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Soil Chemistry: A Way Ahead

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Abstract

Soils are precious. Ancient civilizations perished due to their mismanagement. Modern day soil laboratories are crippled by large number of samples that they can handle in very less time, this indicates the intensity of use of soil is increasing rapidly and there must evolve ways to monitor it on real time basis. Soil solution is the focal point; it's a medium wherein all chemical reactions occur and lends itself to a dynamic equilibrium with climatic components and human manipulations. Spatial and temporal variability's of soil solution constituents are recognized characterized and can be predicted. Diffusive and convective gradients are both established in soils and these gradients are useful when transport processes are involved. When combined with crop growth models they can be conceptualized as soil: Plant: Atmosphere continuum. Therefore a possibility of creating a surveillance system is imminent from making use of vast database generated by soil survey and climatic variables. Advances in precision farming are reviewed to target agro-chemicals to the needs of crop. Latest technology and gadgets to create alarm signals when soil quality indicators are estranged is discussed.

"The unexamined life is not worth living" – Socratus

Keywords: Soil chemistry; Surveillance; Soil quality

A little History

A dramatic change occurred in human history after the last ice age just over ten thousand years ago. Man shifted from hunter/gatherer to the cultivation and domestication of animals [1]. The last four centuries have witnessed fundamental progress in the management of agriculture [2]. During this later period rapid advances have been made in the field of science. The twentieth century has been characterized by unprecedented discoveries in physics by blending of deduction and induction [3]. Induction leads to specific observations to general laws, while deduction leads from general principles to specific predictions. Response of agricultural crops to management factors (such as water, applied nutrients, plant density, harvest interval for perennials) has been of interest to farmers and agricultural scientists for a long time.

The study of soil chemistry has been fostered by man's interest in plant growth and food production. The ability to produce food is a fundamental factor in societal development. The Roman writer Agricola summarized this knowledge and his practical advice on soil husbandry on maintaining soil fertility by shifting cultivation, manures, returning wastes to soil and crop rotation was unsurpassed until the 16^{th} century. From Roman times to renaissance experimental observation and measurement were discouraged in the western world. Without experimentation, progress was impossible. Sir Hugh plat in England in 1590 drew his conclusion that soils were important to plant growth was not verified for more than a century. Shortly after, in early 1600, Francis bacon argued that science required methodical observations and experimentation. In 1699 Woodward confirmed the finding of Hugh Plat by applying rain water, river water sewage water and solids (garden mould) in the growth medium. Soil chemistry, distinct from soil fertility was unrecognized until 1850 when Way and Lawes at Rothamsted, England discovered Cation Exchange capacity. Their work suggested that soils would be studied apart from plants and still has implication for soil fertility. Contributing to the understanding of soil fertility is an important goal of soil chemistry.

