Soil Diversity: A Key for Natural Management of Biological and Chemical Constitute to Maintain Soil Health & Fertility

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Abstract

The environment is being polluted by humans & in doing so, not only air & water but land is also being contaminated. The major contaminant of soil is chemical fertilizer. The definition of soil quality encompasses physical, chemical and biological characteristics, and it is related to fertility and soil health. Due to heavily usage of chemical fertilizers and harmful pesticides on the crops, food security and safety became a daunting challenge. Indiscriminate and imbalanced use of chemical fertilizers, especially urea along with chemical pesticides and unavailability of organic manures has led to considerable reduction in soil health. Biodiversity performs a variety of ecological services beyond the production of food, including recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals. In this paper the role of biodiversity in securing crop protection and soil fertility by linking diversity of soils. Soil biodiversity is a key parameter for maintaining the fertility and productivity of the soils - thereby safeguarding food production. This management systems provide the ideal environment for the re-establishment of ecosystem engineers such as earthworms and scarab beetle larvae, of saprophagous and litter transforming organisms such as termites and millipedes and of predator populations (pseudoscorpions, centipedes, Diplura and spiders), thus enhancing the system's natural biological control and regulation mechanisms to maintain soil health and fertility.

Keywords: *Chemical hazardous, Soil diversity, Soil management*

1. Introduction

Sustainable agriculture aims at long term maintenance of natural resources and agricultural productivity with minimal adverse impact on the environment. It emphasizes optimal crop production with minimal external inputs, reducing dependence on commercial inputs (fertilizers and pesticides) and substituting them with internal resources [1]. At present, there is a need for developing an efficient nutrient management system with the use of organic manures, inorganic fertilizers and biofertilizers to maintain soil fertility and for better crop production [2]. The high content of both micro and macro nutrients in organic manures along with the slow release of phosphorus could reduce the nutrient deficiency problems and lower the magnitude of phosphorus fixation. Requirement of the nutrients has increased too many folds with the adoption of improved technology for obtaining higher yields per unit area. Continuous use of inorganic fertilizers resulted in deficiency of micronutrients, imbalance in soil physicochemical properties and unsustainable crop production [3]. Fertilization increases efficiency and obtains better quality of product recovery in agricultural activities [4]. Excessive use of fertilizers causes many types of pollution and can lead to problems such as greenhouse effect [5]. Soil fertility is fundamental in determining the productivity of all farming systems. It is most commonly defined in terms of the ability of a soil to supply nutrients to crops [6]. Swift & Palm however suggest that it is more helpful to view soil fertility as an ecosystem concept integrating the diverse soil functions, including nutrient supply, which promote plant production [7]. This paper explores how researcher and farmers can utilize diversity of soil to maintain and develop soil fertility in order to achieve wider goals of agriculture and how can reduce the harmful effect of chemical fertilizers on soil.

2. Effect of Chemicals on Soil Nature

Present day chemical and mechanical agriculture is skilful planting on biologically inactive and physically deteriorated soils. It is an expensive technology which regards soil only as "support" for fertilizers, plants and irrigation water. Chemical fertilizers not only nourish plants and microbes, but also may have harmful effects on the soil and its life, especially when they are very concentrated and water soluble. Acidification as well as neutralization of the soil may be very harmful to microbes, which often depend on a sole enzyme. And enzymes are active only in a very specific pH. Changes in pH slow down enzyme reaction, and microbes have to enter into rest, encysting, or die from hunger. Micronutrients are the activators of enzymes. Ammonium sulphate is a very strong biocide, hindering nitrogen fixation and killing nematodes and earthworms. Superphosphate has a negative effect on free-living nitrogen-fixing bacteria, which may be favoured by "mild" fertilizers such as Thomas slag, thermophosphate or bone meal when added to stubble mulch or straw. Soil microbes and soil animals need mineral nutrients like plants do.

3. Chemicals Used in Agriculture and Their Harmful Impact on Soil

3.1 Ammonium Sulfate

$(NH_4)_2SO_4$ contain 24% sulfur. In the soil, reacts with water to produce sulfuric acid (H_2SO_4). Sulfuric acid has a pH of less than 1 and it is extremely toxic and kills organisms [8]. Hydrogen ions released from the acid replace alkaline elements on the cation exchange sites, depleting the soil of nutrients [9, 10]. The free oxygen produced in this reaction oxidizes the organic matter of the soil and causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter [11]. In calcareous soils (soil with excess calcium) the sulfuric acid reacts with calcium carbonate ($CaCO_3$) to form gypsum ($CaSO_4$) [12], Gypsum is a salt and attracts water to itself and away from soil organisms and plant roots [13]. In anaerobic conditions gypsum and water form hydrogen sulfide (H_2S), which is a toxic gas. So Gypsum is banned from landfills [14].

