Chapter 10
Emerging Technologies for Sustainable Soil Management and Precision Farming

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DOI: 10.4018/979-8-3693-1471-5.ch010

ABSTRACT

Conventional agricultural practices often rely heavily on large amounts of fertilizers and pesticides, which can have detrimental effects on both existing organisms and ecosystems. In contrast, sustainable agriculture advocates for minimal use of agrochemicals to safeguard the environment and conserve various species.. Various techniques, including geoinformatics and the utilization of nanoparticles and nanoionics, contribute to advancements in agricultural productivity, poverty reduction, and food security. Geoinformatics methods aid in identifying soil types and their structures. Nanotechnology offers significant benefits in agriculture, including the development of nanofertilizers and nanopesticides, which enhance productivity without soil degradation while providing protection against insect pests and microbial diseases. This chapter aims to critically underscore the importance of geoinformatics, nanoparticles, and nanobionics as emerging tools for achieving sustainable agriculture.

INTRODUCTION

The significance of sustainable agriculture lies in its capacity to fulfill the needs of the present population while preserving resources for future generations (Singh et al., 2021., 2022, 2023). It embodies a contemporary farming approach aimed at maintaining environmental integrity and public health while ensuring nutritional value remains uncompromised. Despite the 20th-century advancements such as plant breeding leading to the development of new crop varieties, the 21st century presents novel challenges including climate change, global warming, and pollution, which have impacted grain production and crop quality (Vardumyan et al., 2024). The agricultural landscape has undergone remarkable transformations over time in response to the escalating demand for food driven by the ever-expanding global population. Projections from the Food and Agriculture Organization (FAO) of the United Nations suggest that by 2050, the world will be home to 9.7 billion people, necessitating a staggering 70% increase in food production. However, this imperative comes against a backdrop of dwindling agricultural land and water resources, compounded by the challenges posed by climate change. Consequently, the task of meeting this demand while minimizing environmental degradation has become increasingly daunting. Fortunately, the advent of emerging technologies offers a beacon of hope for the agricultural sector, promising to revolutionize traditional practices and pave the way for more effective and sustainable food production methods. By harnessing the power of precision agriculture, the Internet of Things (IoT), robotics, genetic engineering, and controlled environment agriculture, farmers stand to optimize their operations, boost productivity, and foster resilient food systems (Marina Voloshina, 2020; Singh, Mehrotra, et al., 2022). These cutting-edge innovations are reshaping the landscape of agricultural research, presenting a myriad of opportunities to tackle the sector's pressing challenges. Through the integration of these advancements, agricultural research can chart a course towards a future characterized by enhanced efficiency, resilience, and environmental stewardship. By leveraging the full potential of emerging technologies, the agricultural sector can ensure global food security and cultivate sustainable farming practices, thereby safeguarding the well-being of both present and future generations. Inadequate grain production poses threats to food security, necessitating measures to bolster production, achievable through three pivotal steps: detection, determination, and diagnosis. These steps entail precise analysis of diverse agricultural elements such as soil composition and the optimal utilization of fertilizers, herbicides, fungicides, insecticides, and pesticides tailored to each crop (Rajput, Singh, Minkina, Rawat, et al., 2021; Rajput, Singh, Minkina,

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