RADemics

Big Data Analytics and AI for Crop Rotation Planning and Sustainable Land Use

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Abstract

The growing pressures of climate change, soil degradation, and food security demands have heightened the need for innovative agricultural practices that balance productivity with sustainability. This chapter explores the transformative role of Big Data analytics and Artificial Intelligence (AI) in optimizing crop rotation planning and promoting sustainable land use. By leveraging real-time data from diverse sources such as soil sensors, satellite imagery, and weather forecasts, AI-driven systems can develop precise, adaptive crop rotation strategies that enhance soil health, mitigate environmental risks, and improve overall farm productivity. The chapter delves into the integration of AI models that predict long-term soil health impacts, optimize resource use, and provide dynamic crop rotation recommendations based on real-time environmental conditions. Emphasizing the importance of data standardization, quality assurance, and predictive analytics, the chapter outlines key challenges and opportunities in implementing these technologies at scale. It also discusses the potential of AI and Big Data to foster climate change adaptation in agriculture, ensuring that farming systems remain resilient to evolving environmental challenges. The integration of these technologies into sustainable land management practices promises to reshape the future of agriculture, enabling both increased food production and environmental preservation.

Keywords: Big Data Analytics, Artificial Intelligence, Crop Rotation, Sustainable Land Use, Climate Change Adaptation, Soil Health.

Introduction

The global agricultural landscape is undergoing a profound transformation driven by both technological advancements and the growing pressures of climate change, resource scarcity, and the need for increased food production [1]. Agriculture, traditionally reliant on empirical knowledge and established practices, is now entering an era of data-driven decision-making [2]. Crop rotation, a foundational practice for soil health and pest control, has long been an essential strategy for ensuring sustainable land use [3]. Yet, as farming systems become increasingly

complex, traditional methods of crop rotation are often inadequate in addressing the dynamic and multifaceted challenges faced by modern agriculture [4]. In this context, the integration of Big Data analytics and Artificial Intelligence (AI) is emerging as a revolutionary approach to optimizing crop rotation and enhancing land use sustainability. These technologies offer the ability to analyze vast amounts of data in real-time, enabling more precise, adaptive, and informed decisions that ensure both short-term productivity and long-term ecological balance [5].

Big Data analytics provides farmers with unprecedented access to information, offering insights into environmental conditions, soil health, crop performance, and weather patterns [6]. When combined with AI, these data streams can be transformed into actionable knowledge that supports optimized crop rotation strategies [7]. AI-driven systems, using machine learning algorithms and predictive modeling, can analyze large datasets to identify patterns, trends, and relationships that might not be immediately apparent through traditional methods [8]. This data-driven approach enables the development of tailored crop rotation schedules based on real-time environmental factors, reducing the reliance on generalized crop planning and fostering more sustainable and resilient farming practices [9]. The ability to continuously monitor and adjust crop rotation based on up-to-date information ensures that farming practices remain aligned with the evolving needs of the soil, climate, and crop production [10].

One of the key advantages of using Big Data and AI in crop rotation planning is their potential to enhance soil health and fertility over time [11]. Traditional crop rotation often involves fixed sequences of crops based on experience and regional knowledge, without considering the nuanced variations in soil conditions across different seasons [12]. By incorporating real-time data into crop rotation decisions, AI models can assess the impact of various crop combinations on soil nutrients, moisture levels, and microbial diversity [13]. This capability not only supports the regeneration of soil health but also mitigates the risks of nutrient depletion, soil erosion, and the buildup of pests and diseases [14]. The ability to predict the long-term effects of crop rotations on soil health allows for more sustainable land management, where crop choices are informed not just by short-term yield considerations but also by the ecological health of the land. This dynamic approach to crop rotation ensures that farming practices remain productive without compromising soil sustainability [15].