OVERVIEW OF SOIL QUALITY FOR SUSTAINING EARTH AND ITS PEOPLE

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Background

Interest in soil quality and health has grown with awareness that *soil is central to the cycle of life on earth.* Soils support the growth of plants and microorganisms, regulate the flow and storage of water in the biosphere, and serve as a primary interface with the global environment affecting quality of both the water we drink and the air we breathe. The thin layer of soil covering the Earth's surface represents the difference between survival and extinction for most terrestrial life. One tablespoon of fertile soil contains up to 9 billion microorganisms, 1 and ½ times the human population of the earth. Soil health (quality) has been broadly defined as the capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health (Doran *et al.*, 1996).

Sustaining Earth and Its People

Two major threats to sustainability in the 21st century are: Population growth and increased demand for agricultural land and resources and over dependence on fossil fuels and the increased monetary and environmental costs of these non-renewable resources. In a 2003 report entitled 'Frontiers in Agricultural Research', the National Research Council of the US National Academy of Science recently defined the need for a new research model to meet the dramatic changes occurring in the last 30 years. To meet the food and nutrition needs of a growing world population, agriculture will need to move beyond the past emphasis on productivity to also encompass improved public health, social well being, and a sound environment.

Developing sustainable agricultural management systems, however, is complicated by the need to consider their utility to humans, their efficiency of resource use, and their ability to maintain a balance with the environment that is favorable both to humans and most other species (Harwood, 1990). More simply stated by a Midwestern farmer in the USA, *" a sustainable agriculture* - *Sustains the People and Preserves the Land."* We are challenged to develop management systems that balance the needs and priorities for production of food and fiber with those for a safe and clean environment. Assessment of soil quality or health is invaluable in determining the sustainability of land management systems (Karlen *et al.*, 1997). Soil quality is conceptualized as the major linkage between the strategies of conservation management practices and achievement of the major goals of sustainable agriculture (Acton & Gregorich, 1995; Parr *et al.*, 1992). In short, the assessment of soil quality or health, and direction of change with time, is the primary indicator of sustainable land management

Agriculture needs economic soil management practices that provide sufficient food and fiber yet maintain environmental stability, ecological integrity, and the quality of essential soil, water, and air resources. Our journey towards sustainable land management starts with identification of our final destination or goals, the strategies or course by which we will get there, and the indicators that we are going the right direction. Strategies for sustainable management include conserving soil organic matter, minimizing erosion, balancing production with environmental needs, and making better use of renewable resources (Table 1). These strategies

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include a more generic set of indicators to assess soil quality and health that are practical for producers. A study conducted in the northern United States corn and dairy belt used a similar approach to determine how farmers assess soil quality and health. Farmers ranked soil organic matter, crop appearance, and risk to erosion as the three most important properties for describing soil health and sustainable management (Romig *et al.*, 1996).

Table 1. Strategies for sustainable management and the crop, soil, and environmental indicators most useful to producers (After Doran *et al.*, 1996; Doran, 2002).

SUSTAINABILITY STRATEGY	INDICATORS FOR PRODUCERS
CONSERVE SOIL ORGANIC MATTER *through* Increase C & N levels by reducing tillage, recycling plant and animal manures, and increased plant diversity. where C inputs > or = C outputs	**DIRECTION AND CHANGE IN ORGANIC MATTER** levels with time using visual or remote sensing by color or chemical analysis OM potential for climate/soil/vegetation Soil water storage/infiltration/aggregation
MINIMIZE SOIL EROSION *through* Conservation tillage and increased protective cover such as crop residue, stable aggregates, cover crops, and green fallow	**VISUAL** (gullies, rills, dust, etc.) **& SURFACE SOIL PROPERTIES** (topsoil depth, organic matter content, texture, water infiltration, runoff, ponding, % surface cover)
BALANCE PRODUCTION & ENVIRONMENT *through* conservation and integrated management systems that optimize tillage, residue, water, and chemical use and by synchronizing available N and P levels with crop needs during year	**CROP CHARACTERISTICS** (visual or remote sensing of yield, color, nutrient status, plant vigor, and rooting characteristics) Soil physical condition/compaction Soil and water nitrate levels Amount/toxicity of pesticides used
BETTER USE OF RENEWABLE RESOURCES *through* relying less on fossil fuels and petrochemicals and more on renewable resources & biodiversity (crop rotations, legumes, manures, integrated pest management)	**INPUT/OUTPUT RATIOS OF COSTS AND ENERGY** (renewable/non-renewable ratio) Use soil electrical conductivity for Leaching losses / Soil Acidification Crop characteristics (as listed above) Soil and water nitrate levels

Translating Science into Practice

Soil and land management practices are primary determinants of soil quality and health. Consequently, indicators of soil quality and health must not only identify the condition of the soil resource but also define the economic and environmental sustainability of land management practices to assist governmental agencies in formulating realistic agricultural and land-use policies.

