



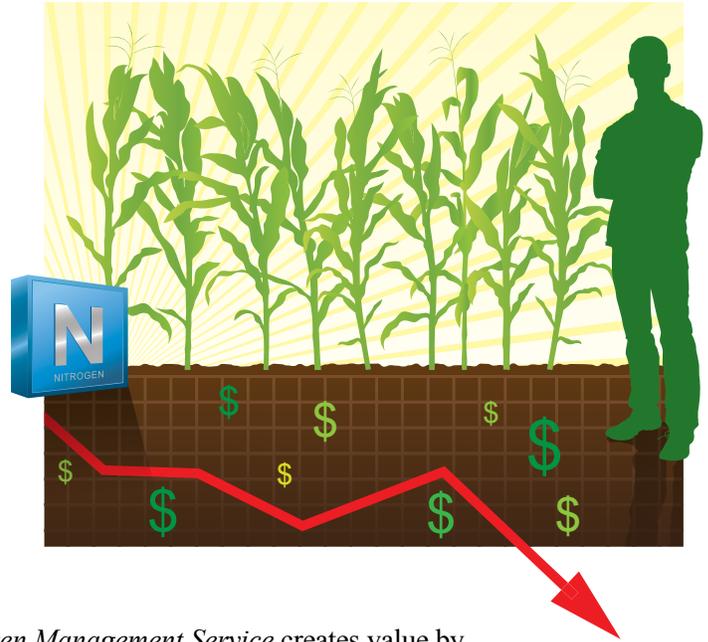
Take the
guesswork
out of
nitrogen management.

EncircaSM Yield Nitrogen Management Service
provided by EncircaSM services



Summary

The EncircaSM Yield *Nitrogen Management Service* offers farmers a new ability to plan, monitor and adapt their nitrogen management practices to maximize profitability and improve environmental quality. The technology behind this service is the result of strategic collaborations, and combines next-generation crop and nitrogen models with high-resolution soil and weather data to dynamically forecast soil nitrogen status and predict corn nitrogen fertilizer needs. DuPont Pioneer delivers this industry-leading nitrogen service to the market through a cloud-based software platform supported by a field team of specialized Pioneer Certified Services Agents who work side-by-side with customers to operationalize improved nitrogen management programs. The Encirca Yield *Nitrogen Management Service* creates value by giving customers access to insights that explicitly account for financial risk and tools that allow them to monitor and manage soil nitrogen in real-time at a finer spatial-scale than ever before.



Introduction

Nitrogen is a critical crop production input, second in importance only to water, and is the major mineral nutrient that farmers must manage to achieve high yields. Nitrogen management, however, is among the most complex and uncertain agronomic aspects of modern farming. Large quantities of organic nitrogen are present in most soils, but only a small and highly-variable fraction of this nitrogen is mineralized each growing season into inorganic forms that are available for crop uptake. Inorganic nitrogen, originating from the soil or from fertilizers, is readily available to crops, but is also highly susceptible to losses. To add to this complexity, all of the processes that control nitrogen availability and loss vary by soil type, moisture, temperature and other factors. Because of the multi-faceted and dynamic nature of nitrogen, farmers regularly over- or under-fertilize in any given field or year, reducing profitability (Lambert et al., 2006) and in some cases this leads to environmental contamination (Jaynes et al., 2001). Today, decisions about nitrogen fertilizer application rates are generally based on yield goals (Hoefl et al, 2000) or generalized empirical relationships (Sawyer et al., 2006) that do not account for weather effects when estimating crop nitrogen requirements. Current nitrogen management practices also emphasize field-uniform, pre-plant applications that ignore variation in landscape factors such as topography, soil texture and organic matter (Cassman 2002;

Mamo et al, 2003; Scharf et al., 2005). Collectively, these current strategies result in inefficient use of nitrogen fertilizer (Raun and Johnson, 1999; Fageria and Baligar 2005). Additionally, farmers do not currently have access to intuitive, user-friendly tools that allow them to compare competing nitrogen management strategies based on financial risk, let alone to assess and manage soil nitrogen in real-time. As a result, a large opportunity exists to provide farmers with decision-support tools that enable them to more effectively manage nitrogen with reduced risk and increased profitability.

Based on strong agronomic expertise, combined with strategic collaborations in the areas of weather data, soils mapping and crop modeling, DuPont

Pioneer now offers its EncircaSM Yield *Nitrogen Management Service*. The Encirca Yield *Nitrogen Management Service* is an advanced solution that provides real-time, actionable insights with field-by-field specific recommendations from fall planning through

in-season application. This white paper describes three key aspects of the Encirca Yield *Nitrogen Management Service*: 1) enabling technologies; 2) service delivery; and 3) validation of the technology.

monitor and manage soil nitrogen
in real-time
at a finer spatial-scale than ever before.



