Soil Physical and Chemical Properties in Relation to Conservation of Natural Resources

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The natural resources of any country are the national treasure and there is need for proper planning to make best use of them. The most important and basic natural resource is soil. It is evident that the production of food, fodder, fuel and feed to meet the requirement of human beings and animals is primarily dependent upon agriculture and allied areas which are dependent on soil resources. Soil resources of the world are finite, easily degraded by misuse and mismanagement, nonrenewable over the human time frame, and shrinking because of degradation and conversion to nonagricultural uses (Lal, 1998). Soil degradation is a severe global issue, and predominant degradative processes are accelerated soil erosion, depletion of soil organic matter and plant nutrients, decline of soil structure, and salinization. Most of these degradative processes are more severe in the tropics than in the temperate climate, in marginal rather than prime agricultural lands, and in resource-based and subsistence agriculture rather than science-based or commercial farming. There is need of judicious and scientific management of soil resources. Degraded soils and ecosystems must be ameliorated, and the depleted organic carbon pool restored so that soil can respond to the use of yield –enhancing input (e.g., fertilizers, improved varieties) and can meet the current and future food demand.

Definition:
Soil is a dynamic natural body developed as a result of pedogenic processes through weathering of rocks, consisting of mineral and organic constituents, possessing definite chemical, physical, mineralogical and biological properties, having a variable depth over the surface of the earth, and providing a medium for plant growth (Velayutham and Bhattacharyya, 2000). Soil supports terrestrial life through five processes: (1) biomass productivity, (2) restoration and resilience of ecosystems, (3) purification of water, (4) detoxification of pollutants, and (5) cycling of C, N, P, S, and H_2O.

Four major components of the soils:
Mineral soils consist of four major components: mineral materials, organic matter, water, and air (Brady, 1988). Figure 1 shows the approximate proportions of these components of these components in a representative silt loam surface soil in optimum condition for plant growth. Note that this soil contains about half soils and half pore space (water and air). Of the total soil volume, about half is solid space, 45% mineral matter and 5% organic matter. At optimum moisture for plant growth, the pore space is divided roughly in half; 25% of the volume is water space and 25% is air. The proportions of air and water are subject to rapid and great fluctuations under natural conditions, depending on the weather and other factors.

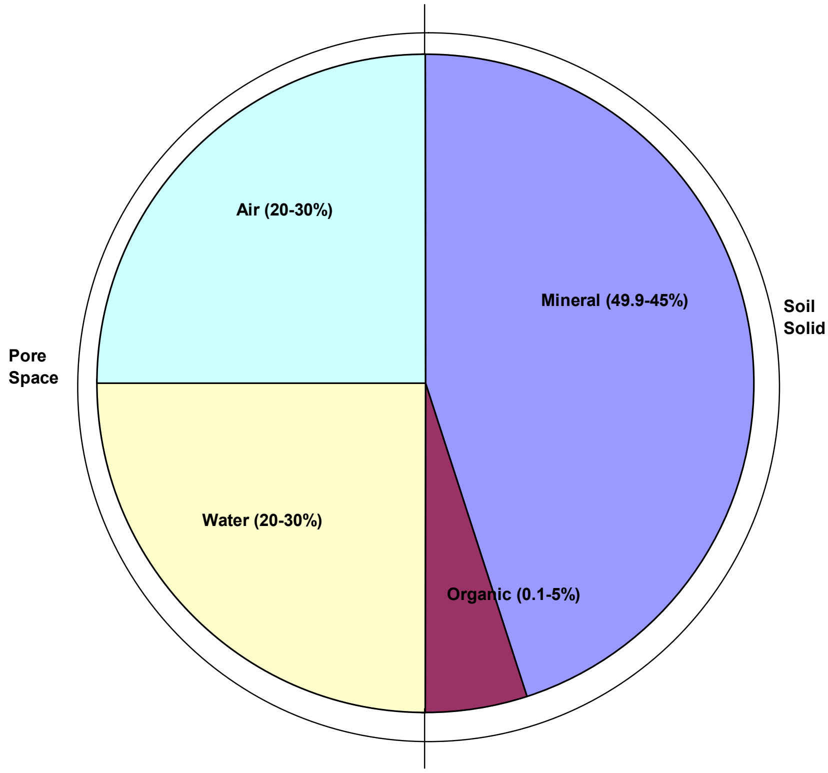


Figure1: Volume composition of a silt loam surface soil when in good condition for plant growth. The air and water in a soil are extremely variable, and their proportions determine in large degree the soil's suitability for plant growth.

