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PN Patle
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India.

PR Kadu
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India.

AR Gabhane
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India.

AL Pharande
Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, (M.S.), India

AP Bhagat
Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India

SM Bhoyar
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India.

NM Konde
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.), India.

MK Rahangdale
Nagarjuna Institute of Technology, Nagpur, (M.S.), India.

Correspondence
PN Patle
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (M.S.) India.

Consequences provoked due to excess application of agrochemical on soil health deterioration – A review for Sustainable Agriculture

PN Patle, PR Kadu, AR Gabhane, AL Pharande, AP Bhagat, SM Bhoyar, NM Konde and MK Rahangdale

Abstract
Soil is the essence of life on earth. It serves as a natural medium for the growth of plants that sustains human and animal life. Healthy soils provide us with a range of ecosystems services such as resisting erosion, receiving and storing water, retaining nutrients and acting as an environment buffer in the landscape. Soil health is the foundation of productive farming practices. Fertile soil provides essential nutrients to plants. The current industrial agriculture systems promotes the belief on agrochemicals, both synthetic fertilizers and pesticides, while neglecting to consider their negative impact on the ecosystems, human health. In high productive regions, excessive and imbalanced use of agrochemicals often leads to decline in soil fertility, quality and soil health. This paper mainly focus on the issues related to the modern agricultural practices with special emphasis on impact of excessive and imbalanced agrochemicals on deterioration of soil health and quality.

Keywords: Agrochemicals, Fertilizers, Pesticides, Soil degradation, Soil health, Soil quality and Soil microorganisms.

Introduction
Soil is crucial to life on earth. Non- renewable resource, composed of mineral and organic solids, gases, liquids and living organism which serve as medium for plant growth. The quantity of these components in the soil does not remain the same but varies with the locality. Soil serves many vital functions in our society, particularly for food production. It is thus of extreme importance to protect this resource and ensure its sustainability. Therefore, it is essential to make an adequate land management to maintain the quality of soil. Soil is a fundamental resource base for agriculture production systems. Besides being the main medium for plant growth, soil functions to sustain plant productivity, maintain environmental quality and provide nutrition for plant, animal and human health. Until the industrial revolution of the early to mid-1900s, farming practices were relatively environmentally friendly. But as agricultural modernization progressed, the ecology-farming linkage was often broken as ecological principle were ignored and overridden. The modernization of farming practices around the 1950's, resulted in extreme increases in productivity often to the detriment of environmental quality.

Agrochemical: The chemicals used in agriculture to maintain or to increase the crop production. There are three classes of Agrochemicals viz., 1) Plant production chemicals (Fertilizers), 2) plant protection chemicals (Pesticides) and 3) plant growth regulators (Adjuvants, Synergists)

Modern agricultural practices use intensive tillage, monoculture, irrigation, application of inorganic fertilizers, chemical pest control and plant genome modification to maximize profit and production. However extensive depend on these practices have les to soil degradation which is one of the most serious consequences of agriculture.

- Pollution of soil and water through the over use of fertilizer.
- Deterioration of soil quality and reduction in agricultural productivity due to nutrient depletion, organic matter losses, erosion and compaction.
- Loss of beneficial crop associated biodiversity that provides ecosystem services such as pollination, nutrient cycling and regulation of pest and disease outbreaks.
- Soil salinization, depletion of freshwater resouces and reduction of water quality due to unsustainable irrigation practices.
- Disturbance of soil physicochemical and biological process as a result of intensive tillage

and slash and burning.

Soil Degradation

Soil can be degraded by salting, water logging, compaction, pesticide contamination, decline in soil structure quality, loss of fertility and erosion (Gliessman 1998) [6]

The term 'Soil Degradation' refers to process that cause a reduction in its capacity to produce goods viz., crop, fodder and services viz., regulation of water and nutrients. Soil degradation is an antonym of soil quality. Soil degradation is a major concern of modern times because of its adverse impacts on productivity, human and animal health, air and water quality, especially on local, regional and global scale. It is estimated that out of the 329 Mha of total geographical area (TGA) in the country, the total degraded area accounts for 120.7 Mha, of which 73.3 Mha area is affected by water erosion, 12.4 Mha by wind erosion, 6.73 Mha by salinity and alkalinity and 25 Mha by soil acidity (Handbook of Agriculture 2009). There are three principal type of degradation: Physical, Chemical and Biological and together they affect the soil productivity as briefly described below.

1) Physical Degradation

It is caused when agricultural practices impact the physical property of soils in ways that result in adversely impacting critical soil functions. In intensively cultivated soils, repeated use of heavy farm machinery for tillage related activities often results in compaction and formation of hardpan at the plough depth. Agricultural practices causing reduction in the soil's organic matter (e.g. repeated tillage, burning crop residues, little or no recycling of farm wastes etc) makes soils more prone to physical degradation.

