AST 426 :Variable Rate Technology in Precision Agriculture

Instructor: **Pappu Kumar Yadav, Ph.D.**
Department of Agricultural & Biosystems Engineering
Machine Vision & Optical Sensors Laboratory
South Dakota State University
Fall 2024

Before we begin….

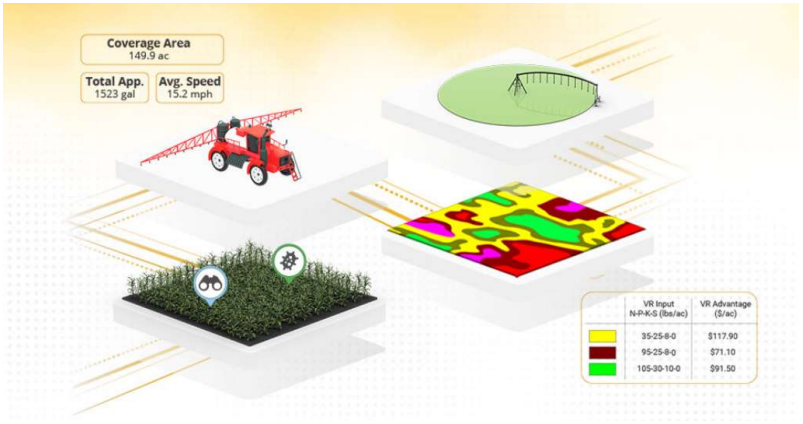
- Considering the variety of soil types, weather conditions, and growing zones across South Dakota, Minnesota, Nebraska, and Iowa, think about the challenges of applying the same rate of seeds, fertilizer, and pesticides across an entire corn, soybean, or wheat field. How might adjusting application rates based on specific field conditions impact crop yield, input costs, and environmental impact on farms in your region?

Introduction to Variable Rate Technology (VRT)

- VRT is a part of broader concept precision agriculture (PA)/Site-Specific Management (SSM)
- VRT is one of the many technologies that enable PA farming practices

Definition

- Variable Rate Technology (VRT) is a precision agriculture practice that allows farmers to **apply seeds, fertilizers, pesticides, and other inputs at varying rates** across different areas within a field.
- Uses data from **soil, crop health, and yield maps**, often combined with **GPS and sensor** technology, to **make site-specific decisions**.
- VRT has been around since the 1980s.
- With VRT farms are managed at **zone levels**



https://farmersedge.ca/variable-rate-why-its-important-now-more-than-ever/

Objectives of Variable Rate Technology (VRT)

- Optimize the usage of inputs
- Improve yield by applying the right amount in the right place
- Reduce waste and environmental impact

https://farmersedge.ca/variable-rate-why-its-important-now-more-than-ever/

Components of Variable Rate Technology (VRT)

- **Sensors**

  Collect data on soil properties, moisture, crop health, and more.
- **Mapping Software**

  GIS (Geographic Information Systems) and GPS are used to map data points and generate application maps
- **Control Systems**

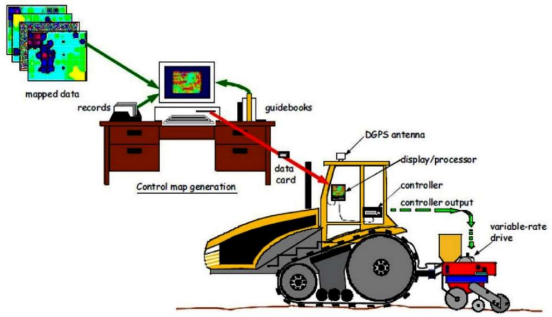
  These are typically integrated with machinery (e.g., sprayers, planters) that can adjust application rates in real time or based on a prescription map
- **Machinery and Equipment**

  Modern VRT systems often use **tractors, sprayers, and planters** equipped with **variable rate controllers**

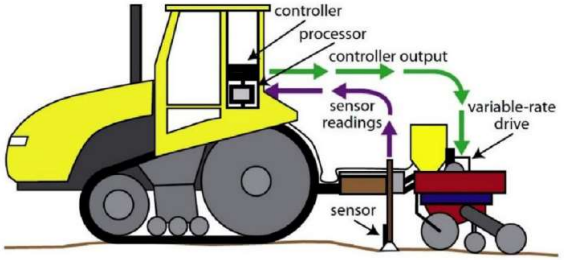
https://farmersedge.ca/variable-rate-why-its-important-now-more-than-ever/