It should be emphasized that the four major components of a typical soil exist mainly in an intimately mixed condition. This encourages interactions within and between the groups and permits marked variation in the environment for the growth of plants. The volume composition of subsoils is somewhat different from that just described. Compared to topsoils they are lower in organic matter content, are somewhat lower in total pore space. This means they have a higher percentage pf minerals and water and a considerably lower content of organic matter and air.

Soil Properties

Physical properties

The physical properties of a soil are important since they determine the manner in which it can be used either for agricultural and non-agricultural purposes. Properties *viz.* infiltration rate, water-holding capacity, permeability, aeration, plasticity and nutrient-supplying ability, are influenced by the size, proportion, arrangement and mineral composition of the soil particles.

Particle shape and size: The soil particles differ in shape like spherical to angular. They differ in size also from gravel (>2mm) and sand (2-0.02mm) to fine clay (<0.002mm). The International System is commonly used to designate textures while the USDA system in used for classifying soils according to Soil Taxonomy which is officially used for grouping soils in the soil-survey organizations all over India.

Textural classes: The relative proportion of the particles of different size groups in a soil is known as texture. The commonly reported soil textural classes are: *clay, sandy clay, silty clay,*

clay loam, sandy clay loam, silty clay loam, loam, sandy loam, silt loam, silt, loamy sand and sand.

The small and large particles differ greatly with respect to physical properties and chemical composition. Coarse fraction, gravel and sand composed mainly of rock fragments or primary minerals, act as individual particle, these particles have low specific surface area and are relatively non-reactive. Since these particles have larger voids they cannot hold water. The silt particles are intermediate between sands and clays. They are more reactive than sands due to higher specific surface. So far as major soil properties are concerned, it is the clay fraction which controls most of the soil properties. They are made-up of secondary minerals called (crystalline) alumino silicates with highly reactive surface area. Retention of water and nutrients are also very high for the clay particles. Besides, the textural classes govern some of the important factors affecting plant growth. They are (a) the movement and availability of water, (b) aeration, (c) workability (tillage operation etc) and (d) the content of plant nutrients.

Sandy soils are highly permeable and excessively well-drained with low water-retentive capacity and thus need more frequent irrigation for successful crop growth than fine textured soils. The clayey soils can hold more moisture, but they have high wilting point. Due to poor infiltration rate these soils are subject to water-logging, resulting in poor aeration and workability. The moderately fine-textured soils e.g. loams, clay loams or silt loams are by far the best group of soils for crop growth, since they have the advantages of balanced proportion of both sands and clays.

Colours: Colour of soil is probably the first soil property for the human perception. Even today soil is described by its colour, such as black, red and yellow soil. A soil attains certain colour depending on pedo-chemical reactions. For example, different degrees of oxidation, hydration and diffusion of iron oxides in the soils may bring either red, yellow or brown colour. Dark colours of soils (e.g. dark brown, etc,) may be associated with impeded drainage conditions, content and state of decomposition of organic matter, and the presence of specific mineral like titanium and/or manganese. Such dark colours are common in black soils. The Munsell Colour Chart is routinely used for reading soil colour in the fields. It consists of coloured chips showing *hue, value* and *chroma,* the three simple variables that form a colour. The hue refers to the dominant spectral colour, the value to relative lightness of colour and chroma to relative purity.

Density: Larger particles in soils are heavier in weight per unit volume than the smaller particles. Particle density of a soil is based on the individual densities of soil constituents and according to their proportionate contribution. The bulk density on the other hand, is the weight per unit volume of dry soil including the particles and pore space and hence it is lower than the particle density. The relationship between the Particle density (PD) and Bulk density (BD) and the pore space (P) of soils is as follows:

$$P\% = \frac{PD-BD}{PD} \times 100$$

In most mineral soils the particle density varies within 2.5 to 2.7 and the bulk density between 1.2 and 1.8 depending on the method of determination.