3.2 Ammonium Nitrate NH_4NO_3

Ammonium Nitrate in the soil breaks down into ammonium (NH_4^+) and nitrate (NO_3^-). The ammonium is consumed by plants and fungi, or by denitrifying bacteria which eventually convert it to nitrate. The nitrates are consumed by soil organisms, leached, or converted to nitrogen gas and volatized. The free oxygen produced through these processes oxidizes the organic matter of the soil and again causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter [20]. Some biological soil scientists [14] advocate the use of small amounts of ammonium nitrate under specific circumstances even though it is prohibited for use under organic standards.

3.3 Urea NH_2CONH_2

The urea is consumed by bacteria which convert it to (excrete) anhydrous ammonia and carbon dioxide [15]. Anhydrous ammonia is highly toxic and kills organisms [16]. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia vapours form. These are heavier than air and can accumulate in low lying areas [17]. If urea is incorporated into the soil, the ammonia gas reacts with water to produce ammonium hydroxide (NH_4OH), which has a pH of 11.6 [18]. It is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills seeds, seedlings and soil dwelling organisms. Within a few days further chemical reactions in the soil release the ammonium ion NH_4^+, which then follows the same path as naturally occurring ammonium, with any excess nitrate created in this way leached into the environment, etc.

3.4 Urea Formaldehyde

The formaldehyde dissolves in water and is leached through the soil. It is a highly toxic substance, killing all soil organisms it comes in contact with. Formaldehyde is used to preserve laboratory specimens! [20].The urea does what it does (see above) - altogether a toxic chemical soup. The effects of some other commonly used fertilizers on the soil Dolomite Lime $CaMg(CO_3)_2$. This is not a synthetic, but a mined natural product (the only natural product in this list). Depending on the source, this contains approximately 22% calcium and 12% magnesium. The ideal calcium: magnesium ratio in soils ranges from about 10:1 (general) to 7:1 (grasses and sandy soil) [21, 22]. Dolomite lime with its 2:1 calcium: magnesium ratio contains too much magnesium in proportion to calcium, especially if used routinely. Excess magnesium in the soil can lead to a calcium deficiency in plants, since plants absorb calcium, magnesium and potassium largely in the ratio in which they are present in the soil. In the soil excess magnesium causes a loss of soil structure (compaction), especially if the calcium base saturation falls below 60%. Reduced soil air levels result in reduced root respiration and the production of toxic compounds in plants. Reduced soil air and insufficient calcium each also result in the reduction of soil microbes and the corresponding reduced breakdown of organic matter / nutrient availability to plants. The effect of magnesium on the soil is well known in drilling, where magnesium is injected into the drill hole to make the drilling mud more viscous and to “tighten” the soil (it separates / expands the clay particles) [23, 24]. This is also the reason why a higher percentage of magnesium is desirable in sandy soils with their loose structure. Magnesium chloride is also used for dust control on roads because it creates a very had surface [25].

3.5 Potassium Chloride/Muriate of Potash KCl

This product contains about 50% potassium and 50% chloride. In the soil the chloride combines with nitrates to form chlorine gas. This kills microbes. Applying 1 pound of potassium chloride to the soil is equivalent to applying 1 gallon of Clorox bleach. Or in other words 2 ppm chlorine are generally thought to be sufficient to sterilize drinking water, hence potassium chloride application typically results in chloride levels as high as 50-200 ppm [26]. Potassium chloride contains very high amounts of potassium, which can result in an unbalanced phosphate: potash ratio. This ratio ideally ranges from 2:1 (most soils) to 4:1 (grasses). Excess potassium in the soil can lead to a calcium deficiency in plants, since plants absorb calcium, magnesium and potassium largely in the ratio in which they are present in the soil. In the soil excess potassium causes a loss of structure [21]. Reduced soil air levels result in reduced root respiration and the production of toxic compounds in plants. Reduced soil air and insufficient calcium each also result in the reduction of soil microbes and the corresponding reduced breakdown of organic matter / nutrient availability to plants. In drilling potassium is used to “close” the soil, because it disintegrates the clay particles (“ages” the clay) and effectively seals the soil [27].

3.6 Triple Super Phosphate

This is produced by treating phosphate rock (apatite) with either sulfuric acid or phosphoric acid, making it extremely acidifying [29]. When applied to the soil it reacts with calcium to form tri-calcium phosphate, which is water insoluble, i.e. requiring microbial action for breakdown [19]. Even in a soil with healthy microbial activity only about 15 - 20% of this phosphorous is easily available to plants, considerably less in soil which does not have good microbial diversity. The production of each ton of phosphoric acid is accompanied by the production of 4½ tons of calcium sulfate, also known as phosphogypsum. This is a highly radioactive product and also contains heavy metals and other impurities. By 1989 phosphogypsum waste covered a total of 8500 acres, stacked between 3 and 60 meters high, causing serious land, air and water pollution [28, 29]. Depending on the production process, radioactive substances and heavy metals can be extracted into the fertilizer. The high concentration of radioactive polonium-210 in tobacco is thought to be associated with the use of acid-extracted phosphate fertilizers [30].