- 1 Enabling Technologies
- 2 Service Delivery
- 3 Opportunity for Value Creation

Enabling Technologies

Crop and Soil Nitrogen Model

The core enabling technology of the EncircaSM Yield *Nitrogen Management Service* is a proprietary crop and soil model that simulates all aspects of crop growth, development and yield for a specific set of soil characteristics and under defined management and weather conditions. The model directly accounts for changes in soil water and nitrogen that occur over time in response to crop growth, management and weather (Figure 1).

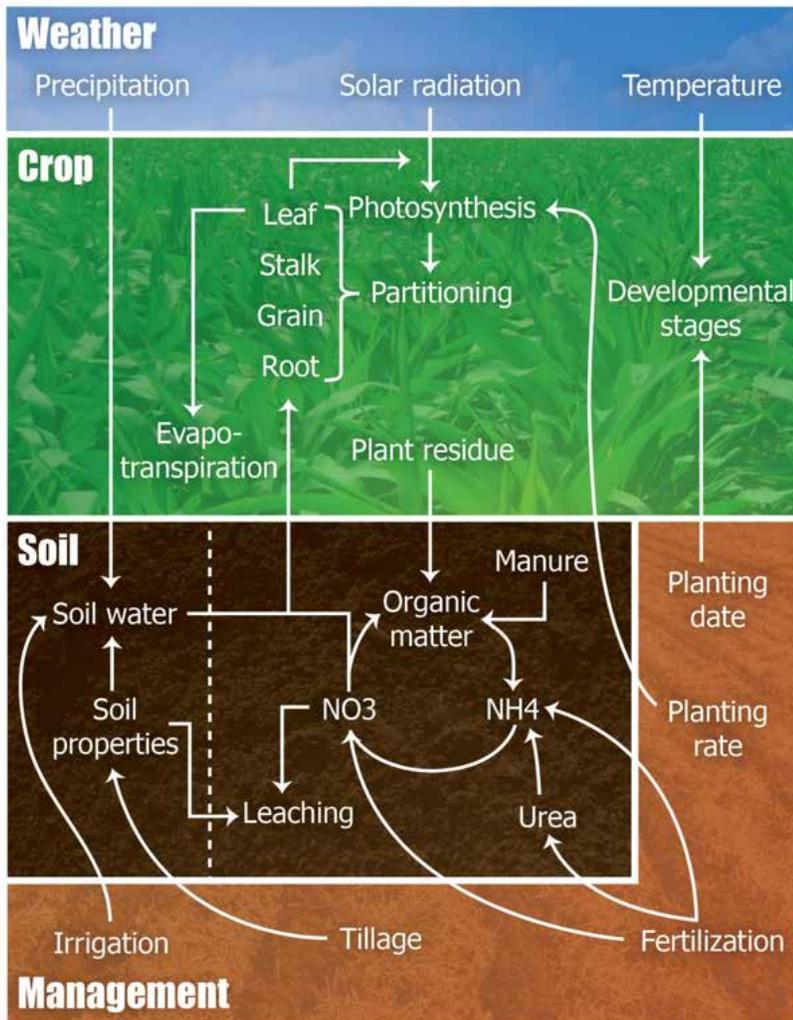


Figure 1:

Graphical representation of the factors affecting crop growth and nitrogen availability in the crop and soil model underlying the Encirca Yield *Nitrogen Management Service*.

A key advantage of EncircaSM Yield *Nitrogen Management Service* is that it is driven by high resolution weather data, updated on a daily basis, to reforecast soil nitrogen status. Through the collaboration with *DTN/Progressive Farmer*, DuPont Pioneer offers farmers access to an exclusive network of weather stations, including those positioned on or near the farms where the Encirca Yield *Nitrogen Management Service* is deployed.

The dynamic nature of the model, combined with high density weather data, will give farmers the ability to monitor changes in soil nitrogen status and assess the impacts of potential management actions in real time. By developing the Encirca Yield *Nitrogen Management Service* around a model-based platform, Pioneer is able to provide customers with a scalable solution that can be implemented across a broad geographic range while incorporating soil, weather and management information for the specific fields customers manage. DuPont Pioneer agronomists have tested the model extensively and are adapting it to predict nitrogen availability across a wide range of soil, climatic and management conditions (Figure 2).

