Gadem, Abu-Elgassim-Y. 2000. "Land resources evaluation: an approach for soil qualtiy assessment and mapping of riparian areas using GIS. Master's thesis, University of Nebraska-Lincoln. 96pp.

Gale, M. R., D. F. Grigal, and R. B. Harding. 1991. Soil productivity index: predictions of site quality for white spruce plantations. *Soil Science Society of America Journal* 55, no. 6 (Nov/Dec) : 1701-1708.

> Field tests on 76 plots of forest "plantations" of white spruce, red pine, jackpine, trembling aspen, red maple, in young (19-34 yr.), and old (35-43 yr.) stands of trees; fields were plowed or furrowed. --comp0ared above-ground biomass with forest site index vs PI models to test index sensitivity. --Soil texture, pH, bulk density, available water capacity, porosity, topography (percent slope), climate, limits to root growth analyzed; --Cultural practices influenced the results; --Static data (although age of stands varied); grouped age-related sites & cultivation practices, to find higher correlations of PI & SI to productivity.

Garcia, S. 1997. Indicators for sustainable development of fisheries. In: "Land quality indicators and their use in sustainable agriculture and rural development." *FAO Land and Water Bulletin* [United Nations Development Programme (UNDP)]***;* Pp. 131-155. Rome, Italy: UN-FAO.**

> This is a discussion paper outlining what considerations need to be included in sustainability indicators (p.134-135). Pressure, state, response are socio-economic indicators requiring sustainability research/study. Level, change, and structure indicators allow dynamic views and functional approaches. The Matrix approach integrates PSR indicators, allowing for development of "Sustainability Reference Systems (SRSs) "such as the Prescott-Allen (1996) "sustainability barometer" -- a normalized PSR index on a scale between 0 and 1, which can be depicted in value-tabular or graphic (e.g. Kite diagram) forms for comparison purposes, can then be scaled or weighted, and attributes targetted (e.g. spawning biomass of a fishery), to demonstrate "ecological well-being." PSR provides a framework for a systems approach to sustainability variables and study of indicators.

Gardi, C., M. Tomaselli, V. Parisi, A. Petraglia, and C. Santini. 2002. Soil quality indicators and biodiversity in northern Italian permanent grasslands. *European Journal of Soil Biology* 38, no. 1: 103-110.

> Permanent grasslands represented a common type of land use in northern Italy traditional agriculture, but its area has been constantly declining over the last 50 years. Three permanent grasslands of the Po valley (northern Italy) were characterized in terms of biodiversity and soil quality and were compared with other agricultural land uses. Two indicators of biological soil quality (BSQ-ar, based on arthropods; and BSQ-c, based on Collembola species) were also applied and validated. Soil in the study area were classified as Fluventic Ustochrepts. Results demonstrate the importance of permanent grasslands as biodiversity 'hot spots' within the intensive agroecosystems. The quality of soils was higher in permanent grasslands with respect to the arable lands, as evidenced by the standard soil quality indicators (organic carbon, aggregate stability) and confirmed by BSQ. This research proposes BSQ as a synthesizing soil quality indicator. --*CAB Abstracts.*

Garlynd, M. J., A. V. Karakov, D. E. Romig, and R. F. Harris. 1994. Descriptive and analytical characterization of soil quality/health. Chapter 10. In: *Defining soil quality for a sustainable environment;* Pp.159-168*.* J. W. Doran, D. C. Coleman, D. F Bezdicek, and B. A. Stewart, editors. Soil Science Society of America.

Geomatics International Inc. 1999. Selecting core variables for tracking ecosystem change at EMAN sites; Final report. 1 v. Environment Canada, Ecological Monitoring and Assessment Network (EMAN). From URL: http://www.eman-rese.ca/eman/reports/publications/d000_eman_core_variables/variables.pdf

Germany. Leibniz-Zentrum für Agrarlandschafts und Landnutzungsforschung (ZALF) e.V. 2002. Traditional soil and water conservation // Soil functions and Soil quality // Soil indicators > Keynotes—valbook3 [web page]. Leibniz-Zentrum für Agrarlandschafts und Landnutzungsforschung (ZALF) e.V. From URL: http://www.zalf.de/essc/valbook3.htm

Gil-Sotres, F., M. C. Leiros-de-la-Pena, and C. Trasar-Cepeda. 2003. A comment on the article by de la Paz-Jimenez et al., "Soil quality: a new index based on microbiological and biochemical parameters." *Biology and Fertility of Soils* 37, no. 4 (Apr): 260.

