Artificial Intelligence Equipped Nutrient Management in Agriculture

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ABSTRACT

Agriculture plays a pivotal role in sustaining global food security and addressing the challenges of a growing population. The efficient use of nutrients in agriculture is crucial to mitigate environmental impact while maximizing crop yield. Artificial intelligence (AI) is revolutionizing nutrient management in agriculture. By analyzing real-time data on weather, soil conditions, and crop health from sensors, robots, drones, and satellites (via machine learning and image analysis), AI empowers farmers to make informed decisions on fertilizer application, minimizing environmental impact. Mobile apps and AI-driven drones further enhance this by identifying plant nutrient deficiencies, enabling targeted interventions. Technologies like plantix, green seeker, and fasal sense leverage sensors and AI to analyze soil composition, recommend nutrient management strategies, and enable targeted fertilizer application. AI offers innovative solutions for optimizing nutrient management, leading to a more sustainable and data-driven future for agriculture.

INTRODUCTION

The world's population is projected to reach nearly 9.7 billion by 2050, demanding a 70% increase in food production. However, with arable land per person shrinking from 0.56 hectares to 0.15 hectares, this presents a significant challenge. To meet this demand, farmers have relied on fertilizers, with India's average application rate

reaching 178 kg per hectare, well above the global average of 119 kg/ha. This has resulted in diminishing returns, with partial factor productivity dropping from 28 kg per kg in the 1970s to 10 kg/kg in 2022 (Shukla et al., 2022). Further, an imbalanced NPK use ratio in India; 11.8:4.6:1 compared to the ideal 4:2:1 has led to reduced crop productivity, increased disease susceptibility, and environmental consequences like soil degradation and water pollution. To address these challenges, effective nutrient management practices following the "5Rs" (right source, rate, time, place, and method) are essential. These practices optimize plant growth, maximize yields, maintain soil fertility, and minimize environmental impact. While various approaches, such as site-specific nutrient management and precision agriculture, have been employed to improve nutrient management, there is a growing need for faster, data-driven, and automated solutions. AI has emerged as a promising technology to meet these needs.

Artificial intelligence (AI):

AI simulates human intelligence in machines, enabling them to learn, reason, and perform tasks like decision-making and image recognition. Machine learning, neural networks, computer vision, natural language processing and big data are some of the key techniques used in AI. **Internet of Things** (IoT) is a network of sensors embedded in devices that collect real-time data on crops, soil, and environmental conditions.

In agriculture, AI leverages existing knowledge, is trained on vast datasets that include historical crop yields, soil composition, and libraries of plant images. This training enables AI to recognize patterns. Real-time data from IoT sensors is then used as raw material. By analyzing this data based on its learned patterns, AI generates actionable insights for farmers. These insights can include recommendations for optimal fertilizer application or early detection of problems. IoT provides the data, and AI performs the analysis, offering valuable recommendations.

AI and IoT in nutrient management:

AI algorithms can be used in diagnosing nutrient deficiencies or imbalances in the soil. Aleksandrov (2022) demonstrated the use of an artificial neural network (ANN) to identify nutrient deficiency based on chlorophyll fluorescence data, highlighting its effectiveness for early recognition. Similarly, an ANN model was developed for predicting macronutrient levels and suggesting fertilizer supplements which estimated NPK supplement levels and recommended appropriate compost treatment and application timing based on weather conditions (Ather et al., 2022). AI provides recommendations on fertilizers and treatments based on specific needs of soil using real-time data from IoT sensors and predicts future nutrient requirements based on historical data and weather patterns.

Applications of AI and IoT in nutrient management

Precision agriculture utilizes a suite of high-tech tools like GPS (Global positioning system), sensors, and drones to collect real-time field data on soil, weather, and crop health. Drones equipped with various sensors like hyperspectral and multispectral capture high-resolution NDVI (Normalized difference vegetation index) imagery for AI analysis. This analysis of plant health and stress from drone data empowers farmers with insights into soil conditions, nutrient deficiencies, and potential pest infestations. AI then guides targeted interventions like precise fertilizer application.

On the ground, tools like the teralytic probe and portable soil analyzer with multi-probes continuously collect real-time data on soil conditions including NPK levels, moisture,

temperature, and aeration. Teralytic sensor, a meter-long device with 26 sensors, gathers data on soil conditions every 15 minutes. This data helps to optimize fertilization.

For on-the-spot analysis, the AgroCares nutrient scanner utilizes AI through the AgroCares app to analyze nutrients in soil, leaves, or feed nutrients using a handheld NIR sensor. The 'Advisor application', which translates the soil data within 10 minutes into direct fertilizer recommendations for farmers was used by 37 organizations in Kenya, 20% of which are farmer cooperatives (Beek et al., 2018). Similarly, AgroPad utilizes a smartphone camera and AI to analyze colorimetric results from a soil or water sample on a test strip using machine learning algorithms. Both provide real-time data for optimizing fertilizer application.

Mobile apps like plantix and OneSoil leverage image recognition and satellite imagery, respectively, to diagnose crop issues and monitor crop health (NDVI). "See and spray" technology uses cameras and AI to target weeds for herbicide application. AI using computer vision locates weeds in field images, allowing for precise spraying (Yeshe et al., 2022).

Green Seeker, a non-destructive optical sensor, calculates NDVI to guide nitrogen fertilization. Nitrogen dose guided by green Seeker at different stages of different crops holds promise in achieving high yield and nitrogen use efficiency (Sahu et al., 2022). Fasal Sense, a sensor device with a companion app, continuously monitors factors like soil moisture and uses AI to analyze this data alongside weather and crop growth stages and suggests adjustments to fertilizer type, application rate, and timing. This approach has shown remarkable results in reducing fertilizer misuse (Ashoka et al., 2023).

KRISHI RASTAA (Rapid automatic soil testing and agronomy advisory) is a portable device that analyzes soil samples in 30 minutes and leverages AI to generate customized fertilizer recommendations. It is available in 6 languages and analyzes 12 soil parameters. By combining rapid soil testing with AI-powered analysis, KRISHI RASTAA offers a promising solution for sustainable and data-driven nutrient management in agriculture.

Nutrient Expert (NE) software analyzes data (soil tests, yields, weather) to create custom fertilizer recommendations for each field, minimizing waste and maximizing yields. NE-based nutrient management had significant effects over farmer's practice and government recommendation leading to positive changes on yield and economic performance under varied growing environments (Timsina et al., 2021).

CONCLUSIONS:

AI is revolutionizing nutrient management. It's dynamic decision-making based on real-time data from sensors, drones, and satellites allows for pinpoint accuracy. Timely preventive measures can be taken to address deficiencies before they impact crops. This data-driven approach ensures crops receive the right nutrients at the right time, promoting sustainability and meeting food demand efficiently.

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