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原著

# 환경적으로 안전한 농업과 미래용도를 위한 토질 기준 평가 검토

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# Review of Assessing Soil Quality Criteria for Environmentally-Sound Agricultural Practices and Future Use

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## ABSTRACT

Unlike water or air quality standards that have been established by legislation using potential human health impact as the primary criterion, soil quality depends on the soils primary function and its relevant environmental factors, which is much more site- and soil specific. A properly characterized soil quality assessment system should serve as an indicator of the soil capacity to produce safe and nutritious food, to enhance human and animal health, and to overcome degrative processes. For our proposed example, a high quality soil with regard to maintaining an adequate soil productivity as a food production resources must accommodate soil and water properties, food chain, sustainability and utilization, environment, and profitability, that (i) facilitate water transfer and absorption, (ii) sustain plant growth, (iii) resist physical degradation of soil, (iv) produce a safe food resources, (v) cost-effective agricultural management. Possible soil quality indicators are identified at several levels within the framework for each of these functions. Each indicator is assigned a priority or weight that reflects its relative importance using a multi-objective approach based on principles of systems to be considered. To do this, individual scoring system is differentiated by the several levels from low to very high category or point scoring ranging from 0 to 10. And then weights are multiplied and products are summed to provide an overall soil quality rating based on several physical and chemical indicators. The framework and procedure in developing the soil quality assessment are determined by using information collected from an alternative and conventional farm practices in the regions. The use of an expanded framework for assessing effects of other processes, management practices, or policy issues on soil quality is also considered. To develop one possible form for a soil quality index, we should permit coupling the soil characteristics with assessment system based on soil properties and incoming and resident chemicals.. The purpose of this paper is to discuss approaches to defining and assessing soil quality and to suggest the factors to be considered.

**Key words** : Soil quality assessment, soil quality index, soil characteristics, soil properties

## 요 약 문

인간의 건강에 관련된 수질이나 대기의 기준설정과는 달리, 토질은 지협적이고 한정적인 토양의 기능과 이와 관련된 환경요소에 근거한다. 적정한 토질평가제도는 안전한 식품을 생산하거나, 인간과 동물의 건강증진, 그리고 토양의 퇴화 과정을 나타내는 토양 성능 지표의 역할을 하여야 한다. 이에 필요한 요소는 첫째로 수분이동과 흡착의 용이성, 둘째로 식물생장의 유지, 셋째로 토양의 물리적 붕괴에 대한 저항성, 넷째로 안전한 식품생산 기반이다. 그리고 끝으로 비용 절감 농업관리와 식품생산 요소로서 토양은 토양과 수질의 영역, 식품사슬, 지속성과 효용성, 환경과 경제성을 포함하여야 한다. 토질지표는 기본 골격 내에서 각각의 기능에 대하여 여러 단계로 분리되며, 각각의 지표는 체계의 원칙에 근거하여 다목적 접근방법을 사용하여 상대적 중요도를 반영하는 우선 순위와 가중치를 정한다. 각각의 점수 환산체계는 낮은 단계부터 높은 단계로 또는 0부터 10의 범위에서 여러 단계로 등급화되어야 한다. 그리고 각각의 범위 수치에 가중치를 곱하고 그리고 토양의 여러 가지의 물리화학적 특성이 고려된 종합 토질등급으로 결론지어져야 된다. 토질 평가 방법을 개발하는데 필요한 기본 골격과 과정은 해당 지역의 대체 또는 기존의 농업방식으로 얻어진 정보를 사용함으로서 결정된다. 토질에 있어서 부수적인 과정, 관리방법, 그리고 정책의 효과를 검증하기 위한 확장된 기본골격의 용도 또한 고려되어져야 한다. 이외에도 하나의 가능한 토질지수의 형태를 개발하기 위해서는 토양의 특성과 토양 내로 유입되는 또는 기존의 화학물질을 연계시켜야된다. 이 연구는 토질의 평가 시 고려되어야 될 요소를 찾기 위한 접근 방법을 제시하고자 한다.

**주제어** : 토질평가, 토질 지수, 토양특성, 토양영역

## INTRODUCTION

Soil is a dynamic, living, and natural body that plays many key roles in terrestrial ecosystems. The components of soil include inorganic mineral matter, organic matter, water, gases, and living organisms such as earthworms, insects, bacteria, fungi, algae, etc. There is continual interchange of molecules and ions between the solid, liquid, and gaseous phases that are mediated by physical, chemical, and biological processes.

Recent interest in evaluating the quality of our soil resources has been stimulated by increasing awareness that soil is critically important components of the earth's biosphere, functioning not only in the production of food and fiber but also in the maintenance of local, regional, and worldwide environmental quality. The apparent force behind these efforts is public recognition that it is essential to balance the worlds finite soil resources with an ever-increasing population and that soil resource are as vulnerable to degradation as air or water.