Two types of VRT Techniques

1. Map-Based
   - Uses pre-collected data and **prescription maps** to guide input application
2. Sensor-Based
   - Adjusts input rates **in real time** based on sensor feedback



Map-based VRT



Sensor-based VRT

Al-Gaadi, K. A., Tola, E., Alameen, A. A., Madugundu, R., Marey, S. A., Zeyada, A. M., & Edrris, M. K. (2023). Control and monitoring systems used in variable rate application of solid fertilizers: A review. Journal of King Saud University-Science, 35(3), 102574.

Sensor-based VRT

Veris Soil Scanning Sensor for Soil Mapping

Sensor-based VRT

Veris Soil Scanning Sensor for Soil Mapping

Veris MSP3 - Soil Mapping

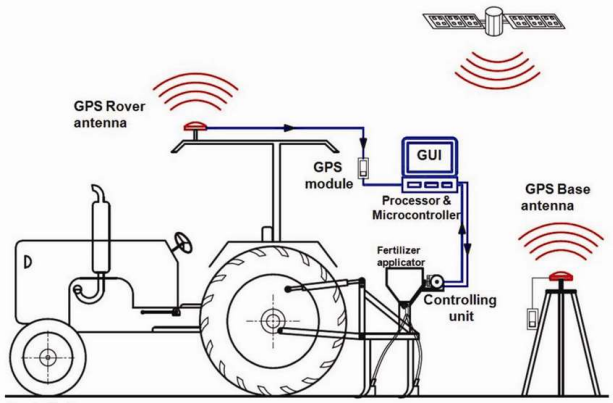
Liming Where You Need It — New Soil Mapping Options from Veris Technologies

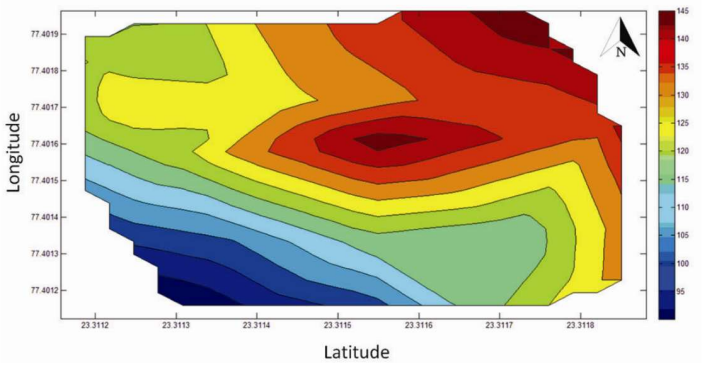
Sensor-based VRT

Syngenta Interra Scan for Soil Health Mapping

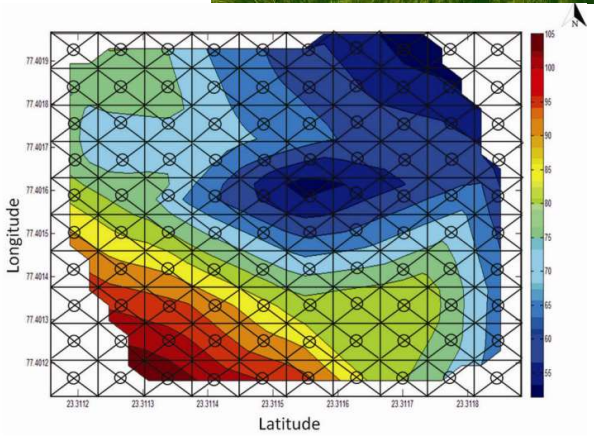
[Syngenta launches Interra Scan soil health mapping service - YouTube]