> Comments are made on the previous article by De la Paz-Jimenez et al. (see Biology and Fertility of Soils (2002) 35 302-306) which aims to assess soil quality by some chemical, physical, biological and enzymatic

parameters and to determine a minimum set of these parameters capable of detecting management-induced changes in soil quality after deforestation. The comments point out the errors in the combination of soil properties which do not constitute a suitable soil quality index as it does not distinguish between the influence of soil use and management of soil quality (results and discussion section), and the errors in considering each one of the eight plots per treatment as individual samples, when they actually correspond to eight replicates of the same treatment (materials and methods section). --*CAB Abstracts.*

Girardin, P., C. Bockstaller, O. Perler, and F. Hani. 1994. Agri-environmental evaluation of arable farms by means of agroecological indices. In: *Proceedings of the Third Congress of the European Society for Agronomy,* Padova University, Abano-Padova, Italy, 18-22 September 1994; Pp.694-695. M. Borin, and M. Sattin, editors. Colmar , France: European Society of Agronomy.

Uses a pie chart and 10 factors to discuss/display "agroecological indexes"; gives 'Nitrogen Index' as an example. Indices set ranges from 0 to 10, and increase in value as a farmer uses 'sustainable practices' (but, considers pesticides & N fertilizers as 'sustainability'; i.e. productivity). --Explanation of weighting is unclear (See p.695).

Glover, J. D., P. K. Andrews, and J. P. Reganold . 1998. Applying a soil quality index to conventional, integrated, and organic apple production systems. *Acta Horticulturae [ISHS]* , no. 525: 217-228.

Four 0.14ha plots, on 3 treatments, in Washington State apple orchards were sampled, and a soil quality index developed for soil properties was modified from Karlen et al, 1994. (See p.219).

"The **soil quality index** used was a weighted additive model of the soil's capacity to accommodate water entry, facilitate water transfer and absorption, resist degradation, and sustain crop productivity and quality. Critical threshold values and relative importance for each soil property based on published data and soil conditions in adjacent permanent grass sites were determined. Soil quality was higher under both the integrated and organic apple production systems, as these systems resulted in increased surface water infiltration, higher microbial biomass carbon and nitrogen, greater surface aggregate stability, and more earthworms than the conventional system." --*Authors' abstract.*
"Our goal for developing such **site-specific soil quality indices** is to assist researchers, consultants, and producers in ... " http://www.actahort.org/books/525/525_26.htm -- *MSN online abstract.*

Glover, J. D., J. P. Reganold, and P. K. Andrews . 2000. Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington state. *Agriculture, Ecosystems & Environment* 80, no. 1/2: 29-45.

Washington State, apple orchards; compared 3 management systems on 4 different 0.14ha fields; 1998 samples; indexing as Karlen & Stott's 1994 approach assigning numerical weights to soil functions, multiplying by normalized, standardized scoring of indicators (more is better, less is better, or optimum function curves); and use of SQ scoring cards; values between 0 and 1. Attributes were: aggregate stability, bulk density, earthworms, pore spaces, porosity, organic C, microbial biomass processes, CEC, pH, total N, nitrate nitrogen, extractable phosphorus, and electrical conductivity. Conventional, integrated, and organic soil management systems were sampled, with soil cores taken from 0-7.5cm, 7.5-15cm depths 4 days post-irrigation on experimental plots in May 1998 at random. Scoring functions of (modified) Karlen et al. 1994 SQ Index presented in table form (p.3;6). --Integrated plots scored significantly higher overall than conventional and organic systems. The SQ Index approach was found to be very useful in this study, which is replicable, field-scale, but static.

Goh, K. M., D. R. Pearson, and M. J. Daly. 2000. Effects of apple orchard production systems on some important soil physical, chemical and biological quality parameters. *Biological Agriculture & Horticulture* 18, no. 3: 269-292.