Thus, a recent call for development of a soil quality and health index was stimulated by the perception that human health and welfare is associated with the quality and health of soils (Haberern, 1992). The rational is that a quantitative index of soil quality may serve as an indicator of a soil capacity for sustainable production of crops and animals in an economically sound, socially acceptable, and environmentally friendly manner. These activities are increasing public awareness that soil quality is affected by natural and human induced processes (Karlen et al., 1992). However, in many areas, inferior soil management practices continue to decrease soil quality through erosion and to create severe off-site damages through sediment, nutrient, and pesticide transport and deposition.

The quality of a soil is largely defined by soil function and represents a composite of its physical, chemical, and biological properties that (i) provide a medium for plant growth, (ii) regulate and partition water flow in the environment, and (iii) serves as an environmental buffer in the formation, attenuation, and degradation of environmentally hazardous compounds. The ability of a soil to store and transmit water is a major factor regulating water availability and transport of environmental pollutants to plants.

Soil quality assessment and evaluation may also be important for addressing environmental problems. For example, Cooper et al. (1985) evaluated environmental issues associated with the U.S. food industry and recommended the development of methods for converting food processing waste to energy and products to improve soil quality. McBride et al. (1989) reported on soil quality impacts when developing practices for renovation of landfill leachate. Soil quality also influences the consumer, as shown by Salunkhe are Desai(1988), who reported that soil quality affected nutrient composition of vegetables. Hornick(1992) also identified several soil and management factors that affect soil quality and the nutritional quality of crops. However, an assessment of soil quality and health is complicated by the need to consider the multiple functions of soil and to integrate the physical, chemical, and biological soil attributes that define soil function. (Fig 1).

Mechanical cultivation an continuous growing of row crops resulted in excessive loss of topsoil through wind and water erosion. Development of saline and sodic soils after initiation of cultivation resulted from both inefficient irrigation techniques and natural processes. In certain areas, improper disposal of hazardous, recalcitrant

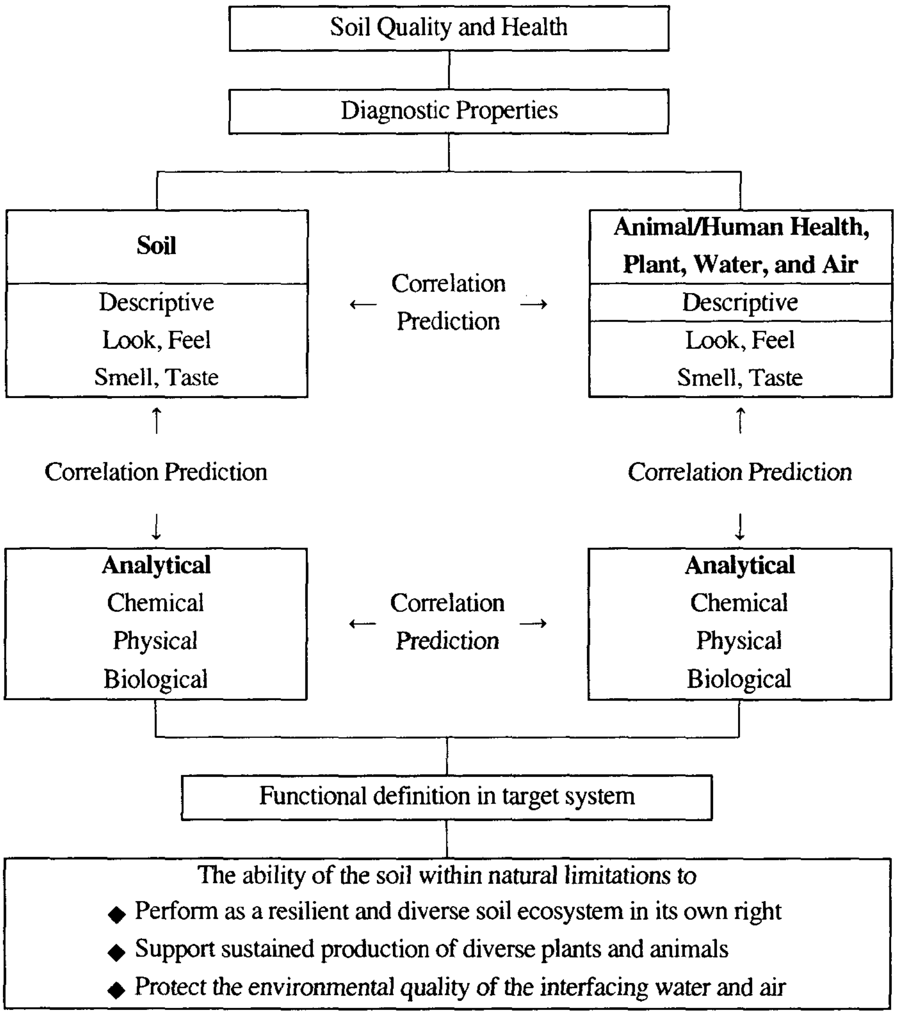


**Figure 1. Soil quality and health interpretative framework**

chemical pollutants contaminated soils, so they are unsuitable for crop production or development and pose a threat to environmental quality and animal health. As a result of the above, we can conclude that the quality of many soil has declined significantly since cultivation was initiated.