Map-based VRT

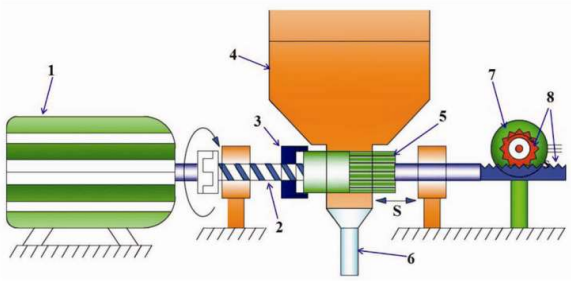




Soil nitrogen availability map



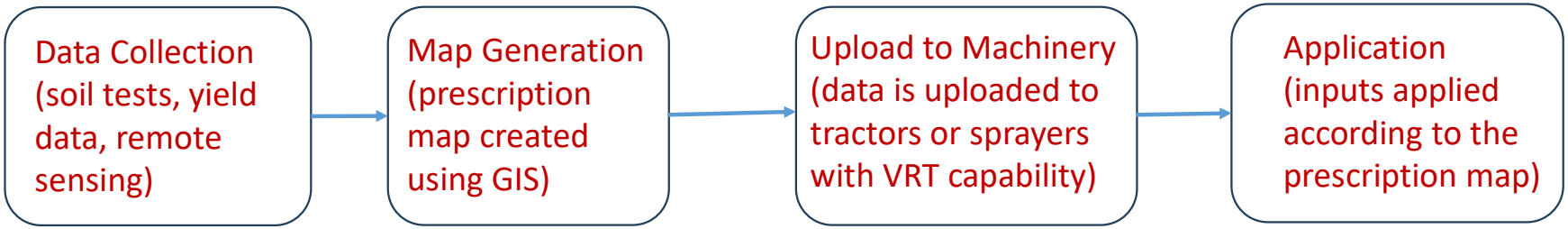
Soil nitrogen application map



CAD view of arrangement of DC motor and position sensor of VRFA system. 1, DC motor; 2, Threaded screw; 3, Threaded nut; 4, Fertilizer box; 5, Fluted roller; 6, Delivery tube; 7, Potentiometer; 8, Rack and pinion set; S, Lateral displacement of flute (0–44 mm)

Chandel, N. S., Mehta, C. R., Tewari, V. K., & Nare, B. (2016). Digital map-based site-specific granular fertilizer application system. Current science, 1208-1213.

Map-based VRT Workflow



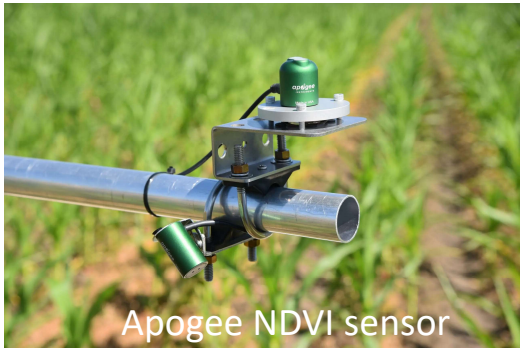
Sensors and Data Collection in VRT

Types of Sensors

- NDVI sensors (Normalized Difference Vegetation Index)
- Soil moisture sensors
- Nutrient sensors

Data Collection Methods

- Drones: Can capture aerial images to assess crop health
- Satellites: Provide broader field data on factors like vegetation health
- Soil Sampling: Provides ground-truth data on soil properties, especially useful for nutrient management


Apogee NDVI sensor

Soil Nutrient sensor

Types of VRT Applications

Seed Rate Variation

Optimizes planting density based on soil fertility and moisture levels to maximize yield

Fertilizer Rate Variation

Adjusts **nitrogen, phosphorus, and potassium** levels based on specific crop needs and soil nutrient levels.