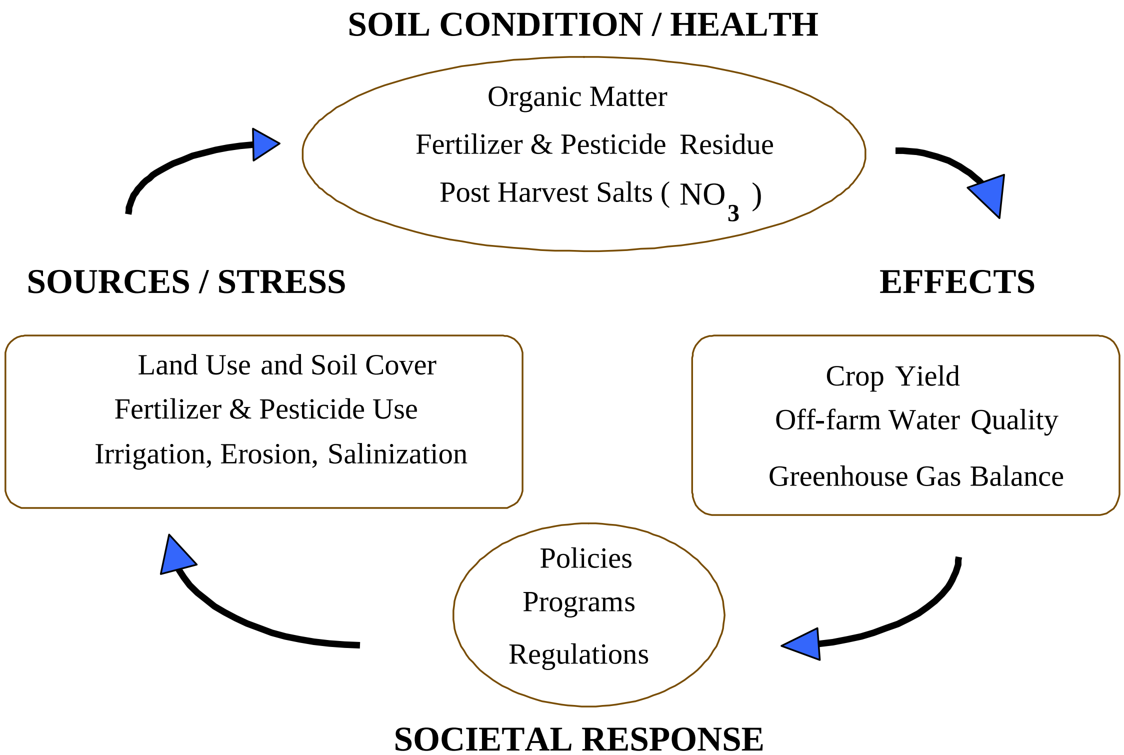

Figure 1. The politics of soil quality and health (After Doran & Gregorich 2002).

The theme of an international conference in Australia, "Soil Quality is in the Hands of the Land Manager," highlights the critical importance of the land manager in determining soil quality (MacEwan and Carter, 1996). A cotton grower at this conference shared his frustration with the direction soil quality indicators were taking - "I need help from scientists more with tools for management than with indicators of soil quality." Economic viability and survival are the primary goals of managers of the land, even though most recognize the need for environmental conservation. Its hard to be green when you're in the red.

Although much remains to be done, useful models exist for translating soil science into practice. Gomez *et al.* (1996) provide a unique framework for determining the sustainability of hill country agriculture in the Philippines. It employs indicators of both the satisfaction of farmer needs (i.e., productivity, profitability, stability, and viability) and those needed for conservation of soil and water resources. On a given farm, indicator values were deemed sustainable if they exceeded a designated threshold level. Sustainability thresholds were set relative to average local conditions for crop yield, profit, risk of crop failure, soil depth, percent soil cover, and soil organic matter content. This framework for assessment of sustainability can be expanded to include other needs of society and environmental conservation as illustrated in Table 2. Adding a category for balancing input and output of energy and monetary costs would better assess short and long-term sustainability and the value of depending more on renewable resources and less on fossil fuels and petrochemicals. This would enhance economic, ecological, and environmental resources. Also, expanding resource conservation variables to include leachable salts (especially NO_3), measured as soil electrical conductivity at time of fertilization and after harvest, would permit land managers to better quantify the impact of agricultural practices on air and water quality. Soil electrical conductivity can also estimate the release of 'small molecules' to the environment and verify if agricultural management systems enhance sustainability by minimizing system entropy (Addiscott, 1995).

Table 2. Simple tool for on-farm assessment of economic and environmental sustainability (After Gomez *et al.*, 1996 and Doran, 2002).

FARMER & SOCIETY NEEDS, *Acceptable*	**RESOURCE & ENVIRONMENTAL CONSERVATION**, *Adequate/Acceptable*
YIELDS relative to locale, climate, and soil type	**SOIL ORGANIC MATTER** change with time, relative to local potential
PROFITS relative to net return and degree of subsidization	**SOIL DEPTH** of topsoil and rooting relative to local potential
RISK / STABILITY economic shortfall in 1 of 5 years	**SOIL PROTECTIVE COVER** (%) effective – continuous or stratified
INPUT / OUTPUT RATIO of energy (amount and type: renewable and non-renewable) and monetary costs	**LEACHABLE SALTS** (NO_3) at planting and post-harvest as indexed by soil electrical conductivity

Conclusion

Soil quality is a major indicator of the success of strategies for conservation management and sustainable agriculture. Confirmation of the effectiveness of integrated systems for residue management, organic matter formation, nitrogen and carbon cycling, soil stability, and biological control of pests and diseases will assist in finding approaches that are both profitable and environmentally sound. Ultimately, the indicators of soil quality and strategies for sustainable management must be linked to development of systems that optimize inputs of nonrenewable fossil fuels and petrochemicals, achieve acceptable levels of productivity, and maintain the quality of our air, water, and soil resources.

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