Pankhurst, C. E., B. G. Hawke, H. J. McDonald, C. A. Kirkby, J. C. Buckerfield, P. Michelsen, K. A. O'Brien, V. V. S. R. Gupta, and B. M. Doube. 1995. Evaluation of soil biological properties as potential bioindicators of soil health. Australian Journal of Experimental Agriculture 35, no. 7: 1015-1028.

Two long-term field trials in South Australia were used to detect and characterize changes in soil biological properties that were a consequence of different agricultural management. The sensitivity of these biological properties was assessed to no-tillage vs. conventional cultivation, stubble management (stubble retained vs. stubble harvested), crop rotation (continuous wheat vs. wheat-sown pasture), and N fertilization (0 and 80 kg N/ha applied during the crop phase). Tillage, stubble management, crop rotation, and N fertilization significantly ($P<0.01$) affected C mineralization and microbial biomass. Tillage with stubble management significantly affected root pathogenic fungi, protozoa, collembola, earthworms, and cellulose decomposition. Crop rotation affected mycorrhizal fungi, protozoa, and soil peptidase activity, and N fertilizer had a significant effect on mycorrhizal fungi, protozoa, and cellulose decomposition. As these biological properties are responsive to agricultural management, thay may have potential as bioindicators. Total bacteria, fungi, and actinomycetes, cellulose-decomposing bacteria and fungi, soil phosphatase and sulfatase activity, and N mineralization were less affected by these treatments and may therefore have limited potential as bioindicators. *--CAB Abstracts.*

Pankhurst, Clive E. 1994. Biological indicators of soil health and sustainable productivity. In: *Soil resilience and sustainable land use*: Proceedings of a Symposium held in Budapest, 28 September to 2 October 1992, including the Second Workshop on the Ecological Foundations of Sustainable Agriculture (WEFSA-II); Pp.331-351. D. J. Greenland and I. Szabolcs, editors. Wallingford, UK: CAB International.

This conference discussed: (1) types of bioindicator; (2) bioindicators of soil productivity and sustainability; (3) bioindicators of soil pollution; and (4) role of bioindicators in sustainable land use. Research needs are briefly outlined.

Pankhurst, Clive E., and Australia. CSIRO Land and Water, Davies Laboratory. 1998. Bioindicators of soil health: Assessment and monitoring for sustainable agriculture. From URL: http://www.csiro.au/research/mdb/biodbiot.html

Soil Processes and Indicators for Land Management
-- Project Leader: Doug Reuter.
-- Project Objective: Development of generic indicators of landscape health.

Biodiversity and Management of the Soil Biota for Sustainable Rural Production
-- Project Leader: Pankurst, Clive.
Project Objectives:
To develop and apply new techniques for the rapid diagnosis of the biological status of soils. To develop methods to characterise and quantify the biodiversity of soil microbial populations. To determine the impact of agricultural practices on the biological health and functioning of soils and define the linkages between soil biology, soil functioning, soil health and sustainable crop production. To provide strategies, based on soil biology assessment, that will improve soil health and sustainable crop production. To use soil biodiversity as a tool to facilitate and monitor bioremediation of contaminated soils.
Main Deliverables:
Biological Indicators of Soil Health

Identification of four soil biological properties as having high potential as bioindicators of soil health. Report to GRDC(95), publication in AJEA (95), 4 conference presentations (93-95).

Evaluation of biological indicators of soil health. Review in Adv. Pl. Pathol. (95) Chapters in books (96-one), (97-four), (98-two); Editors of book "Biological Indicators of Soil Health" (CABI).

Assessment of soil health indicators at 10 long-term trials across Australia - demonstration that sustainable crop yield significantly related to soil biology (Waite long-term trial). Progress reports to GRDC (96,97); 2 conference presentations (96,97), consultations with GRDC representatives.

Soil Biodiversity

Establishment of GC-FAME technology as a tool to investigate soil microbial diversity (95).

Establishment of metabolic profiling (BIOLOG) as a tool to investigate the functional soil microbial diversity (96).

Capacity to predict the quantity fatty acid methyl esters (FAMEs) in soil s that are signatures for bacterial and fungal biomass, from mid-infrared soil analysis.

Development of DNA markers for identification of two cereal root pathogens.

Papendick, R. I., and J. F. Parr. 1992. Soil quality—the key to a sustainable agriculture. *American Journal of Alternative Agriculture* 7, no. 1-2: 2-3.

