## INTRODUCTION

A literature review for the Alberta Environmentally Sustainable Agriculture (AESA) Soil Quality Monitoring Program was initiated within the Conservation and Development Branch of Alberta Agriculture, Food and Rural Development (AAFRD), with the intent to synthesize current literature on soil quality indices. This review has included coverage of publications dealing with the various approaches used in developing soil quality indices. It will assess the literature, by March 2004, for indices appropriate to western Canadian conditions and with respect to the needs of the AESA Soil Quality Program.

A professional librarian, Connie Hall, provided the project component of searching for and compiling all relevant literature, from September to December 2003. This work included the creation and administration of electronic databases to include all of the search results, to rate them according to project parameters for relevance, to provide brief comments in the form of annotations concerning content of the most highly-related publications found, and to record these in the databases for use by the reviewer and AESA staff. Deliverables of the literature review, by Eric Bremer, will incorporate this information to produce a final report, with a target completion date of March 31, 2004.

The Soil Quality Literature project of 2003 was required in order to compile science-based literature for review. Most specifically, this project identifies soil quality indices and indicators that may be used in Alberta according to the needs of the AESA program, and will contribute to soil quality reporting and monitoring within the province.

## INDICES

The *American Heritage® Dictionary of the English Language*, Fourth Edition Copyright © 2000 by Houghton Mifflin Company defines an **index** as:

> Something that serves to guide, point out, or otherwise facilitate reference; …
> Something that reveals or indicates; a sign; …
> An indicator or pointer; or, in mathematics, as …
> A number derived from a formula, used to characterize a set of data.

Econometrics, geometrics, and geostatistics are fields that use indices (plural of ‘index’) to indicate measures of condition—the state of factors at a point in time or space—and for trends analyses—the changes in factors through time. We are familiar with some of these indices, such as the Consumer Price Index or the Index of Social Progress in socio-economics; or with Canada’s recently-developed Water Quality Index, for example.

The Pembina Institute (2003) recently examined sustainability in terms of indicators which it terms “Genuine Progress Indicators”:

> (GPI) is a measurement system for use by nations, states and communities to determine their progress towards a sustainable future. The GPI provides a

comprehensive account of sustainable development - including economic, social and environmental factors - as compared to a more narrow and traditional measure of development, such as Gross Domestic Product (GDP), which considers only economic growth.

The World Bank (2003; Dumanski, Gameda & Pieri, 1998), the Organisation for Economic Development (OECD 1998; 1999; 2001), the Food and Agricultural Organisation of the United Nations (UN-FAO 2003), and the European Union (Jesinghaus, 1998; 1999) all have dealt with the development of sustainability indicators, such as "Environmental Sustainability Indicators," for example. In order to examine and monitor land-use and human activity effects on arable land in Europe and throughout the world, index development has progressed throughout the 1990s and into the 21st Century. Cooperative research has occurred in order to assess land quality and soil health for sustainable agricultural production, as well as for pollution and soil degradation or mitigation amid growing pressures on land and soil resources from the earth's ever-increasing human population.

## SOIL QUALITY INDICES

In considering soil quality, attempts have been made to examine the factors that indicate 'good' soil health or soil quality, to reach consensus on the definition, upon the key soil attributes that translate into variables (pedotransfer functions) to be examined, on their data value ranges, their value limits, threshold values, comparability; and to aggregate or integrate the variables/values in such a way as to then develop meaningful indices that characterize the quality/health of varying soils in various world regions, across nations, or in local areas, and at the farm level. In order to analyze the body of scientific results available concerning these efforts, a literature survey was undertaken by the AESA Soil Quality Program. Literature was examined that deals with soil quality index discussion, definition, description, development, assessment and evaluation, testing and measurement, refinement, laboratory and field application, with farmer input and expert analyses, as well as related soil quality, soil monitoring, land-use assessment, and environmental indicators, and assessment or monitoring programs.

The goal of this literature project was to characterize the existing body of currently-published and 'grey' literature, by identifying the most relevant papers that specifically deal with soil quality indexing in concept or in practice, with an emphasis upon agricultural soils, their productivity, and sustainability. No geographic limits or language restrictions were imposed. 'Current' literature was considered as that published within the last 10 to 15 years, with some older publications being considered if they met project criteria for inclusion.

At the same time that searches for relevant literature were being conducted, databases were designed to compile the bibliographic information discovered, using ProCite™ bibliographic software (ISI-ResearchSoft. ©1995-1999. *ProCite for Windows, Version 5.0*. Web site at URL: http://www.procite.com ). Search results that matched project

parameters were entered into the databases, based upon suitability criteria developed for this project.