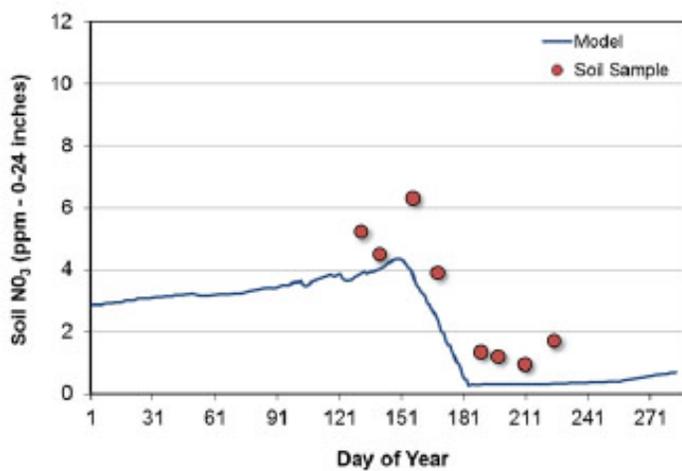
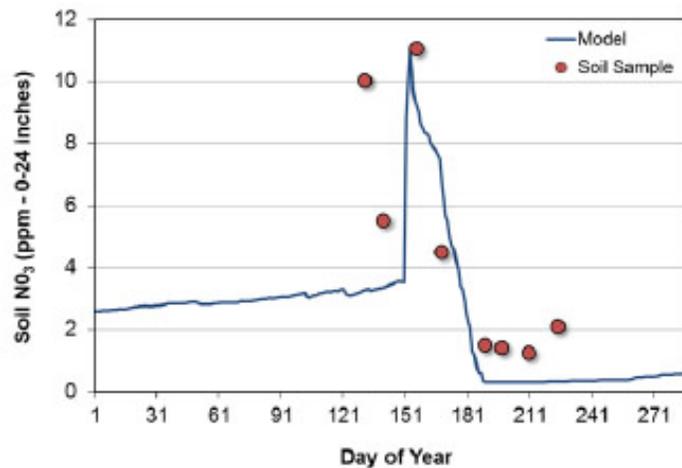


Figure 2: Modeled and measured soil NO₃-N concentration to a 24” depth for two soils in fields where the Pioneer nitrogen model was evaluated in 2014.



High Resolution Soil Maps

Traditional soil maps include information that can be used to model crop growth and nitrogen availability, but the resolution of these maps is limited by the tools that were available when they were created decades ago. DuPont Pioneer collaborated with scientists at the University of Missouri and the USDA-Agricultural Research Service (ARS) to create a new generation of soil maps that dramatically improve the resolution of decision-making in agriculture.

The improved soil maps are based on a proprietary technology that creates new soil spatial definitions called Environmental Response Units (ERUs). These ERUs are generated using a machine learning clustering algorithm that reclassifies the spatial distribution of soil properties within fields based on high resolution digital elevation data. In essence, the technology reverse-engineers the process that soil scientists used to create the original soil map boundaries, using landscape information that was not available when the original maps were produced. The result is a more precise soil map that better reflects field-scale hydrological attributes that strongly influence crop growth and nitrogen availability (Figure 3).

Because the best models are only as good as their inputs, Pioneer launched EncircaSM Yield *Nitrogen Management Service* with the most advanced soil data inputs in the industry. Like the Pioneer crop and soil model, ERU soil mapping technology has been developed with both flexibility and functionality in mind. The ERU maps generated for customers are the only soils information required to make nitrogen forecasts for growers' fields. However, in situations where farmers or their advisors have historical yield data, it can be directly incorporated into the soil mapping framework, to further improve the precision and accuracy of the soil nitrogen recommendations.

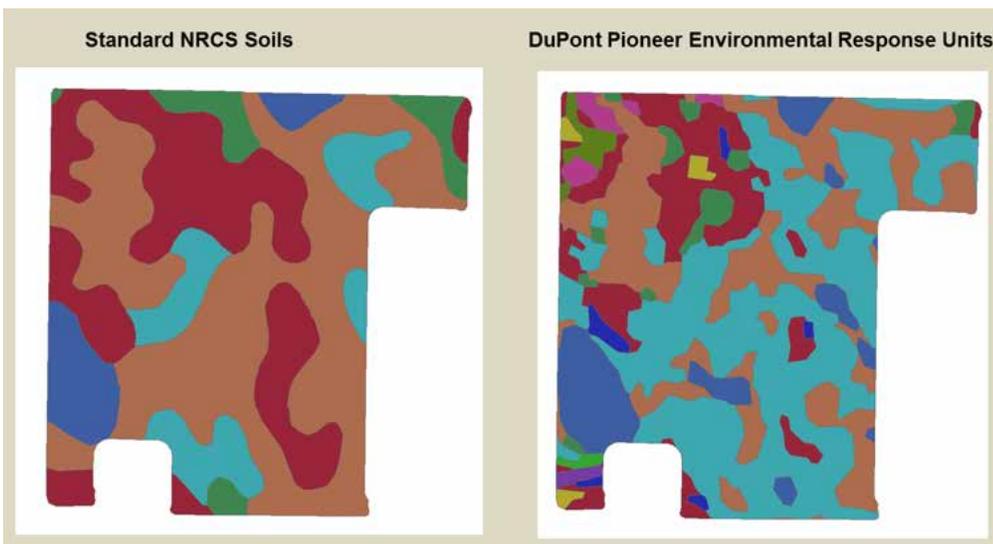


Figure 3:
Standard NRCS soil map compared to Pioneer Environmental Response Unit (ERU) map.

