Karlen, Douglas L., Susan S. Andrews, and John W. Doran. 2001. Soil quality : Current concepts and applications. *Advances in Agronomy* [San Diego, Calif.: Academic Press] Special issue; 74: 1-40. Donald L. Sparks, editor. New York, NY: Academic Press.

This is a review of the "soil quality" concept, and includes perceptions by academia, industry, and government, with advocacy positions nicely summarized. As an assessment tool, we must recognize "inherent and dynamic soil properties and process" (p.12). Dynamic soil quality = changes due to current and past land use (implying benchmarks for 'inherent' must be pristine/"native" / undisturbed soils / sites /s amples [are there any left?]). Section VI. "Indexing Soil Quality" (pp.14-21), summarizes the visual soil assessment procedure developed in New Zealand (2000), the use of scorecards and on-farm user-based indexing of a variety of soil attributes for single-assessment, spatial scale determinations of SQ. Then SQ test kit levels to gather data for composite analyses, to derive a SQ Index are discussed. SQ ratings will always be relative, based on the soil management questions driving the assessment, and thus the indicators chosen (philosophical viewpoint). Criteria are given for SQ [p.17]: a) knowing SQ indexing is an iterative process; b) establishing ranges for appropriate values (not a single value); c) determining [and reporting!] how data values per indicator are collected and scored; d) determining relative weight/rank/importance to be given to each indicator, ensuring representativeness. Spatial and temporal scale are important; must be accurate and include intent. Minimum data set selection is important; expert opinion and principal component analysis are best interpretive/analytical tools for data treatment. Selection of reference conditions for each study to account for differences in inherent soil characteristics should be included and discussed, in the viewpoint of these authors.

Karlen, Douglas L., John W. Doran, B. J. Weinhold, and Susan S. Andrews. 2003. Soil quality: Humankind's foundation for survival. Journal of Soil and Water Conservation 58, no. 4 (Jul-Aug).

See URLs: http://www.swcs.org/docs/Karlen%20Research%20Editorial.pdf ;

http://www.swcs.org/t_pubs_journal_JulyAug03_Soil.htm

This paper is a response to the criticisms of Sojka and Upchruch, 1999, and Sojka et al. 2003 (in *Advances in Agronomy*), to deal with misconceptions surrounding the soil quality concept and soil quality assessment/research. It includes key comments concerning soil quality indexing literature.

Karlen, Douglas L., N. S. Eash, and P. W. Unger. 1992. Soil and crop management effects on soil quality indicators. American Journal of Alternative Agriculture 7, no. 1-2: 48-55.

Karlen et al. (1992) identify physical, chemical, and biological indicators that could be used to evaluate human-induced effects on soil quality. Physical indicators include soil tilth and resistance to wind and water erosion. Chemical indicators include inherent soil fertility properties (such as pH, cation and anion exchange capacities, total and available plant nutrients, and salinity) and nutrient cycling or transformation rates. Biological indicators include microbial activity and natural processes of respiration, mineralization, and denitrification. Nutritional indicators also could assess the nutritional quality of plants in relation to the soil in which they grow. Yet without rigorous evaluation, statements attributing either good or bad nutritional effects to soil quality are likely to be invalid and should not be made. In examining soil and crop management practices, they find no single strategy that has the answer, because human-induced and natural factors are not constant. Soil and crop management strategies that focus on soil organic matter and related biological components appear to be the best ways to improve or sustain soil quality. Conservation tillage, cover crops, and crop rotations are specific practices around which programs should be formed. --[from Freyenberger's et al. annotated bibliography: SQI Lit.ID #214, p.9]

Karlen, Douglas L., J. C. Gardner, and M. J. Rosek. 1998. A Soil quality framework for evaluating the impact of CRP. Journal of Production Agriculture 11, no. 1: 56-60.

These authors present a framework to use in soil quality evaluation, which delimits the appropriate indicators to use for different scales of study, delineating five levels of research from point scale (re processes and mechanisms); plot (re treatment responses); field, forest, or tract (re topography); farm and watershed; and regional/national/international (re productivity, environmental quality, and sustainability). Relevance to assessment of Conservation Resources Program (CRP) lands and resources in USA is discussed.