Relevance criteria were developed in consultation with the staff expertise within the Soil Quality Monitoring Program unit, Conservation and Development Branch, AAFRD, in order to include or to exclude references from the vast amount of world literature about soil quality.

## CRITERIA

Project parameters were delineated and factors for determining the relevance of articles were discussed with staff experts, in order that articles could be selected for inclusion or exclusion. The questions were recorded and grouped as a result of these discussions.

Characterization of the literature on soil quality indexes involved examining and indicating the following:

- Consideration of what characterizes any index, what is involved in the indexing process in general, and provision of examples of other indices -- such as in econometrics -- with their background; e.g. Consumer Price Index, GDP, stocks; and other examples of indexes.
- Consideration of specific Soil Quality studies, in which an index or indices are developed or modeled, and that include all of the following:
    1. Approaches/ Methodologies used
        a. Characteristics
        b. Weighting factors
        c. How approach was developed / philosophy behind approach (derivation)
    2. Temporal & Spatial factors
        a. Whether static or dynamic
        b. How often index(es) are calculated, repeated, at what interval(s)
        c. What trends are dealt with or revealed
        d. What monitoring or forecasting uses may be involved
        e. Scale-related information; such as whether site-specific, farm-level, regional (comparative to ?what/?where), or national/international in scope
    3. Data sources
        a. Whether the study used their own, or ‘adapted’/borrowed [field-scale or theoretical?]
        b. Quantitative/qualitative
        c. Validity & verification given (verifiable data?)
        d. Accountability / tracking / forecasting (monitoring spinoffs)
        e. Data dynamics; changing?
        f. Reliability; that is, the ‘fit’ to hypotheses/investigations?
        g. Data sensitivity to the methods/tests/measurements used and results?
    4. Models & data
        a. Many or few indicators; How sensitive to change?
        b. Approach sensitive to the indicators used? / Philosophy
    5. Pros & Cons / Assessments / Results
        a. Preliminary study, or Ongoing?
        b. Final results (after what time period)? Relatable to other results & uses? That is, applicability of the research?

These five main areas were used when scanning literature citations and abstracts, introductions, or executive summaries and conclusions of the papers obtained as a result

of searches, in order to (i) include or exclude them from the project, and to (ii) rate them for relevance to the project parameters. The project compiler provided comments within each database record for highly-related publications obtained for review.

## SEARCHING THE LITERATURE

The databases, library catalogues, and web sites searched within the timelines for this project are presented in Appendix A. The search strategies specifically designed to meet the relevance criteria for inclusion in our databases are presented in Appendix B. This approach provided maximum coverage of the current agricultural literature available concerning soil quality indices for the past ten to fifteen years, given the project timelines. Numerous searches were crafted due to the semantics involved in defining soil quality / soil health and given a professional debate which appears within the current literature concerning the utility of the soil quality concept (Sojka & Upchurch, 1998; 2003; Karlen and others, 2003). The methods used for compiling the results of the literature searches are outlined in Appendix C.

It was confirmed that a body of literature exists for land-use planning and classification, as well as for agricultural sustainability within the broader arena of environmental research (Appendix D). A common theme in this literature is the worldwide concern to determine representative indicators of 'land quality' related to human and ecosystem health. Within these contexts, there are research results and ongoing studies involving indicators of soil quality from a number of countries. Some of the research projects do involve aggregation of indicator value ranges and means into efforts toward integration and thus toward derivation of indices of soil quality.

Various statistical methods are being used and are encountered in this literature, as attempts to quantify soil quality continue. Some examples of the statistical methods used are: analysis of variance / multivariate analysis, regression analysis, pedotransfer functions, fuzzy set theory / Gaussian mathematics, representation through variograms / spidergrams, graphing / charting, to name the majority in use. Indices in this body of literature are additive or multiplicative, and encompass both small and large data sets. Data are from a single locale as well as from large-area studies, with single-year or multiple-year sampling, and include comparisons by proxy or 'representative' ecosystems to characterize pristine vs. disturbed field conditions. Research was conducted in all types of soils under various types of 'treatments' and management practices, in varying topography or terrain and climatic regions.

Translation of the exact phrase for "soil quality indices" or "index(es) of soil quality" into other languages, such as Portuguese, Spanish, or French, yielded some interesting results and ‘leads’ as a means to discovering current soil assessment research projects in the 'grey' literature. This approach could be expanded to other languages, but was not fully possible to pursue for all languages due to time factors for the current project.