Pore space: The portion of soil occupied by air and water is pore space which is largely governed by structural conditions. Low pore space of about 30 per cent is common for sands, whereas clays may have a pore space of as much as 50-60 per cent. Although clays possess greater total porosity than the sands, the pore spaces in the latter, being individually larger, are more conductive to good drainage and aeration. Pore spaces are of two kinds *macro* and *micro*. Sands have more macro pore space whereas clays contain more micro space. Therefore, sands are more porous and do not pose any drainage problem in spite of having less total pore space.

Plasticity and cohesion: Plasticity is a soil property which enables a moist soil to change shape on an applied force and retain this shape even when the force is withdrawn. Thus sandy soils are considered as non-plastic and clayey soils as plastic. Cohesion, on the other hand, is a property of the particles to stick to one another by cohesive force. Plastic soils are cohesive. Plasticity and cohesion reflect the soil consistency and workability of the soils. Black soils are highly plastic and highly cohesive making tillage operation difficult.

Soil temperature: The main source of heat energy for soil is solar radiation, which determines the thermal regime of soil and growth of plants. It has been found that the role of organic-matter decomposition and the mineralization of organic form of nitrogen increase with temperature. The amount of organic matter is thus expected to be more in soils with low temperature. Soil temperature is an important factor affecting seed germination, plant growth and micro-biological activity. Germination has been found to be a slow process in a cold soil. For germination and root growth the required temperature varies with crops and varieties. The winter crops viz. wheat, barley and oat require low temperature for germination as compared to the summer crops like cotton and sorghum. The soil colour, composition, and the water content in soils influence soil temperature.

Soil air: It is an established fact that restricted soil aeration affects root development, respiration and other biological processes and can thus change the soil environment. The knowledge of soil air and its composition assumes a greater importance in view of this fact. The pore space, not filled by water, is occupied by space (macropores) that generally constitutes the air space, the capillary pore space (micropores) being occupies by water. Normally if one-third of the pore space in the soil is filled by air and two-third of by water, the plant growth is assumed to be optimum.

The soil air composition is controlled by a balance between two competing processes. The consumption of oxygen and a concomitant release of CO_2 by plant roots and the soil organisms, tend to increase the differences in the composition of the soil air and the atmosphere above the soil surface. Gaseous diffusion tends to reduce the difference in composition. The measurement of the aeration status in soil has been reported as *oxygen diffusion rate* (ODR) which determines the rate of oxygen replenishment due to its continuous consumption by plant roots and micro-organism. It has been found that the growth of most of the plants is affected when ODR is less then 20×10^{-8}g/cm^2 per minute.

As observed in the atmospheric air (with an average composition of nearly 21% O_2, 0.035% CO_2 and more then 78% N_2), the soil is also composed largely of nitrogen and oxygen, but differs from the former in containing more moisture, more carbon-di-oxide and a little less oxygen. The content of carbon-di-oxide varies during the crop season due to higher rates of crop growth and microbiological activities in the soil.

Soil water: The maximum influence on the growth and yield of a crop depends on the availability of soil water since it is required in larger quantity than any other substance contributing to the growth and yield. Water serves the following functions in relation to plant life:

a) Essential part of plant food constituting more than 90 per cent of plant tissues.
b) Solvent and carrier of plant nutrients.
c) Maintains cell turgidity and regulates soil temperature.

Soil-water retention: The retention and movement of water in soils and plants with its subsequent loss in the atmosphere are related to the energy with which the water is held. Different kinds of energy are involved in this process *viz*. potential, kinetic and electrical. The energy status of water is termed as free energy which is a sort of summation of all other forms of energy to do work. Three important factors which control the free energy of soil water are *matric, osmotic* and *gravity*. So far as retention of water in soil is concerned, there can be four different forms of water as follows:

Maximum water holding capacity: This is the saturated state of soil just during heavy rain or while being irrigated when both macro and micro pores are completely filled with water.

Field capacity: After the soil reaches maximum retentive capacity, water moves downward in response to the hydraulic gradient, mostly gravity. After 1-3 days when the water in the macropores will be drained out the soil is said to be at the field capacity.

Permanent wilting percentage or wilting coefficient: With time the water in the soil will be utilized by plant, some may be lost by evapo-transpiration. The soil will gradually become dry and plants begin to wilt first during the daytime and then they will remain wilted night and day. The soil moisture content of the soil at this stage is called the wilting coefficient or permanent wilting percentage.

