

Impact of Modern Agriculture Practices on Soil Health: A Review

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Abstract:

Soil is the major source and important component for the production of crop in the field of agriculture. The leading productions by the field crops are due to the physical, chemical and biological properties which directly influence the soil productivity. The nature of the soil mainly depends upon the different parameters such as pH, Conductivity, Salinity, Alkalinity, Bulk density, Moisture content etc. The heavy use of inorganic chemical fertilizers, pesticides include herbicides, insecticides, intensive farming and monoculture in a part of crop production which directly showing impact on physicochemical parameters of soil health. For maintaining soil fertility, this study shows that agricultural yields could be increased by modern agriculture practices. This review identifies the most suitable farming practices for improving soil health while boosting crop production with minimal negative impact on the soil health. It also highlights the benefits of these practices in maintaining soil quality. Therefore this review is obtained for concluding that the soil quality was degraded because of heavy loads of chemical fertilizers, pesticide, Monoculture and other intensive practices in modern agriculture.

Keywords: Soil quality, Pesticides, Monoculture, Herbicides, Chemical fertilizers Salinity, Alkalinity etc.

Introduction:

Modern farming is a term used to describe the application of scientific and advances techniques in farming practices. It involves the use of chemical fertilizer, farm equipment's and intensive farming as well as application methods to improve crop and livestock production, increase efficiency and reduce the environmental impact of farming. Agriculture has been considered as a way of life ever increasing population place greater demand on agriculture to increase the production to match increasing demand of food supply with agriculture development through food production has successfully nearly everywhere.

Other modern farming practices include the use of genetically modified crops, which have been engineered to resist pests and tolerate herbicides, as well as the use of drip irrigation systems, which conserve water by delivering water directly to plant roots. Modern farming often incorporates precision agriculture techniques, which involve the use of sensors, GPS mapping and other tools to monitor and manage crops and livestock more precisely. This approach can help farmers optimize inputs, reduce waste, and increase yields while minimizing the use of chemicals and other resources. Overall, modern farming is focused on increasing the productivity and profitability of farming while minimizing its impact on soil health.

Soil quality as “the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality and promote

plant and animal health.” On the other hand, the ability of soil to function as a living system that supports plant, animal and human life is referred to as soil health Doran and Parkin (1994) and Baveye, (2016). Fertile soil contains a balanced mixture of organic and inorganic matter, such as minerals and nutrients, as well as microorganisms like bacteria and fungi. Soil fertility is essential for agriculture because it directly affects the productivity and yield of crops. The availability of essential nutrients like nitrogen, phosphorus and potassium, as well as trace elements like iron, copper and zinc can impact on plant growth and development.

Soil fertility can be influenced by a variety of factors including climate, soil type, topography and land use practices. Farming practices that can improve soil fertility include crop rotation, cover cropping and the use of organic fertilizers like compost and manure. These practices can help to maintain or increase the organic matter content of the soil, which can enhance soil structure and water-holding capacity. Overall, maintaining soil fertility is essential for sustainable agriculture and long-term food security, as it can help to increase crop yields, reduce the need for synthetic fertilizers and other inputs, and enhance soil health and resilience.

Concept of Soil Health:

The terms “soil health” and “soil quality” are used frequently as soil gains more attention in the global policy field. However, it is currently unclear how the two ideas differ and operational processes for measurement are still being developed (Lehmann, *et al*, 2020 and Arshad, *et al*, 2024).