## USE OF PROCITE™

In order to manage and fully survey related literature, a database had to be created in order to describe not just the publisher information in the form of bibliographic citations and abstracts, but also with the capability to compile, describe, track, and provide access to the detail of the variability involved in all of the above considerations. Therefore, a comprehensive database of related literature, compiling references of relevance, was created from September to December 2003 using a bibliographic management software product known as ProCite™ (ISI-ResearchSoft. ©1995-1999. *ProCite for Windows, Version 5.0*.). ProCite™ is available for trial or purchase via the world-wide web at URL: http://www.procite.com , has the capacities described above, so was chosen, and a main "Soil Quality Index Literature" database was created.

Another database -- the "Soil Quality Park" -- corrals other leads to more literature which occurred during the searches. The references in this secondary database may be of broader and related interest, but did not satisfy all of the criteria outlined above for this project and specific literature survey. These databases are located on a server within the Conservation and Development Branch, AAFRD, for access by AESA and Soil Quality Program staff. One copy of project files was provided on CD to the reviewer and another CD resides with the compiler.

The data occurs within the "SQI Lit" database via workforms for the types of publications encountered in the scientific literature. Primarily, these are: journal articles, conference presentations, chapters within books, scientific or government agency reports, as well as electronic citations from websites residing on the Internet.

The core scientific literature relating to soil quality indices and determined to be of relevance to the Alberta situation was thus identified (see Appendix D). Copies of articles of greatest relevance were obtained largely via interlibrary loan services of the Neil Crawford Library within AAFRD (Canadian library code = 'AEAG'; now known as one component of the 'Alberta Government Library' or AGL as of 2002). All articles were included in the database of SQI literature, using the ProCite™ 5.0 software, with input of bibliographic elements: author, title, date of publication, place of publication, publisher, journal title, volume, issue, pagination; together with conference information where relevant; electronic links; availability information; authors' abstracts, and compiler's comments (as time permitted, for the items of highest project interest) wherever possible.

An extensive subject classification was developed within the database, via keywords input within each record (per article) so that output can be generated in the form of custom-designed bibliographies or publishable bibliographic and Internet products. ProCite™ allows for 'controlled vocabulary' and standardization of subjects through a drop-down list in the Keywords field within each record, as well as allowing for the grouping of records into subject categories which may be generated by searches in all or subsets of the data within the Soil Quality Index Literature ("SQI Lit") database.

## Procedures

The entire process may be summarized as follows:

- Identify the literature
  - Design, develop and document search strategies
  - Search existing document files
  - Consult staff and experts
  - Examine bibliographies and references cited
- Conduct online searches in: --
  - Library catalogues (local, regional, provincial, federal)
  - NEOS: Alberta Agriculture, Food & Rural Development Library, University of Alberta's Gate/library system, Alberta Environment Library, Alberta Research Council Library
  - National Library of Canada's CISTI-CAL, to search: Canada Agriculture Library, Canadian Institute of Scientific and Technical Information -- for Environment Canada Library, Natural Resources Canada Library, etcetera
  - Other: universities and colleges: Calgary, Lethbridge, Fairview College, Lakeland College, Olds College Library, TAL --The_Alberta_Library (+ other local libraries) etcetera
  - Databases
    - Agricola
    - CAB Abstracts
    - Conference Index
    - Internet and WWW
    - Agency websites (provincial, national, international)
    - Search engines (Google, MSN, AskJeeves, AltaVista)
- Structure the database
  - Include required bibliographic elements
  - Consult researchers re value-added fields
  - Incorporate needs
  - Develop evaluative criteria for inclusion
  - Test for data input variables
- Compile the literature
  - Obtain interlibrary loans
  - Arrange for photocopying
  - Search electronic journals online; download e-documents and print copies (where permitted by copyrights)
  - Conduct file management: coding, access, labelling, special collection retrieval processes
- Develop ranking and relevance indicators
  - Collaborate with experts
  - Test the database and ranking factors
  - Make any required modifications
- Maintain the database and library of documents
  - Continue file management: coding, labelling, filing, retrieval
  - Add citations as literature arrives, leading to more references
  - Maintain a standardized classification for the database
  - Edit records for consistency of database (error detection and correction)
- Make value-added enhancements
  - Scan and include abstracts
  - Scan references cited and bibliographies within articles
  - Add compiler's notes
  - Assign relevance to records
  - Classify the literature using keywords and subject heading assignments

- Make products available
  - Provide full records and/or database to the reviewer & AESA personnel
  - List citations; prepare subject bibliographies
  - Add recommendations or suggestions based on expert's feedback
  - Extract reviewer's notes for publication as needed
  - Prepare web-accessible groupings of the literature if desired
  - Create CD-R/W or other products as needed
- Seek client needs re further literature if necessary

It was decided to rank each publication as of Highest (H), Moderate (M), or of Lowest (L) interest in terms of its project relevance, and to delineate a status of Undetermined ('u') for those articles which needed expert review or further examination before a determination of fitness to the project criteria could be made. [See Appendix B]