Hygroscopic coefficient: When the content of soil moisture is still decreased below wilting point in a way that water is held very tightly and may be at a state of vapour around the soil colloids, the stage is called hygroscopic coefficient.

Soil-water classification: Based in soil-water-plant relations the soil water may be classified into the following based on its availability to plants

a) Gravitational water

Water above field capacity (0.1 to -0.3 bar and upward (1 bar: a unit of pressure with which water is held in the soil particle equal to 1 million dynes per square centimeter (10^6 dynes/ cm^2).) is termed gravitational. Since it remains in soils for a short time, gravitational water is of limited use for plants.

b) Capillary water

Since the water held between 0.1 to 31 bar tension is present in the capillary of soils, this water is mostly available for the growth of plants. However, the capillary water held within 15 bar in relatively more easily available to the plants.

c) Hygroscopic water

This water is held tightly (greater than 31 bar tension) below the permanent wilting coefficient and is termed as hygroscopic water. Except few microbial activities almost all the plants fail to absorb hygroscopic water.

Crops differ greatly in their water requirement according to growth characteristics, climate and water-supply. Water requirement of a crop includes the evapo-transpiration needs, the water needed for metabolic activities, for leaching and other unavoidable losses. It is the water needed for raising a crop in a given period and is expressed as depth of water in millimetres. Generally, the water requirement of a crop is related to the potential evaporation during the growth of the crop.

Soil structure: Soil structure is defined as the arrangement of primary and secondary soil particles. Soil structure is recognised as one of the most important properties since it influences aeration, permeability and water capacity. In the field, the structure is described in terms of (i) *type* (shape and arrangement), (ii) *class* (size), and (iii) *grade* (degree of aggregation).Structure is primarily influenced by texture. However, there are other factors also as mentioned under:

1. ***Soil management***
   Ploughing and other operation may break the soil mass and can thus adversely change the soil structure. A good soil management with a proper system of crop rotation has the effect of maintaining the soil in a good state of aggregation.
2. ***Adsorbed cations***
   The general trend of sodium and magnesium ions on the clay complex is to disperse the soils, thereby forming an undesirable soil structure. By contrast, Ca^{2+} ions on the other hand, have favourable effects on the aggregation. Similarly, the presence of soluble salts also favours flocculation.
3. ***Organic matter***
   Organic matter not only stimulates the formation of soil structures but also stabilizes them by forming bridges between individual soil particles and thereby forming water stable aggregates.

Since soil structure influenced ease of tillage and root penetration, it has been found that the crumb and granular structures (spheroidal) are favourable for plant growth. It has also been found that soil management in terms of using legumes in the rotation system and green manuring can improve the structure and physical qualities of soils.

Chemical properties

The chemical properties of soils largely depend on the soil collides. It is, therefore, important to know about the soil colloids and their nature to have an insight into their influence on various chemical properties of soils.

Soil colloids and their nature: Soil colloids refer to the most reactive part of the soil solids. Soil colloids can roughly be grouped into two phases namely organic and inorganic phase. The organic phase consists of either fresh of decomposed residues of plant, animal, and microbial residues which may remain associated with inorganic phase or may be present in free form. The inorganic phase of soil colloids is dominated by the clay which governs almost all the soil properties.

Nutrient elements in soils: The soil supplies all the essentials minerals elements required by the plants. Depending on their requirements by plants these elements are grouped into two types viz.

1. Macro elements: These are nitrogen, phosphorus, potassium, calcium, magnesium and sulphur.
2. Micro elements: these include iron, manganese, zinc, copper, molybdenum, boron, cobalt and chlorine.

The plants get nitrogen mostly through soil organic matter. The availability of plant elements depend on the type of soil. The total amount of elements contained in the soils depends on the nature of the parent material. The chemical composition of different horizons of a soil also shows a good deal of variation. Usually, some of the elements that are commonly leached out are the ones that are also required by plants.

