particularly monitoring soil quality. However at any point in time one needs to be able to assess quality based on current knowledge.

The following discussion is based on a recent initiative by an Expert Committee on Soil Survey / Agriculture Canada working group to quantify our assessments of soil interpretations. It will deal with the development of a standardized, quantified assessment of the suitability of a tract of land for a specified agricultural pursuit. Preliminary work defined a number of constraints and assumptions.

1. It must cover the range of Canadian conditions
2. It must be specific and explicit
3. It should follow the 7 class concept of the CLI
4. It must be flexible and adaptable
5. It should separate and rate individual components
   - climate, soils and landscape
6. It should be as inductive as possible
   - based on an expert system approach
7. It must be suitable for automation

8. It should use present or commonly available data
9. It should use a mathematical or continuous scale approach- not classes
10. It would be modified.

This provided a general framework but did not address the issue of the specific factors to be used for an assessment of soil quality. Huddleston (1984) concluded from a review of rating schemes in the U.S. that a mixture of inductive, process related, and deductive, direct measure, approaches would be effective and practical. With this in mind, the working group analysed systems presently in use and drew up a list of critical factors for determining land quality. The factors were selected according to 4 main criteria:

1. known to affect the ability of soil to produce crops,
2. known to affect the ability of soil to respond to management imposed stresses (resilience),
3. must be measurable or estimatable and
4. should be commonly available.

Because we wanted to deal with the whole land system it was necessary to consider the factors (qualities) and criteria[2] (measured parameters) for climate and landscapes as well as soils (Table 1).

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[2] The term 'criteria' is commonly used for assessments while the term 'indicators' is often used when discussing change.

Table 1. Selected criteria for assessing land quality for arable agriculture.

Component	Factor (quality)	Criterion
Climate	- heat or energy factor	growing degree days (growing season)
	- moisture factor	precip.- potent.evap. (growing season)
Soils	- moisture supply water table	texture (with climate)
	- nutrient supply	reaction (pH) organic matter content
	- rooting condition	surface structure subsurface structure
	- chemical problems	salinity sodicity
	- drainage	water table (climate)
Landscape	- erodibility/management	slope steepness slope length stoniness flooding

Following the conclusions of Huddleston (1984) a mixture of inductive and deductive approaches was used. The next step was to develop ratings for each factor. This required a crop(s) designation and the small grains (wheat, barley, oats). a group of similar crops which could be grown across Canada, were selected. The approach was to establish critical values for each factor which related to our concept of excellence and then place these in a continuous value table or chart.

The following table for salinity was developed based on general relationships to crop yield.

Table 2. Critical levels of salinity for small grains.

Salinity value E.C. (dS/m)	Limitation	Point deduction
2	no effect (class 1)	0
4	slight effect (class 1-2)	20
8	moderate limitation (class 3)	50
12	very severe limitation (class 5)	70
16	growth stopped (class 7)	90

This could also be represented as a graph (Figure 2).

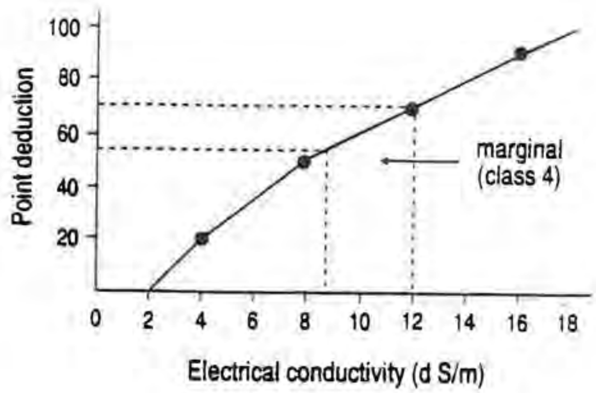

Figure 2. Relationship of point deductions to salinity for spring seeded small grains.

All the soil factors were combined into a final soil rating. The same procedure was used for the climate and landscape components. Each step is documented in the procedure so any discrepancies can be quickly identified and clarified. The overall rating is the most limiting of the three components, with accommodation made for the identification of significant limiting factors. This allows for informed land use comparisons including valuation of remedial measures.

