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Brief career highlights (less than 250 words): Dr. Steve Phillips is the Nutrients for Life Foundation Professor of Crop Nutrition at Oklahoma State University, USA and President of the International Society of Precision Agriculture (ISPA). He earned his Ph.D. from Oklahoma State University and has over 25 years of experience in leading applied crop nutrition and precision agriculture (PA) research and educational outreach programs worldwide. He began his academic career at Virginia Tech, USA as a soil fertility research and extension specialist, where he developed the first crop sensor–based nutrient management algorithms for the eastern USA. He later served as North American Director for the International Plant Nutrition Institute and most recently, he was Principal Scientist at the African Plant Nutrition Institute, based in Morocco, where he led PA research and extension activities across the continent. He is the founder of the African Association for Precision Agriculture and the African Conference on Precision Agriculture and has been an active ISPA member since 2010. Steve has authored over 200 scientific and extension publications and delivered keynote lectures in more than 20 countries. His research focuses on spatial and temporal drivers of crop yield response and multi-layer precision management effects on nutrient dynamics.

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PRECISION NUTRIENT MANAGEMENT IN THE USA: CURRENT TRENDS AND FUTURE OPPORTUNITIES

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ABSTRACT

Precision nutrient management (PNM) has become integral to modern U.S. agriculture, particularly in optimizing fertilizer use efficiency, reducing environmental impacts, and sustaining profitability. As detailed in recent analyses, the adoption of precision technologies for nutrient management in the U.S. is advanced, especially among large-scale operations in the Midwest Corn Belt. Key technologies facilitating PNM include variable rate technology (VRT), remote and proximal sensing, soil and yield mapping, and integrated decision support systems.

Keywords: Precision Management, Variable Rate, Soil Testing, Phosphorus Fertilization, Predictive Accuracy

INTRODUCTION

In the Corn Belt, VRT for fertilizer application has been widely adopted, with USDA data indicating that approximately 44% of corn acreage and 41% of soybean acreage receive fertilizers via VRT. Fertilizer management zones are commonly developed through grid soil sampling (e.g., 1-ha resolution) or by delineating zones using soil electrical conductivity, elevation, and historical yield data. This zonal approach supports tailored applications of nitrogen (N), phosphorus (P), and potassium (K), often driven by commercial service providers using prescription maps developed in GIS platforms.

Sensor-based N management is also maturing in the U.S., particularly in wheat and corn systems. Tools like the GreenSeeker and Crop Circle enable real-time adjustment of nitrogen application rates based on NDVI and similar indices. Mounted on high-clearance sprayers or sidedress applicators, these optical sensors have demonstrated the potential to maintain or improve yields while reducing nitrogen inputs by 15–30% under certain conditions. While adoption of this technology has been low, the use of drone-based imaging employing the same concept of using canopy nitrogen status to guide in-season decisions, has increased.

ADOPTION OF PRECISION SOIL SAMPLING

The adoption of precision soil sampling has seen significant growth over the past decade. According to the CropLife-Purdue Precision Agriculture Dealership Survey, the percentage of ag retailers offering grid or zone soil sampling increased from 67% in 2015 to 85% in 2024. This trend reflects a broader shift toward data-driven decision-making in nutrient management. However, it's important to note that these figures represent the percentage of dealers offering these services, not the percentage of area where these services are applied. The actual adoption at the farm level may vary based on factors such as farm size, resource availability, and perceived return on investment.

CHALLENGES IN PREDICTING CROP RESPONSIVENESS TO P AND K FERTILIZATION

Despite advancements in precision agriculture technologies, accurately predicting crop responsiveness to P and K fertilization remains a challenge. Traditional soil test recommendations, while valuable, have limitations in their predictive accuracy. A study focusing on irrigated soybean in Arkansas found that soil-test phosphorus (STP) interpretations had an overall accuracy of only 40% to 48% in predicting yield response to P fertilization, with the highest error rates occurring in the very low and low STP levels.

Further complicating the issue, a regional study in Missouri found that corn grain yield response to P and K fertilization occurred most often at low soil test levels. However, the accuracy of established recommendations diminished as soil test values reached or exceeded critical concentration thresholds, indicating that current physiochemical soil fertility tests may not effectively predict yield responses across diverse soil types and environmental conditions. Efforts to integrate soil health metrics with traditional soil fertility indicators did not improve the prediction of yield increases from phosphorus or potassium fertilization, highlighting the complexity of nutrient dynamics in agricultural systems.

Moreover, a national survey of soil testing practices revealed inconsistencies across state boundaries in soil sampling protocols, analysis methods, and fertilizer recommendations. The survey found that many states have not updated their phosphorus and potassium correlation and calibration data in over two decades, leading to discrepancies in recommended soil nutrient levels and fertilizer rates. This lack of harmonization poses challenges for farmers, agronomists, and researchers working across multiple states and underscores the need for coordinated efforts to update and standardize soil-test-based fertilizer recommendations.

CONCLUSIONS

The integration of cloud-based platforms, real-time weather data, machine learning models, and artificial intelligence holds promise for enhancing the capabilities of precision nutrient management. However, addressing the current challenges requires a concerted effort to refine soil and tissue testing methodologies, update fertilizer recommendation guidelines, and promote multi-state collaborations to develop comprehensive strategies that reflect modern agronomic, economic, and environmental considerations.