Yoder(1937) suggested that soil structure characteristics essential for ideal tilth would (i) offering minimum resistance to root penetration, (ii) permitting free intake and moderate retention of rainfall, (iii) providing an optimum soil-air supply with moderate gaseous exchange between soil and atmosphere, (iv) holding to a minimum the composition between air and water for occupancy of pore space volume, (v) providing maximum resistance to erosion, (vi) facilitating placement of green manure and organic resistance, (vii) promoting microbiological activity, and (viii) providing stable traction for farm implements.

As such the ability to define and assess soil quality is essential to development, performance, and evaluation of sustainable land and soil management system. Two important uses for soil classification system to determine soil quality are (i) as a management tool or aid for farmers, (ii) as a measure of sustainability for its agricultural practices, and (iii) production of a safe products with respect to a human health.

Therefore, we need to understand the precise information of soil physical and chemical properties to define and characterize the soil quality in field soils due to the variability of the inherent soils and the wide range of variation in soil hydraulic properties. The primary objective is to propose a modified soil classification for evaluating soil quality, which reflect environmental and economic consequences of alternate farming practices. This approach is to develop multi-factor combination of other relevant natural resource problems and complex relationships among factors contributing to a site-specific soil quality index. We anticipate that this approach will be more useful when tailored to site-specific situations and used to quantify soil quality changes when factors such as short-term economics vs. long-term sustainability.

## THEORETICAL BACKGROUNDS

A set of basic indicators of soil health or quality have not been clearly defined, largely due to the difficulty in defining and identifying what soil quality represents and how it can be measured. Therefore, the basic indicators of soil quality will need to be compared with standards for a range of soils, climate, and management situation. Available databases will be invaluable to formulation of standards, critical values, and thresholds for soil quality indicators. Defining soil quality and reaching a consensus with regard to the specific criteria required for a modified soil classification system should meet the following suitability criteria : such as (i) encompass ecosystem processes and relate to process oriented modeling, (ii) incorporate soil physical, chemical, and biological properties and processes, (iii) be accessible to many users and applicable to field conditions, (iv) be sensitive to variations in management and climate, finally (v) where possible, be components of existing soil data bases.

Larson and Pierce (1991) suggested that all indicator measurement could be combined to produce an overall measure of soil quality, a change in quality or a change in quality over time in response to alternate management practices. They did not state whether all indicator values should be equally weighted or how they might differ for various soil functions problems. They have also established several goals related to soil quality. They include (i) identifying parameters that are measurable with current technology, (ii) establishing criteria or values for quantifying those parameters, (iii) developing a structure for evaluating soil quality for both short and long term periods, (iv) identifying all management components and their effects of soil quality, and (v) evaluating existing knowledge and research data determine appropriate indicators and procedures for combining them. They also proposed several physical indicators of soil quality including infiltration, soil texture, aggregation, soil structure, bulk density plant root development, drainage, permeability, water retention, aeration available water capacity, capillary water capacity, heat transfer, crusting, tilth, depth to restrictive layers, surface roughness, and soil depth. As chemical indicators, they proposed using cation exchange capacity, fertility and organic matter content.

The critical component that appears absent from many of these investigations is a framework for combining various physical, chemical, and eventually biological properties into either general or specific soil quality indices. Within the framework, it is essential that flexibility be provided to accommodate differences in landscape factors including the drainage or erosion sequence, slope, proximity to an aquifer or other water body, and what the potential land use options may be.

At an international conference on the assessment and monitoring of soil quality (Papendick, 1991), infiltration, available water holding capacity, and soil depth were proposed as first-order soil physical properties affecting soil quality, with water stable aggregates, dispersible clay, and bulk density verified as second-order properties. Chemical indicators included pH, salinity, cation exchange capacity, organic matter, and site-specific toxicities such as heavy metals, toxic organics, nitrate, or radioactivity. Several biological indicators were also discussed and are currently being evaluated, but currently none have been agreed on and recommended for routine measurement.