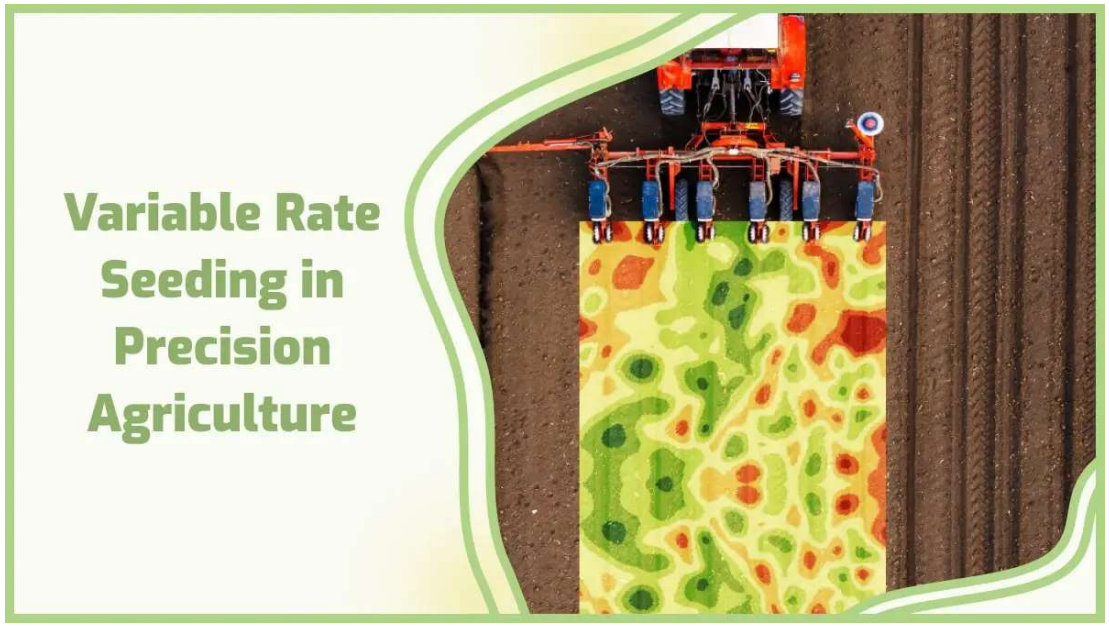
Pesticide Rate Variation

Targets areas of high pest presence and **reduces application in unaffected areas**, reducing chemical use and costs

Irrigation Rates

Applies water based on **soil salinity and water retention** needs

Seed Rate Variation VRT



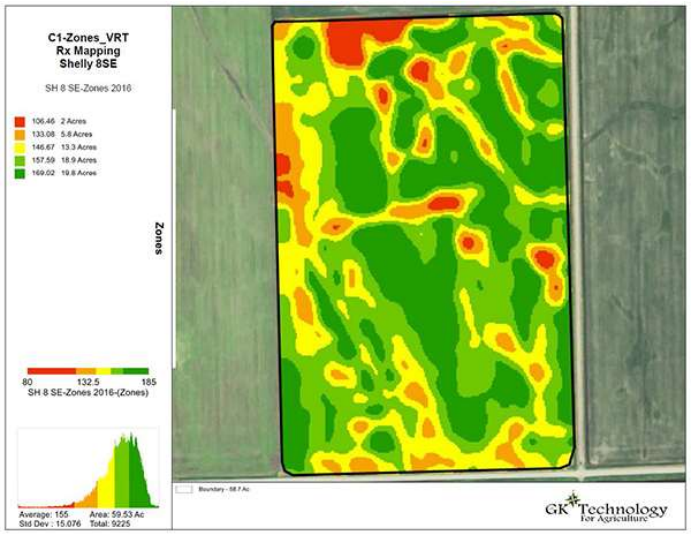
- Smoothens outfields inconsistency to produce a more uniform and consistent crop establishment in various managing zones
- Seeding rate of a highly productive zone will be very different from a soil zone with more subordinate productivity
- Variable rate seedling **aims to produce more even crops** because land varies and the nutrient portion in one section differs from the other
- Before considering a variable seed rate as an option, the **seeding rate must differ by more than 3,000 seeds per acre**

https://geopard.tech/blog/variable-rate-seeding-how-does-it-work/

Maps for Variable Rate Seeding

Nitrogen Map for Variable Rate Seeding

- A nitrogen map shows the variability in soil nitrogen levels across the field.
- High nitrogen areas can support higher plant densities, while low nitrogen areas may struggle to sustain high-density planting without additional nitrogen input
- In zones with high nitrogen, the seeding rate can be increased to maximize yield potential, as these areas can support more plants.
- In low-nitrogen zones, the seeding rate may be reduced to prevent plant competition, or it may trigger plans for targeted nitrogen fertilization before or after planting.