Karlen, Douglas L., and M. J. Mausbach. 2001. "Soil Quality assessment." [U.S.] National Soil Tilth Laboratory. From URL: http://www.nstl.gov/research/onepage/karlen1.html ; http://www.nstl.gov/research/quality.html

Problem

Soil Quality, which can be simply defined as the "capacity of a soil to function," has been a primary research focus at the National Soil Tilth Laboratory (NSTL) during the past five years. Continued cooperative efforts are needed to develop science-based protocols for quantifying soil quality as a tool for natural resource assessment and evaluation of soil management practices.

Approach

Collaborative research and technology transfer activities conducted in partnership with the Natural Resources Conservation Service (NRCS) Soil Quality Institute personnel and numerous other ARS and University research partners have raised the concept of soil quality from obscurity to an issue that is publicly recognized, scientifically debated, and actively evaluated as a tool for assessing the sustainability of agricultural practices and other land uses.

Findings and Application of Results

Soil quality considers physical, chemical, and biological properties and processes within the living and dynamic soil body. Scientific controversy has surrounded the concept, because soil quality *per se* cannot be measured. It must be assessed by evaluating various qualitative and quantitative indicators. Soil quality evaluation is complicated because assessment must distinguish between inherent or natural differences caused by the basic soil forming factors and the changes occurring in response to land use or management practices. Inherent differences in soil quality are illustrated for two soils in Fig. 1.

Physical, chemical, and biological changes occurring in a specific kind of soil reflect dynamic soil quality. This type of assessment, unlike inherent soil quality that reflects the "quality of a soil" formed in response to the natural soil forming factors, examines spatial and temporal variation created by land use, policy, or management decisions. Dynamic soil quality also reflects how the soil resource may be affecting air, water, and other natural resources. The most important use for dynamic soil quality assessments is as a tool for quantitatively evaluating sustainability (Fig. 2).

Current research is focused on identifying the most responsive soil quality indicators, using those indicators to develop soil quality indices, and using the indices as tools for point, field, watershed, and regional assessment. Soil quality assessment was used to evaluate post-Conservation Reserve Management practices and to assess soil quality within four Major Land Resource Areas.

Goal: Develop and evaluate soil quality assessment tools that will guide the development of sustainable food, feed, and fiber production systems that satisfy human needs over time while conserving natural resources.

Objectives:1) Identify appropriate indicators, threshold values, and ranges for assessing soil quality by region and/or practice throughout the U.S.

2) Discern the biological, chemical, and physical processes and mechanisms that influence and control nutrient and water-use efficiencies in agroecological systems.

3) Quantify spatial and temporal variability associated with critical soil quality indicators for soils and management practices used in various regions throughout the U.S.

4) Develop user-friendly, transferable processes to integrate soil quality indicator information for guiding subsequent land use and management decisions.

5) Refine alternative soil and plant management strategies so that they have positive effects on soil quality and the long-term sustainability of our Nation's soil, water, and air resources.

Project Summary: Long-term sustainability of our Nation's soil resources requires a better understanding of how various soil and crop management strategies affect productivity and environmental endpoints. This project will use soil quality assessment as a tool to provide the framework for developing this understanding. Basic laboratory studies, controlled rhizotron investigations, plot- and field-scale experiments, watershed analyses, and regional evaluations will be used to accomplish five primary objectives: (1) identifying appropriate indicators and interpretation values for soils throughout the U.S.; (2) understanding the processes and mechanisms that control nutrient and water-use efficiencies; (3) quantifying spatial and temporal variability associated with critical soil quality indicators; (4) developing user-friendly, transferable soil quality indexing processes; and (5) developing soil and plant management strategies that ensure long-term sustainability of our Nation's soil, water, and air resources. This project will be conducted at several scales and for both organic and conventional farming operations. Effects of landscape position and hydro-geological setting and various crop rotations, tillage practices, fertilizer management strategies, and manure management practices will be evaluated for their effect on carbon and nitrogen cycling, plant growth and development, yield, and nutrient or pesticide loss from the plant root zone. Soil properties and processes that are sensitive to management will be identified and used to develop soil quality indices that attempt to balance productivity, environmental, and economic factors. This information will be used to help design soil and plant management strategies that will sustain or enhance soil resources. A better understanding of relationships between soil quality, crop yield and quality, and losses of carbon, nitrogen, and phosphorus from various land management systems will be a primary outcome.