There is general consensus that soil quality encompasses three broad issues; (i) plant and biological productivity, (ii) environmental quality, and (iii) human and animal health. To effectively do this, two different approaches have been proposed for establishing reference criteria for assessing the quality of soil : (i) conditions of the native soil or (ii) conditions that maximize production and environmental performance. Thus, the following index of soil quality as a function of six specific soil quality elements (Eq. 1) :

$$SQ=(SQ_{E1}, SQ_{E2}, SQ_{E3}, SQ_{E4}, SQ_{E5}, SQ_{E6}) \quad [1]$$

where the specific soil quality elements ($SQ_{Ei}$) are defined as follows :

- $SQ_{E1}$, =food and fiber production
- $SQ_{E2}$, =erosivity
- $SQ_{E3}$, =irrigation water quality (surface and groundwater)
- $SQ_{E4}$, =air quality
- $SQ_{E5}$, =food quality
- $SQ_{E6}$, =characteristics and behavior of hazardous chemicals

At this equation, there is no sufficient information to identify, with certainty, the optimum functional relationship used to combine the different soil quality element shown in Eq. [1]; however, one possibility is a simple multiplicative function (Eq. [2]).

$$SQ=(K_1SQ_{E1})(K2SQ_{E2})(K_3SQ_{E3})(K_4SQ_{E4})(K_5SQ_{E5})(K_6SQ_{E6}) \quad [2]$$

where K=weighting coefficients.

In a manner analogues to the soil quality element, these element may be evaluated with regard to five specific soil functions, which define the capacity of soil to (i) provide a medium for plant growth and biological activity, (ii) regulate and partition water flow through the environment, and (iii) serve as an effective environmental filter. These specific soil function factors (Eq. 3) are :

$$SQ_{Ei}=f(SF_1, SF_2, SF_3, SF_4, SF_5)$$

where SF1=ability to hold, accept, and release water to plants, streams, and subsoil

- $SF_2$=ability to hold, accept, and release nutrients and other chemicals
- $SF_3$=promote and sustain root growth
- $SF_4$=maintain suitable soil biotic habitat
- $SF_5$=respond to management and resist degradation

The evaluation of each soil quality element will take the form of a functional relationship that describes how the five soil functions listed above impact each of the different soil quality elements. The rationale for this approach is necessitated by the fact that soil function in a duplication manner. The next step in the process is to develop mathematical expressions relating the five soil functions. An example of this approach is represented as a function of infiltration rate and water retention. such as;

$SF_1$=f(Infiltration rate, Water retention)

To be practical use, this approach requires separate evaluation for some soil functions.

## CONCEPTUAL SOIL CLASSIFICATION OF QUALITY MODEL

We classify soil by common properties for the purposes of systematizing knowledge about soils and determining the processes that control similarity within a group and dissimilarities among groups. The numbers of individual soils in a group are a function of the limits one allows in the defining properties. Thus, there are many soil series and types at the lowest category of classification because many restrictions are imposed by the diagnostic properties.. Different series can be grouped together at higher levels of classification, and these, in turn, can be regrouped until one ends up at the highest category with a few orders, each with wide limits on allowable variations in differentiating properties. In spite of the large number of members, soils in each order should share many properties in common because they have been formed under a somewhat similar set of pedogenic processes (Table 1).

To be really useful, however, classification has to be based on soil properties and not geological, climatic, or vegetational properties.. Quisenberry et al., (1994) proposed a soil classification system based on selected soil properties which can be used to described water and chemical distribution patterns through soils, depending on surface texture, clay mineralogy and nature of soil structure (Table 2). The methodology of this soil classification system are characterized as follows : (i)Determination of horizon (Surface and subsurface horizon), (ii) Analysis of soil texture and structure, (iii) Analysis of soil chemical properties (pH, CEC, Base saturation, anions, cations, etc), (iv) Soil hydrologic system, (v) Topography, and (vi) Soil mineralogy (characteristics of clay minerals).

A classification system shown above may show variations within each units.

**Table 1.** Categories of the basic soil classification system

| Category | Distinction |
|---|---|
| Order | Diagnostic horizons (Surface and subsurface horizons) |
| Suborder | Genetic homogeneity : Moisture, Temperature, Vegetation |
| Great group | Soil color, Ionic characteristics and contents, Soil moisture and temperature |
| Subgroup | Whether or not the soil is typical for the great group |
| Family | Texture, Mineralogy, Temperature and thickness |
| Series | Soils delineation on soil maps to the interpretation |