Service Delivery

Software as a Service

The EncircaSM Yield *Nitrogen Management Service* is a powerful, accessible and scalable nitrogen management decision support tool. The service uses a cloud computing framework to manage weather, soil and operational data for tens of thousands of fields on a daily basis, while also giving customers instantaneous access to real-time soil nitrogen status updates via web browsers and mobile applications (Figure 4). Farmers also have the option to automatically share information and prescriptions generated by the service with associates and trusted advisors. Because Encirca Yield *Nitrogen Management Service* operates from the cloud, innovations and updates made to the nitrogen model and soil mapping software are seamlessly delivered to users.

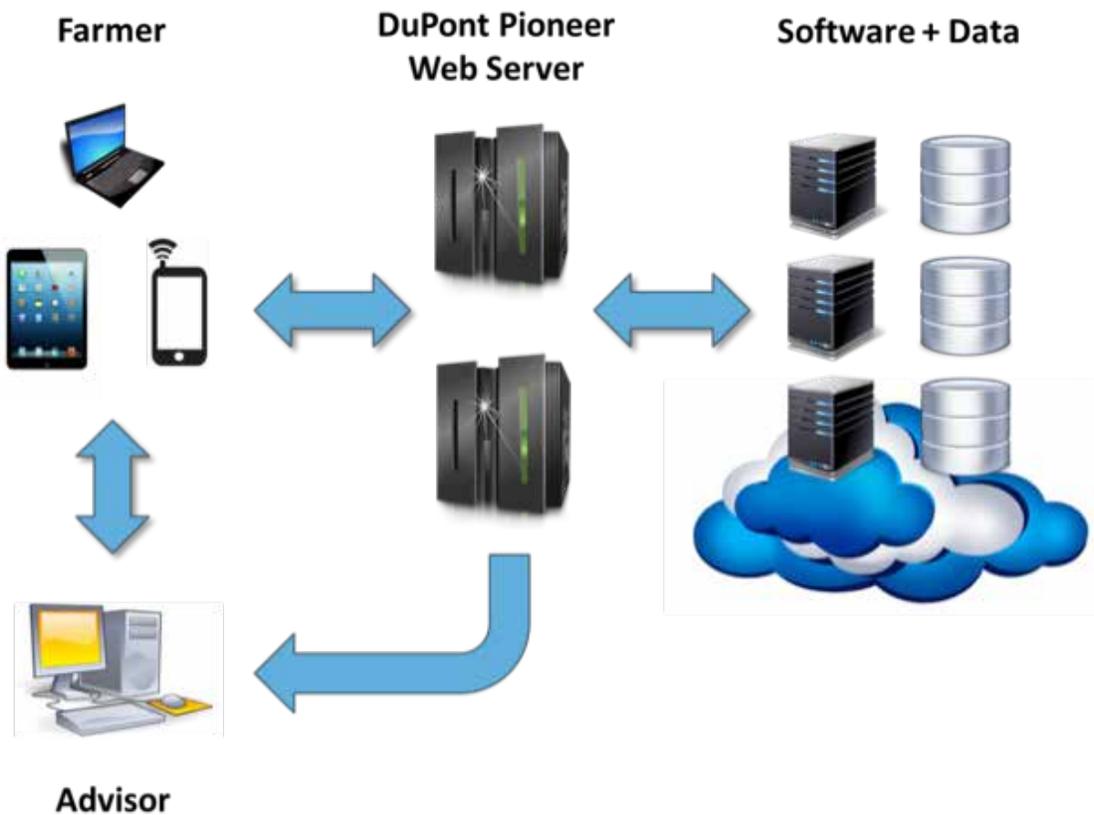


Figure 4:

Architecture and information exchanges underlying the Pioneer cloud-based Encirca Yield *Nitrogen Management Service*. Pioneer places grower data privacy as a high priority. Pioneer abides by data privacy laws and does not sell any personal grower data to third-parties. Pioneer collects and uses grower information as stated in the DuPont Global Information Privacy Policy and DuPont Pioneer Privacy Statement. These documents are available at: http://www2.dupont.com/Privacy/en_US/global_policy_english.html, and at: <https://www.pioneer.com/home/site/us/privacy-statement>

Encirca Certified Services Agents

A key differentiator in the EncircaSM Yield *Nitrogen Management Service* is how the service is delivered to customers. Software-based solutions are coupled with direct, in-field support from the Encirca certified services agent force. This highly-specialized and trained channel work side-by-side with Encirca Yield *Nitrogen Management Service* customers to ensure that plans, prescriptions and management decisions are tailored to the context of individual farming operations. With the service being supported by the expertise of Encirca certified services agent, customers are able to extract greater benefit from the nitrogen management offering.

