Acton, D. F. 1993. *Soil quality evaluation report*, National Soil Conservation Program (NSCP). NCSP Monitoring, 1989-1993. 210pp. From URL: http://res2.agr.gc.ca/initiatives/manurenet/env_prog/nscp/sqep.html

In 1993, work was continuing in order to develop a soil quality index for soil organic matter.

———. 1994. *A Program to assess and monitor soil quality in Canada : Soil Evaluation Program Summary*, Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research, Ottawa, ON.

This report "identifies the requirements and provides a framework for soil quality evaluation. It summarizes the development of improved capabilities for assessing soil quality and for analyzing the impact of soil degradation on soil quality and crop productivity. It also provides insights into the status of soil quality in Canada that have been forthcoming as part of the system developments." --Quoted from: *Annotated Bibliography* in J. Dumanski, S. Gameda, & C. Pieri. 1998. *Indicators of Land Quality and Sustainable Land Management*, p.7.

Al-Dabbagh, T. H., and R. M. Al Rizzo. 1994. A Proposed soil index for soil stabilization evaluation. *Journal of Environmental Science and Health*—Part A, Environmental Science and Engineering [Monticello, NY : Marcel Dekker Inc.] 29, no. 8: 1531-1540.

A Soil Index is proposed, using the example of, or application to, soil stabilization in Iraq. This theoretical discussion paper outlines how to develop the index and sub-indices.

Alberta Environmentally Sustainable Agriculture Program (AESA), and Karen Cannon. 2003. *Alberta soil quality card,* AESA Soil Quality Monitoring Program 2003, Agdex 525-2. Alberta Agriculture, Food & Rural Development, Edmonton, AB.

Alberta Environmentally Sustainable Agriculture (AESA) Soil Quality Monitoring Program has developed an Alberta Soil Quality Card for producers. Producers can use this new tool to assess soil quality in their fields and to complete a do-it-yourself soil quality rating system. ... The Soil Quality Card uses sensible, farm level indicators and descriptions that qualitatively measure soil quality. Indicators, such as organic matter color, erosion, compaction or salinity, are ranked low, medium or preferred quality.

From URL: http://www1.agric.gov.ab.ca/$department/newslett.nsf/all/agnw3549?opendocument ; August 11, 2003.

Alonso, P., C. Sierra, E. Ortega, and C. Dorronsoro. 2003. Soil development indices of soils developed on fluvial terraces (Peńaranda de Bracamonte, Salamanca, Spain).

From URL: http://edafologia.ugr.es/comun/trabajos/catecron/catecrt.htm - 19k

The purpose of this methods paper was to rate soil horizons & describe them relative to one another. --A "soil taxonomy" study on Spanish fluvial soils, it used correlation coefficients & regression analysis; --Static; field-scale, single site studied. --Composition of soil is based on overall profile of Carbon, at all depths examined, rated using an overall Morphology Index (MI). The MI is derived by normalizing data values for properties of: structure, texture, soil class/consistency, wetness, clay film, melanization, & rubificaton (color: hue & chroma).

Amacher, Michael C., and Katherine P. O'Neill. 2003. *Soil vital signs: a New index for assessing forest soil health.* p.37. Poster [tables, figures, map] USDA Forest Health Monitoring Program.

Soil Quality Index values were developed using the entire United States Forest Inventory and Analysis (FIA) program database, "to integrate all the FIA measured physical and chemical properties of soils into a single index value as an indicator of forest soil quality or health." [quote from web site, at URL: http://www.na.fs.fed.us/spfo/fhm/posters/ posters03/posters03.htm - 51k or http://www.na.fs.fed.us/spfo/fhm/posters/ posters03/soil_vital.pdf]
--The use of forest soil properties at a database level, and USA national scale are demonstrated. The index was developed to reduce soil physical & chemical properties to an index number relative to a critical threshold value for that property. The method then sums those values [i.e. is 'additive' index]. A higher value indicates overall higher quality soil, expressed as a percentage of the total number of measured properties. This interpretive tool is used to simplify uses/analyses of the U.S. national data set. Presentation is as a table on the Internet, and needs Acrobat Reader & Zoom capacity on a 17" color monitor for farmers to use it properly.

Andrews, Susan S., and C. Ronald Carroll. 1998. Creating a minimum data set to compare soil quality under poultry litter management alternatives. Chapter 3 In: *Sustainable agriculture alternatives: Ecological and managerial implications of composted and fresh poultry litter amendments on agronomic soils* [Ph.D. thesis]. Susan S. Andrews. Athens, GA: University of Georgia.