**Table 2.** Summary of characteristics of the eight classes for soil classification system.

| Class | Characteristics |
|---|---|
| 1 | Spodosols : Flow patterns dependent on properties of spodic horizon |
| 2 | Layered sand : Unstable flow(Figuring) developing at boundaries between different sand fractions |
| 3 | Uniform sands or arigillic horizons of non-expandable clays with weak blocky structure and no tertiary peds : Uniform or Darcian type flow, piston type displacement |
| 4 | Sand surfaces and arigillic horizons of non-expandable clays with moderate blocky structure and primary and tertiary peds : preferential or macroflow. |
| 5 | Clay arigillic horizons of expandable clays : strong preferential flow primarily along shrink-swell surfaces. Influenced markedly by water content. |
| 6 | Loamy surfaces and arigillic horizons of non-expandable clays with strong blocky structure and primary peds : Strong preferential or macroflow, mostly along tertiary ped faces |
| 7 | Loamy surface and arigillic horizons of non-expandable clays with strong fine blocky structure and no tertiary peds : Preferential flow on small scale, along primary ped faces |
| 8 | Loamy surfaces with arigillic horizons of non-expandable clays with moderately blocky structure and primary and tertiary peds : Preferential flow along tertiary ped faces |

Therefore, it requires to define a criteria to evaluate this classification scheme using field studies which quantify the influence of structure and texture on mobility's and water and reactive solutes throughout soil profiles.

To encourage soil quality evaluations, Larson and Pierce(1991) proposed developing a minimum data set (MDS) and suggested using pedotransfer functions (Bouma, 1989) to estimate those parameters if actual measurements were not available. These site-specific, soil quality evaluations could be used to measure changes caused by soil and crop management practices used to control soil management system. Therefore, we can assume that ion exchange capacity, nutrient availability, total organic carbon, labile organic C, pH, and electrolytic conductivity as chemical indicators.

A set of basic soil quality indicators and soil attributes and methodologies that meet suitability criteria are given in Table 3 and 4. Presumably this reflect the diversity in properties and characteristics that must be considered because of the numerous alternative uses for the soil resource, including production of agronomic, vegetable, and forestry corps; disposal of agricultural municipal, and food-processing wastes; or as a filter to protect groundwater resources.

The major rationale for descriptive information is to provide insight into a definition of soil quality and health that could be used as a basis for the identification of a meaningful set of analytical properties. The approach may be summarized in the form of a first approximation interpretative framework that recognizes (i) the presumed need for a

**Table 3. Proposed soil physical, chemical, and biological characteristics to be induced as basic indicators of soil quality.**

| Item | Soil characteristics | Remark |
|---|---|---|
| Physical | Soil texture, Water content<br>Depth of soil and rooting, Soil temperature<br>Soil bulk density and infiltration, Water holding capacity | Methodology<br>Interpretation[1] |
| Chemical | Total Organic C and N, pH<br>Electrical conductivity, Mineral N, P, and K | Methodology<br>Interpretation[1] |
| Biological | Microbial biomass C and N, Respiration/biomass ratio<br>Potentially mineralizable N<br>Soil respiration, Biomass C/Total organic C ratio | Methodology<br>Interpretation[1] |

[1] The importance of standardized sampling methodologies and threshold values for interpretation of soil quality indicators can not be over emphasized.

**Table 4. Soil attributes and methodologies for measurement to be included in a minimum data set for monitoring soil quality.**

| Soil Attributes | Methodologies |
|---|---|
| Nutrient availability | Analytical soil test |
| Total organic C | Dry or wet combustion |
| Labile organic C | NH4-N release from hot KCl digest |
| Particle size | Pipette or hydrometer methods |
| Plant-available water capacity | Determined in the field or from water desorption curve |
| Soil structure and types | Intact soil cores and field measured permeability or Ksat |
| Soil strength | Bulk density or penetration resistance |
| Maximum rooting depth | Crop specific, depth of roots or standard |
| PH | Glass/calomel electrode, pH meter |
| Electrical conductivity | Soil Extract or soil solution itself, Conductivity meter |

reference definition of soil quality and health, and (ii) diagnostic soil quality and health properties based on look, smell, and feel descriptive properties of soil and chemical, physical, and biological analytical properties of soil.

Soil Conservation Service (1983) developed the National Agricultural Land Evaluation and Site Assessment Handbook to determine the quality of land for agricultural uses under what conditions agricultural land should or should not be converted to nonagricultural uses for their agricultural variability and alternative. It recognizes the merits of the following individual methods as it integrate them : (i) land capability classification that is inherent in the soils of a given area, (ii) soil productivity from the standpoint of soil productivity for a specified indicator crop, (iii) soil potentials according to a standard of performance and taking into accounts the costs of overcoming soil limitations plus the cost of continuing limitations, if any exist. This methodology is enable us to identify prime and other important farmlands at the local level. Use of the national criteria for definition of prime land provides a consistent basis for comparing local farmland with farmland in other areas.

Any protocol designed to determine soil quality must provide essential guidelines for economically and environmentally sustainable use of soil resources. For practical soil classification of most agricultural areas, it will be logically impossible to establish a protocol to classify all the descriptive and particularly analytical diagnostic properties of the soil quality and health of the soil and crop. However, knowledge of the ideal protocol may allow for more informed decisions to be made and defined as to which properties are to be included and which are to be ignored while still achieving a viable experimental program.