This paper provides a general introduction to the papers presented in this Special Issue on Soil Quality. The themes discussed in the individual contributions include: the need for developing a soil quality index based on local and regional considerations; recent international activities directed toward assessing and monitoring soil degradation; soil crusting: its effects and control; soil biological criteria as indicators of soil quality; the physical and chemical attributes needed for proper characrerization of soil quality; the effect of soil and crop management practices on different soil quality indicators; and factors that can affect the nutritional quality of crops. *--CAB Abstracts.*

Papritz, A. 1993. Interference between spatial variability and the detection of temporal changes in soils. *Soil monitoring: Early detection and surveying of soil contamination and degradation*; Pp.309-328. R. Schulin, A. Desaules, R. Webster, and B. von Steiger, editors. Basel, Switzerland: Birkhauser Verlag.

Temporal changes; spatial variability.--jw.

Parr, J. F., R. I. Papendick, S. B. Hornick, and R. E. Meyer. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. American Journal of Alternative Agriculture 7, no. 1-2: 5-11.

This macro-political discussion paper adopts Haberern's (1992) notion of a "Soil Health Index" re soil capability for crop production, taking the position that "no single reliable index of S.Q. has been developed" (p.7); --surveys the philosophy of S.Q. & conceptual framework for its study. --SQ improvements indicated by Granatstein's (1990) soil properties/attributes approach, according to these authors. --SQI = f(SP,P,E,H,ER,BD,FQ,MI) : SQ Index is a function of: soil properties, potential productivity, environmental factors, health, erodibility, biological diversity, food quality/safety, & management inputs. --Interaction of these indicators has to be determined; then lists all socio-economic & political factors of influence on purposes of soils analysis (all-things-to-all-people-approach is advocated.--ch notes). --Emphasizes need to monitor & assess, provide baselines for degradation & erodibility in soil quality studies/research.--ch.
--Parr et al. emphasize that attributes of soil quality (increased infiltration, aeration, macropores, aggregate size stability, soil organic matter, decreased bulk density, soil resistance, erosion, and nutrient runoff) should not be limited to productivity but must include the more dynamic environmental (species diversity or genetic diversity) and social qualities. [*from Freyenberger's et al. annotated bibliography: SQI Lit.ID #214, p.9*]

Paz-Jimenez, M. de la, A M. de la Horra, L. Pruzzo, and R. M. Palma. 2002. Soil quality : a new index based on microbiological and biochemical parameters. Biology and Fertility of Soils [Berlin, Germany : Springer Verlag] 35, no. 4 (Jun): 302-306.

Agroforestry analysis in Argentina, precursor minimum data set analysis for establishing a soil quality index. This short communication of research results from La Paz summarizes the soil properties (organic C, soil respiration, enzyme activity, total N, P, pH) found to be of interest on lands with 4 treatments (native forest, pasture deforested 8-10yrs, no-till 6yrs & deforested 26 yrs, & conventional tillage on deforested 40 yrs.). --Used ANOVA, Turkey's test, correlation and multiple regression analyses; results presented in table form (p.304). --Organic C & enzyme variables were the focus; extractable P & pH were excluded as not sensitive indicators of management practices (although 'highly correlated').

Pembina Institute for Appropriate Development. 2003. Sustainability measurement: Genuine Progress Indicators [web site at URL: http://www.pembina.org/sustainability_mea.asp]

The Sustainability Measurement team researches and develops practical tools that can be used by organizations to measure, monitor and report on their progress towards economic, social, and environmental sustainability.

The 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.

As advisors to the National Round Table on the Environment and the Economy, the Sustainability Measurement team is developing national environmental and sustainable development indicators. The team is also working closely with others, including Canadian Policy Research Networks and GPI Atlantic, to develop a Canadian **index** of well-being and sustainability. -- *Pembina Institute web site at URL:* http://www.pembina.org/sustainability_mea.asp

Pennock, D. J., D. W. Anderson, and E. de Jong. 1994. Landscape-scale changes in indicators of soil quality due to cultivation in Saskatchewan, Canada. Geoderma 64, no. 1/2: 1-19.