A Soil Quality Index is advocated. The study uses a minimum data set concept & multivariate statistical analyses to evaluate 2 fescue sites, 2 soil types (silt-loam & loamy sand), & treatments with land-applied poultry litter vs. composted poultry litter, in Georgia, USA. Andrews' method integrates soil attributes, several indicators into the SQ Index, which involves reduction of large data sets. Both fescue sites are experimental farm sites. Sampling from a randomized complete block on 4 blocks & 6 soil amendment treatments, treatments analyzed were of multiple harvests on the silt-loam site vs. no harvest/no grazing on the loamy sands. Andrews compared 2 litter applications types at 2 rates, synthetic fertilizer N/P/K, and no-amendment as a control. Samples were from the field 3 years after the amendments, were lab-analyzed from soil cores to 0-5cm depth, on 40 variables, including: total C, total N, extractable macronutrients (soluble C, mineral N, P); extractable micronutrients & heavy metals (microbial biomass C & N, soil enzyme activity, soil respiration); CEC, pH, soil moisture, plant available water, bulk density, water stable aggregates. Methodology: The study considered management goals re crop yield; used non-parametric, uni- & multivariate statistics, plus expert opinion, to select indicators representative of a minimum data set re these goals (as the research framework); then performed Principal Component Analysis for each statistically significant variable, for each site. [PCA is summarized, p.76]; followed with transforms normalized to a value between 0 & 1, scoring as in Karlen & Stott (1994); & setting ranges of scoring functions per indicator (the 'more-is-better'/'less-is-better' scenarios); finally adding the MDS variable scores for a SQ index, for comparing the amendment treatments at each site.
Interpreted Results: --MDS scoring functions are reported, & SQI values for both sites showed compost treatments at highest index values; increases in pH & P showed need for some sort of weighting of MDS values, or changes to range values for scoring functions in the index; i.e. modifications.--ch.

———. 1998? Identifying a soil quality minimum data set for guiding poultry litter management. Abstract at http://www.nal.usda.gov/ttic/tektran/data/000009/77/0000097748.html

This single study in California is focused to reduce large data set to a representative index. Field testing at two pasture sites. " We used the index to evaluate the effects of applying either fresh broiler litter or composted litter at two different rates at two pasture sites that differed primarily by soil type and climate. A common framework was used for the index at each site but different indicator variables were used to accommodate local conditions. The common criteria for evaluating indicator performance were the management goals at each site: maximizing litter disposal, maximizing forage yield, and minimizing environmental risk. Results from soil analyses showed significant differences between management alternatives." [see abstract]. This study used different indicator variables, with conflicting results (inconclusive); it was not long-range, not dynamic; done at field scale; is a data reduction attempt, & not comparable with other studies' results.

Andrews, Susan S. and C. Ronald Carroll. 2001. Designing a soil quality assessment tool for sustainable agroecosystem management. *Ecological Applications* [Ecological Society of America] 11, no. 6: 1573-85.

Using her thesis results (Andrews 1998), Andrews & Carroll reiterate the viewpoint that "indices are specifically designed to compare management practices" (p.1573). She refined the soil quality index using regression & Principal Component Analysis (PCA) to validate the chosen minimum data set indicators as independent variables, and management goals as dependent variables; thus, achieving high correlations. SQI additive values showed that at both Georgia experimental farm sites (with different soils but similar climates), the composted litter achieved the best soil quality.

Andrews, Susan S., C. B. Flora, and J. P. Karlen D. Mitchell. 2003. Growers' perceptions and acceptance of soil quality indices. *Geoderma*—Special Issue: *The Assessment of Soil Quality* 114, no.3/4: 187-213.

This study, at field scale, used lab-analyzed soil samples for regional comparison of 12 paired sites on 11 farms in the San Joaquin Valley of Central California, comparing 'conventional' & 'alternative' treatments; with 1995 to 1998 sampling from "bulked cores" (8 to 12 per field, randomly selected). The research involved focus groups of farmers to test perceptions, compared with numeric indices derived on several SQ indicators: SOM Olsen phosphorus, exchangeable potassium, CEC, sodium absorption ratio, electrical conductivity, pH; physical properties of: soil texture, bulk density, wet aggregate stability; soil biological properties, as: potentially mineralizable n, microbial biomass Carbon (methods & results reported in a detailed paper elsewhere, 2002). A minimum data set of indicators was chosen with experts' opinions, then interpreted "based on their performance of soil functions" (p.191); then scored, summed, and scoring transformed to a value between 0 and 1. Experts rated the scoring function distribution shapes using a 'more is better' function logistic for ranking SOM, WSA, PMN; a 'less is better' for bulk density (re root growth & soil porosity); and midpoint optimum Gaussian functions (i.e. 'fuzzy set theory') for soil pH, exchangeable K/CEC; midpoint optimum curve for Olsen-P; and SAR scores dependent on EC & environmental risk (pp.193-194). --Indicator scores were summed for each, dividing by total indicators, then multiplied by 10. Farmers' questionnaire responses were compared to the SQ Index. The results on 'alternative treatments' scored higher and declined less than 'conventional treatments'. Farmers were interested in crop yields, and Radar graphs are used to present their ratings of indicators (p.205). Researchers believed the calculated SQ Index accurately reflected farmers' perceptions. According to the authors of this paper, differences were due to crops and soil types, plus statistics/data complexities.