Soil chemistry is the study of the chemical characteristics of soil. Soil chemistry is affected by mineral composition, organic matter and environmental factors. From the point of view of soil chemistry, soil is open, multicomponent, biogeochemical system containing solids, liquids and gases. That they are open means soils exchange both matter and energy with surrounding atmosphere, biosphere and hydrosphere. These flows of matter and energy to or from soils are highly variable in time and space, but that are essential fluxes that cause development of soil profiles and govern the patterns of soil quality [4]. The soil concentrations refer to samples taken approximately 0.2 m beneath the land surface from uncontaminated mineral soils. The major elements in soils are those with concentrations that exceed 100mg kg^{-1}, all others being trace elements. The major elements include O, Si, Al, Fe, C, K, Ca, Na, Mg, Ti, N, S, Ba, Mn, P and perhaps Sr, and Zrin decreasing order of concentration. Notable among the major elements is the strong enrichment of C and N in soils relative to crustal rocks whereas Ca, Na, and Mg show significant depletion. The strong enrichment of C and N is a result of the principal chemical forms these elements assume in soils-namely, those associated with organic matter. The major elements C, N, P, and S also are macronutrients meaning they are essential to the life cycles of organisms and are absorbed by them in significant amounts. Soils are biological milieu teeming with microorganisms. These microorganisms play essential roles in humification, the transformation of plant, microbial and animal litter into humus. Biomolecules are compounds in humus synthesized to sustain directly the life cycles of the soil biomass. They are the products of litter degradation and microbial metabolism, ranging in complexity from low-molecular mass organic acids to extracellular enzymes. Soil solution, more precisely is a aqueous liquid phase in soil with a composition that is influenced by exchanges of matter and energy with soil air, soil solid phases, the biota and the gravitational field of the earth. This identifies soil solution as open system and its designation as a phase means it has uniform macroscopic properties (e.g., temperature and composition) and that it can be isolated from the soil profile and investigated experimentally in the laboratory. A complex is a unit comprising a central ion or molecule that is bound to one or more other ions or molecules such that a stable molecular association is maintained. There are several examples of soluble complexes formed in soil solution. The total concentration of dissolved constituents in a soil solution represent the sum of "free" (i.e., solvation complex) and complexed forms of the constituents that are stable enough to be considered well-defined chemical species. The distribution of given constituent among its possible chemical forms can be described with conditional stability constants concentration of dissolved chemical species in a soil solution can be calculated if three items of information are available: the measured total concentration of the metals and ligands, along with pH value, the conditional stability constant for all possible complexes of the metals and H+ with the ligands and expression for the mass balance of each constituent in terms of chemical species (i.e., free ions and complexes). Uniformity of macroscopic properties obviously cannot be attributed to the entire aqueous phase in soil profile, but instead to a sufficiently small element of volume in the profile (e.g., a soil ped or clod). Spatial variability in the chemical properties of the soil solution at the pedon or landscape is axiomatic and temporal variability, even in a small element the size of a ped is commonplace because of diurnal fluctuations and seasonal changes punctuated by direct influence of the biota. On both larger and smaller timescales than those typified by the variability of solar inputs, temporal variation in the properties of the soil solution also occurs because of the kinetics of chemical reactions. Constants of several metal chelates are tabulated [5]. Before the stability constants of metal chelates have any real meaning in soils, the many competing equilibria must be considered. Soil chemistry is the study of the chemical characteristics of soil. Soil chemistry is affected by mineral composition, organic matter and environmental factors.

Historically thermodynamics developed by Nicolas Leonard Sadi and Carnot in 1824. In 1865, the Germen Physicist Rudolf Clusius suggested the principles of thermochemistry. Lewis, Randall and Guggenheim are considered as founders of modern chemical thermodynamics. One problem in dealing with chemical systems is how to decide when equilibrium has attained. Equilibrium constants are derived from thermodynamic data. Oxidation and reduction reactions are common in soils and generally ignored by soil scientists. Electrons can be treated as other reactants and products so that both chemical and electrochemical equilibrium can express by a single equilibrium constant. Soil solutions attain their chemical composition through a variety of reaction and physicochemical processes. Among these are acid-base reactions, gas-solution process, oxidation-reduction, precipitation-dissolution of solid phases, chelation reactions, adsorption-desorption process. Chemical kinetics is useful in determining rates and mechanism towards equilibrium whereas thermodynamics views equilibrium as a state of maximum stability. Soils are chemically different from rocks and minerals from which they are formed in which soils contain less of the water soluble weathering products Alumino-silicates comprise a major portion of the mineral fraction of soils and include primary and secondary minerals. Most primary minerals were formed at temperature and pressure much different from those that exist at the earth's surface today. Thermodynamic relationships can be used to predict soil mineral transformation [6]. Stability diagrams are developed and used to predict the stability, formation and weathering of many alumina-silicates minerals in soils [7]. The solubility of several minerals occurring in natural soils has been compiled by Lindsay [5]. Estimates of ionic activities in soils can be used to test solubility relationships. Metal chelates are important in soils because it increases the solubility and mobility of metal ions.