2) Chemical Degradation

Refers to processes that cause changes in the chemical environment of soils adversely impacting their productivity. Amongst common farming practises, inappropriate use of chemical fertilizers and pesticides can contributes significantly to the degradation process. There is evidence that prolonged use of heavy doses of fertilizers can results in soils becoming more acidic that has serious implications in terms of long term productivity of soils. Pest control chemicals utilised to eliminate unwanted pests are also detrimental to living organisms in the soil, vitol to soil health and productivity.

3) Biological Degradation

Soils are a habitat to a large variety of flora and fauna that contribute a significant part of our biodiversity resource. Organic matter is the main food base of living organisms in the soil and soil organisms perform vitol functions that contributes to sustained productivity of soils. Reduced recycling of organics throught the soil is the primary factor leading to a decline in the extent and diversity of living organisms within it. Mono cropping where the same crop are grown repeatedly year after year without adopting crop rotations also lead to decline in soil biodiversity.

The causes of soil degradation are anthropogenic perturbations related to socioeconomic pressures and population growth. These causes trigger human activities or factors responsible for soil degradation. Some important factors are deforestation cultivation of marginal lands, intensive farming, excessive and indiscriminate use of chemicals, excessive grazing with high stocking rate, population transmigration and infrastructure development in ecologically sensitive areas, etc. (Lal and Stewart 1990)

Soil Quality and Soil Health

The terms soil health and soil quality are becoming increasingly familiar worldwide. Doran and Parkin (1994) [2] defined soil quality as "the capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality and promote plant and animal health. Soil health is defined as the continued capacity of soil to function as a vital living system by recognizing that it contains biological elements that are key to ecosystem function within land use boundaries. These functions are able to sustain biological productivity of soil, maintain the quality of surrounding air and water environments as well as promote plant, animals and human health. The quality and health of soil determine agricultural sustainability environment quality and as a consequence of both plant, animal and human health.

Impact of agrochemical used on soil quality

It is commonly known that extensive farming uses relatively small amounts of labor and capital. It produces a lower yield per unit of land and thus requires more land than intensive farming practices to produce similar yields, so it has a larger crop and grazing Footprint. However, intensive farms, to achieve higher yields, apply various external agricultural inputs to agricultural production systems which include mineral fertilisers such as urea, ammonium nitrate, sulfates, and phosphates; organic fertilisers such as animal manures, composts, and biosolids; various other organic products such as humic acids and microbial inoculants, and pesticides including herbicides, insecticides, nematicides, fungicides, veterinary health products, and soil fumigants. All these products are applied with the ultimate goal of maximising productivity and economic returns. However, extensive application of external agricultural inputs to agricultural production systems leads to deterioration of soil quality. Agricultural practices that use high amounts of external-inputs, such as inorganic fertilizers, pesticides, and other amendments, can overcome specific soil constraints to crop production. These practices have led to considerable increases in overall food production in different parts of the world. Agriculture has affected the quality and quantity of SOM on many different levels. Agricultural practices contribute to the depletion of SOC through deforestation and biomass burning, drainage of wetlands, tillage, crop residue removal, summer fallow, cultivation, and overuse of pesticides and other chemicals (Lal, 2002) [8]. However, especially in the most intensively managed systems, this has resulted in continuous environmental degradation, particularly of soil, vegetation and water resources, such as in the state of Haryana in India. Amongst common farming practices, inappropriate use of chemical fertilisers and pesticides can contribute significantly to the soil quality degradation process. Soil organic matter levels are declining and the use of chemical inputs is intensifying (Singh, 2000) [16].

According to the (USDA) Natural Resource Conservation Service, "Soil quality is how well soil does what we want it to do". Soil fertility is only one component of soil quality. Fertile soils are able to provide the nutrients required for plant growth. These are the chemical components of soil. Soil contamination or soil pollution is caused by the presence of man-made chemicals or other alterations in the natural soil

