Chapter 1
Nanotechnology in Restoration of Degraded Soil Fertility

Chadetrik Rout
https://orcid.org/0000-0003-3582-1776
M.M. Engineering College, Maharishi Markandeshwar, India

Diwakar Aggarwal
https://orcid.org/0000-0001-6920-4341
Maharishi Markandeshwar, India

ABSTRACT

Soil fertility degradation caused by factors such as erosion, organic matter decline, loss of biodiversity, compaction, point-source and diffused contamination, pollution, salinization, and unsustainable agricultural practices poses serious challenges to global food security and ecosystem health. However, in recent years, nanoparticles, nanomaterials, and nanocomposites have shown promise in improving soil structure, nutrient availability, water retention, microbial activity etc. The development of nanoscale soil amendments is a key application of nanotechnology in soil restoration. These include nanoparticles that have been engineered to release nutrients gradually, increasing nutrient uptake by plants and reduce nutrient leaching. Furthermore, nanomaterials can act as carriers for beneficial microorganisms, shielding them from environmental stressors and ensuring efficient delivery to the soil.

1. INTRODUCTION

The capacity of soil to execute ecological activities such as promoting plant growth, regulating water and nutrient cycles, and providing habitat for soil organisms is referred to as soil quality (Giller et al., 1997). We all are aware of the fact that soil fertility must be maintained for sustainable agriculture and food security. Fertile soil contains the nutrients and minerals that plants need to flourish and thrive, resulting in high quality harvests. Without soil fertility, it would be difficult to sustainably produce enough food to support the world's population. To maintain soil fertility, it is important to implement sustainable agricultural practices such as crop rotation, cover cropping, reduced tillage, and organic farming. These

DOI: 10.4018/979-8-3693-1471-5.ch001

practices can help to maintain soil health and productivity over the long term while reducing negative impacts on the environment.

Soil degradation is the decline of soil quality caused by a variety of physical, chemical, and biological variables. It refers to the loss of the soil's basic physical, chemical, and biological qualities, which leads to decreased production and ecosystem functioning (Lal et al., 1989; Parr et al., 1992). This deterioration can occur naturally, but it is frequently hastened by human actions. Changes in soil structure, texture, and erosion induced by elements such as wind and water are examples of physical features of soil deterioration (Lal et al., 1989). Chemical degradation refers to the loss of critical nutrients, pH changes, and pollution from contaminants and chemicals (Lal, 2015). Deforestation, poor farming practices, urbanization, and industrialization all contribute considerably to soil degradation (Wairiu, 2017; Bhandari et al., 2015). Overexploitation, improper irrigation, and the excessive use of chemical fertilizers and pesticides further exacerbate the issue. As soil degradation progresses, affects soil fertility, water-holding capacity, and overall productivity as it develops, providing significant challenges to sustainable agriculture and ecosystem health (Doran et al., 2018). Soil deterioration must be addressed through a multidimensional strategy that includes soil conservation practices, afforestation, responsible land management, and the adoption of sustainable agriculture techniques. Recognising the significance of healthy soils in the maintenance of ecosystem services and food security is vital for minimising the effects of soil degradation on both the local and global scales (Zdruli et al., 2017; Rojas et al., 2016; Hurni et al., 2015; Montanarella and Vargas, 2012).

Nanotechnology has emerged as a positive approach to the restoration of degraded soil fertility (Upadhyay et al., 2022a, b; Rajput et al., 2022). As, soil degradation, characterized by a decline in its health and capacity to support ecosystems, is a significant challenge globally. The use of nanomaterials in soil restoration entails the enhancement of nutrient availability (Kah et al., 2019), microbial activity (Dinesh et al., 2012), and overall soil health (Usman et al., 2020). Nanoparticles can be engineered to release nutrients gradually, improving nutrient uptake by plants and reducing nutrient leaching (Liu and Lal, 2015). Furthermore, nanoparticles can act as transporters for beneficial microbes, accelerating their transportation to the soil and promoting plant development (Zvinavashe et al., 2021) and nutrient cycling (Zhang et al., 2021). Nanotechnology based approaches also enable the remediation of contaminated soils by facilitating the degradation of pollutants via photocatalysis and other processes (Bakshi and Abhilash, 2020). Soil restoration activities use nanotechnology to reverse deterioration trends, improve soil structure, boost water retention, and encourage sustainable farming practices. This technique has the potential to address global food security and environmental sustainability concerns by revitalising damaged soils and maintaining their long-term fertility and production. As a result, prevention, as well as treatment and revival of contaminated soils, is essential. Following cleanup, revitalised land may be used to satisfy the world's food and bioenergy demands.

2. NANOMATERIALS FOR SOIL RESTORATION

Soil restoration is a technique of revitalising and increasing soil health that is frequently used in the field of restoration ecology. It seeks to build new soil and improve current soil quality by reducing topsoil loss, preserving carbon, enhancing biodiversity, and guaranteeing correct water and nutrient cycling (Filho et al., 2023). Nowadays nanomaterials (due to their unique properties and potential benefits)