Transport Mechanism

Transport of solutes in porous materials such as soils is important in understanding problem of availability of solute for plant uptake. Transport of solute in soil occurs by two physical process-diffusion and convective flow. Advancements have made it possible to quantify the amounts of solute over space and time. The approach usually taken to study soil chemistry can be based

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as recognition that all components of the field environment – the soil, the plant and the atmosphere when taken collectively form a physically unified and dynamic system. In this system the chemical flow processes occurs interdependently. This unified system has been dubbed as the SOIL: Plant: Atmosphere: Continuum or SPAC by J.R Phillip [8]. If transport of water, heat, solute and oxygen in soils is to be integrated with plant growth and development, conservation laws and rate equations must be combined which account for the spatial and temporal distribution of mass and energy in soil system.

Spatial Variability

Up to this point, soils have been discussed as a uniform entity. Plants in a field are usually growing in soil that has been developed over hundreds to thousands of years. The development of soils and its characterization by horizon is discussed in detail by Buol et al. [9]. It needs to be emphasized that vast differences can occur between soils and even horizons of the same soil. The soil profile is divided into A, B, and C horizons, which are characterized by different effects of soil- developing processes. All the soil Physical properties vary with space and time. Mathematically this relationship can be written as

$$SP = f(x,y,z,t)$$

SP can be any soil physical parameter such as soil water content, pressure, temperature (row in which sample is taken), y(position along the row), z(depth in the profile) are Cartesian coordinates; and t is time.

If the data is available already the first task is to summarize them which normally a geostatistical practitioner would do. A basic statistical quantity such as mean, variance and skewness describes the normal distribution and transformations to stabilize the variance. It is followed by computation of variograms or their equivalents, fits models to them, and then uses the models to krige. The functional departure of a soil physical property on x, y and z is known as spatial variability and is expressed for the landscape. The functional dependence of soil physical properties on time indicates that it should also consider the time of sampling and the change of magnitude of soil property during the designated time interval-that is the time rate of change. "This is known as temporal variability". The concept of REV (representative soil volume) was developed because of the need to describe or lump the physical properties at a geometrical point. We say that we give to one point in space and time the value of the property of a certain volume surround this point. Soil scientists are concerned with phenomena that are the result of interaction between the solids, liquids and gaseous phases of soils. The relationships between these phases are unknown, are complex and many exhibit continuity within the landscape. The variability of soil properties results from the factors of soil formation and change induced by humans. Since soil properties play a central role in the soils capacity to transmit, store and react to water, solute and gases, knowledge of the variability of these properties in the landscape is important [10]. Precision agriculture is an innovative approach to solve problems of green revolution agriculture, where input application does not consider the concept of spatial and temporal variability within the field adequately.

Crop growth models

One of the earliest efforts at modelling crop response to management factors was that of E.A. Mitscherlich [11]. They focused on response of seasonal dry matter to applied nutrients. Overman [12] described crop growth with the probability model drawing attention to accumulation of dry matter and plant nutrients with time. It became evident there was an environmental, or climatic, input to crop growth. This was evident in seasonal changes in rates of growth caused by variations in solar radiation over the calendar year. While the empirical growth model appears to fit field data rather well, it offers no insight into the physics of the system. The presence of the empirical model suggests the presence of a Gaussian component in the system. Overman et al. [13] wrote a growth rate equation (differential equation) as a product of a Gaussian environmental function and a linear intrinsic growth function. Mathematical details such as solution of differential equations and characteristic of some functions are discussed. Overman [14] integrated the plant system with the soil components, such as extractable elements. Linkage of animal production with forage production, and in turn with applied N has been established also. When one is introduced to Mitscherlich and multivariate regression, it is clear that these were empirical models without any physical basis. The next step was to expand the mathematical models to incorporate dry matter and plant nutrient accumulation as related to multiple levels of applied nutrients N, P, K in a mathematically self-consistent manner. Thus empirical model was expanded to a phenomenological model with a physical basis.