Cation and anion exchange properties of soils: Ion exchange is a reversible process which involves both cations and anions. The exchange takes place between solid and liquid phases and between solid phases which are in close contact with other. The exchange of cations and anions is termed cation exchange and anion exchange, respectively. Ion exchange is the most important of all the processes occurring in a soil. Soil colloids, are the seat of ion exchange processes.
Adsorption and exchange of cations and anions varies greatly with the nature and amount of clay and the organic matter present in soils. A soil, with calcium and magnesium is considered normal and fertile. If a soil has more than 15% exchangeable sodium, it is considered to be sodic soil. On the other hand, if the soil are base-unsaturated, i.e. the portion of exchangeable hydrogen and aluminium are more, the soil is acidic.

Organic matter: Although organic matter is a small part of mineral soil, it plays a vital role in the productivity and conditioning of soils. Organic matter act as a source of food for soil bacteria and fungi, which are responsible for converting complex organic materials into simpler substances, which are easily available to the plants. The presence of organic matter also helps to improve the physical conditions of the soil in terms of its working quality. Presence of organic matter, clay and Ca in right proportion may form a good soil physical condition for better crop performance. Organic matter can also be used as mulch and can prevent the soil from losing moisture by evaporation.

Soil properties and soil quality:
Soils have chemical, biological and physical properties that interact in a complex way to give a soil its quality or capacity to function. Soil function describes what the soil does. Five soil functions as described by karlen et al. (1997) are:

1. Sustaining biological activity, diversity and productivity;
2. Regulating and partitioning water and solute flow;
3. Filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic materials, including industrial and municipal by–products and atmospheric decomposition;
4. Storing and cycling nutrients and other elements within the earth's biosphere; and
5. Providing support of socioeconomic structures and protection for archeological treasures associated with human habitation.

Thus, soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as indicators. Indicators of soil quality should give some measure of the capacity of the soil to function with respect to plant and biological productivity, environmental quality and human and animal health. They should also be used to assess the change in soil function within land use or ecosystem boundaries. Effective indicators (1) respond to change in management practice and provide trends over time (2) integrate soil physical chemical and biological properties and processes (3) be easily measured (4) Have expected or threshold values (5) Have low error associated with measurement (6) Be stable in short term to enable measurement (7) Not be required to be frequently measured (8) be cost effective (9) Have the ability to be aggregated from paddock or site to farm/catchment region.(10) be mappable in space and time (11) Have community acceptance and involvement.

The suite of indicators used for assessing soil quality can vary from location to location depending on the kind of land or land use, soil function and the soil forming factors. Some of the soil physical, chemical and biological properties suggested as soil quality indicators are listed in Table 1 (Subba Rao et al., 2005). Soil organic matter is one of the most useful universal indicators of soil quality, because it interacts with other numerous soil components influence other soil properties. There are also descriptive indicators which are inherently qualitative can be used in assessing soil quality. Some of the descriptive indicators include soil crusting/surface sealing, rills, gullies, ripple marks, sand dunes salt crusting and standing or ponding water. Crop yield (grain or biomass production), plant vigour, rooting patterns, and other aspects of the crop have been used as indicators of soil quality. Crop yield is an important indicator because it gives information about the interacting soil properties of the system as whole as in a bioassay. The dimension of scale influence soil quality assessments in both space and time. The area of consideration can be as small as a point on the landscape, a research plot, or as large as a nation or the world. Time frames are important because of the effect of climate, soil moisture conditions, human actions, stage of plant growth, and other factors that give
rise to temporal variability in indicator status. Doran and Parkin (1996) have given a list of soil attributes (Table 2) which can be estimated from basic soil properties presented in Table 1 and can be used to assess the soil resources and monitor its changes. Theses soil quality indicators (Table 1) may be used to take a stock of the comparative assessments between different agricultural management practices in order to explore the degree of sustainability of the later. Furthermore, a quantitative assessment of sol quality that considers the specific soil functions in a given land use and societal context obviously addresses the threshold values of such key indicators.