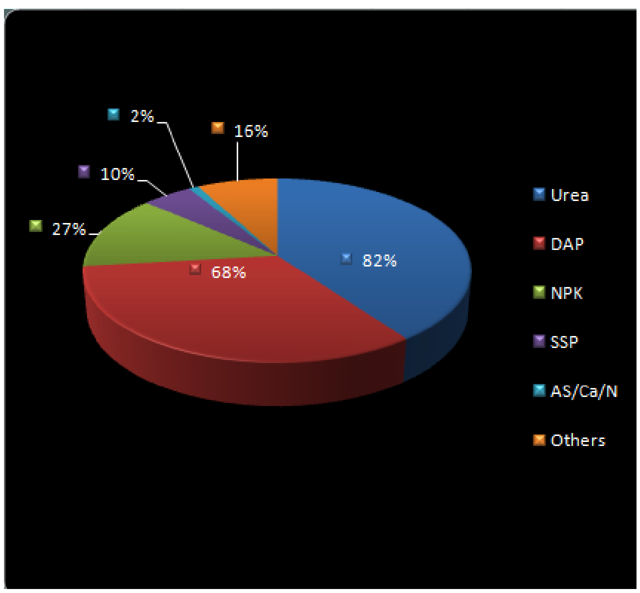

Figure 1. Quantity of Different Chemical Fertilizers used in India

4. Diversity of Soil in India and their properties

4.1 Black Soil

The colour of these soils varies from deep black to light black and chestnut and is dependent on the colour of the mechanical fractions. The black color is attributed to the presence of titaniferous magnetite, compounds of iron and aluminum, accumulated humus and colloidal hydrated double iron and aluminum silicate. In general these soils have clay texture, average clay content being 50% and the range being 40 – 50%. The structure of these soils is usually cloddish but occasionally friable. Regard soils are calcareous neutral to mild alkaline in reaction, high in carbon exchange capacity and low in organic matter. In general these soils are rich in iron, lime, calcium, potash, aluminum and magnesium carbonates but poor in nitrogen, phosphorus and organic matter. Black soils are highly retentive of moisture, extremely compact and tenacious when wet, considerably contracted developing deep wide cracks on drying and self-ploughing. Black soils are credited with high fertility. These are well suited to leguminous crops like cotton, turn and citrus fruits. Other crops include wheat, jowar, millets, linseed, castor, tobacco, sugarcane, safflower, vegetables etc. On the uplands these soils are comparatively less fertile than on the low lands.

4.2 Red Soil

Red soil lack nitrogenous material, phosphoric acid and organic matter but rich in iron and potash. It is mainly seen in the state of Tamil Nadu, Madhya Pradesh, Rajasthan and Maharashtra. They are mainly formed due to the decomposition of ancient crystalline rocks like granites and gneisses and from rock types rich in minerals such as iron and magnesium. The term 'red soil' is due to the wide diffusion of iron oxides through the materials of the soil. Suitable for rice, millets, tobacco and vegetables (also groundnuts and potatoes at higher elevations).

4.3 Laterite Soil

This soil found in typical monsoon conditions – under conditions of high temperature and heavy rainfall with alternate wet and dry periods. The alterations of wet and dry season leads to the leaching away of siliceous matter and lime of the rocks and a soil rich in oxides of iron and aluminium compounds is left behind. Found in parts of Western Ghats, Eastern Ghats, Rajmahal hills, Maharashtra, Karnataka, Kerala, Orissa, West Bengal, Assam, Tamil Nadu, etc. Poor in nitrogen and minerals. Best for tea, coffee, rubber, cinchona, coconut and suitable for rice and millet cultivation if manure.

4.4 Forest and Mountain Soils

Such soils are mainly found on the hill slopes covered by forests. The formation of these soils is mainly governed by the characteristic deposition of organic matter derived from forest growth. In the Himalayan region, such soils are mainly found in valley basins, depressions and less steeply inclined slopes. Apart from the Himalayan region, the forest soils occur in higher hills in south and the peninsular region. Very rich in humus but are deficient in Potash, phosphorous and lime and needs fertilizers. Plantation of tea, coffee, spices and tropical fruits.