This is a very pragmatic approach based on documented relationships which are linked together using an expert system procedure. The relationships, the use of a measurable soil attribute to assess another factor, have been termed 'pedotransfer functions' by Bouma (1989) and, along with 'proxies' for unmeasurable attributes, are the key to the system. For example, we use % clay in the estimation of water supplying ability and % organic matter in the assessment of fertility and structural resilience. It would be nice to know every detail about every process but this is not the case and the need to utilize empirical relationships will be required for some time.

This suitability rating system documents our present knowledge and identifies problem areas for priority research. It integrates climate and landscape components into the analysis but maintains flexibility by dealing with each separately. It is explicit and quantitative and can be automated. It is best viewed as a relative index rather than an absolute value. While the approach can be used for other crops, the rating scales, as developed, are specific for small grains. Future work will address the factor ratings for other crops such as forages, corn, potatoes and specialty crops as required. This system does not model plant growth or predict change. Nor does it rate economic viability or best land use. These require additional considerations. It simply assesses the suitability (quality) of a particular set of biophysical conditions for a specified purpose. While links to more complex analyses were considered in the design of the system they also are the weakest part of the assessments and should be a focus for future work.

5.5 DISCUSSION

Soil (Land) quality includes a number of aspects which need to be related and integrated to support a variety of decisions ranging from individual field management to national policy development. The questions can vary from "can I grow onions", to "what is the most appropriate landuse", to "how might an international tariff affect sustainability". As a result, there is no single, simple answer or process for describing soil quality. It depends on the objective and may include a physical assessment, a comparison of alternative uses, socio-economic evaluations and environmental considerations. It may be a present determination, an analysis of change, or a prediction of sustainability.

Our challenge is to clearly identify the component parts and requirements and to provide the linking procedures. This has long surpassed the purview of one discipline or even one industry. As the complexity of the issues and the solutions has increased so too has the need for cooperation and integration. This is not to say that we all have to develop and use a single procedure, but we must understand the needs and implications of the other players. Our information must be available in forms that are meaningful and useable by others. For example, people in agriculture must broaden their concept of soils to include other functions than those relating only to productivity; particularly those relating to water movement and "environmental filtering".

In a small region with relatively uniform conditions or limited number of options the complexity can be difficult but when considered for a country as large and varied as ours it often seems overwhelming. Indeed, it can be, without some overall logic or concept which provides for both the partitioning and linking of activities. For example, the development of a national ecological framework allows one to partition or separate parts of the country with similar environmental constraints and land use issues with defined boundary conditions. Within these limits, one could reasonably expect to have similar responses to external stresses whether environmental, economic or social in nature. For such a stratification to function it is critical that all concerned agencies agree to use a single standard. This agreement is much more important than being absolutely correct, a concern which often hampers the sharing of information and ideas. There does need to be reasoned background and documentation based on available research. There must also be continuing investigation, testing and validation, and a process for changing the standard when appropriate.

One of the requirements for cooperation and integration is consistency in terminology and standards. The people assessing soil suitability and those monitoring change should be measuring the same attributes or at least reporting on the same quality component. If we are going to exchange information and build on the experience of others it is essential that we have standards. Again agreement is more important than absolute correctness. If a standard is found to be incorrect or inappropriate it can be changed and any system must be able to accept this inevitable occurrence. We are continually approximating and research to refine or change our assessments is essential.

The search for definition and establishment of environmental indicators is the source of much discussion (Hamblin 1992) and will be an important issue over the next few years. The consideration of sustainability demands a focus on quality change which in turn requires the identification of indicators sensitive to change. At present much of our knowledge about soil quality relationships is empirical. The future will see more emphasis on process based research and model development. Crop growth models are a good example. These will need to include feedback loops for changing conditions and will certainly be based on probability analyses. Such models will become the basic tools for predicting change or assessing sustainability. A current problem area is our inability to link or extrapolate experimental site data to an areal or geographic projection. This includes not only the single discipline concerns but the added links to other parts of the environment. For example, fertilizer-yield relationships when extrapolated to a field or watershed now need to consider movement of chemicals to a water table or off-site effects from surface runoff. As these kinds of initiatives progress more of our soil survey activity will be directed to validation and monitoring in contrast to basic data collection.

