


... Farmers increasingly demand more information and better tools for monitoring the sustainability of their agricultural management. This paper describes work in progress [presenting] an overview of research and development of a Soil Quality Monitoring System (SQMS). The SQMS is designed as an on-farm tool for monitoring and interpreting changes in soil quality that reflect on the sustainability of agricultural management practices... One of the major challenges to quantifying agricultural productivity involves normalising the measurements to account for differences in land-use (e.g. arable cropping, dairy pasture, etc.), crop type (e.g. wheat, maize, asparagus) and environmental constraints (e.g. soil type, climate etc). This is particularly important in a monitoring programme where the objective is to compare year-to-year changes in paddock productivity under different crops. Our solution to this challenge is to index measures of paddock productivity against the regional (or local) average annual productivity of a specific crop (e.g. pasture cover, wheat yield). Productivity threshold (PT) levels are set as a fixed percentage of the productivity index (PI) to denote boundaries between sustainable and unsustainable practices. Using this approach, the threshold levels for a sustainable practice can be tailored to the specific expectations of farmers, farm consultants and regional governing bodies. Depending on regional or local circumstances, PT values may be judged to be greater than, less than or equal to one (i.e. where PT = 100% of the regional average annual productivity). Examples of productivity indices for 13 performance assessment paddocks located on the Lincoln University and Crop & Food Research farms are given. --From URL: http://www.hortnet.co.nz/publications/nzpps/proceedings/97/97_520.htm


This article follows the functional definition of 'land quality' used by Karlen & Stott.


Nematode community analysis may provide a useful tool to quantify soil health. Nematode communities were monitored for 5 years during a 12-year period in the sustainable agriculture farming systems (SAFS) project at UC Davis, where conventional (CONV), low-input (LOW) and organic (ORG) management treatments were compared. After the completion of three 4-year crop rotation cycles, a uniform crop of oats was grown in 2001. The composition of the nematode genera was different from year to year, but there were significant management effects on genus composition in each year.... Important contributors to the differences in genus composition among treatments were plant parasitic nematodes. Nematode community indices (enrichment (EI), basal (BI) and channel (CI) indices) of the CONV treatment differed from those of the ORG and LOW treatments in 1993, 1994, 1995 and 2000 ... BI and CI appeared to be most valuable as
indicators for long-term effects of management on nematode suppression. However, BI and SI may be more suitable as general indicators for the health status of a soil, since CI can be high in highly disturbed agro-ecosystems as well as in undisturbed natural ecosystems. A high BI would indicate poor ecosystem health, while a high SI would indicate a well-regulated, healthy ecosystem. For agricultural soils the presence of large populations of plant parasitic nematodes forms an additional indication of poor ecosystem health, as natural regulation is limited...


The required increase in agricultural production to meet future food demand will further increase pressure on land resources. Integrative indicators of the current status of the agricultural production capacity of land and their change over time are needed for promoting land management practices to maintain or improve land productivity and a sustainable use of natural resources. It is argued that such land quality indicators should be obtained with a holistic systems-oriented approach. Two land quality indicators are elaborated that deal with (1) yield gaps, i.e. the difference of actual yield and yield obtained under optimum management practices, or yields determined by the land-based natural resources, and (2) a soil nutrient balance, i.e. the rate at which soil fertility is changing. The yield gap is based on the calculation of land-based cereal productivity at three different levels in terms of potential, water limited, and nutrient limited production, considering weather, soil and crop characteristics. These modelled production levels do not incorporate socio-economic aspects, which may impede agricultural management in its effort to release stress because of inadequate soil fertility, water availability and/or occurrence of pests and diseases. Therefore, location specific actual yield levels are also considered. Besides an evaluation of the actual status of the land, it is important to consider the rate of change. The quantification of changes in soil nutrient stocks is crucial to identify problematic land use systems. The soil nutrient balance, i.e. the net difference between gross inputs and outputs of nutrients to the system, is used as measure for the changes. The indicator for the soil nutrient balance combines this rate of soil nutrient change and the soil nutrient stock. Indicators for yield gaps and soil nutrient balances are defined, procedures for their quantification are described and their general applicability is discussed. --Authors' abstract from © 2000 Elsevier Science B.V. All rights reserved.


Decreases in land cover diversity can lead to decreases in soil quality. This study proposes using the National Resources Inventory (NRI) to develop a biodiversity index as a biological indicator of soil quality. Index values for Major Land Resource Areas in the southeastern USA were calculated using land use based upon whether the Primary Sampling Unit was either: (1) all cropland; (2) multi-cropped; (3) cropland with at least one non-cropland use; or (4) cropland having some vegetative diversity (cover crop, buffer strip, etc.). Forestland and range/pasture land uses provided high biodiversity index values for most of the southeastern USA. Cropland enrolled into the Conservation Reserve Program was attributed with the increase from 1982-97 of those acres with a score of 4. Irrigated cropland tended to have lower index values than non-irrigated...
cropland. Maize (Zea mays) and soyabean (Glycine max) seed yields tended to decrease as index values increased. Using the NRI did show promise for developing a biodiversity index.