More than a Prescription: Planning, Monitoring and Adaptive Management

The Encirca Yield *Nitrogen Management Service* is differentiated from other offerings that only provide side-dress recommendations and variable rate prescriptions. At its core, the Encirca Yield *Nitrogen Management Service* helps users plan, monitor and adapt their nitrogen management practices to help maximize profitability in the face of variable soils and weather.

From fall through spring, Encirca certified services agents assist farmers in developing nitrogen management plans for their fields. These plans include guidance regarding the least-risk dates for targeting nitrogen applications, as well as the overall risk that yields will be limited by nitrogen availability given historic weather conditions at the location. With just a keystroke, users have access to soil nitrogen forecasts for any plan they have created and can compare its current risk profile against alternative management scenarios (Figure 6), or generate a variable rate prescription for in-season nitrogen application at any future date (Figure 7).

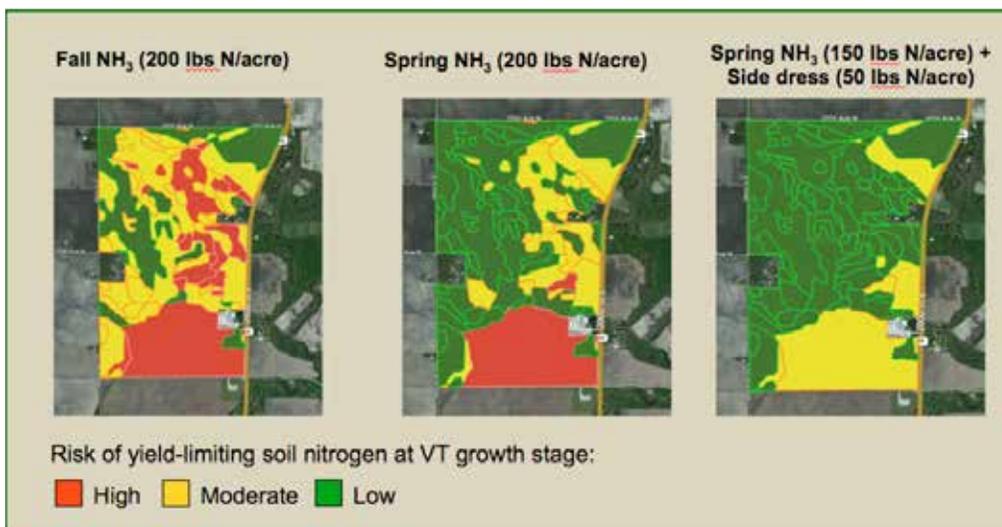


Figure 6:

Pre-season planning field maps showing risk of yield-limiting soil nitrogen at VT corn growth stage for three different nitrogen management plans forecasted for the same field on November 15, 2014.



Figure 7:

Variable Rate prescription maps can be automatically generated at any point to minimize the risk of yield-limiting soil nitrogen. Prescription files can be exported for direct use with variable rate application equipment.

Modeling previous weather years is a key feature of EncircaSM Yield Nitrogen Management Service that enables dynamic nitrogen planning that directly accounts for risk. Whenever a user creates or accesses a nitrogen management plan, the model will work from the cloud to simulate soil nitrogen availability from that date forward based on the 10 day DTN/*The Progressive Farmer* forecast and previous 50 years of weather data for the location.

From the range of possible future weather outcomes, the model estimates the risk of yield-limiting soil nitrogen, factoring in observed weather to the current date (Figure 8). By simulating a wide range of possible weather, the service gives farmers the ability to assess and compare the financial risks associated with different nitrogen management plans, and make nitrogen management decisions in real-time.



Figure 8:

Soil nitrogen forecast for 50 years of historical weather. The shaded regions beginning at the current date represent the range in soil nitrogen level for 50% (inner shaded region), 80% (middle shaded region) and 100% (outer shaded region) of modeled historical weather years.

User Interface

DuPont Pioneer customers have access to the software components of the EncircraSM Yield *Nitrogen Management Service* via an agile and intuitive web interface (Figure 9). The Encircra Yield Nitrogen Management Interface is connected directly to other agronomic, business and logistical services offered by Pioneer, allowing customers to navigate quickly between subscribed services.

From the user interface, customers have access to a number of interactive decision support features:

- ① Expandable window for quick navigation between fields.
- ② Name and nitrogen status of the currently selected field.
- ③ Crop status and real-time climatic information for the currently-selected field.
- ④ Total cost of nitrogen applications assigned to the currently selected field.
- ⑤ Accesses to the nitrogen management plan for the currently-selected field.
- ⑥ Map of all enrolled fields, color-coded to indicate soil nitrogen status.
- ⑦ Map of the currently-selected field with soil nitrogen status by ERU.
- ⑧ Drop-down list to view current or forecasted soil nitrogen status.
- ⑨ Toggle switches to customize user interface elements.