Agro Meteorology

Agricultural meteorology in its various forms and facets help with sensible use of land, to accelerate the production of food and to avoid the irreversible abuse of land resources [15]. Attempts to relate agricultural production to weather go back at least 2000 years and are still evolving. Qualitative studies in the ninetieth century were followed by statistical analysis, then by microclimate measurements and most recently by modelling [16]. Agriculture industry is the most sensitive to variability in weather and climate. The availability of agro meteorological database is major prerequisite for studying and managing processes of agricultural production. Historical data and observations during the current growing season will play a critical role in increased application of crop models. Combined with soil and agronomic data will be invaluable to conserve resources such as water and fertilizers, the two major agricultural inputs .One of the most prominent current

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problems of humankind is global warming and its impact on agriculture. These findings will permit the development of more adaptive, more tolerant and more productive plants in stressful environments [17]. Solar radiation is the main source of heat energy to the biosphere. Temperature is the intensity aspect of heat energy. Temperature governs the physical and chemical process that in turn controls biological reactions within plants. It controls the diffusion rate of gases and liquids within plants and solubility of plant nutrients substances is dependent on temperature. Almost all the water available on the earth, 97 per cent, occurs as salt water in the ocean. Of the remaining 3 per cent, 66 per cent occurs as snow, which leaves only 1 per cent of global water as liquid fresh water. More than 98 per cent of fresh water occurs as ground water, while less than 2 per cent occurs in rivers and lakes. Ground water is formed by excess rainfall (total precipitation minus surface runoff and evapotranspiration) that infiltrates deeper into the ground. In most parts of the world, rainfall is, for at least part of the year, insufficient to grow crops, and rain fed food production is heavily affected by annual variations in precipitation. Patwardhan and Nieiber proposed a soil –water balance model based on the equation of conservation of water in the soil profile. The water balance of the entire soil profile is considered in terms of individual processes:

$$P+I-R-RN=ET+D+\Delta S$$

Where P is rainfall, I is irrigation, R is run off, RN is rainfall interception, ET is evapotranspiration is deep drainage and delta S is the change in the water content in the profile.

Each of the components can be directly measured or experimentally determined in the field or laboratory or estimated from soil properties through appropriate mathematical treatments over a period of time. The concentration of elements in soil solutions vary with water content in the pores. The average soil solutions concentrations can be readily estimated when information about moisture content is available.

Bringing Precision into Farming

GPS (global positioning system) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground station, which provides. Geospatial accuracy to farm practices by enabling farmers to identify each field site. GPS accuracy has considerably improved to about 20 meters. Differential GPS (GPS receiver used along with ground reference station) is necessary to get accuracy of 1-3 m critical for yield mapping, crop scouting and variable input application. GPS are also used to create field boundary and topographical map series. Maps with each field identified with the crop grown in each season can help in tracking crop rotations in a region from year to year. Recently, GPS auto-guided (automatic steering for application equipment) is attracting attention as a measure to save labour. GIS (Geographical information system) is a software application for computerized data storage, retrieval, and transformation and is used to manage and analyse spatial data relating to crop productivity and agronomic factors. Data is derived from different fields from various sources including existing digital maps and photographs, topographical surveys, soil and crop samplings and sensor data with location information derived using GPS. A GIS for precision agriculture contains base maps such as land ownership, crop cover, soil type, topography, N, P, K and other nutrient levels, soil moisture, pH, porosity, bulk density including a list of soil properties. Data on crop rotations, tillage, nutrients and pesticide applications, yields, etc., is also stored. GIS is used to create fertility, weed and pest intensity maps and for making prescription maps that show recommended application rates of farm chemicals at various fields locations. Low flying aircraft and satellites have become major source of spatial data due to reduction in both cost and time. Although the use of remote sensing in agriculture is several decades' old, improvements in spatial, spectral and temporal resolutions of recent satellites and systems such as airborne video graphy and recent developments in new – spectral sensors are increasingly becoming useful to determine size, location and cause of variation. Imagery can show all fields in a region and spot anomalies related to crop vigour and biomass much earlier than ground inspections, thereby improving the efficiency of crop scouting in large fields and allowing prompt remedial treatments. Temporal changes in vigour, as determined from NDVI (Normalized difference Vegetation index) analysis of images with other data layers in a GIS, maps can be prepared. Technologies employing electronic in-field crop and soil sensors to quantify variability in crop and pH, EC (electrical conductivity). N content and organic matter are currently in use. The introduction of Veris soil pH senor automates the soil sampling process [18]. VRT (variable rate technology provides "on-the-fly" delivery of field inputs. AGPS receiver is mounted on truck so that a field location can be recognized. An in-vehicle computer with the input recommendation maps controls the distribution valves to provide suitable input mix by comparing to the positional information received from the GPS receiver. VRT systems are either map-based or sensor- based. VRT has been largely used for applying N, P, K, lime, pesticide, and herbicides. Systems such as manure applicators, which enable precise application of animal wastes, are also in development. Technologies such as fax, cable TV and internet (World Wide Web) offer capability to send, receive and aggregate information at much lower cost than ever before. This enables crop consultants to examine and evaluate them in preparing appropriate recommendations. Devices integrating geospatial and communication technologies are in development. To name a few, GPS –enabled voice recognition system which permits data collection with simple, easy to remember application protocols and GIS liked Infielder crop records system are useful for mapping various field operations and stress zones voice commands regarding weed or insect problems, crop lodging and other farm operations. Likewise, systems employing GIS-based wireless application protocols and GIS-linked infielder Crop