The soil capability is referred to in terms of soil health and soil quality. Soil health and soil quality are frequently used synonymously. In actuality, it is difficult to distinguish the two concepts apart, as stated by Lal (2016) and Lehmann *et al.*, (2020). In this context, Bünemann, *et al.* (2018) expressed the definition of soil quality as “the capacity of a soil to function within ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health.” On the other hand, the ability of soil to function as a living system that supports plant, animal and human life is referred to as soil health by Bonfante, (2020)

Impact of chemical fertilizer on soil health

Chemical fertilizers are synthetic substances that are applied to crops to provide essential nutrients for growth and productivity. They are widely used in modern agriculture to increase crop yields and meet the demands of a growing population. The application of fertilizers not only increases crop productivity, but also alters soil physicochemical and biological properties. However, the use of chemical fertilizers has both positive and negative impact on soil health. On the positive side, chemical fertilizers can increase crop yields and improve plant growth by providing essential nutrients such as nitrogen, phosphorus and potassium. This allows farmers to produce more food on the same amount of land, which can help to feed a growing population. However, the excessive and improper use of chemical fertilizers can have negative impacts on soil health. Overuse of chemical fertilizers can lead to soil compaction, nutrient imbalances and soil acidification. It can cause a decline in soil fertility, reduce crop yield over time, and increase the risk of soil erosion and runoff. (Phad, 2023)

However, continuous utilization of chemical fertilizers is responsible for the decline of soil organic matter (SOM) content coupled with a decrease in the quality of agricultural soil. The overuse of chemical fertilizers hardens the soil, reduces soil fertility, pollute air, water and soil. The continuous utilization of chemical fertilizers led to reduces microbial activity in soil. Constant use of chemical fertilizer can alter the pH of soil, increase pests, acidification and soil crust, which results in decreasing organic matter load, humus and useful organisms, stunting plant growth and even become responsible for the emission of greenhouse gases. (Heena, *et al.*, 2021)

Soil acidity can occur as a result of using chemical fertilizers. Chemical fertilizers can increase soil acidity when they contain ammonium-based compounds such as ammonium nitrate or ammonium sulphate. When these compounds are applied to the soil, they undergo a chemical reaction that releases hydrogen ions, which increases the acidity of the

soil. Over time, the repeated use of chemical fertilizers can lead to a build-up of acidic compounds in the soil. This can have negative effects on plant growth and soil health. Plants require a specific pH range to grow optimally, and if the soil becomes too acidic, it can reduce the availability of nutrients and make it more difficult for plants to absorb water. Furthermore, soil acidity can also impact soil organisms such as earthworms, fungi and bacteria. These organisms play an important role in maintaining soil health and fertility, but their populations can decline in acidic soils. (Phad, 2023)

While chemical fertilizers provide essential nutrients to plants, their overuse can lead to nutrient depletion in the soil. Chemical fertilizers typically provide only three macronutrients such as nitrogen, phosphorus and potassium and sometimes a few micronutrients. However, they do not add organic matter to the soil, which is an essential source of nutrients for plants. When chemical fertilizers are applied to the soil in excess, they can lead to the build-up of salts and other compounds that can increase soil density and reduce pore space between soil particles. This can make it harder for roots to penetrate the soil and limit the amount of water and nutrients that plants can absorb. It can also reduce the water holding capacity of the soil, leading to decreased crop yields and increased susceptibility to drought. (Phad, 2023)