--CAB Abstracts.


From URL: http://www.zalf.de/essc/valbook3.htm

This paper discusses the concept of soil quality and the possibility of defining soil quality indicators for specific soil functions, ranging from biomass production, filtering, buffering and transformation activities and the soil as a gene reserve, up to soil as a memory or soil as a basis for infrastructural development and a source of raw materials.


The response and consistency of different soil organic matter (SOM) attributes to changes in soil management practices were compared in eastern Canadian agroecosystems. Soil samples (0-10 cm) were obtained at sites of several replicated experiments throughout eastern Canada, and 16 paired comparisons were selected to determine the effect of conservation (no-tillage, rotations, organic amendments) vs. conventional (autumn mouldboard ploughing, continuous cropping, no organic amendments) management practices. A sensitivity index was calculated for each of the attributes by dividing the values for conservation treatments with their conventionally managed counterparts. …--Authors' abstract, p.37.


Since nematodes respond rapidly to new resources, and the nematode fauna can be efficiently analysed, the structure of the nematode community offers an instrument to assess (changes in) the conditions of soils. A functional grouping of nematodes is generally synonymous with allocation into feeding groups. However, soil quality assessment indices based on the presence of all feeding groups still provide insufficient information regarding the functioning of soil ecosystems and their threats. An alternative concept of functional groups is based on the life history of nematodes. In this paper the most recent colonizer-persister allocation and the application of this scaling in the Maturity Index, cp-triangles, MI(2-5) and PPI/MI-ratio is presented. It is proposed to integrate the life strategy approach and trophic group classification to obtain a better understanding of nematode biodiversity and soil functioning. Attention is given to competitive exclusion and coexistence and present concepts regarding succession and degradation are summarized.

--CAB Abstracts.

Bowman, Bruce T. 2003. FAQ - What is Soil Quality or Soil Health? Is there a difference between Soil Quality and Soil Health? From URL: http://res2.agr.ca/london/faq/soil-sols_e.htm

In a recent publication from the Research Branch of Agriculture and Agri-Food Canada entitled "The health of our soils: toward sustainable agriculture in Canada" (D.F. Acton and L. J. Gregorich, editors; 1995), the editors state that the terms Soil Quality and Soil Health can be used interchangeably. In a Statement on Soil Quality by the Soil Science Society of America [SSSA] (Agronomy News, June 1995, Page 7), the editors added the following Footnote on Soil Quality:

The terms soil quality (favored by scientists) and soil health (favored by farmers) tend to be used interchangeably, especially in the general press. Characterization of soil quality by scientists focuses on analytical/quantitative properties of soil with a separately defined quantitative link to the functions of soil quality. Characterization of soil health by farmers focuses on descriptive/qualitative properties of soil with a direct value judgement (unhealthy to healthy) integrated into the options for a given property; in addition, interwoven into the properties of soil per se are value-based descriptive properties of plant, water, air, and animal/human systems considered by farmers to be an integral part of soil health characterization.


Public interest in soil quality is increasing throughout the world as humankind recognizes the fragility of earth's soil, water, and air resources and the need to protect them to sustain civilization. To understand soil quality however, one must first be aware of the complexity of soil and its intrinsic value.
Soil is a living system that represents a finite resource vital to life on earth. It forms the thin skin of unconsolidated mineral and organic matter on the earth's surface. It develops slowly from various parent materials and is modified by time, climate, macro- and micro-organisms, vegetation, and topography. Soils are complex mixtures of minerals, organic compounds, and living organisms that interact continuously in response to natural and imposed biological, chemical, and physical forces. Vital functions that soils perform within ecosystems include:

--sustaining biological activity, diversity, and productivity;
--regulating and partitioning water and solute flow;
--filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric depositions;
--storing and cycling nutrients and other elements within the earth's biosphere; and
--providing support for socioeconomic structures and protection for archeological treasures associated with human habitation.

Conceptually, the intrinsic quality or health of a soil can be viewed simply as "its capacity to function." More explicitly, SSSA defines soil quality as:

*The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.*

By encompassing productivity, environmental quality, and health as major functions of soil, this definition requires that values be placed on specific soil functions as they relate to the overall sustainability of alternate land-use decisions. Although unstated, the definition also presumes that soil quality can be expressed by a unique set of characteristics for every kind of soil. It recognizes the diversity among soils, and that a soil that has excellent quality for one function or product can have very poor quality for another. The functions encompassed by soil quality integrate chemical, physical, and biological properties and processes occurring within every soil and are responsive to human use and management decisions.