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Records system are useful for mapping various field operations and stress. GPS, GIS, remote and proximal sensing, VRT and crop models are combined to build decision support system (DSS). There provide an integrated framework for assessing the degree of sustainability of a farming system. They can be used for understanding yield variability in both space and time so as to optimize production, indicate future trends and prescribe suitable actions to minimize environmental impact. Process -oriented and crop simulation models, such as CERES and CROPGRO, integrate the effects of temporal and multiple stress interactions on crop growth process under different environmental and management conditions [19]. Can you provide the farmer with spatially referenced values that he can use in his automated fertilizer spreader? This is not fanciful. The technology minded farmer can position his machines accurately to 2 m in the field, he can measure and record the yields of his crops continuously at harvest, he can modulate the amount of fertilizer he adds to match the demand. However all this can be possible with data accumulation of soil plant atmosphere and making useful applications

Nutrient Uptake

Plant growth involves the interaction of soil and plant properties. It has been a scientific axiom that more basic information can be obtained by studying the smallest segment of a system. To provide a useful basis for investigating a plant's root growth and nutrient uptake, a mechanistic uptake model was developed describing the more significant process involved in soil nutrient uptake [20]. The uptake model describes size and growth of the roots, kinetics of nutrient uptake by roots, and supply of nutrients from the soil to root surface. Plant nutrient availability in soils depends on the amount and nature of nutrients in soil solution and their association with nutrients adsorbed by or contained within the solid phase of the soil. Plant roots absorb nutrients from the soil solution, so the equilibrium level of nutrients in the soil solution at the time absorption begins is a factor in determining the rate at which plant roots can absorb nutrients. Several processes as solubility, adsorption and desorption, and exchangeability effect the concentration of ions in the soil solution. It is not known to date whether ion activity or concentration determines the uptake rate of anion. While we might expect activity to be important for ion uptake where uptake is active (energy dependent) processes, it may not be as important where uptake is passive. It is difficult to determine the significance of activity for many ions, because uptake is usually from dilute solution where activity is nearly the same as concentration. Relations between concentration and activity have been calculated by Adams [21]. In soils, the nutrient concentration at the root changes with time as nutrients and water are absorbed at rates differing from the rates of supply by the soil. These changes must be considered in measuring nutrient flux from the soil into the plant root. The uptake of nutrients by plant roots growing in soil depends on both nutrient-influx characteristics of the root and the nutrient supply characteristics of the soil. When root interception and mass flow do not supply the root with sufficient quantities of a particular nutrient, continued uptake reduces the concentration of available nutrients in the soil at the root surface. Fick's second law applies to transient – state diffusion. It is more applicable to plant root-soil situation.

$$dC/dt = D\, d^2C/dx^2$$

Hence, dC/dt is the rate of change in concentration with time at a fixed linear distance.

