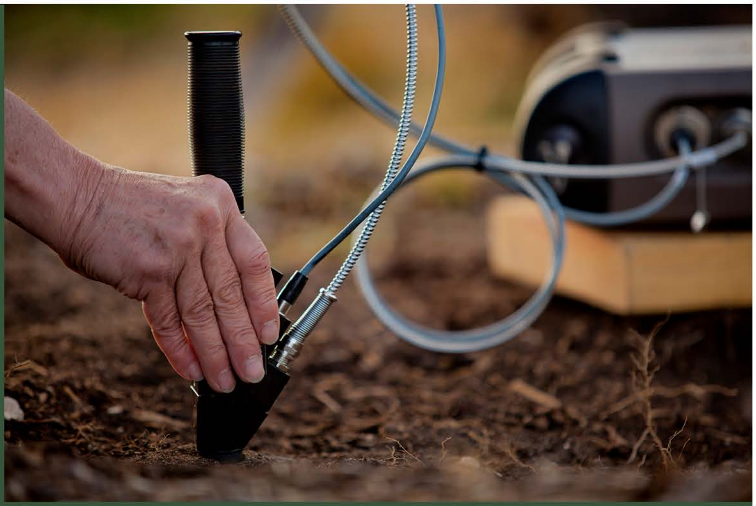
9200 Watson Rd. Suite 200, St. Louis, MO 63126
(314) 729 - 0055
www.roesleinae.com

# "Enhanced Nutrient Management: Optimizing Nutrient Use Efficiency by Producers"

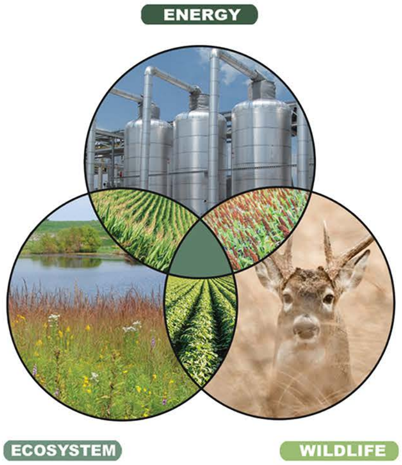



## AUTHORS:

Bryan Sievers
Director, Government Relations
Roeslein Alternative Energy

Dr. Jerry Hatfield
Retired USDA-ARS Laboratory Director
Agriculture Consultant

Dr. Martin L. Battaglia
MSc., Ph.D. (Crop and Soil Environmental Sciences)

**White Paper:**
**Enhanced Nutrient Management: Optimizing Nutrient Use Efficiency by Producers**

**April 8, 2024**

## Introduction

The ***purpose of this white paper*** is to encourage the U.S. Department of Agriculture (USDA) and Congress to create a new initiative to develop a more accessible path for producers to improve fertilizer use efficiency in general, and more specifically nitrogen use efficiency (NUE), by considering changes to the Conservation Practice Standard Nutrient Management Code 590 (CPS 590). The Inflation Reduction Act (IRA) of 2022 mandates that funds for Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program, and the Regional Conservation Partnership Program be allocated for 'Climate Smart Agriculture and Forestry' practices that directly enhance soil carbon, reduce nitrogen losses, or mitigate greenhouse gas emissions like nitrous oxide, methane, and carbon dioxide in agricultural production. CPS 590 is the best option to deliver IRA funding to American farmers to improve their fertilizer use efficiency and NUE. However, the current practice standard contains several requirements that are challenging to meet by producers. As a result, CPS 590 is an underutilized practice that is scarcely used among farmers. During the 9 years period between June 2014 – June 2023, only 1.7% of EQIP funding went to CPS 590, making it the 18$^{th}$ most funded EQIP practice standard during that period.[1] CPS 590's lack of adoption represents a substantial barrier to realizing the vision and benefits of the IRA as Congress intended. We strongly suggest USDA and Congress to create a new initiative to meaningfully address the barriers to farmer adoption of CPS 590, including creating an alternative practice standard for organic fertilizers and improving the existing one for synthetic fertilizers so that farmers can focus on improving NUE through by ensuring more nitrogen is taken up by their crops and less is lost to nitrous oxide emissions and nitrate leaching and runoff. This proposed new, national initiative to elevate prioritization of nitrogen management would make it easier for farmers to adopt technology and management practices that improve their NUE and enhance their farming operations and profitability**.** while addressing climate change, protecting biodiversity, and improving water quality.