If a systematic protocol for the descriptive components of the quality and health of these systems were available, a farmer-scientist partnership analogous to a patient doctor collaboration on descriptive classification would appear to be a feasible goal. To do this we propose one approach to facilitate identification of the critical issues and major categories of information that need to be gathered for development of correlation to establish soil quality and health as the target systems including the plant, animal-human, water, and air interfacing with soil. The descriptive components are grouped into the major sensory categories of look, feel, smell, and tastes, and analytical components into classical chemical, physical, biological, and toxicological properties as shown in Fig. 1. The most important implication of the descriptive framework is that all experimental designs of soil quality and health work should take into account all target systems recognized as being an integral part of soil quality and health.

Having identified critical soil functions and potential physical and chemical indicators that could be used to assess soil quality relative to its ability to resist erosion by water, it is essential to develop a mechanism to combine the distinctly different functions and indicators. This can be done by using standard scoring functions (Fig. 2) that were developed for systems engineering problems (Wymore, 1993). A similar approach has been used for multi-objective problem solving by Yakowitz et al. (1992).

Use of standard scoring functions enables the user to convert numerical or subjective ratings to unitless values on a 0 to 1 scale. The procedure begins by selecting the

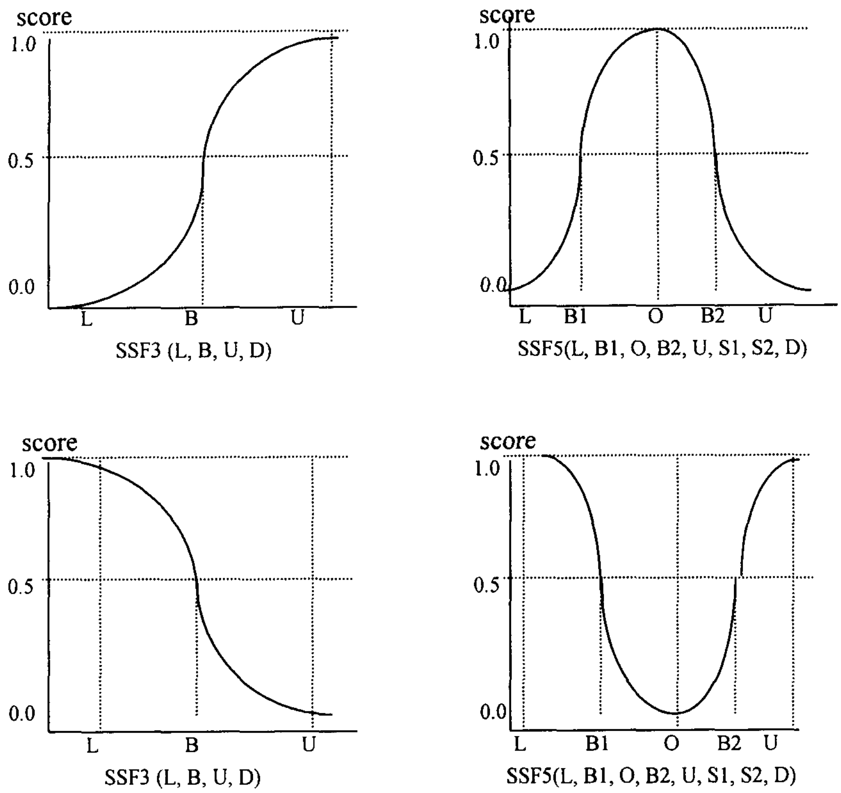


**Fig 2. General shapes for standard scoring functions. The upper left indicates "more is better." the upper right "an optimum range," the lower left "less is better," and the lower right "an undesirable range."**

appropriate physical and chemical indicators of soil quality that effect a particular function related to soil erosion. An appropriate scoring function (Fig.2) and realistic baseline and threshold values for each indicator must be established. Information from experts, specific data bases, or general knowledge can be used for these processes, but for future reference or modification, the source and reason for selection must be documented. For example, Lane et al. (1991) and Yakowitz et al. (1992) used computer simulation models to obtain values of criteria that were important to their problems.

All indicators affecting a particular function are grouped together as shown in Table 6 and assigned a relative weight based on importance. All weights within each level must sum to 1.0 or the decimal equivalent of 100%. Four of the most common shapes for scoring functions are presented in Fig 2 and are often referred to as more is better, less is better, an optimum range, and an undesirable range (Wymore, 1993). After scoring each factor, the value is multiplied by the appropriate weight. When all indicators for a particular function have been scored, the user has a matrix that can be summed to provide a soil quality rating as related to erosion by water.