The highly variable nature of adsorption and desorption usually makes measurement of b (buffer power) arbitrary, so we measure the value of Cs (Concentration of labile ions in the soil) that involves equilibrating the soil for a length of time comparable to the average time that much of the ion will be diffusing to the root. Rates of release that are great enough to significantly contribute to the rate of supply from soil to the root depend on the specific nature of the soil minerals. Highest rates usually occur in soils where little weathering and leaching has occurred.

In the palm of the farmer

Clearly, the language of modern science is mathematics. It is also a tool for reasoning. There is an important need to cope up with the changing conditions and transformations induced by human interventions on the planet. It is possible by creating a surveillance system in the palms of the decision maker, the crop producer (the farmer)". A dynamic model is the one whose output varies with time and in which processes are characterized. To characterize processes, the state variables must be known. State variables are those necessary to define the system at a point of time. Dynamic simulation models predict changes in crop status with time as a function of biogenetic parameters. The application of crop simulation models for forecasting and yield prediction is a useful area of information. One of the limitations of current crop simulation models is that they can simulate crop yields only for a particular site for which weather and soil data as well as crop management information are available. One of the recent advancement is the linkage of crop models with a geographical information system (GIS). A GIS is spatial database in which the value of each attribute and its associated x- and y- coordinates are stored. To describe a specific situation, all the information available on a territory, such as water availability, soil types, forests, grasslands, climatic data and land use are used. Each informative layer provides to the operator the possibility to consider its influence on the final result. This approach has opened a new field of crop modelling applications at a spatial scale, from the field level for site-specific management to the regional level for productivity analysis; Decision support systems (DSS) are integrated software packages comprising tools for processing both numerical and qualitative information. A DSS pointed the way for better decision making in cropping. It

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offers the ability to deliver the best information quickly, reliably and efficiently. The choices of planting, varietal selection, fertilizer, irrigation and spray applications are complex decision at the farm level. Any Farmer, given his spatial coordinates, the type of soil, the fertilizer and water resources in his custody, the prevailing atmospheric conditions and taking into consideration economic and social conditions -should be advised appropriately by an expert system, perhaps through simple mobile apps. There will be a greater need for application of crop simulation models and decision support systems to help provide guidance in solving real-world problems related to production, sustainability, the use of natural resources and protection of environment .A software or product of this kind will enable the plant producer to take immediate steps by responding to an alert from his gadget because all pieces of Knowledge are integrated, working in space and time. Fortunately the advancement in simulation modelling has even made it possible to analyse various scenarios by asking "What if?" In the recent years, mobile devices have gained popularity due to lower cost, small and sleek sizes, and the capability to act as a computer with you at times. In recent years, the bandwidth the mobile apps use has increased drastically. With the growing use of mobile devices for everyday web browsing, it's important to provide website interfaces that are easy to use on these devices. iOS, the technology that is run on Apple mobile devices. The language is Objective-C, with Cocoa Touch as the interface layer. At this time iOS can be developed only using Apple's XCode, which can only run on a Macintosh. The Android framework is written in Java and can be developed using any Java tools the specific tooling recommended by the Google community is Eclipse with the Android toolkit. Unlike iOS, it can be developed on PC, MAC, or Linux framework on the market is Windows Phone Linux. BlackBerry device framework is also written in Java. The newest native framework on the market is Windows Phone 7 and its framework sits on top of the Microsoft's .NET Framework. The language of choice is C# and the framework lies in a subset of Silver light (The Microsoft's multiplatform web technology). Its Microsoft Windows Phone tools only run on Windows.