Karlen, Douglas L., M. J. Mausbach, J. W. Doran, R. G. Cline, R. F. Harris, and G. E. Schuman. 1997. Soil quality : a Concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61, no. 1 (Jan/Feb): 4-10.

For more recent treatment, see Karlen, D. L., Andrews, S. S. and Doran, J. W. 2001. *Soil quality: Current concepts and applications.*

Karlen, Douglas L., T. B. Parkin, and N. S. Eash . 1996. Use of soil quality indicators to evaluate conservation reserve program sites in Iowa. In: Methods for assessing soil quality. SSSA Special Publication no.49: 345-355. J. W. Doran, and A. J. Jones, editors. Madison, WI: Soil Science Society of America.

Results from field evaluations conducted during 1993-1994 in the title area of the USA have demonstrated that soil quality indicators (aggregate stability, bulk density, total C, total N, nitrate, microbial biomass, respiration, hyphal length, ergosterol content) measured at various sites show differences associated with soil and management practices. The differences between Conservation Program Reserve (CPR) and adjacent cultivated sites were hardly significant after 2 years of CPR even though the sites had been under grass for 6 years. Management practices had significant effects on both adjacent cultivated sites and CPR sites. It is suggested that no-tillage can extend the beneficial impact of CPR. *--CAB Abstracts.*

Karlen, Douglas L., M. J. Rosek, J. C. Gardner, D. L. Allan, M. J. Alms, D. F. Bezdicek, M. Flock, D. R. Huggins, B. S. Miller, and M. L. Staben. 1999. Conservation Reserve Program effects on soil quality indicators. *Journal of Soil and Water Conservation* 54, no. 1: 439-444.

Soil aggregate stability and size distribution, bulk density, total organic C and N, nitrate-N, ammonium-N, pH, cation exchange capacity, microbial biomass C and N, soil respiration, fluorescein diacetate hydrolysis, fungal hyphal length, and ergosterol concentrations were measured in paired Conservation Reserve Program (CRP) and cropland sites in Iowa, Minnesota, North Dakota, and Washington, USA. CRP sites in Iowa generally had a higher percentage of water stable soil aggregates than cropland sites. In Minnesota, the mean aggregate diameter was significantly higher in CRP than cropland samples, but differences in North Dakota were not significant. In all states, microbial biomass carbon was 17-64% higher at CRP sites than at cropland or fallow sites. Nitrate-N was 18-74% higher in cropland than CRP sites. Soil respiration values were greater (but not significantly different) in CRP than cropland sites in all 4 states. Hyphal length, measured only in Iowa, increased by 26-62% under CRP. CRP samples had higher ergosterol only in Henry County, Iowa, where cropland was chisel-ploughed and disced each year. Overall, soil biological indicators showed more significant differences than either chemical or physical indicators. This multi-state project showed that several soil quality indicators were improved by placing highly erodible cropland into perennial grass, and that with refinement, those indicators could be used to assess long-term impacts of agricultural management practices. --CAB Abstracts.

Karlen, Douglas L., and Diane E. Stott. 1994. Framework for evaluating physical and chemical indicators of soil quality. Chapter 4. In: Defining soil quality for a sustainable environment; Proceedings of a symposium, Minneapolis, MN, USA, 4-5 November 1992. SSSA Special Publication no.35: 53-72. J. W. Doran, D. C. Leman, D. F. Bezdicek, and B. A. Stewart, editors. Madison, WI: Soil Science Society of America.

A procedure that can be applied to site-specific situations and used to quantify soil quality impacts is illustrated. An example is given using data collected from an alternative and conventional farm in central Iowa, USA. Hypothetically a fine-loamy mixed, mesic Typic Hapludoll in alternative fields would have a soil quality rating of 0.73 compared with 0.54 for the same soil under conventional farming, when calculated with regard to water erosion. Physical and chemical measurements made at different levels of investigation are identified as a method for quantifying system response as related to those functions. Each parameter is given appropriate priority and used to compute a soil quality index for a specific problem, process, practice or policy. --CAB Abstracts.