## Why is improving nutrient use efficiency important?

*Out of the 17 essential nutrients for plant growth and development, nitrogen (N), phosphorus (P), and potassium (K) are the ones needed in the largest amount. Applying these nutrients at the right time, at the right rate, with the right source and in the right place (also known as 4R principles of nutrient management) increases nutrient use efficiency and overall farm profitability while also reducing externalities to our agroecosystems.*

## Background

Federal and state level nutrient management guidelines for N, P, and K are currently incorporated into the NRCS 590 standard. The purpose of these guidelines is given as:

- Improve plant health and productivity
- Reduce excess nutrients in surface and ground water

[1] https://www.farmers.gov/data/financial-assistance-practices

- Reduce emissions of objectionable odors
- Reduce emissions of particulate matter (PM) and PM precursors
- Reduce emissions of greenhouse gases (GHG)
- Reduce emissions of ozone precursors
- Reduce the risk of potential pathogens from manure, biosolids, or compost application from reaching surface and ground water
- Improve or maintain soil organic matter

The 590 guidelines are not widely adopted by producers because their application is general, which does not address how field-scale nutrient management could be improved or adjusted over time, and requires extensive reporting. Currently, there are two main N recommendations systems used in the US: the yield goal system and the maximum return to N (MRTN). The first approach, developed in the 1970s in the Corn Belt, was the main system utilized to determine N rates until the creation of the MRTN system in 2005 (Sawyer et al., 2006; Morris et al., 2018). In the Corn Belt, the 590 guidelines do not often allow for practical N application rates to achieve maximum yields, and there is not a specific separation of N, P, or K in how the major fertilizers can be managed from recommendation to application. Estimates for P and K caution to avoid overapplication beyond the crop requirements but still provide no feedback on whether the rate is sufficient to meet crop demand. However, the principles in the 590 standard can meet the general goals of the standard and, with our enhanced capabilities to quantify and manage the spatial and temporal variation within fields, agriculture needs to begin to develop and adopt more rigorous methods for nutrient management. The ***main weakness in the 590 standard approach*** to nutrient management, especially N management, is the feedback system to evaluate the efficacy of the recommendation**.** The standard makes reference to the 4R approach but does not incorporate these aspects into the evaluation process.

## The 590 Practice Standard

The 590 standard can be revised to guide producers to improve their nutrient management practices and evaluate the impact of different nutrient sources, organic compared to synthetic forms on production, environment and economic goals. Congreves et al. (2021) summarized 21 different approaches to quantifying nitrogen use efficiency (NUE), ranging from fertilizer, to plant, soil, isotope, ecology, and system-based approaches; however, the most useful form for producers is to simply calculate a fertilizer-based NUE as yield/fertilizer N applied. Indeed, producers do not evaluate their actual NUE but rather assume the NUE is the recommended amount of N applied per bushel of expected yield. Agriculture has the opportunity to use a new nutrient management approach that builds upon the current knowledge with the goal of increasing NUE and farm profitability while concomitantly minimizing environmental outcomes.

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## Nitrogen Use Efficiency

Nitrogen use efficiency provides a framework for producers to quickly evaluate their agronomic return on applied N by calculating the ratio yield/fertilizer N applied. By taking the yield in selected areas of the field and the N rate that produced that yield, this simple approach can be used to evaluate NUE across soils and positions in a field. Although this is an easy step to determine the grain yield return of applied N and the initial step in determining the effectiveness of any recommendation, it is rarely performed. While the index has mostly been used in the realm of synthetic fertilizers, the same approach can be utilized for both manure and biological fertilizers. For manure, the NUE approach collects data on the N analysis, the application rate, and the expected availability of manure N across time (i.e., manure N credits).