Three different grassed-down apple orchard production systems (organic or biological, BFP; conventional, CFP; and integrated, IFP) in New Zealand were compared for their effects on some important soil physical, chemical and biological quality parameters. A total of 17 grassed-down apple orchards with alley and treeline areas from BFP, CFP and IFP systems in experimental sites and two commercial (organic and conventional) orchards were studied. At each orchard, soils were sampled at three depths (0-50, 50-150, 150-300 mm) in the treeline and alley and were analysed for soil physical properties (soil bulk density, SBD; and soil infiltration rate, IR). Samples from the top two depths (0-50 and 50-150 mm) were also analysed for soil chemical (pH, P, K, Ca, Mg, S) and biological (earthworm number, fresh biomass and composition; microbial biomass C, BC; microbial biomass N, BN; CO2 evolution) parameters. Earthworm parameters were determined to a depth of 0.25 m. In general, significantly lower SBD and higher IR occurred in treeline than alley in all orchards due to soil compaction by orchard vehicles in the alley. The BFP treeline and commercial organic orchard showed lowest SBD and highest IR. Soil chemical parameters were found to be related to nutrient management practices imposed such as increased K and S in BFP treelines due to pea straw additions. Returns of mown clippings from alleys to treelines enhanced nutrient transfers and increased nutrient levels in treelines of BFP and IFP orchards. Earthworm number and biomass were sensitive indicators and were high in pea straw-treated treelines of BFP orchards due to substrate additions. Although earthworm biomass varied in the alleys between orchards, high earthworm numbers occurred in most orchard alleys. Highest number of earthworm species were found in BFP and commercial organic orchards. The measured soil respiration (CO2 evolution) showed significant differences between soil depths but no significant differences between orchard systems except in one site where BFP showed higher CO2 evolution than IFP or CFP. The BC and BN were significantly higher in commercial organic than conventional orchards and in topsoils than subsoils in about half of the orchards studied. Overall, sensitive soil quality indicators found, capable of distinguishing between orchard management treatments, were SBD, IR, earthworm number, fresh biomass and composition while those which distinguished between topsoils and subsoils were CO2 evolution, BC and BN. *--Authors' abstract.*

Gomez, A. A., D. E. Swete-Kelly, J. K. Syers, and K. J. Coughlan. 1999. Aggregating indicator values by rating—an Example. In: Section D: Assessment of sustainable land management Sustainable land management—Guidelines for impact monitoring (SLM-IM Guidelines) --Toolkit Module: a Selection of practical tools and cost effective methods. Karl Herweg, Kurt Steiner, Joep Slaats, Julian Dumanski, Andreas Klay, Cordula Ott, and Christian PieriBerne, editors. Switzerland: Centre for Development and Environment (CDE).

In this particular case study land management was considered sustainable at farm level if the needs of the farmer are satisfied and natural resources are conserved. Indicators for the first issue were crop yield, net farm income, and frequency of crop failure; those for the second issue were soil depth, organic C, and permanent ground cover. Indicator values for ten farms in Guba, Philippines, are shown in the first table. Threshold values, denoting the boundary between sustainable and unsustainable indicator values, were defined (second table) and teh indicator values for the ten farms were converted into the threshold values (third table). A converted value of one indicates that the specific indicator is at a sustainable level. Subsequently, the indices fsor farmers' satisfaction and natural resource conservation were computed as averages of their three respective indicators. To be considered sustainable, the individual converted values as well as both averages should exceed 1.0 (only farms 1 and 5). The final index for sustainability is obtained by computing the average of both indices; the higher the value, the more sustainable land management is at farm level. *--Tookit Module abstract, SLM-IM Guidelines, Section D, 1999:117.*

Granatstein, D. and D. F. Bezdicek. 1992. The Need for a soil quality index : Local and regional perspectives. American Journal of Alternative Agriculture [Greenbelt, MD: Institute for Alternative Agriculture] 7, no.1/2: 12-16.

"Need for" SQ index, ie. discussion paper/philosophy/viewpoint presentation. --Includes consideration of change, benchmark establishment; --Sees indicators as "isolated measures" and their interaction as indicative of soil quality (so, must combine or "integrate" quantified properties/data to deduce quality; also must consider local or regional conditions for parameters), change, and types of sites; supports need for dynamic approach. --Advocates a suite of meaningful soil tests developed into an index. --Long term changes (40yrs.) in enzyme levels, microbial biomass, & SOM (after Bolton et al. 1985); large data sets needed; crop yields important; SOC levels deemed "most universal gross indicator". --Uses of index: farmers, managers, & policymakers all need; for management practices to be "best" ones. --Advocates reference points on Central Great Plains of North America and prairie ecosystem for interpretation of changes in soil quality in semi-arid cereal cropping (p.14); native soil as benchmark to compare management systems (p.15). SQ Index "must be sensitive to how a soil is used" (p.15). --Guidelines for selection of analytical assays to represent specific agroecosystems and their changes. --Physical tests need to be *in situ*, in undisturbed soil conditions; Chemical tests must be consistent, repeatable, and ratios of results are more meaningful than individual measures. --Quantitative measures of "health" require careful definition. The References at the end of this paper are important ones in the SQ Literature (Bibliography, p.16). --This paper (1992) sets the tone for future research needs.--ch.