Karlen, Douglas L., N. C. Wollenhaupt, D. C. Erbach, E. C. Berry, J. B. Swan, N. S. Eash, and J. L. Jordahl. 1994. Crop residue effects on soil quality following 10-years of no-till corn. *Soil Tillage Research* 31, no. 2/3: 149-167.

Upper Mississippi Valley soils in NW Illinois, SW Wisconsin, SE Minnesota, & NE Iowa were studied. Indicators sensitive to management practices were the soil properties selected: microbial biomass, respiration, amino acids, soil enzymes, earthworm activity in 10-year long-term, cropped field plots at University of Wisconsin experimental farm in May 1991. Plots were 15 x 15 x 5cm. Soil aggregate stability, penetration resistance, hydraulic conductivity; microbial biomass, respiration, fungal biomass, ergosterol, earthwork activity were assessed. The researchers used SAS PROC GLM software for analysis. SQ Index (quote p.155 & P.163) used normalized standard scoring functions on a scale from 0 to 1, weighted by importance, and presented in a table (Table 7, p.164). Products were summed to give a weighted value per indicator. This was static, at plot level, and a single-season study, but with replicable measurements.

———. 1994. Long-term tillage effects on soil quality. Soil Tillage Research [New York, NY: Elsevier Sciences Publishers B.V.] 32, no. 4: 313-327.

This paper gives the detailed methods (jw); used in a study outlined in a 1994 paper (re "crop residue effects" in which a Soil Quality Index is detailed.

Kelting, Daniel L., James A. Burger, S. C. Patterson, W. M. Aust, M. Miwa, and C. C. Trettin. 1999. Soil quality assessment in domesticated forests - a Southern pine example. Forest Ecology and Management—Special Issue: Indicators of Sustainable Forest Management 122, no. ½: 167-185.

This forestry paper gives a good definition of benchmarks (jw) and SQ Indexing and monitoring; applies agro-economic studies and Productivity Index (Burger 1996) to forest plots on Lower Coastal Plain sites in South Carolina, USA. In 1991, there were three study blocks, six 3-ha plots per block (i.e. 18 sites), with 3 differing "site preparations": none, bedded, or mole-plowed in terms of fall 1993 and spring 1994 harvests (wet or dry). Lab analyses on variables included determining "sufficiency levels" per location, per indicator, and the development of "sufficiency curves" (graphically depicted). Additional study was done of 54 plots of loblolly pine, identically-spaced and concurrently planted in February 1996; from 2.1m x 6.3m size to test productivity in correlation to soil properties and processes. Multilinear regression analysis was used to explain variation in productivity, with 60% by the SQ Index model. The authors include suggestions to improve the SQ Index results in future studies for certain attributes, such as bulk density, and in terms of short-term management issues; as well as in terms of longer-term variation (e.g. total organic C not being a good indicator for short-term management-induced change). The authors find the SQ Index approach useful for "point-in-time measures" (p.182).

Kenney, E. A., J. W. Hall, and C. Wang. 2002. Temporal trends in soil properties at a soil quality benchmark site in the Lower Fraser Valley, British Columbia. Canadian Journal of Soil Science 82, no. 4 (Nov): 499-509.

This paper presents a soil quality benchmark site case study in British Columbia, Canada. --At 5-year data interval, sampled 1996 compared to 1991 for trends analyses in soil compaction & penetration resistance, hydraulic conductivity to 609cm. depth; under variable treatments (liming, liquified manure, pasture) & crop rotation (forage, hay, corn, rotational grazing of stubble). --25m x 25m grid & point sample locations, annual transects, sampling depth to parent material, using 1991 f9or baseline values compared to 1996; with annual sampling on some "selected chemical & physical properties" at 40 of the 80 overall grid points. --Lab analyses of air-dried samples, on particle size, soil pH, total N, available potassium, bulk density, total C --at 2 different labs (except total C) --for 1991 vs 1996. --Performed analysis of variance, semivariograms, covariance, and transforms used in statistical analyses. <u>Results</u>: "Between 1991 and 1996 in the A horizons, pH, available P, C:N ratio and bulk density increased by 4.6, 7.8, 2.5, and 8% respectively, and available K, total C and total N decreased by 21, 16.5, and 18.3% respectively. In the BCg horizon, pH, available P and C:N ratio increased by 5, 126, and 8%, respectively, and the available K and total N both decreased by 21%. Bulk density remained unchanged;" Soil chemical properties did not remain stable over the 5-yr interval.