As discussed, soil quality evaluations will most likely have to be made with regard to specific problems. Our assessment in this report is focused on the problem of soil hazardous compounds. We suggest that a similar framework could be used to develop a soil quality index relative to other problems, such as crop production, wind erosion, groundwater quality, surface water quality air quality, or food safety. After evaluating soil quality for several problems, a similar framework could be developed to compute soil quality indices for numerous problems at lower and higher scales of evaluation.

Table 5 shows how soil quality assessments might be developed to evaluate soil quality impacts at scales. At the process level, soil quality evaluations might focus on specific questions with regard to aggregate formation and stability; impacts of crop rotation and vertical integration on soil quality might be evaluated at the farm management level; national policy implications on soil quality might affect decisions such as how to structure the long-term management of lands; or at an international scale, relationships could be developed to relate soil quality to socio-economic problems such as expansion of agriculture onto fragile lands in response to increasing population. We propose that it is possible to assess soil quality at the multiple scales shown in Table 5, provided a consistent framework and approach are used. Our rationale is that evaluation of soil quality criteria at each level can be viewed

**Table 5. Soil quality criteria at various scales of evaluation**

| Scales of evaluation | Causes | |
|---|---|---|
| | Socio-economic | Biophysical |
| Process | Lack of knowledge | Understanding of components |
| Problem | Erosion by water | Water entry, transmission, soil properties, Crop growth and Cropping system |
| Management | Farm economics | Tillage, shapes of crop Rooting system |
| Health Hazard | Diversity of toxic compounds | Types of contaminants, Plant root uptake, and Degradation rate |
| National Policy | Urban demand for decreased soil erosion | Soil erosion, sediment control |
| International Policy | Increasing human population | Expansion of agricultural onto fragile lands |

as an expansion or combination of factors influencing the soil suitability for habitat of crop growth environment. The critical requirement for this approach is to reach consensus on what actual measurements will be valid, reliable, sensitive to change, replicable at the various levels of land. Thus, appropriate weights and priorities can be established.

The natural system digests the animal and plant wastes to become part of the soil. The soil is traditionally the site for disposal of all wastes produced from agricultural, industrial, and other operations, because the soil matrix is a huge biodigestion system over millions of years. As a consequence of the accelerating threat of pollution to the soil environment, the role of soil receives increasing attention due to the quantity and variety of wastes that present a serious potential threat to the quality of surface and groundwater and plants as well as to the soil itself.

Land treatment as used involves application of hazardous industrial wastes to the land when no crop is being grown because of an incompatibility with successful plant establishment and/or economic crop production. This does not preclude the use of the land or soil after a period of biodegradation that would render the remnants of the waste compatible for plant establishment and economic production. Therefore, the complexities of waste-soil and natural process interactions must be understood if land treatment is to be an acceptable practice and develop on a sound technical basis. However, certain constraints are required for waste materials and waste water to be used on land where food and fiber plants are established and grow productively. Some of the essential

**Table 6. The essential constraint required for waste materials and wastewater to be used on land**

| Constraints | Contents |
|---|---|
| Plant or crop growth quality | Free of toxic properties<br>Free of excessive concentrations of heavy metals<br>Free of excessive concentrations of common salts |
| Loading rates | Optimum loading rates to insure maximum crop yields |
| Land application | Energy need and additional farm practice |
| Amenability for biodegradation | Biodegradation rate within a reasonable period of time |
| C/N ratio | C/N ratio of 30 or less |
| Benefits to crop | Soil conditioning, utilization and behavior |
| Costs | The economy of return |
| Health factors | No health hazard to the food chain, human, or animals |
| Off-site pollution | Susceptibility to natural condition Minimal order problem |
| Soil properties | Soil physical, chemical, and biological properties |

constraints are as listed in Table 6. Wastes adapted for use on cultivated land, therefore, must classify as resources (not waste) and fit into the ongoing agricultural practices as well as be sufficiently beneficial to crop production that their use will prove economically feasible and environmentally safe.

Although the information about soil quality addressed the levels of our concern associated with the spectrum of soil environment, there are no consensus to define and classify soils which encompasses soil physical, chemical, biological, and environmental aspects. Therefore, we desperately need to develop the soil classification system to characterize the soil quality that can be used to standardize evaluation guidelines at a particular sites. This guideline may necessarily provide production, risk-based environmental management. It should include a detailed database approaches for developing soil classification system that can take into account more complex soil conditions than the simple soil classification both simple and more detailed approaches which focuses on the application of a step-by-step methodology emphasized in the above soil classification systems.

One of the specific proposals of this study is to develop the flexible tool that uses the agricultural land-specific data in a methodology that can be applied across the world. In Table 7, we propose a soil evaluation system to describe the agricultural land quality with regard to soil properties, crop yields and quality, soil conservation and management, socio-economic, and safe soil environment for agricultural practices and future uses.