Andrews, Susan S., D. L. Karlen, and J. P. Mitchell. 2002. A Comparison of soil quality indexing methods for vegetable production systems in northern California. *Agriculture, Ecosystems and Environment* 90: 25-45.

The abstract of this article adequately describes its purpose -- to compare methods of SQ Index development as adequate decision support tools for on-farm management practices. At the University of California-Davis' 8.11-hectare experimental farm site in Sacramento Valley, California, in September 1996, 30 soil cores were taken from 0-15 cm depth in loams/fluvisols, used for vegetable production of tomato, corn, oats, vetch, safflower, dry beans crops. The soil samples were from conventional, low-input (fertilizer & pesticides) & 'organic' treatments with 2-yr., 4-yr. & annual rotations. Samples studied in Univ. of Calif. lab analyzed these indicators of soil quality: SOM, total organic C, total N, soluble P; exchangeable K, Ca, Mg; total S, Zn, & sodium absorption ratio; electrical conductivity, pH; soil moisture; soil nitrate (NO_3-N) & ammonium (NH_4-N); potentially mineralizable N; & soil microbial communities (via phospholipid fatty acid testing). This static study used statistical methods: linear and non-linear scored multivariate analyses, ANOVA, regression, principle component analysis, Pearson correlation; and Expert Opinion decision support systems were tested and compared. Minimum data sets were attempted for establishment of data reduction technique comparisons. Results were not conclusive, as the most variability in indicators was chosen to develop the indices, and so highly correlated with high SQ Index values. Results require a statistician to verify if data/methods are truly replicable and valid [in the compiler's opinion--ch].

Andrews, Susan S., Jeffery P. Mitchell, Roberto Mancinelli, Douglas L. Karlen, Timothy K. Hartz, William W. Horwath, Stuart G. Pettygrove, Kate M. Scow, and Daniel S. Munk. 2002. On-farm assessment of soil quality in California's central valley. *Agronomy Journal [Madison, WI: American Society of Agronomy]* 94, no. 1 (Jan/Feb): 12-23.

This is a farm-level assessment, on 11 farms with intensive production practices in San Joaquin Valley, California. There were some 'conventional' & some 'organic' practices compared in 1995 through 1998. At Field scale (30- to 60-ha sites), 6 spring field-moist soils were sampled for: Electrical conductivity, soil texture, SOM, bulk density, total Kjeldahl N, NO_3-N, soluble Olsen P, exchangeable K & Ca, CEC; Zn, Fe & Mn; extractable micro-nutrients; pH; soil aggregate stability; microbial biomass. On 6 farms in 1998, performed non-parametric sum test on the data, and one-way analysis-of-variance, transformed after Student's t-test on one other farm. --The SQ Index was determined for the minimum data set on this 7th farm (one farm only) to demonstrate utility of SQI to help in management decision-making. The researchers used Stella Research software (version 5.1.1) to score the variables. Also, Principal Components on 4 significantly different eigenvalues for 1998 point-source data on Farm 7 revealed electrical conductivity, soil organic matter, pH, WSA, Zn, and bulk density as important for the minimum data set. When weighted variations were considered, EC & SOM "appear to drive the SQI results" (p.21). On-farm participatory research was used to analyze management practices.

Armstrong-Brown, Sue. 2002. Summary: Indicators for a European soil monitoring network. From URL: http://homepage.tinet.ie/~jc stie/etcs/indicsmn.htm ; Accessed Sept.10, 2002 (jw). 3pp.

Minimum data set for prediction of soil quality, based on pedotransfer functions, for soil quality monitoring, are delineated on this web site.

Arshad, M. A. 2002. Monitoring selected soil quality indicators for sustainable land management. In: *Man and soil at the Third Millennium*; Proceedings [of the] International Congress of the European Society for Soil Conservation, Valencia, Spain, 28 March 1-April, 2000; Volume 1: 861-869 . J. L. Rubio, R. P. C. Morgan, S. Asins, and V. Andreu, editors. Logrona, Spain: GEOFORMA Edicions, S.L.