Remedies for negative impacts of chemical fertilizers on soil health

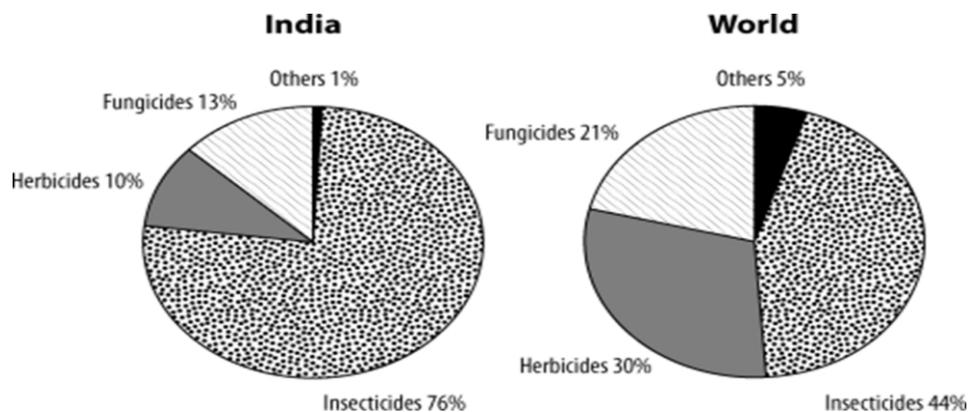
- **Use organic fertilizers:** Organic fertilizers are derived from natural sources, such as compost, manure, and other organic materials. They can provide nutrients to the soil and support the growth of beneficial soil organisms, while reducing the risk of nutrient runoff and pollution.
- **Adopt integrated nutrient management (INM) practices:** INM is a holistic approach that involves the use of chemical fertilizers in combination with organic fertilizers, crop residues and other nutrient sources. This can help to optimize nutrient use efficiency and minimize the negative impacts of chemical fertilizers on soil health
- **Implement precision agriculture techniques:** Precision agriculture involves the use of technology, such as sensors and drones, to optimize the use of inputs, such as fertilizers and water, based on the specific needs of each crop and soil type. This can help to reduce the amount of chemical fertilizers used, while maximizing crop yields and minimizing environmental impacts.
- **Use cover crops:** Cover crops are crops that are planted in between main crops to protect and improve the soil. They can help to reduce soil erosion, improve soil health and reduce the need for chemical fertilizers.

- **Practice crop rotation:** Crop rotation involves the alternating of different crops in the same field over time. This can help to improve soil health, reduce the risk of plant diseases and reduce the need for chemical fertilizers.
- **Soil health card:** Soil Health Card (SHC) provides information to farmers on soil nutrient status (low, medium & high) and recommendation on appropriate dosage of nutrients to be applied for improving soil health to increase agricultural production.
- **Soil testing:** Soil testing helps reduce the negative impact of chemical fertilizers by providing data-driven recommendations for application rates, minimizing nutrient losses, and promoting sustainable soil health. By understanding the specific needs of your soil, you can apply the right amount of fertilizer at the right time, avoiding over-fertilization and its associated problems.
- **Role of legumes crop:** Legumes can significantly reduce the reliance on chemical fertilizers by fixing atmospheric nitrogen through a symbiotic relationship with bacteria. This process, called biological nitrogen fixation (BNF), adds nitrogen to the soil, a key nutrient for plant growth, and can substitute or reduce the need for synthetic fertilizers. Legumes also enhance soil health and fertility in other ways.

Impacts of pesticides on soil health:

The pattern of pesticide usage in India is different from that for the world in general. As can be seen in Figure 1, in India 76% of the pesticide used is insecticide, as against 44% globally (Mathur, 1999). The use of herbicides and fungicides is correspondingly less heavy. The main use of pesticides in India is for cotton crops (45%), followed by paddy and wheat.

Figure 1, Pattern of pesticide usage in India and World.



The pesticides and their transformation products (TPs) are retained by soils to different degrees, depending on the interactions between soil and pesticide properties. The most influential soil characteristic is the organic matter content. The larger the organic matter content, the greater the adsorption of pesticides and TPs. The capacity of the soil to hold positively charged ions in an exchangeable form is important with paraquat and other pesticides that are positively charged. Strong mineral acid is required for extracting these chemicals, without any analytical improvement or study reported in recent years. Soil pH is also of some importance. Adsorption increases with decreasing soil pH for ionizable pesticides (e.g. 2,4-D, 2,4,5-T, picloram, and atrazine) (Andreu and Pico', 2004).

Effect of pesticides on soil properties:

- **Harm to Beneficial Organisms:** Pesticides, especially persistent ones, can kill or harm beneficial soil organisms like earthworms, fungi, and bacteria, which are crucial for nutrient cycling, soil structure and overall soil health.
- **Reduced Soil Fertility:** The loss of beneficial microorganisms can lead to reduced soil fertility, making it harder for plants to absorb nutrients.
- **Soil Contamination:** Pesticides can contaminate soil, water and air, posing risks to human and animal health.
- **Altered Soil Chemistry:** Pesticides and fertilizers can alter soil pH, leading to acidification and potentially harming plant growth and beneficial microorganisms.
- **Soil Degradation:** Overuse of pesticides can contribute to soil degradation, reducing its ability to support plant growth and ecosystem function.