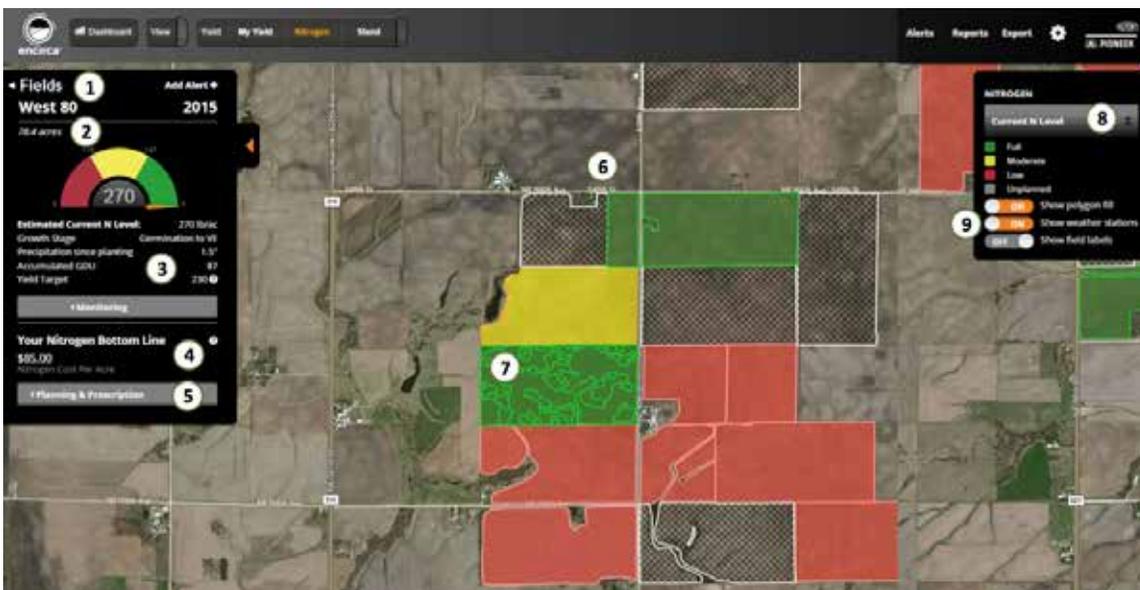


Figure 9:

User interface for accessing software components of the EncircraSM Yield *Nitrogen Management Service*.

Opportunity for Improved Nitrogen Management

The EncircaSM Yield *Nitrogen Management Service* can help farmers plan, anticipate and execute improved nitrogen management strategies that minimize risk of profit loss and improve environmental quality. Today, many farmers apply higher than economically optimal nitrogen fertilizer rates because they do not know in advance how much nitrogen mineralization or loss will occur in any given field or year. While the economic penalty resulting from inadequate fertilization is much greater than the cost of excess fertilizer, high fertilizer application rates can be associated with air and water pollution. Given the limited information available to make nitrogen application decisions, additional fertilizer has historically been a rationale nitrogen risk management strategy for many farmers. The Encirca Yield *Nitrogen Management Service* provides new insights that can help farmers make timelier, higher resolution nitrogen management decisions that better protect profitability and environmental quality.

Validation of the Encirca Yield *Nitrogen Management Service*

To validate the Encirca Yield *Nitrogen Management Service*, DuPont Pioneer conducted on-farm strip trials at 124 locations across nine states in 2015 (Figure 9). At each trial location, an Encirca services based nitrogen recommendation was applied to the majority of the field area, with one or more field-length, grower determined nitrogen rate check strips imbedded in the prescription for comparative purposes (Figure 10). Yield of grower rate strips was compared to adjacent, equally sized field areas managed with Encirca services. Comparisons were only made between applications that occurred on the same day. The majority of comparisons were mid-vegetative stage, side-dress applications (Figure 11).

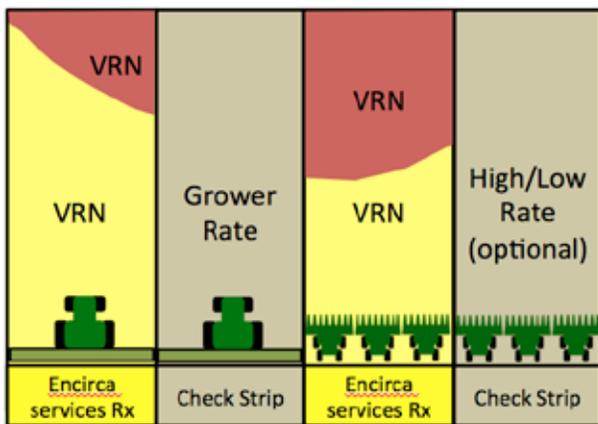


Figure 10: On-farm trial design used to evaluate the Encirca Yield *Nitrogen Management Service* in 2015. Encirca services strips were variable rate nitrogen (VRN) applications based on Environmental Response Units (ERUs). Grower strips were flat rate nitrogen applications based on grower standard practice.