4.5 Arid and Desert Soils

A large part of the arid and semi – arid region in Rajasthan and adjoining areas of Punjab and Haryana lying between the Indus and the Aravallis receiving less than 50 cm of annual rainfall is affected by desert conditions. This area is covered by a mantle of sand which inhibits soil growth. The phosphate content of these soils is as high as in normal alluvial soils. Nitrogen is originally low but its deficiency is made up to some extent by the availability of nitrogen in the form of nitrates. Thus the presence of phosphates and nitrates make them fertile soils wherever moisture is available. The changes in the cropping pattern in the Indira Gandhi Canal Command Area are a living example of the utility of the desert soils.

4.6 Saline and Alkaline Soils

In the drier parts of Bihar, Up Haryana, Punjab, Rajasthan and Maharashtra, are the salt – impregnated or alkaline soils. Known by different names : Reh, kallar, USAR, *etc.* Some of the salts are transported in solution by the rivers and canals, which percolates in the sub – soils of the plains. The accumulation of salts makes the soil infertile and renders it unfit for agriculture.

4.7 Peaty and Marshy Soils

Peaty and Marshy Soils originate in the humid regions as a result of accumulation of large amounts of organic matter in the soil. They contain considerable amounts of soluble salts and 10-40% organic matter. Peaty soils are found in kerala and marshy soil high in vegetable matter are found in Bihar, U.P., Orissa.

4.8 Alluvial Soil

They are by far the largest and the most important soil group of India. They are composed of sediments deposited by rivers and the waves. Their chemical composition makes them one of the most fertile in the world. Usually deficient in nitrogen and humus (thus fertilizers are needed). Occupy the plains (from Punjab to Assam) and also occur in the valleys of Narmada and Tapti in M.P. & Gujarat, Mahanadi in the MP and Orissa, Godawari in A.R and Cauvery in T.N.

5. Management of Soil Fertility According to Soil Variability

For optimum plant growth, and microbial health nutrients must be available in sufficient and balanced quantities. The most important constraint limiting crop yield in developing nations worldwide, and especially among resource-poor farmers, is soil infertility [31].

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems. Many techniques are available their aims at optimizing production while maintaining a rich biological diversity of the soil [32]. Linking soil management practices and services can be considered as a new management tool. The choice of services reflects the local use of the soil by farmers [33]. The soil food web structure and the life support services of soil organisms can be indicated by a selection of suitable parameters. With standardized parameter, it is possible to determine the effects of management on these biodiversity parameters which should be measured [34]. Different variety of soil contains different properties which support the organism of soil which maintain fertility. In linking soil management practice, variety of soil mixed together so that all important constitute and organism of all soil mixed and create a symbiotic relation to each and their sheltering plants and improve the soil quality and productivity.

Figure 2. Soil Management According to Soil Diversity: 1) Arid Soil; 2) Black Soil; 3) Alluvial Soil; 4) Mountain Soil; 5) Red Soil; 6) Marshy Soil; 7) Saline Soil; 8) Laetrile Soil

6. Conclusion

Soil biodiversity, which is the multitude of organisms living under our feet, has many important characteristics and functions. Soil organisms show a fascinating diversity of body shapes, ways of living, and ecological interactions. Soil biodiversity is a key parameter for maintaining the fertility and productivity of the soils - thereby safeguarding food production systems provide the ideal environment for the re-establishment of ecosystem engineers such as earthworms and scarab beetle larvae, of saprophagous and litter transforming organisms such as termites and millipedes and of predator populations (pseudoscorpions, centipedes, Diplura and spiders), thus enhancing the system's natural biological control and regulation mechanisms. The greater species diversity and the enhancement of populations and activity of some organisms increase the heterogeneity of biological activity in this management. This feature should enhance the soil system's resilience and resistance to stressful environmental conditions.

The combination of a diversity of biological activities and functions, natural and regulatory mechanisms in the soil, with the other benefits provided by management, form the basis for the widely-held notion that systems can be sustained over the long term. Research on macrofauna and soil function in this systems would be especially useful if it concentrated on providing more detailed taxonomic identification of the organisms involved (down to genera and/or species, when possible) and attempting to link this diversity, or the role of particular species, to soil function (*e.g.*, water infiltration, soil aggregation, soil protection, decomposition, nutrient cycles, C sequestration, pest control). This should be the case particularly for the ecosystem engineers (especially earthworms and beetle larvae), litter transformers (*e.g.*, millipedes, termites) and populations of predatory organisms (*e.g.*, centipedes, diplura, pseudoscorpions, beetles), important in biological control. Finally, more attention should also be focused on adequately assessing the role of specific groups of soil macrofauna, its diversity and the multiple biological interactions in soil, on reducing the chemicals (herbicides, insecticides, fertilizers), thus enhancing the quality of the final products, and the long-term sustainability of this increasingly important and widespread land-use system.

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