environment. Agricultural chemicals, industrial activity or improper disposal of wastes typically causes it. Agrochemicals are used in agricultural setting in an effort to ensure an abundant food supply. Many important benefits are achieved by the use of agrochemicals. These are largely associated with increased yields of plant and animal crops, and less spoilage during storage. These benefits are substantial. In combination with genetically improved varieties of crop species, agrochemicals have made important contributions to the successes of the "green revolution." This has helped to increase the food supply for the rapidly increasing population of humans on Earth. However, the use of certain agrochemicals has also been associated with some important environmental and ecological damages. Extensive application of external agricultural inputs to agricultural production systems leads to soil quality degradation. Organic (carbon-based) pollutants that impact soil quality include pesticides. Pesticides, which are very persistent in soil, slowly break down and result in source of contamination. (Stephenson and Solomon, 1993) [18]. Soil acts as filter, buffer and degradation potentials with respect to storage of pollutant with the help of soil organic carbon (Burauel and Bassmann, 2005), but it is recognized that the soil is a potential pathway of pesticide transport to contaminate water, air, plants, food and ultimately to human via, runoff and sub-surface drainage; interflow and leaching; and the transfer of mineral nutrients and pesticides from soil into the plants and animals that constitute the human food chain (Abrahams, 2002). The capacity of the soil to filter, buffer, degrade, immobilize, and detoxify pesticides is a function or quality of the soil. Soil quality also encompasses the impacts that soil use and management can have on water and air quality, and on human and animal health. Inappropriate use of chemical fertilisers and pesticides, amongst common farming practices, can contribute significantly to the soil degradation process. There is evidence that prolonged use of heavy doses of fertilisers can result in soils becoming more acidic that has serious implications in terms of long term productivity of soils. Inappropriate, viz. imbalanced or excessive, use of fertilisers is a major cause of pollution of ground waters or surface water bodies resulting from inefficient use of applied nutrients. Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation. Environmental risk due to soil pollution is of particular importance for agricultural areas, as extensive reliance on agrochemicals for agricultural productions have immensely resulted in the accumulation of various heavy metals in the soil leading to serious consequences. Thus pollution of heavy metals poses a threat to a country's food production. Some fertilizers and pesticides are known to contain various levels of heavy metals, including Cd and Cu (Kabata-Pendias and Pendias, 1992) [7]. Therefore, continuous and heavy application of these agrochemicals and other soil amendments can potentially exacerbate the accumulation of heavy metals in agricultural soils over time (Siamwalla, 1996; Chen *et al*. 2007) [15].

Impact of agrochemical on soil microorganisms

Soil microorganisms play a key role in soil. They are essential for maintenance of soil structure, transformation and mineralization of organic matter, making nutrients available for plants. External agricultural inputs such as mineral fertilisers, organic amendments, microbial inoculants, and pesticides are applied with the ultimate goal of maximising productivity and economic returns, while side effects on soil organisms are often neglected. The excessive agrochemicals application reduces the biodiversity of the soil. The microorganisms of soil are more spoiled by soil disturbance by application of chemicals than any other parameters. The communities of beneficial microorganisms in soil have declined due to overuse of pesticides, which has a negative impact on the available nitrogen, phosphorus and potassium (NPK) from soil (Sardar and Kole, 2005) [14], thereby degrading the soil quality. Important processes like mineralization, nitrification and phosphorus recycling are dependent much on the balanced equilibrium existing among various groups of organisms in the soil. However, extensive pesticidal usage disturbs the presence of soil enzymes, which are pivotal for the mentioned processes and for matter turnover. Fungicides generally had even greater effects on soil organisms than herbicides or insecticides. As these chemicals are applied to control fungal diseases, they will also affect beneficial soil fungi and other soil organisms. Copper- based fungicides were found to have very significant negative effects, which caused long-term reductions of earthworm populations in soil (Van Zwieten *et al*. 2004; Eijsackers *et al.* 2005; Loureiro *et al.* 2005) [19, 3, 9]. Merrington *et al.* (2002) [11] further demonstrated significant reductions in microbial biomass, while respiration rates were increased, and showed conclusively that copper residues resulted in stressed microbes. Organophosphate insecticides (chlorpyrifos, quinalphos, dimethoate, diazinon, and malathion) had a range of effects including changes in bacterial and fungal numbers in soil (Pandey and Singh 2004), varied effects on soil enzymes (Menonetal. 2005; Singh and Singh 2005), as well as reductions in collembolan density (Endlweber *et al.* 2005) [4] and earthworm reproduction (Panda and Sahu 1999) [12]. A few studies show that some organochlorine and organophosphorus pesticides suppress symbiotic nitrogen fixation resulting in lower crop yields. (Fox *et al.,* 2007; Potera 2007) [5].

Conclusions

The dynamic nature of soil biology, and the effects of environment on the fate of chemical or fertiliser added and on the populations of different functional groups of biota, makes it very difficult to draw conclusions about the impacts of various inputs in our agricultural systems. Healthy soil is essential for the production of crops used to feed humans and livestock. In addition to providing a stable base to support plant roots, soil stores water and nutrients required for plant growth.

Unfortunately, industrial agriculture practices continue to damage and deplete this valuable natural resource. While intensive plowing and monocrop agriculture systems have caused nutrient depletion and wide-scale soil erosion, over-application of fertilizers and pesticides has contaminated our soils and polluted our waterways. There are proven alternatives to this expensive agriculture system: farmers are aware of and already fertilizing soils and protecting crops with organic and sustainable techniques that work with nature, not against it, and can provide food for all (Pretty *et al*. 2003, Badgley *et al.* 2007) [13, 1]. Fortunately, many farmers are choosing to use sustainable agricultural techniques such as conservation tillage, crop rotation, and organic manure, use of biopesticides, bioinsecticides, crop residue management in order to protect our valuable soil resources.

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