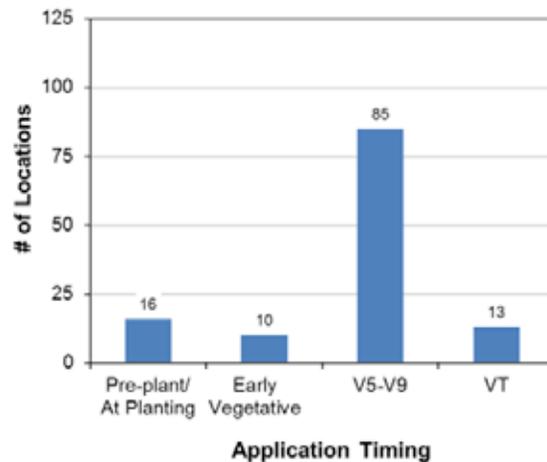


Figure 11: Application timing for on-farm comparisons between the nitrogen rates recommended the Encirca Yield *Nitrogen Management Service* and grower determined rates at 124 locations in 2015.

Trial results indicated that the EncircaSM Yield *Nitrogen Management Service* provided greater return on nitrogen fertilizer expense than standard grower practice at 74% of trial locations (Figure 12). Improved profitability for EncircaSM services recommendations was the outcome of both improved corn yield (Figure 13) and a reduction in the field-average nitrogen application rate (Figure 14) compared to standard grower practice. These strip trials demonstrated that the Encirca Yield *Nitrogen Management Service* was successful in increasing fertilization rates where more nitrogen was needed by the crop and reducing fertilization rates where additional nitrogen was not necessary to maximize corn yield.

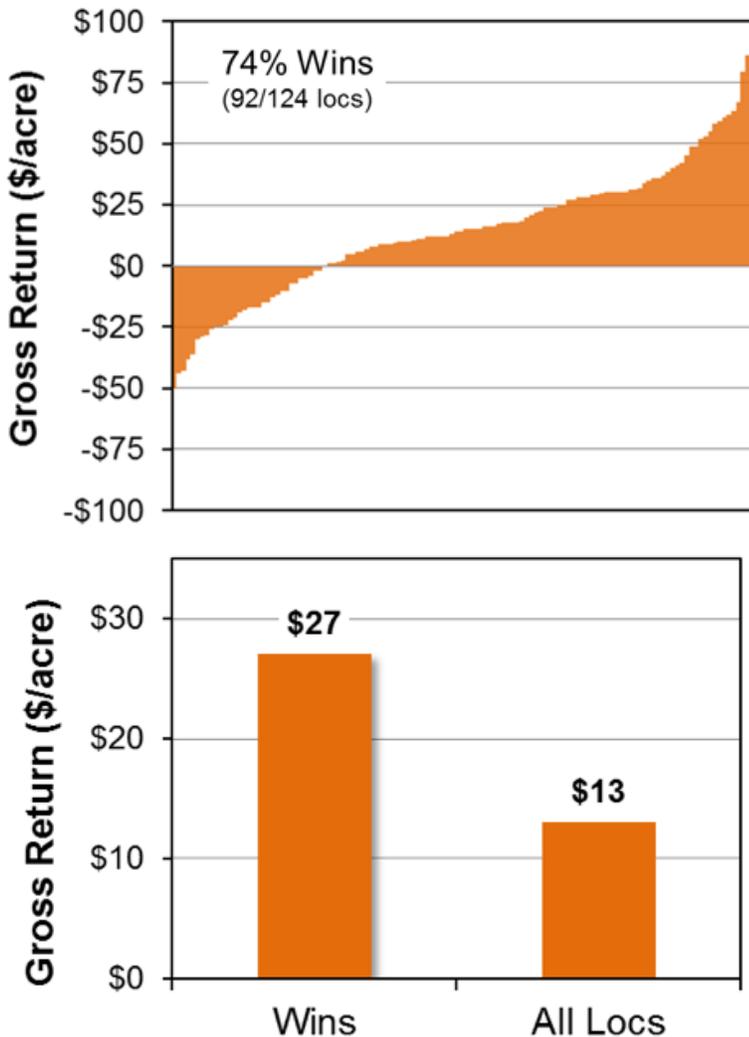


Figure 12:

Gross return on investment in the Encirca Yield *Nitrogen Management Service* compared to standard grower nitrogen rate across 124 on-farm locations in 2015.

Return on investment was calculated as: (Encirca services strip yield – Encirca services strip N rate) – (Grower strip yield – Grower strip N rate). Corn and nitrogen prices were set as \$4.00/bu and \$0.5/lb., respectively. Cost of the Encirca Yield *Nitrogen Management Service* was not included in the analysis (average cost of \$8/acre).