Using these components to decide the soil class level, we need to stratify each factor and assign values and limits to each possible condition. In most factors, maximum points are assigned when onsite condition supports continuation of agricultural use for a given crop. Thus, we recommend that each factor be stratified into conditions rated from 0 to 10, such that zero would represent the lowest value of the particular factor and 10 would represent its best or highest value. This factor increases in value as the amount of land in agricultural uses increases, and optimum size level should assigned a value 10, and the value should decreases as the size of the land decreased. Weights ranging from 1 to 10 should be considered for each factor selected.

The most important factor, from a local standpoint, should be assigned the highest weight, not to exceed 10. The weight of each factor is multiplied by the maximum points for the factor. The weights must then be adjusted so that the total maximum number of points for all factors equals no more than sum of total points. However, there may be situation where determination of each component is not possible, or where it is desirable to make a final consideration of the soil before the value acquisition. In these cases certain visual indicators may be

Table 7. A proposed soil assessment system to determine the agricultural uses of soils

| Groups | | Factors |
|---|---|---|
| Soil Properties | Physical | Soil texture, soil structure, Soil consistence, Soil color, Soil pore<br>Soil structure and mechanical properties, Bulk density<br>Soil temperature and heat transfer, Plant-available water capacity |
| | Chemical | Soil pH and lime requirement, Electrical conductivity<br>Soil buffer capacity and organic matter content<br>Ion exchange capacity and chemical reactions |
| | Biological | Soil microbes and its interaction, Total and labile organic C,<br>Rooting depth and Biodegradation rate |
| Food Chain | Yield | Yield potential, Cropping system |
| | Quality | Nutritional sources, Toxicity |
| | Cultivars | Susceptibility to natural condition, Variety of crop species<br>Adaptation within a reasonable period of time |
| Sustainability & Utilization | Conservation | Slope gradient and its length, Complexity, Vegetation cover<br>Soil erosion and control, Depth to water restricting layer |
| | Management | Soil conditioning, Tillage, Water resources and efficiency |
| | Fertility | Macro-and micronutrient sources, Salinity and sodicity<br>Soil acidity and lime requirement |
| Environment | Climate | Precipitation(Intensity and duration)<br>Soil moisture and temperature regimes |
| | Toxicity | Variety of pesticides and heavy metals<br>Environmental impact, Liability of food transition |
| Economic | Profitability | Economic analysis of nutrients management<br>Land targeting and policy, Alternatives of land conversion |

used to assign the soil quality value. These visual and quantitative values can be assigned as significance or degree such as low, moderate, high, and very high for some interval bases. And then these significance can be calculated as point system, which is used in scoring system.

Such these way of soil classification method, we can identify groups of soils for agricultural value relative to the value of the best soils indicating that rating of soil classification depending on the point calculated is the capacity of soils within landscapes to sustain biological productivity, maintain environmental quality, and promote plant and animal health.

## DISCUSSION

Our knowledge of soil quality is confused by lack of an acceptable definition and concept of what soil quality represents. Soil quality is (i) as vital to natural resource management, agricultural sustainability, and human well being as are air and water quality, and (ii) relates to the ability of soil to perform three functions : a medium for plant growth, regulator of water and energy flux in the landscape, and filter for pollutants.

Soil quality is largely determined by the physical, chemical, and biological characteristics of soil as influenced by soil tillage and cropping management systems as modified by soil type and climate. Relative importance of specific soil quality indicators also depends on cropping such as crop rotations and tillage management systems.

Both of qualitative and quantitative determination of soil quality may be useful for optimizing agricultural land uses and its future plans. However, before this type of soil assessment system can be applied to identify the soil quality, valid, reliable, sensitive, repeatable and accessible indicators must be identified and a framework for overall evaluation of soil properties related to soil quality must be defined and developed.

Multivariate methodology will allow us to extract and summarize information from different variables using many observations. This methodology should reasonable suits the need of this project to assess real-life management practices on numerous soil variables from fields across the nation. To achieve this, this first phase of the study is to gather enough data about soil properties in typical systems to refine our methodology and to sort out the effect of management from inherent soil properties and transient weather and environmental patterns. And then, this methodology should be expanded to include more farms and more farming practices in a given area.

However, soils are also different from region to region across the nation. It is essential to develop and determine reliable methods of defining and classifying the interactive effects of cropping sequence and tillage system on soil quality and crop productivity; to minimize environmental contamination and sustain groundwater quality by developing soil management practices that will reduce the risk of contaminant movement to plants and groundwater; and to reduce the risk of environmental contamination by developing farming systems that reduce pesticide use and, where necessary, increase the efficiency of soil classification system in our agricultural practices and land remediation purposes.

For this, we need to examine soil quality as the capacity of a soil to function, within ecosystem and land-use boundaries, to sustain biological productivity, maintain or enhance environmental quality, and promote plant, animal, and human health.

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