--"Granatstein and Bezdicek (1992) recognize that understanding of soil is based primarily on the quantitative analysis of isolated physical, chemical, and biological properties and argue for an index adaptable to local or regional conditions. Parameters differ as one compares soil quality across crops, for example semi-arid wheat and paddy rice." [*from Freyenberger's et al. annotated bibliography: SQI Lit.ID #214, p.9*]

Gregorich, E. G., M. R. Carter, D. A. Angers, C. M. Monreal, and B. H. Ellert. 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Canadian Journal of Soil Science [Ottawa: Agricultural Institute of Canada] 74, no. 4 (Nov): 367-385.

Gregorich et al. (1994) propose a minimum data set for estimating soil organic matter quality. Soil structural processes, such as the formation and stabilization of aggregates and macropores, are affected ty the toal organic matter, microbial biomass, and carbohydrates. Nutrient storage in soils can be assessed by evaluating the quantity of organic carbon (C) and nitrogen (N). Also, the total amount and the proportions of total organic C and N, microbial biomass, mineralizable C and N, and thelight refraction also will provide information on soil nutrient storage. Attributes such as microbial biomass, enzymes, and mineralizable C and N are measures of biological activity in soils. --[*from Freyenberger's et al. annotated bibliography: SQI Lit.ID #214, p.9*]

Gregorich, E. G., and Martin R. Carter. 1997. Soil quality for crop production and ecosystem health. Amsterdam / New York: Elsevier.

Grinchenko, T. A., and I. I. Filon. 1998. Fertility of typical chernozems over the left bank Ukrainian forest-steppe. Pochvovedenie , no. 2: 223-226. [Russian, with English abstract]

An integral assessment of fertility evolution was carried out for typical chernozems of different granulometric composition under continuous fertilization and irrigation during long-term experiments on permanent field sites. A desirability function was applied for the assessments. A close and reliable correlation was obtained between crop productivity and the integral **index of soil quality**. *--Authors' Abstract.*

Grinchenko, T. A., E. I. Grigor'ev, A. A. Egorshin, A. F. Gavron, and V. G. Utochkin. 1991. Evaluation of fertility development based on a common index of soil quality. Agrokhimiya , no. 1: 52-60. [Russian]

Grossman, R. B., D. S. Harms, C. A. Seybold, and M. T. Sucik. 2001. A Morphology index for soil quality evaluation of near-surface mineral horizons. In: Sustaining the global farm—Selected papers from the 10th International Soil conservation Organization Meeting (ISCO99)D. E. Stott, R. H. Mohtar, and G. C. Steinhardt, 637-40West Lafayette, IN: International Soil Conservation Organization in cooperation with the USDA and Purdue University.

Regional scale attempted; --Purpose to apply a protocol for morphological info. to S.Q. --0 to 30cm depth, or root-restrictive layer (for shallower soils); --soil structure, moist rupture resistance, raindrop impact crust, surface-connected macropores (so, water-penetration resistance & infiltration are diagnostics--ch notes); soil texture.--Class sets ranked 5(best) to 1(poorest); 100-base expression; used to establish a range of values, or "indices" between 73 & 20 for soils across the Northern Great Plains of North America.--Examples of Colorado & Nebraska sites were compared, where winter wheat = crop on Argiudolls [compare with Brejda & Moorman, pp.535-540 of same publication; SQLit.Project 2003 ID#224--ch notes].--Measured 9 soil series in spring & fall, over a 2 1/2-yr. study period, for 38 measurements on cropland, to a mean index of "47". --Authors suggest their study methods could be applied to penetration resistance, infiltration, bulk density tests of soil physical properties as an in-field protocol, could be applied to NRCS soil surveys/staff inquiries, & might be useful if mandatory programs occur in future in the USA.

Grossman, R. B., Deborah S. Harms, C. A. Seybold , and M. T. Sucik. 2001. A Near surface Morphology Index for soil quality evaluation. In: International Soil Conservation Organization Abstracts 1999; Abstract A-0388, p.42.

Guldin, J. M., J. B. Baker, and B. R. Lockhart. 1989. Evaluation of four soil-site index estimators for loblolly pine in the West Gulf Region; Paper presented at the Fifth Biennial Southern Silvicultural Research Conference, Nov 1-3, 1988, Memphis, Tennessee. U.S. Dept. of Agriculture, Forest Service, Southern Forests Experimental Station,General Technical Report no.74, Pp.489-493 (+maps)