Examples of adverse effect of pesticides:

- **Imidacloprid, chlorpyrifos, and phorate:** have shown negative impacts on earthworms.
- **Carbofuran, iprodione, and simazine:** they have negative impacts on soil microflora.
- **Glyphosate,** a widely used herbicide, can harm soil bacteria and mycorrhizal symbiosis with plant roots.

Heavy treatment of soil with pesticides can cause populations of beneficial soil microorganisms to decline. According to the soil scientist Dr. Elaine Ingham, "If we lose both bacteria and fungi, then the soil degrades. Overuse of chemical fertilizers and pesticides have effects on the soil organisms that are similar to human overuse of antibiotics. Indiscriminate use of chemicals might work for a few years, but after a while, there aren't enough beneficial soil organisms to hold onto the nutrients" (Savonen, 1997).

For example, plants depend on a variety of soil microorganisms to transform atmospheric nitrogen into nitrates, which plants can use. Common landscape herbicides disrupt this process: triclopyr inhibits soil bacteria that transform ammonia into nitrite (Pell *et al.*, 1998); glyphosate reduces the growth and activity of free-living nitrogen-fixing bacteria in soil (Santos and Flores, 1995) 2,4-D reduces nitrogen fixation by the bacteria that live on the roots of bean plants (Arias and Fabra, 1993) inhibits the transformation of ammonia into nitrates by soil bacteria (Frankenberger *et al.*, 1991, Martens and Bremner, 1993). Mycorrhizal fungi grow with the roots of many plants and aid in nutrient uptake. These fungi can also be damaged by herbicides in the soil. One study found that oryzalin and trifluralin both inhibited the growth of certain species of mycorrhizal fungi (Kelley and South, 1978).

Roundup has been shown to be toxic to mycorrhizal fungi in laboratory studies, and some damaging effects were seen at concentrations lower than those found in soil following typical applications (Chakravarty and Sidhu, 1987). Plants can also suffer indirect consequences of pesticide applications when harm is done to soil microorganisms and beneficial insects. Pesticides including those of new the generation, e.g., dacthal, chlorothalonil, chlorpyrifos, metolachlor, terbufos and trifluralin have been detected in Arctic environmental samples (air, fog, water, snow) (Rice and Cherniak, 1997),

Impacts of Monoculture on Soil Health:

Mono cropping is the practice of growing the same crop on the same plot of land, year after year. This practice depletes the soil of nutrients (making the soil less productive over time), reduces organic matter in soil, cause significant erosion and finally decline in crop productivity. Mono-cropping system is varied from place to place due to a large share of farmers in cropping system is resource poor, with limited access to off-farm income, and has been pushed into maize mono-cropping in an effort to meet household's staple food consumption requirements (Nielson, H. H., 2009). Effect of Monoculture Farming Planting the same crop in the same place each year zaps nutrients from the earth and leaves soil weak and unable to

support healthy plant growth. Because soil structure and quality is so poor, farmers are forced to use chemical fertilizers to encourage plant growth and fruit production. Continuously growing the same crop in the same field leads to a low diversity of functional soil microbial community, accumulation of some host-specific soil-borne pathogens and an imbalance of soil nutrient contents (Ryszkowski *et al.*, 1998).

Monocultures can negatively impact soil health by depleting nutrients and reducing species variety. Monocultures, can have significant impacts on soil health. This is primarily due to the fact that different plants require different nutrients from the soil. When the same crop is grown repeatedly, it continuously draws the same nutrients from the soil, leading to nutrient depletion. Over time, this can result in soil degradation, as the soil becomes less fertile and less able to support healthy plant growth. This can lead to increased reliance on synthetic fertilizers, which can further degrade soil health by disrupting the natural balance of nutrients in the soil. Mono cropping practice in agriculture, and usually causes serious economic losses due to soil degeneration, decreased crop yield and quality and increased disease incidence and pest occurrence. It may due to changes in soil microbial communities, nutrient availability and allelopathy effect. Tegegn and Eshetu, (2023).