This paper builds on the relationship which has been demonstrated to exist between small (5 m by 5 m) slope segments and soil distribution in order to define larger landform element complexes in till landscapes of Saskatchewan, Canada. Distinctive pedogenic regimes are associated with these complexes. These complexes were then used to stratify the landscape at four conterminous sites with different cultivation histories and to assess changes in indicators of soil quality. Soil redistribution (as assesed by 137Cs redistribution) has had a major impact on these landscapes. The shoulder and level summit complexes have experienced continued high rates of soil loss. The shoulder complexes have lost 55% of their original soil organic carbon (a loss of 64 mg ha-1) over 80 years and 70% of this loss is attributable to net soil export from these positions. The portions of the footslope complexes dominated by Orthic Black Chernozemic soils initially act as sediment deposition sites in the first 22 years of cultivation, but ultimately this soil is removed from these positions and a moderate decline in soil quality occurs. The Gleysolic-dominated portions of the footslopes and the level depressional complexes occupy 15% of the landscape and are the major long-term sediment depositional sites; the biochemical indicators of soil quality (soil organic carbon and total soil nitrogen) show a major and beneficial increases in these positions.

The relationship which exists between small (5 m x 5 m) slope segments and soil distribution was built on to define larger landform element complexes in till landscapes of southern Saskatchewan, Canada. Distinctive pedogenic regimes associated with these complexes were used to stratify the landscape at four conterminous sites with different cultivation histories and to assess changes in soil quality indicators. Soil redistribution (assessed by 137Cs redistribution) has had a major effect on these landscapes. The hill shoulder complexes have lost 55% of their organic soil carbon (a loss of 64 mg/ha) over 80 years and 70% of this loss is attributable to net soil export from these positions. The footslope complexes dominated by Orthic Black Chernozemic soils acted as sediment deposition sites in the first 22 years of cultivation but ultimately the soil is removed and a moderate decline in soil quality occurs. The Gleysolic-dominated portions of the footslopes and the level depressional complexes occupy 15% of the landscape and are major long-term sediment depositional sites; the biochemical indicators of soil quality (soil organic carbon and total soil nitrogen) show a marked and beneficial increase in these positions.

Pierce, Francis J., and W. E. Larson. 1993. *Developing criteria to evaluate sustainable land management. Utilization of soil survey information for sustainable land use*; Proceedings of the 8th International Soil Management Workshop, May 1993., 7-14. Lincoln, NE: USDA-SCS, National Soil Survey.

Development of land quality indicators is discussed in this summary, presented at the 89th International Soil Management Workshop. The position paper maintains that quantification of quality involves pedotransfer functions of soil attributes, collection of minimum data sets, development and establishment of quality standards that include threshold levels, benchmark soils, productivity considerations, acceptable performance limits, and adequate statistical assessment methods, including trends analysis for comparative, meaningful evaluation. Control charts, variability, and system design using process control models for soil quality monitoring are discussed.

Pinzari, F., A. Trinchera, and A. Benedetti. 1996? Soil quality indicators for the assessment of the risk of desertification in Mediterranean ecosystems. --From URL:
http://www.desertification.it/asv/doc/ASINARA%20WEB/34pinzari.htm

"This study was carried out to compare soils undergoing the pressure of a range of different degenerative processes that increase the risk of erosion. The aim is to test microbial biomass activity and organic matter quality parameters as both indicators of disturbance, and soil-state descriptors of natural systems." *-- Online abstract.*

Popp, Jennie, Dana Hoag, and James AscoughII. 2002. Targeting soil conservation policies for sustainability : new empirical evidence. *Journal of Soil & Water Conservation* [Ankeny, Iowa: Soil and Water Conservation Society] 57, no. 2 (Mar/Apr): 66-74.

Sustainable resource management is one of the most complex concerns today. Society has spent billions of dollars conserving soils in production, yet it is unclear whether these efforts buy sustainability, or even what sustainability is. Further study about which soils need conservation merits consideration. We use a simulation model, regression and optimization analysis to examine the sustainability of resource management in objective, measurable ways Soil quality, represented by a new index, and other non-irrigated corn production data are placed into a dynamic model to identify: 1) the conditions where soil conservation is efficient, and 2) under what definitions conservation is sustainable. Results show that decisions to use or conserve soil and the impacts of these decisions are highly dependent upon soil type and how sustainability is defined. In general, while soil conservation slowed degradation on erodible soils, it seemed to be more effective and economically efficient the better the initial quality of the soil. This calls into question whether U.S. conservation policy that focuses on marginal soils supports sustainability. Economic research was undertaken to study which soils might best be targeted for conservation, using economic and sustainability criteria. An economic model of non-irrigated corn production was created to determine nder requirements of maintaining a certain level of production or maintaining soil qualityif, when, and where it was best to apply conservation practices. Results show that decisions to use or conserve soil and the impacts of these decisions are highly dependent upon the characteristics of the soil and how sustainability is defined. In general, while soil conservation slowed degradation on erodible soils, it seemed to be more effective and economically efficient the better the initial soil quality. *--Authors' abstract, p.66.*