Table 1. Proposed minimum data set of soil physical, chemical, and biological properties for screening the condition, quality and health of soil

Indicators of soil condition	Relationship to soil condition and function; rationale as a priority measurement
Physical	
Texture	Retention and transport of water and chemicals; needed for many process models; estimate of degree of erosion and field variability of soil types
Depth of soil, top soil, and rooting	Estimate of productivity potential and erosion, normalizes landscape and geographic variation
Soil bulk density and infiltration	Indicators of compaction and potential for leaching, productivity and erosivity, density needed to adjust soil analyses to field volume basis.
Water holding capacity (water retention character)	Related to water retention, transport and erosivity; available water can be calculated from soil bulk density, texture, and soil organic matter
Chemical	
Soil organic matter (total organic C and N)	Defines soil fertility, stability and erosion extent; use in process models and for site normalization.
pH	Define biological and chemical activity thresholds; essential to process modeling.
Electrical conductivity	Defines plant and microbial activity thresholds, soil structural stability, and in filtration of added water, presently lacking in most process models, can be a practical estimator of soil nitrate and leachable salts.
Extractable N, P and K	Plant available nutrients, productivity and environment quality indicators
Biological	
Microbial biomass C and N	Microbial catalytic potential and repository for C and N; modeling; early warning of management effects on organic matter
Potentially mineralizable N (anaerobic incubation)	Soil productivity and N-supplying potential; process model; surrogate indicator of microbial biomass N
Soil respiration, water content, and temperature	Measurement of microbial activity (in some cases plants); process modeling;

Soil properties and its restoration or conservation

It is also important to establish and define critical limits of soil properties for adapting appropriate land use and cropping/farming systems once the soil is in the process of being restored. Understanding processes, factors, and causes of soil degradation is a basic prerequisite toward successful restoration of the productivity of degraded soils. It is necessary to establish the cause- effect relationship, because elimination of the causative factors may reverse the degradative trend and set in motion the restoration processes (Lal and Stewart, 1992). For example, knowledge of tolerable levels of salinity, acidity, or aluminum toxicity of different crops and cultivars may be necessary to obtain economic benefits by growing tolerable crops and to accelerate the process of restoration.

Knowing the category of soil degradation is an important stage because the approach to restoration depends on the category. Approaches to restoration for soils degraded by intensive farming are outlined in Fig.2. There is a critical level of soil organic matter below which favorable structural attributes are difficult to maintain. Understanding the critical levels of soil organic matter, and adopting soil/ crop management systems to achieve these levels is an important strategy for improving soil structure. Enhancing activity and species diversity of soil fauna is another useful strategy. The zonal tillage concept, limiting wheel compaction to the traffic zone, and adopting conservation tillage for the soil/water management zone, will reduce risks of soil compaction.

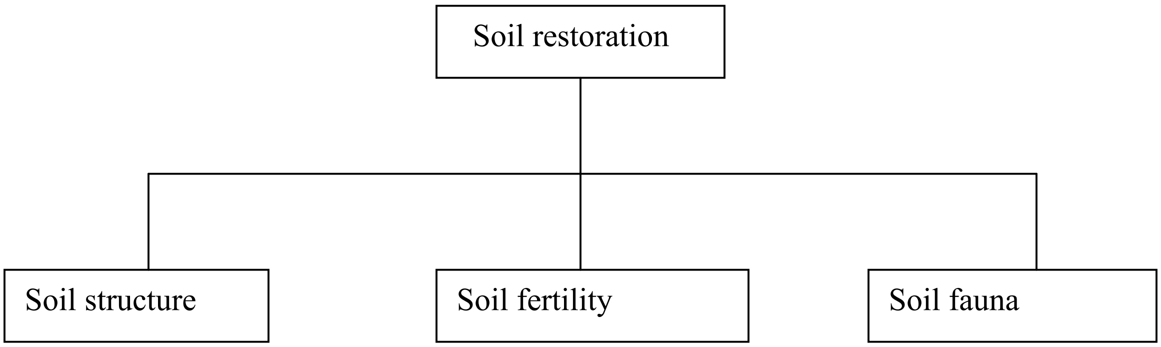
Table 2. A limited listing of soil attributes or properties that can be estimated from basic input variables using pedotransfer functions or simple models

Soil attribute or property	Basic input variables
Cation exchange capacity	Organic carbon+ clay type and content, % sand
Water retention characteristic, available water holding capacity(AWHC)	Silt+ organic carbon+ Bulk density (BD)
Hydraulic conductivity, aerobic and anaerobic microbial activity C and N cycling	Soil texture, water filled pore space (WFPS) as calculated from BD and water content, soil respiration (soil temperature + WFPS)
Plant /microbial activity or pollution potential	Soil pH + EC
Soil productivity	BD, AWHC, pH, EC and aeration
Rooting depth	BD, AWHC, pH
Leaching potentials	Soil texture, pH organic C (hydraulic conductivity, CEC, depth)