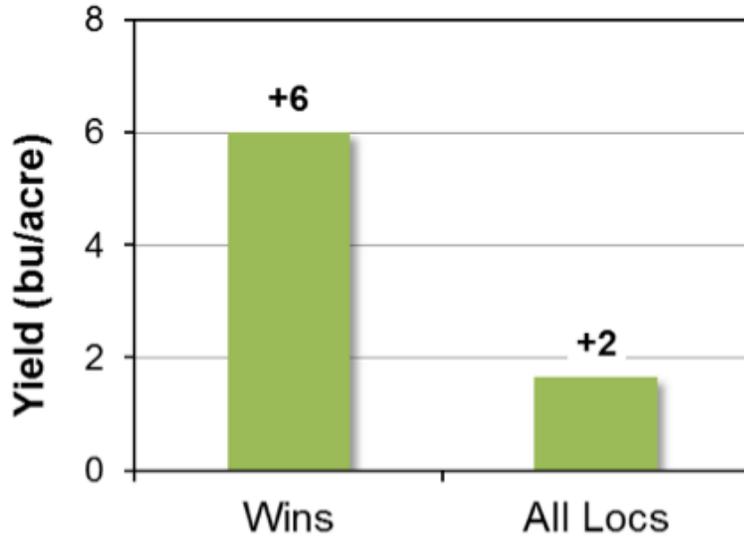


Figure 13: Average corn yield advantage for the EncircaSM Yield Nitrogen Management Service compared to standard grower nitrogen rate at locations where Encirca services resulted in improved profit and across all locations where the service was evaluated in 2015.

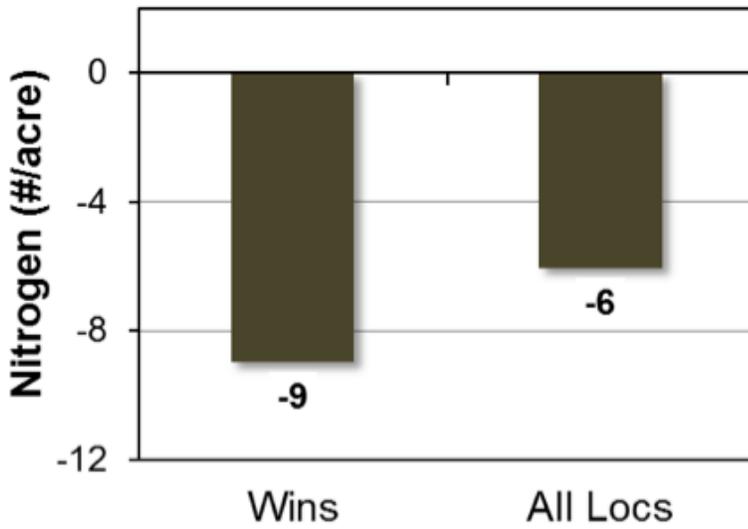


Figure 14: Average reduction in nitrogen application rate for the Encirca Yield Nitrogen Management Service compared to standard grower nitrogen rate at locations where Encirca services resulted in improved profit and across all locations where the service was evaluated in 2015.

References

- Hoelt, R.G., E.D. Nafziger, R.R. Johnson, and S.R. Aldrich. 2000. Modern corn and soybean production. MCSP Publ., Champaign, IL.
- Lambert, D.M., J. Lowenberg-DeBoer, and G.L. Malzer. 2006. Economic analysis of spatial–temporal patterns in corn and soybean response to nitrogen and phosphorus. *Agronomy Journal*. 98: 43–54.
- Fageria, N.K., and V.C. Baligar. 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy*. 88: 97–185.
- Jaynes, D.B., T. S. Colvin, D. L. Karlen, C. A. Cambardella, and D. W. Meek. 2001. Nitrate loss in subsurface drainage as affected by nitrogen fertilizer rate. *Agronomy Journal*. 30:1305-1314.
- Mamo, M., G.L. Malzer, D.J. Mulla, D.R. Huggins, and J. Strock. 2003. Spatial and temporal variation in economically optimum nitrogen rate for corn. *Agronomy Journal*. 95: 958–964.
- Raun, W.R., and G.V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Agronomy Journal*. 91: 57–351.
- Sawyer, J., E. Nafziger, G. Randall, L. Bundy, G. Rehm, and B. Joern. 2006. Concept and rationale for regional nitrogen rate guidelines for corn. PM 2015. Iowa State Univ. Ext., Ames. www.extension.iastate.edu/Publications/Pm2015.pdf (accessed 2 Feb. 2014).
- Scharf, P.C., N.R. Kitchen, K.A. Sudduth, J.G. Davis, V.C. Hubbard, and J.A Lory. 2005. Field-scale variability in optimal nitrogen fertilizer rate for corn. *Agronomy Journal*. 97: 452–461.