## RESULTS

Thousands of references were examined, from the multiple searches performed in databases, library catalogues, literature reviews, bibliographies, lists of references cited, agency web sites on the Internet, and from information provided by agronomy experts. Standardized online searches were performed in the indexing and abstracting services, publications lists, library catalogues, and on the Internet. Search strategies were documented and are on file along with the literature collection. The commercial indexing services used were Agricola and CAB Abstracts, Conference Index, Science Citation Index, and LibNet. Publications lists were from Agriculture and Agri-Food Canada, the Canadian Institute for Scientific and Technical Information, the U.S. Department of Agriculture's Agricultural Research Service and Natural Resources Conservation Service, the Soil Quality Institute, as well as the UN-FAO, the World Bank, the European Union (EU; formerly European Commission), and others (Appendix A). Online catalogues searched were the Alberta Agriculture Food and Rural Development Library; the NEOS library consortium -- Alberta research, university and college libraries; the Canadian Agriculture Library; the National Library of Canada; and the U.S. National Agriculture Library.

The search results were matched to project parameters and relevance ranking criteria developed during discussion with staff experts. The compiler provided full keyword classification on all records. Additionally, compiler comments regarding article contents were provided for a 150-sample set of records; these were provided to the reviewer for further consideration of project parameters to assist in sorting the literature during the review process.

The most significant result of the literature research was to identify the key papers of importance to the scientific study of soil quality assessment (Appendix D). The literature on soil quality indices of most relevance to Alberta were made available to the reviewer, Eric Bremer, and the AESA Soil Quality Program Coordinator, Karen Cannon, in the form of annotated bibliographies produced from the ProCite™ SQI database.

This bibliographic research also confirmed that within North America, soil quality indices have been studied primarily at federal government agencies' experimental research farms, and at universities within departments of soil science or agronomy. Recent research (within the last ten years) within forestry also shows a growing tendency to apply agroecosystem and soil quality assessment methods with regard to soil quality assessment, as an enhancement to productivity modelling. Forestry researchers and land-use planners present and publish their findings in a different forum, or set of journals (See Appendix D). Also, the indexing and abstracting services of these disciplines do not consistently overlap, so that only by comprehensively researching through references cited is it possible to become and to remain aware of the totality of soil quality indices research and development.

**Ranking**

The "SQ Index Lit" project database now (December 12, 2003) contains 488 citations to the soil quality assessment literature (as of December 2003). Rating of articles has resulted in the following designations:

| | |
|---|---|
| Of Highest project interest | 81 records |
| Of Moderate project interest | 128 records |
| Of Least project interest | 101 records |
| Undetermined, (pending further examination): | 178 records |
| TOTAL = | 488 records |

Additionally, 150 records exist in a database for items related to soil quality assessment and monitoring; but these do not deal specifically with soil quality indexes.

Compiler comments were added to the SQI Lit database. A 150-sample set was ranked for the project, with the results that: 54 were H-, 42 were M-, 36 were L-, and 17 were 'u'-rated papers.

Of the 488 database records, 294 selections were deemed of some importance to the concept of soil quality indices (Appendix D). Keyword searches in these selections reveal the following occurrences of terms (but conclusions cannot be drawn based on the statistics, until the literature reviewer component of this project is completed):

126 "soil quality index" OR "index of soil quality" OR "soil quality indices"

75 "soil quality index"

21 "static", 31 "dynamic"

3 "point-scale", 9 "regional", 8 "farm-level", 9 "national"

79 "soil organic matter", 96 "microbial"

69 "forest", 12 "rangeland", 25 "grassland", 14 "catchment", 4 "riparian"

Of the total 488 records, 220 copies were provided for review to Eric Bremer, in December 2003, and will be housed (in 2004 following his review) in files of the Conservation and Development Branch, AAFRD. The AAFRD Library holds another 82, while other NEOS libraries have another 36, and 177 are also accessible via the World Wide Web. In all, 327 items, or 78% of the items identified for this literature project, and 100% of the Highest-Ranked items (n=81), are within the building or within a day's reach for the reviewer, project staff, or interested researchers.

### *Products*

As a result of this literature review project, a library of scientific literature concerning soil quality indices has been compiled, building upon previous files compiled by agronomist Jody Winder. ProCite™ databases have been designed, developed, produced, and are being maintained as an integral part of the AESA Soil Quality Program. An annotated bibliography has been produced by the project's compiler. Other products, in the form of subject-classified bibliographies, lists, research groupings, or web-based information for application to other programs, can now be created from the interactive ProCite™ databases as needed.