This fact sheet speaks of 'indicators', field 'indices' by combining 3 most-easily observable, testable, on-farm, in-field soil attributes. It deals with 'Quality soil' as one that is resilient after change (sod is broken), not too sandy or clayey (loamy is best; deep loam). Texture, pH & SOM are the three main parameters used. Indicators are given: soils series/family, slope/topography, texture/particle size distribution, soil pH/reaction, SOM content/residue, presence of earthworms/macropores, depth, fertility (nitrates & SOM), salinity (electrical conductance), aggregate stability (turbidity), and infiltration. Combines SOM, soil texture and depth-to-lime for a quick field-applicable Soil Quality Index. The article makes recommendations and provides guidance for proper agricultural management practices to achieve soil health. This is a field-scale, farm-level study, for 'awareness' of best practices and for extension purposes.


Diversity of soil series present in a region may hinder identification of soil quality factors and indicators at a regional scale. Our objectives were (i) to identify soil quality factors for a diverse population of soils at the regional scale, (ii) determine which factors vary significantly with land use, (iii) to select indicators from these factors that can be used with the US National Resource Inventory (NRI) for monitoring soil quality, and (iv) to compare these results to a similar study involving only a single soil series. One hundred eighty-six points representing 75 soil series in the Northern Mississippi Valley Loess Hills and 149 points representing 58 soil series in Palouse and Nez Perce Prairies were sampled from a statistically representative subset of NRI sample points and analysed for 20 soil attributes. Factor analysis was used to identify soil quality factors and discriminant analysis was used to identify factors and indicators most sensitive to land use within each region. In the Northern Mississippi Valley Loess Hills, five soil quality factors were identified. Discriminant analysis selected potentially mineralizable N, microbial biomass C, water stable aggregates, and total organic C (TOC) as the most discriminating attributes between land uses. In the Palouse and Nez Perce Prairies, six factors were identified. Discriminant analysis selected TOC and total N as the most discriminating attributes between land uses. The soil quality factors were similar among three of the four regions, but TOC was the only indicator common to all regions for distinguishing among land uses.

Appropriate indicators for assessing soil quality on a regional scale using the US National Resource Inventory (NRI) are unknown. Our objectives were to (i) identify soil quality factors present at a regional scale, (ii) determine which factors vary significantly with land use, and (iii) select soil attributes within these factors that can be used as soil quality indicators for regional-scale assessment. Ascalon (fine-loamy, mixed, superactive, mesic Aridic Argiustoll) and Amarillo (fine-loamy, mixed, thermic Aridic Paleustalf) soils were sampled from a statistically representative subset of NRI sample points within the Central and Southern High Plains Major Land Resource Areas (MLRA) and analysed for 20 soil attributes. Factor analysis was used to identify soil quality factors, and discriminant analysis was used to identify the factors and indicators most sensitive to land use within each MLRA. In the Central High Plains, five soil quality factors were identified, with the organic matter and colour factors varying significantly with land use. Discriminant analysis selected total organic C (TOC) and total N as the most sensitive indicators of soil quality at a regional scale. In the Southern High Plains, six factors were identified, with water stable aggregate (WSA) content, TOC, and soil salinity varying significantly with land use. Discriminant analysis selected TOC and WSA content as the most sensitive indicators of soil quality in the Southern High Plains. Total organic C was the only indicator that consistently showed significant differences between land uses in both regions. --Authors' abstract, p.2115.


Sustainable Forestry Practices are in demand, and therefore require assessments and monitoring of indicators within available SQ models. Monitoring is a process of detecting change in one or more determinants of productivity. Soil-based indicators have to be 1) soil- and site-specific; considering natural forests, plantation forestry needs to look at multiple variable indicator transforms (MVIT) to study SQ in the future; to study forestry, from the agricultural research literature (to 1997) on SQ monitoring. These authors conclude that forestry needs to look at multiple variable indicator transforms (MVIT) to study SQ in the future; to study SQ, organic matter, and soil disturbance functionally.


Position of soil health and ecosystem stability/resilience is taken, in order to discuss SH indicators as useful in disease suppression, as biological responders to stress/soil disturbance.


This study sought to collaborate with farmers in the development of a soil health checklist. The research process acknowledged the importance of local conditions, farmers' existing knowledge on soils and their preferences for delivery and presentation of the final product. The study focused on farmers located in the north-west cropping region of New South Wales, Australia. This article reports on a prototype for a farmer's soil health checklist - the features they use, how they recognise those features, especially the language they use to describe a healthy and unhealthy soil, and finally the techniques they use to determine those features.