Another issue which will need to be addressed in the near future is the valuation of all aspects of environmental quality including soil quality. (MacNeil et al. 1991). That is, the assigning of dollar values and the internalizing of these factors in land evaluation. At the present time, environmental issues tend to be handled as external to assessment of economic viability and sustainability. Until they become an integral part of such evaluations, a balanced analysis which will stand up to public scrutiny will not be possible. The wildlife/recreation sectors have attempted for many years to put a value on the positive aspects of our natural resource base with varying degrees of acceptance. Like human health, it is often the cost of correcting which is the only value available. For example, we don't have a value for a good, non-limiting subsoil but we can measure the loss in yield due to a restricting compacted layer or the cost of deep ripping to remove it. Following this line of reasoning, if it is easily (cheaply) fixed it is less valuable than if it is more difficult or expensive. That still does not put a positive value on a rural landscape or wildlife habitat or cover the cost of a sustainable management practice but it does provide some basis for decision making. We need to address this issue and we need help to do it. In many ways this is a societal as much as a technical issue and input from social scientists will be required. Society also influences our definitions of sustainability and acceptability. These can and will change as knowledge and awareness increases. The "value" of endangered species habitat and wetlands are examples. It is important that we understand this process and not get frustrated when the technical targets we identified yesterday are no longer valid today.

5.6 SUMMARY

The concept of soil quality has evolved over the past few years to include a holistic environmental context. It now includes time and change components as they relate to health and sustainability. The whole complex is dynamic and our definitions and assessments must be flexible enough to respond. We have tried to place agricultural soil quality in this broader context and to provide some working definitions which reflect process rather than static data. The need for clarity of definitions and standards is essential as is the need for cooperation and integration of many agencies and disciplines. The current assessment of soil quality for agricultural purposes is based on an expert system approach which is explicit, flexible and can be automated. It does not address the aspects of quality change or best land use which require additional inputs. This underlines the importance of defining boundary conditions and the need to be able to partition as well as integrate.

Future activities will undoubtedly centre around process modelling, monitoring quality change, developing links with other data sources for holistic assessments of sustainability and the evaluation and internalizing of environmental and 'soil health' factors. An immediate challenge is to identify soil quality standards and indicators which are sensitive to environmental change. It should be remembered that there are rarely quantifiable absolutes in the natural resources and often many equally valid approaches may be used to address an issue. However, this should not be used as a reason to avoid setting or selecting standards. The establishmnet of standards highlights the difference between a research perspective which must keep probing and changing, and an application mode which requires some stability. Both are required and need to be accommodated in our overall approach to soil quality.

5.7 ACKNOWLEDGEMENTS

We would like to acknowledge the many people who have contributed to discussions on this topic;to the Alberta and National Agricultural Rating Working Groups who have attempted to encapsulate our present knowledge; and to the National Soil Conservation Program which gave us the opportunity of putting some of our ideas into practice and to tackle some major knowledge gaps.

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AND

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PREFACE

The Environmental Soil Science conference was held August 8-13, 1992 at the University of Alberta, Edmonton, AB. It was sponsored jointly by the Canadian Land Reclamation Association (CLRA) and the Canadian Society of Soil Science (CSSS). The objective of the conference was to share theoretical and applied aspects of soil science. It also served to get participants from the sponsoring groups together to find areas of mutual interest. There were 330 participants from Austria, Bangladesh, Canada, England, France, Germany, India, Japan, New Zealand, Norway, Spain, the Netherlands, and USA.

Abstracts of the oral and poster papers were published in the Canadian Journal of Soil Science (Vol.72, No.3, August 1992. (p.299-353). Volunteer papers covered all aspects of land reclamation, soil science, and public participation in the environmental review process. Seventy six of the 164 volunteer papers were presented as posters.

The invited papers presented in the plenary sessions focused on soil quality and interaction of soils with anthropogenic chemicals, and are published in this proceedings. Publication of the proceedings has taken an unduly long time due to unavoidable circumstances and we apologize for the delay.

Grateful acknowledgement is expressed to our colleagues on the organizing committee (J.A. Robertson, Chair) for their contributions to the success of the conference.

Y.P. Kalra and W.W. Pettapiece, Compilers

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