Although N rates are a paramount driver for crop yields, other factors are also important. Recent studies conducted in the Corn Belt region showed that variation in yield across a field is more often due to soil water availability limiting the N response than N availability (Hatfield, 2012; Basso et al., 2019). Basso et al. (2019) expanded on these analyses and found that corn production fields in the Corn Belt could be segregated into three major zones: a high-yielding stable zone, a low-yielding stable zone, and an unstable zone. The high-yielding stable zone was always the highest yielding area in the field regardless of the seasonal precipitation patterns. Conversely, the low-yielding zones were always in the lower portion of the yield distribution regardless of precipitation. The unstable zones were linked to the seasonal variation in precipitation. In years with excessive precipitation in the spring, unstable zones were often subjected to saturated soils which in turn reduced plant vigor or even resulted in plant death, while in above normal precipitation during the grain-filling period in summer, unstable zones equaled or exceeded the high-yielding stable zones. Working in Northern Iowa, Hatfield and Fredricks (2023) found that implementation of regenerative agriculture practices promoting crop residue cover and cover crop changed corn yield distributions as soils improved, NUE increased, the yield variation across years decreased, and the seasonal weather variations decreased. Finally, Basso et al. (2019) found that 1) N loss from the low-yielding stable zones and the unstable zones in the field, two zones representing half of the area in Midwestern states, averaged 1.27 MT N $yr^{-1}$ (i.e., N that was not used by the crop) with GHG emissions of 6.8 MMT $CO_2$ equivalents, and 2) NUE in the low- and the unstable field zones were lower than the high-yielding zones.

These field-scale analyses suggest that greater attention to the spatial variation in producers' fields could lead to enhanced NUE. Hatfield (2024) concluded that water and nutrient availabilities and rates are important and must be linked within and among fields to increase NUE and overall profitability. Variation in the soils ability to infiltrate and store water are mainly linked to its texture, soil organic carbon content, aggregate stability, and management practices, including crop residue management, cover crops, crop rotation and tillage practices, which ultimately determines how effective the crop response is to nutrient application.

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## Producer-Friendly Tools

Producers need tools to examine a field as a library of data from which they can understand how their management decisions impact production and profitability. There are a couple of examples of emerging spatial tools used by agricultural consultants that serve as examples. The first is the TopSoil Program offered by Continuum Ag, LLC from Washington, IA which provides a detailed map of each field with the different soil parameters and soil tests that have been collected. Producers can examine nutrient availability patterns for each field and evaluate the impact of changes in soil management practices across time. The second platform is Spatial4D from Anex Consulting in Lake Mills, MN that uses a combination of soil tests, remote sensing, and production records to continually evaluate how each field is responding to different management practices. Both tools provide producers with a quantitative assessment of what is changing spatially within a field over multiple growing seasons.

The analysis conducted on the Wayne Fredericks farm in Mitchell County, IA used 16 years (2002 – 2018) of yield monitor data segregated by soil type across 10 fields to determine how yield changed over time. As the soil organic matter increased and soil water became more available, low yields were less frequent with the yields becoming more tightly distributed around the mean (Hatfield and Fredericks, 2022). These results, consistent across soils and fields, resulted in increased NUE, profitability, and water use efficiency, and a lower yield variation across years. Nitrate-N concentrations from the tile lines were less than 5 ppm, indicating that both a production efficiency and a water quality improvement occurred. Similar analysis could be performed in most current situations, as producers have multi-year yield monitor data that can be coupled with the information on N rates to calculate the NUE and from the production records a profit variation across fields. Furthermore, development of tools that can easily incorporate soils data from NRCS soil survey data, producers' production and yield data all at once will reduce current limitations, but this will require an investment of resources to make these tools readily available as part of the nutrient management planning process.

Agriculture has an abundance of data that is being collected on a daily-basis through equipment mounted sensors, drones, aircraft, satellites, hand-held sensors, and smart-phone apps; however, these data are not often being effectively used to increase the useability of actionable information for a producer. The primary question remains on how to effectively integrate these data into tools for decision-making during the growing season and provide feedback on the impact that different management practices have on crop productivity, profitability, and environmental outcomes.