Whereas in agriculture, soil quality has more recently been studied and monitored separately from crop productivity, this paper recognizes that forestry management traditionally has included soil quality as part of overall forest maturing and sustainability. Thus, soil quality analysis has more bearing on short-term forest stands where erosion, degradation, and reclamation are important. This chapter follows the philosophical positions of Doran (1994), Karlen et al. (1997), the Montreal Process (1998) re sustainability (i.e. "perpetual resource availability" (p.17)), the Santiago declaration for forest soil functions, Doran et al. (1996), Burger (1996), Parr & Papendick (1992). The authors propose use of a pie-chart model as a soil quality index, wherein 100% quality is expressed as the total area of a circle, weighted indicators are wedges, and the rated SQ Index is a fraction of 1 (the 100% total area). Indicators are to be the site-specific soil attributes applicable to the climate, soil type, and forestry practice for a particular forest soil, which is seen as dynamic, subject to human and climatic influences, and necessarily comparable to a baseline, hypothetical state for that soil (as some are of inherently poor quality for forest productivity), reflecting "natural levels in managed forests" with optimal plant growth (p.32). --Cases are examined from the Atlantic Coastal Plain, the Appalachian Piedmont, NW Florida, S Carolina, the Mobile River Delta of Alabama as examples of natural variation across landscapes, wherein soil attributes exhibit SQ as spectrum functions from High to Low based on capacity to (1) hold, supply, & cycle nutrients (soil fertility), and (2) accept, hold, & supply soil, water, & air (water-air balance) (p.34). --SQ. monitoring will first require qualitative description of a high quality soil; then to substitute quantitative measures of attributes (that vary each within a range of 'acceptable values'). Measurable indicators are 'substitutes' (ie. pedotransfer functions), such as: organic C, pH, macro- & micro-nutrients for 'plant productivity'. The Soil Tilth Index (Singh et al., 1992) and Productivity Index (Kiniry et al., 1983) are examined as possible models, to use pH, depth to mottling, bulk density, or biomass to derive "sufficiency relationships" and values, expressed as arithmetic means, which can then be multiplied at the geometric mean by weighting factors per attribute, to derive the PI, & to produce sufficiency curves for comparison. --Karlen & Stott's (1994) soil quality model was also examined (an additive model, not multiplicative like the PI) to consider how to assign relative weights to soil attributes. --Discussion is thorough, but not definitive; investigatory and summary in approach; searching for potential models to apply to forestry, from the agricultural research literature (to 1997) on SQ monitoring. These authors conclude that forestry needs to look at multiple variable indicator transforms (MVIT) to study SQ in the future; to study FSQ, organic matter, and soil disturbance functionally.
forests, & short-rotation woody crops (after Burger 1997); and 2) considering productivity differences among
the soil orders, in terms of a) soil fertility & b) soil water/air balance; and 3) considered over time; measured
at intervals, and compared. Data is stratified by these parameters. Functions, attributes, indicators selected (to
measure attributes, which reflect soil functions); --indicators can be state variables, process variables, or
complex constructs (such as soil tilth index); which includes bulk density, strength, plasticity, aggregate
uniformity, SOM (after Singh et al 1990); which combine several soil properties into "pedotransfer
functions" (after Bouma 1989. Good indicators include: --a baseline, range, sensitivity to a soil function, areal
applicability, provision for continuous assessment, are easy/inexpensive/calculable, discriminate between
natural or management-induced states; showing correlation to long-term response; responsive to corrective
measures/treatments. [There is a companion paper: Kelting & Berger, 1999; discussion paper & review; that
discusses their SQ model & Index/case study.] Results are illustrated in a pie chart, and SQ is indexed as a
fraction of one (as a wedge of the total area of a circle), as weighted by the angle of the wedge to show
importance of an indicator. This study identifies the minimum set of indicators to be placed in the SQ Index
chart. It provides an example of combining into an overall index is given in the productivity index model of
Kiniry et al (1983), which integrates field measurements for soil variables; it produces a "sufficiency curve"
for each SQ attribute. Then one can monitor, and produce probability maps based upon critical thresholds.

Use of fuzzy-set mathematical theory to assist in soil and land classification where large & complex data sets must be
reduced, but without losing the means to accurately convey information. Case studies included: --a 45ha. farm in
Turen, Venezuela with a variety of soil types, as a crop yield test site for IBSNAT-CERES maize crop simulation
model. 75m² grid, 69 soil profiles on 12 x 6 point grid were sampled at 0-20cm, 30-40cm & 70-80cm in-field, with 11
soil physical properties mapped to 25m grid using point kriging (p.485, Table 1), and variograms were produced to
predict mapping minimums and maximums to locate sandy soils. A data set from Kisii, Kenya; used point kriging to
map areas with potential for optimum planting, to compare Boolean vs fuzzy set approaches, and to verify using GIS.
Conventional 4km soil series maps for Kenya, using standard FAO "soil characteristics" (i.e. 'land qualities') which by
convex combination method confirmed the best land areas for planting maize, whereas fuzzy sets showed additional
areas were possible to use, by means of a "semantic import model" (pp.489-490)