Effect of Monoculture on soil properties:

- **Nutrient Depletion:** Monoculture farming concentrates on a single crop, leading to the repeated extraction of the same nutrients from the soil. Different plants have different nutrient requirements, and monoculture depletes the soil of specific nutrients needed by that particular crop, leading to imbalances and reduced overall fertility.
- **Reduced Soil Structure and Erosion:** Monoculture can negatively impact soil structure, making it more prone to compaction and erosion. The lack of diverse root systems in monoculture systems can lead to reduced soil aggregation and water infiltration, further exacerbating soil degradation.
- **Decreased Soil Biodiversity:** Monoculture reduces the diversity of plant species, which in turn impacts the diversity of soil organisms, including beneficial bacteria, fungi, and earthworms. A diverse soil ecosystem is crucial for maintaining soil health, nutrient cycling, and overall soil fertility.
- **Increased Reliance on Synthetic Inputs:** Due to nutrient depletion and soil degradation, monoculture farming often necessitates the use of synthetic fertilizers and pesticides to maintain crop yields. These synthetic inputs can further disrupt the natural balance of the soil and have negative environmental consequences.

- **Soil Organic Matter Loss:** Monoculture farming can lead to a decline in soil organic matter, which is essential for soil fertility, water retention, and nutrient availability. Reduced plant diversity and root biomass in monoculture systems contribute to lower organic matter inputs into the soil.

Impact of Intensive farming on soil health:

Intensive farming can have severe impact on soil such as acidification, nitrification, desertification, decline in organic matter in soil, soil contamination (e.g., by heavy metals and agrochemicals), soil compaction and erosion. Such degradation can result from inappropriate farming practices such as excessive fertilization, improper use of pesticides and the use of heavy machinery.

Some intensive agricultural activities implement inadequate soil management practices, such as the cultivation of monocultures and the excessive and inadequate use of chemical fertilizers and pesticides, reducing soil biodiversity and provoking leaching processes, the eutrophication of aquifers due to runoff phenomena, and salinization/acidification (Wang, et al., 2019). The leading issues like erosion, nutrient depletion and reduced organic matter, ultimately decreasing soil fertility and productivity

Mitigation Strategies for improving soil health:

- **Sustainable Farming Practices:** Implementing sustainable farming practices, such as crop rotation, cover cropping, and reduced tillage, can help improve soil health and reduce the negative impacts of intensive farming.
- **Organic Farming:** Organic farming avoids synthetic fertilizers and pesticides, which can help reduce soil contamination and improve soil health.
- **Conservation Agriculture:** Conservation agriculture practices, such as no-till farming and covers cropping, can help improve soil structure, reduce erosion and increase water infiltration.
- **Soil Health Management:** Implementing soil health management practices, such as building soil organic matter and improving soil structure, can help improve soil fertility and productivity.

Conclusion:

In conclusion, modern agriculture practices have had both positive and negative impacts on agriculture. While application of modern agriculture practices that have led to increased productivity, improved market access, reduced risk, better resource management and new employment opportunities, they have also contributed to soil degradation, biodiversity loss and other environmental problems. To ensure that modern agriculture methods continue to provide

benefits to farmers while minimizing their negative impacts on soil health. It is important to promote sustainable farming practices that prioritize soil health, biodiversity and resource efficiency. This can include practices such as conservation agriculture, crop rotation, cover cropping, sustainable agriculture, organic farming and integrated nutrient management. Additionally, it is also important to ensure that small-scale farmers have access to these modern farming methods and are not left behind as agriculture continues to evolve. By promoting sustainable farming practices and ensuring that all farmers can benefit from modern farming methods, we can create a more resilient and sustainable agricultural system that benefits both farmers and the soil environment.

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Conflict of Interest: Nil

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