Kim, K. Barham B. L., and I. Coxhead. 2001. Measuring soil quality dynamics: a Role for economists, and implications for economic analysis. Agricultural Economics [Amsterdam; New York : Elsevier] 25, no. 1 (Jun): 13-26.

Use of field data and 'dynamic production function' modelling to infer soil quality changes, useful for land management policy in Wisconsin, USA.

Klevtzov, A. 2001. Soil quality indices and sustainable agriculture. Pochvoznanie, Agrokhimiya i Ekologiya 36, no. 4/6: 92-96.

This theoretical/philosophical paper clearly describes, in overview, the current thinking on what is required for a numeric SQ Index. The author's position is that agricultural sustainability requires measures of system reliability, resilience and vulnerability, and that using SQ Indexing provides advantages. He proposed (1994) modifications to Doran and Parkin's (1994) SQ Index equation (p.95).

Knoepp, J. D., D. C. Coleman, D. A. Crossley Jr. , and J. S. Clark. 2000. "Biological indices of soil quality: an ecosystem case study of their use." UDSA-Forestry Service, Southern Research Station Publications.

Forests, indicators, & indices; --Field scale; ranked soils in five forest ecosystems in N.Carolina, then compared four indicators (N, litter decomposition, soil micro-arthropods, C) for variability ratings.—Gives clear overview of literature, and rationale for choice of indicators. Soil chemical and physical characteristics—'CP'--: total C, total N, cation concentrations (of K, Mg, Ca), P concentrations, pH, & bulk density (presented in Table 2, p.362) were used to rank sites, ranking by significant difference over 2 years, and by summing the indicators (!).—Six years of data were used for N mineralization measure, as a proportion of total N, from weekly lysimeter readings "composited monthly". These data were combined for an overall ranking of each site.—Litter accumulation and microfaunal abundance sampling were measured, but frequency not given (once only? or over time? no interval data given—Same as the 6yr. N measure?).—Mean soil CO2 flux measured by closed chamber method, used to rank greatest amount per site; NH as microbial C quotient for microbial biomass C measured also.—'Litter fall' measured and used to index overall site productivity above-ground (i.e. an 'abundance' measure as indicator of plant/tree canopy productivity). The quality of sites then compared by a composite of all indicators, but no method of quantification /combination is given, in order to replicate or reconstruct these data/indices. The reader must rely on the researchers' interpretations re overall site quality rankings. The researchers express difficulty with the complexity/comparability of indicators (flaw in design of the study?).—Lots of good references at end of paper, such as: Doran & Parkin 1994, Larson & Pierce 1994, Ramann 1997, Jenny 1997, Elliott 1997, Duxbury & Nkambule 1994, Anderson 1994, Linden et al. 1994, Rice & Garcia 1994, Sparling 1997, van Straalen 1997.—ch.

Knowles, Porter C., and Dames & Moore. 1992. Fundamentals of environmental science and technology. Rockville, MD: Government Institutes. xii, 138 pp.

Koppen, D. 1993. Agrochemical soil fertility indices for the agroecological evaluation of soil use systems: selected points // Original Title: Agrochemische Bodenfruchtbarkeitskennziffern zur agrarokologischen Beurteilung von Bodennutzungssystemen: Ausgewahlte Schwerpunkte. Verlag Darmstadt, Germany: VDLUFA Schriftenreihe.

In experiments conducted over some 10 years on a loess-chernozem soil at Bad Lauchstadt, Germany, soil fertility indices (SFIs) were constructed using chemical, biological and physical characters. Data reported in the literature were also included in the investigation. The variations and correlations among the SFI values under different rotations and on no-intervention plots were observed, and the relationship between SFI and yield noted. The construction of SFIs is important in monitoring the effects of different soil management and cropping regimes. --CAB Abstracts.