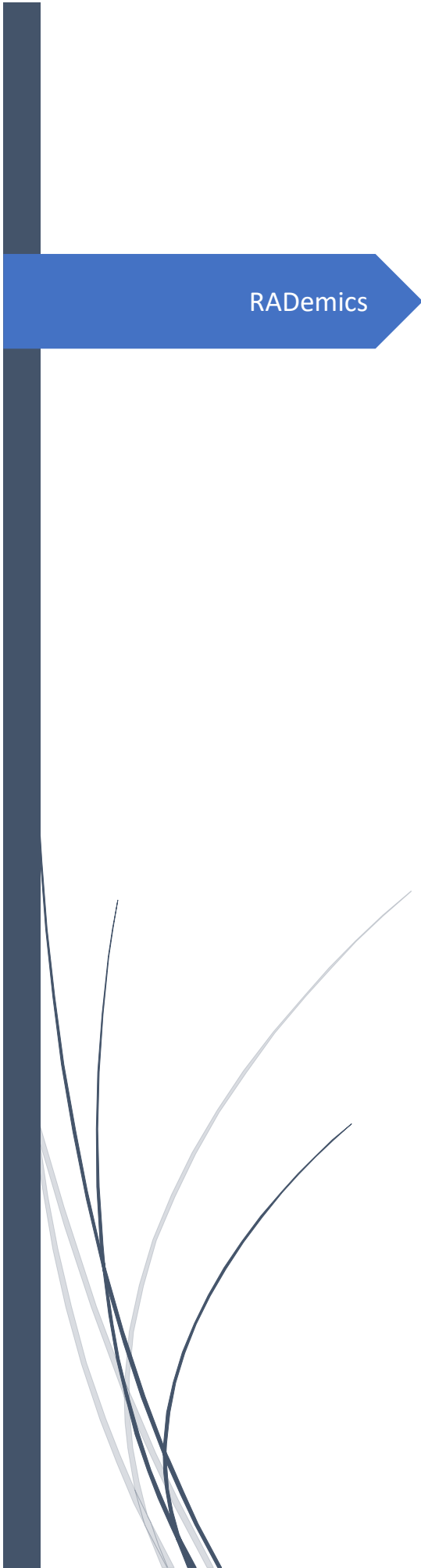


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RADemics

AI-Driven Fertilizer Recommendation Systems Using Big Data, Soil Health Indicators, and Predictive Models

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Abstract

The rapid advancement of artificial intelligence (AI) and big data technologies has revolutionized agricultural practices, particularly in the realm of fertilizer optimization. Traditional fertilizer application methods, often based on generalized recommendations, fail to account for the complex, dynamic nature of soil health, crop requirements, and environmental conditions. This chapter explores the integration of AI-driven fertilizer recommendation systems, focusing on the role of big data, soil health indicators, and predictive models in enhancing fertilizer efficiency. By leveraging real-time data from soil sensors, satellite imagery, weather forecasts, and crop performance metrics, AI models offer precise, context-specific recommendations that optimize nutrient application, reduce waste, and minimize environmental impact. The chapter highlights the significance of predictive models, particularly machine learning and deep learning techniques, in developing dynamic, adaptive systems capable of continuously adjusting fertilizer prescriptions based on changing field conditions. Furthermore, the role of transfer learning in adapting AI models across diverse agricultural regions is discussed, emphasizing its potential to overcome data scarcity and regional variability. Key challenges, including data integration, model interpretability, and the need for economic and environmental sustainability, are also addressed, providing a comprehensive overview of the current state and future trends in AI-driven fertilizer optimization. Ultimately, this chapter offers valuable insights into how AI, big data, and predictive analytics can drive sustainable agricultural practices while enhancing food production efficiency worldwide.

Keywords: Artificial Intelligence, Fertilizer Optimization, Big Data, Soil Health Indicators, Predictive Models, Precision Agriculture

Introduction

The global agricultural sector faces an increasing need for efficient resource management to meet the demands of a growing population [1]. Fertilizer management, in particular, plays a pivotal role in achieving higher crop yields, improving soil health, and ensuring sustainability [2]. Traditional approaches to fertilizer application, such as blanket recommendations based on crop type or region, often lead to inefficiencies, such as over-application or under-application of nutrients [3]. These inefficiencies result not only in economic losses for farmers but also contribute

to environmental degradation, including nutrient runoff and soil degradation [4]. To address these challenges, AI-driven fertilizer recommendation systems are emerging as a powerful solution, offering precision and adaptability in optimizing fertilizer use across diverse farming systems [5].

The integration of AI in agriculture, particularly in fertilizer management, represents a significant departure from traditional practices [6]. Big data, machine learning, and deep learning algorithms enable the analysis of large volumes of data from a variety of sources, including soil sensors, weather forecasts, and crop performance metrics [7]. These data-driven approaches allow for highly accurate and context-specific fertilizer recommendations [8]. By incorporating real-time environmental data, AI models can provide dynamic and adaptive fertilizer prescriptions that consider the unique conditions of each field [9]. This approach not only improves fertilizer efficiency but also reduces environmental impact, helping to move the agricultural sector toward more sustainable practices [10].

Incorporating AI into fertilizer optimization requires the use of predictive models that can process and analyze diverse data sources, such as soil nutrient levels, crop growth stages, and climate patterns [11]. Machine learning models, such as decision trees and regression models, are widely used in fertilizer recommendation systems to identify patterns and correlations within the data [12]. These models predict the appropriate fertilizer requirements based on the current state of the soil and the crop's nutrient needs [13]. More advanced AI techniques, such as deep learning, can handle large, complex datasets and learn intricate relationships between soil characteristics, environmental conditions, and crop responses [14]. This level of sophistication enables AI models to recommend precise, location-specific fertilizer applications that account for variations in soil type, climate, and other variables [15].