This paper presents the guidelines that can be followed to identify the critical limits for the key indicators and the procedure for monitoring changes in soil quality trends. The suggested steps to monitor soil quality are as follows: (i) divide the region or the country into different ecological zones; (ii) select the ecological zone, farms or watershed with similar soil types; (iii) define the goal or requirements for sustainability; (iv) select a set of indicators for ecological zone, farms or watershed, e.g. organic matter, topsoil depth, infiltration, aggregation, pH, electrical conductivity and soil respiration; (v) select a reference point or baseline value for each indicator; (vi) specify the critical limits for selected indicators; (vii) **transform the indicators into a soil quality/sustainability index**; and (viii) test the procedure using the actual data from different soil and land management practices being used in the ecological zones, farms or watersheds. From URL: http://www.zalf.de/essc/valbook3.htm#moniqual

Arshad, M. A., and G. M. Coen. 1992. Characterization of soil quality : Physical and chemical criteria. *American Journal of Alternative Agriculture* 7, no. 1 & 2: 25-31.

Arshad and Coen (1992) examine the principle physical and chemical attributes that can serve as indicators of change in soil quality under particular agroclimatic conditions. Proposed indicators include soil depth to a root-restricting layer, available water-holding capacity, bulk density/penetration resistance, hydraulic conductivity, aggregate stability, organic matter, nutrient availability/retention capacity, pH, and (where appropriate) electrical conductivity and exchangeable sodium. They briefly touch on socioeconomic factors. They say that the absence of information on land managers' attitudes, knowledge, and practices as they affect soil quality, combined with scientists' traditional focus on the soil rather than its managers, reflect the serious state of degradation. *from Freyenberger's et al. annotated bibliography: SQI Lit.ID #214, p.9*]

Arshad, M. A., and S. Martin. 2002. Identifying critical limits for soil quality indicators in agroecosystems. *Agriculture, Ecosystems and Environment* [Amsterdam; New York : Elsevier] In the Special Issue: S*oil Health As a Indicator of Sustainable Management* **88, no. 2 (Feb): 153-160 / edited by J. W. Doran and S. I Stamatiadis.** Paper presented at a workshop held June 24 -25, 1999, Athens/Kifissia, Greece**.**

This discussion paper surveys the literature in order to synthesize approaches to defining and characterizing a soil quality index. Discusses needs and ways for identifying the measurable soil attributes, key indicators, indicator critical limits, models for soil assessment, monitoring soil indicator requirements; suggests parameters for monitoring, giving guidelines and steps to take, and advocates long-term research, case studies, combination of management practices, identification of minimum data sets of soil indicators, and development of simple techniques for use by farmers and extension workers. Very good overall summary of SQI needs.

ASA-CSSA-SSSA. 2002. Soil quality as an indicator of sustainable land management: Demonstrated successes and continued needs; Papers presented at the symposium. *Agronomy Journal* 94, no. 1: 1-47.

The five papers published in this special section of *Agronomy Journal* represent a broad range of soil quality applications and geographic regions. The works encompass literature review, theory, applied research results, a report of US government agency efforts, and on Canadian regions. © *DialogWeb*

Astier-Calderon, M., M. Maass Moreno, and J. Etchevers-Barra. 2002. Derivation of soil quality indicators in the context of sustainable agriculture. *Agrociencia [Montecillo]* 36, no. 5: 605-620.

Excellent, up-to-date review of the prevailing definitions of soil quality, with a very clear discussion of what soil quality indexing requires. This paper provides 3 case studies from Mexico concerning study of soil quality indicators; presents attributes/soil properties (Table 1, p.610). It advocates a relativist position in respect to selecting which indicators are most relevant or part of a minimum data set; these authors accept the FAO framework for sustainable land use/management, but advocate using the MESMIS framework of Masera et al. (1999) instead of use of a "predetermined list of indicators" (as with Doran et al, Olson et al, Karlen et al.), so that, "the indicators are derived at the moment of study and for each system in particular." (p.612).

Australia. CSIRO. 2003. Landscape function analysis: a Systems approach to assessing rangeland condition. From URL: http://www.cse.csiro.au/Research/Program3/efa/lfa_summary.htm

We propose a procedure for the assessment of rangeland function, comprised of three components: a conceptual framework, a field methodology and an interpretive framework. The conceptual framework treats landscapes as systems: defining how landscapes work in terms of sequences of processes regulating the availability of scarce resources. The field methodology uses indicators at landscape and patch scale to provide and structure information to satisfy the needs of the conceptual framework. The interpretational framework provides a process to identify critical thresholds in landscape function and thus provide a function-based state and transition landscape assessment. The approach is quick and simple in the field, is applicable to all range landscapes and amenable for use by a wide range of end-users. -- *Online abstract.*

"**Calculation of Indices**

The soil surface data are combined in different combinations to reflect three major soil habitat quality indices: stability or resistance to erosion, infiltration/water holding capacity and nutrient cycling (Figure 2). The data are presented in percentage terms." --From URL: http://www.cse.csiro.au/Research/Program3/efa/lfa_summary.htm