## Path Forward for Effective Nutrient Management Practices

The path forward has to recognize that soil regeneration is critical to increasing the efficiency of nutrient use and reducing the environmental impact on water quality and GHG emissions. Adoption of management practices that increase the return of carbon to the soil and decrease its loss by minimizing tillage intensity, maintaining soil coverage, increasing the length of time with living roots in the growing season, increasing the crop diversity, and utilizing animals as part of the cropping system all contribute to soil restoration. The field-scale evidence from using reduced tillage and cover crops in the Wayne Fredericks example has been observed in other fields but not documented as extensively (Hatfield and Fredericks, 2022). Although the focus is often on the soil and crop management piece, there is emerging evidence that the source of nutrients is important in soil regeneration. For example, animal manures contain carbon and the utilization of manures has a synergistic effect on other regenerative practices. The carbon:nitrogen ratio of manures or products derived from manure such as digestates from anaerobic digesters, and compost, are ideal as an energy source for soil microbes. Producers utilizing different forms of nutrients, i.e., synthetic versus organic, require specific recommendations and approaches. Developing integrated approaches that link carbon, water, and nutrients together will link nutrient management decisions more effectively with production, economic, and environmental goals. Martinez-Feria and Basso (2020) found that not considering the impact of water-stressed areas of fields in nutrient management could lead to $536 million/year in economic loss, over 4 million MT/year of less C captured and more than 53 Gg/year of more reactive N into the environment across the Midwest. These estimates suggest that we need to address nutrient management with a more comprehensive approach to utilize all of the current knowledge available.

An innovative new approach should consider the development and implementation of a specific nutrient standard for each nutrient source. Over the past 20 years, the advances in understanding of how to manage nutrients has changed along with the tools available to producers to evaluate the impact of nutrient management on crop productivity, profitability, water and air quality, and GHG emissions and these advances need to be incorporated into nutrient management recommendations. The first recommendation is to convene two panels that would address one approach for nutrient management of organic sources and one for synthetic sources. These panels' task would be to develop a comprehensive analysis of how these sources could be used to achieve the goals of NRCS in addressing the components of SWAPA+H (soil, water, air, plant, animals and humans) framework for gauging the impact of conservation practices.

Developing this pathway will require a number of steps, as follows:

1. Develop two expert panels to address nutrient management for organic and synthetic sources of nutrients and provide recommendations on practice standards applicable to each source.
2. Increase the educational effort to producers, consultants, technical service providers, and NRCS nutrient management specialists on nutrient management.
3. Utilize cost-share programs for producers to participate in nutrient management programs that utilize the enhanced nutrient management tools and demonstrate and document improvement in nutrient management based on the guidelines developed by the expert panels.

4. Conduct yearly evaluations of the process along with producer interviews to obtain their feedback on the strengths and weaknesses.

**Impacts of a Comprehensive Approach to Nutrient Management**

Agriculture production is a complex problem and requires innovative solutions to achieve a goal of increased nutrient use efficiency, decreased environmental impacts, increased profitability, and increased return on investment of natural resources. This problem will not be solved by a single adjustment of one component of the system, but rather a more comprehensive approach of examining why production variability exists in fields, how they can be changed, and understanding both the spatial and temporal changes that occur through management. Producers recognize that fields are variable; however, they lack the means to effectively quantify that variation and more importantly the tactics to reduce this variation and understand if their changes are making a difference. The potential impact for agriculture and society is large and would ensure food security and an agricultural system capable of being agronomically and environmentally sustainable.

**For More Information contact**:
Bryan Sievers
Director, Government Relations
Roeslein Alternative Energy
bsievers@roesleinae.com

Dr. Jerry Hatfield
Retired USDA-ARS Laboratory Director
Agricultural Consultant
Jerryhatfield67@gmail.com

Dr. Martin L. Battaglia
MSc., Ph.D. (Crop and Soil Environmental Sciences)
martinb1@vt.edu
LinkedIn: https://www.linkedin.com/in/martin-battaglia-msc-ph-d-605a9637/
GoogleScholar:
https://scholar.google.com/citations?hl=es&user=e6J4DIIAAAAJ&view_op=list_works#
Ranked 8th globally (Google Scholar) as per expertise in "Regenerative Agriculture"
https://scholar.google.com/citations?view_op=search_authors&hl=es&mauthors=label:regenerative_agriculture

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