Finally its soil quality that makes the difference

Placing a value upon soil in regard to a specific function, purpose or use leads to the concept of "soil quality". Various studies have attempted to identify sets of attributed or properties that can characterize a soil process or processes in regard to a specific soil function [22]. A major goal in soil quality studies is to ascertain, where possible, links between properties and a specific function of the soil e.g., soil productivity). Once a property is identified for a specific soil type or situation, information about soil quality standards for a given set of conditions is needed. This involves information on the critical ("threshold") level and range of the attribute (property) associated with significant changes (usually adverse) in soil function of interest (e.g., optimum crop production). In response to these concerns, the International organization for Standardization (ISO) is developing various standards for soil quality measurements. It can only be assessed by measuring properties. Functions of soils, and thus soil quality, can be assessed at the field, farm, ecosystem, pedo sphere and global scale. Terrestrials ecosystems contain soil, atmosphere, water, vegetation and animals. As components of ecosystems, soils function to both regulate biotic processes (e.g., supplying plants with mineral nutrients and water) and flux of elements (e.g., turnover and storage of C, N, P, and S). These soil functions also affect other component of the ecosystem (i.e., aquatic, atmosphere and biological, as well as adjacent ecosystem. The fundamental unit for assessing soil quality at ecosystem level is usually the soil horizon. The properties of soil horizons (e.g., thickness, organic matter content, pH) are used to characterize the pedon. At higher level or scales of organization, pedons can be grouped into Catena, Soil types, Landscape units, Zones and Eco zones. Levels or scales of soil organization below the horizon, such as aggregates and organo- mineral colloids, control the internal processes or physiology of soil. Understanding these processes is fundamental to understanding the higher levels or scales of soil organization and the overall functioning of soil in an ecosystem. It is recognized, that management of soil becomes increasingly difficult at larger scales. Soil, and consequently soil quality, cannot be managed at the global scale. The goal of the land manager is to sustain and improve the quality of the soil resource case. This, soil quality is in the hands of the land manager [23]. The primary function of soil in relation to its chemical quality for crop production is to provide nutrients for crop growth. Because of the use of pesticides and fertilizers and application of sewage sludge and other wastes to agricultural lands, the capacity of a soil to immobilize pesticides and detoxify and immobilize heavy metals must also be considered when determining the chemical aspects of soil quality. Soil chemical properties that affect one or more of these three aspects are Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP), pE, pH, Electrical conductivity (EC), Organic matter content and Mineralogy. These properties, or chemical attributes may be used to assess to soil quality and to monitor changes caused by degradation [24]. The soluble concentration of an element or compound often determines plant nutrient uptake, phyto-toxicity, and contaminant mobility in soils. The dependence of these aspects on soil chemical properties (attributes) can be explained based on the speciation of a nutrient or contaminant in the soil. Chemical speciation is the distribution of an element or compound in solid, aqueous and gaseous phases and is controlled by the chemical processes (reactions) occurring in soil environment. Knowledge of chemical reactions controlling the speciation of an element or compound in soil assist in predicting how a change in one or more of the soil chemical attributes will affect nutrient variability and also contaminant bio toxicity and mobility. Using the same framework i.e., function ,process, attributes and indicators are described for soil quality, Doran [25] defined soil health as "the continued capacity of a soil

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to function as a vital living system, within ecosystem and land use boundaries, to sustain biological productivity, maintain the quality of air and water environments and promote plant, animal and human health".

Conclusion

Agriculture dominates the world's land use decisions. By 2050 there will be 9 billion people on the planet. From the total of 196.9 million square miles surface area of the earth, out of which only 19 million square miles can be cultivated. .Further we are losing farmland at the rate of more than one acre every minute. Our accumulated knowledge on soil-plant-climate interactions in the biosphere is vast, however many laws are yet to find their practical application. Increasing crop productivity in future will depend upon improving physical conditions of soil which will indirectly benefit plant nutrient and water availability. Failure to realize the functional relationship of chemical processes with state and transport of energy and matter is evident from the deteriorating soil health, climate change and Physiological potential of the plants. Soils properties have changed. No doubt! The delicate equilibrium within this system and between the systems needs to be constantly monitored to prevent the total disaster of the planet earth which is our only "home". Farmers unknowingly do a noble work of feeding the population and Industries but they lack the technology to monitor agricultural resources which include the climate, genetic pool, soil, Farm machinery, labour and time. They also lack the ability to quantify the impact they make during the whole process of plant production. The smaller the farm, the greater is the need for marketable surplus. The ultimate goal of any technological upgrading of agriculture should be happy farming families and sustainable farming system.

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