Source: Doran and parkin (1996)

Nutrient management in soils with fertility problems is crucial to sustained production. Reliable and quantitative information on the nutrient supplying ability of soils (both capacity and intensity factors) and response functions for different cultivars, crops, and cropping/farming systems is necessary for the judicious use of inherent and applied nutrients. Intensive land use and high yields on soils of low inherent fertility can only be achieved by raising the nutrient levels. Technological options for nutrient recycling should be explored. Excessive use of synthetic fertilizers can be avoided by decreasing losses (erosion, leaching, volatilization) and enhancing nutrient recycling. An adequate level of activity and spices diversity of soil fauna is also essential for restoration of soil structure and enhancement of nutrient cycling. The effects of soil fauna on properties of soils are not well understood, especially with regard to different cropping/farming systems. There is a need for soil scientists and ecologist to work together to understand the interaction between fauna and soil properties.

Knowledge of basic processes and about the cause-effect relationship is also necessary for restoring soils with crop restrictive inherent characteristics. Restoration of eroded lands and prevention of degradation by new erosion are crucial to sustainable management of soil resources. Taking pressure off the marginal lands, by creating off-farm employment and developing income- generating opportunities are important policy considerations. Research is also needed on erosion-preventive measures and their effectiveness for diverse agro-eco regions. Productivity of eroded soils is constrained due to loss of soil organic matter, clay fraction and colloid complex, decrease in rooting depth, and reduction in plant-available water capacity. Exposure of unproductive sub soil is another major effect of accelerated erosion. Agronomic research is needed to develop packages (s) of cultural practices to alleviate these constraints.



Soil structure
- Maintain soil organic matter
- Enhance activity soil fauna
- Soil- restorative farming systems
- Compatible tillage methods

Soil fertility
- Balanced nutrient application
- Supplement mineral fertilizers with organic manures
- Nutrient recycling

Soil fauna
- Enhance species diversity
- Improve habitat including micro- environment
- Ensure food availability and diversity

Figure 2. Approaches to restoration for soils degraded by intensive farming (Source: Lal and Steward, 1992)

Salt-affected soils, are widely distributed throughout the arid and semi arid regions. Predominance of sodium on the exchange complex can adversely affect soil structure and infiltration and percolation rate. In addition to physical measures of salt removal (leaching, scraping), research on cropping systems, with new crop species and improved cultivars, is crucial to alleviating production constraints. The problems of nutrient toxicity and deficiency can also be addressed through the judicious use of chemicals, adoption of ameliorative soil and crop management systems, and growth of adaptive crops and cultivars.

Soil is increasingly being used or abused for disposal of industrial and urban wastes. Indiscriminate disposal of toxic wastes is unwise and unethical. Legislative measures are needed to ensure safe disposal methods of industrial wastes.

Conclusions

World soil resources being finite, intensive land use is inevitable to meet the global demands for food and fiber. Intensification of agriculture on existing arable land increases risks of soil and environmental degradation. Therefore, it is important to understand land use and management impacts on soil quality, establish links between soil quality on the one hand and agricultural sustainability, and environmental quality (e.g., water pollution, green house effect) on the other.

Establishment of such functional relationships involves identifying criteria for quantitative assessment of sustainability and soil quality (Lal, 1998; Lal, 2001; Lal, 2007).

Restoration of quality of degraded soils is a high global priority. To do so involves establishment of critical limits of key soil properties in relation to specific soil degradative processes, and study of temporal variations in such properties and processes under different restorative measures.

There is a need to adopt multidisciplinary and holistic approach to soil science for addressing global issues of food security and environmental quality. In cooperation with anthropologists and economists, soil scientists must identify reasons for the lack of or slow rate of adoption of research- proven technology. Alleviation of soil-specific constraints to an intensive land use must be done in adopting a team approach through establishment of close linkages with other disciplines, e.g., biology, ecology, earth sciences, social and behavioral sciences, and those disciplines involved in production and management.

Soil resource of the world are adequate to meet the needs of the present and future population. Soil scientists can play a key role in achieving food security and enhancing environmental quality by improving/ restoring soil quality through development of multidisciplinary and holistic approaches to natural resources management.

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