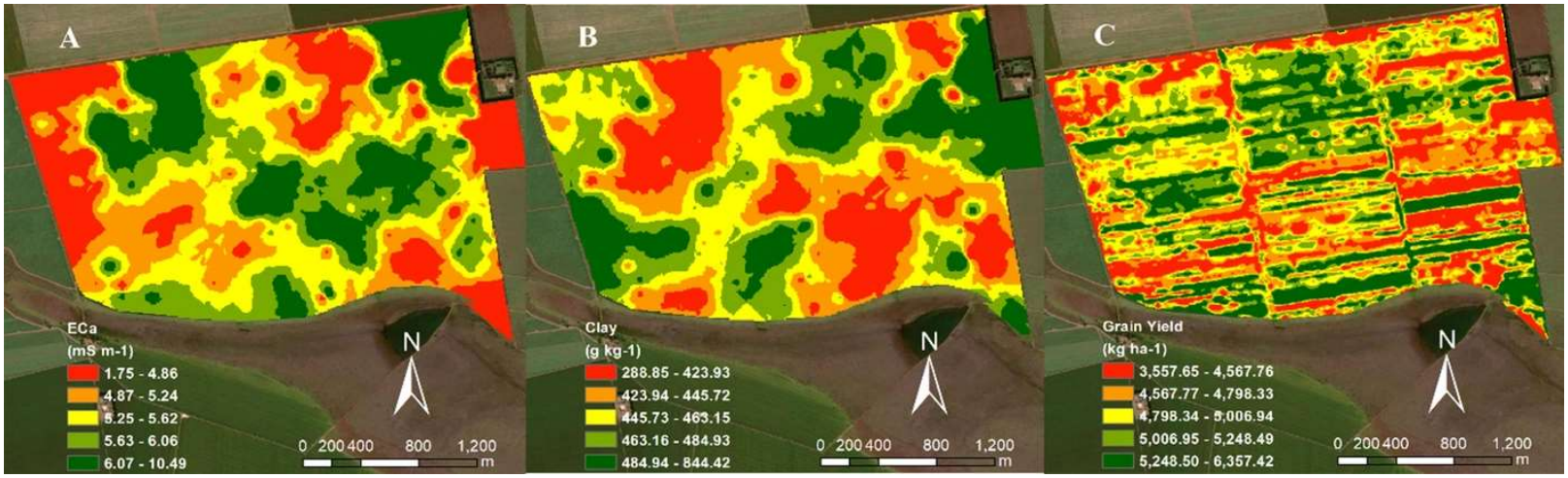


Maps for Variable Rate Seeding

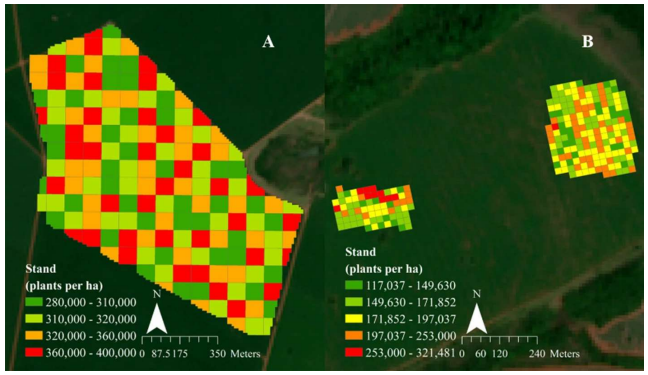
Soil EC Map for Variable Rate Seeding

- Soil EC maps reveal soil texture and moisture-holding capacity, indicating areas of high or low water retention and potential nutrient availability
- Higher soil EC typically means higher clay content, which holds more moisture, while lower EC areas may indicate sandy soils that drain more quickly
- In high EC zones (more moisture retention), seeding rates can be increased because the soil can better support plant growth.
- In low EC zones, reduced seeding rates may be more suitable due to potentially lower moisture and nutrient availability, which could lead to poor plant growth if planting density is too high

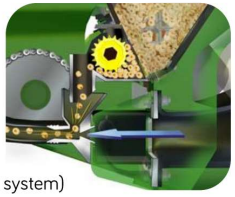
Maps for Variable Rate Seeding

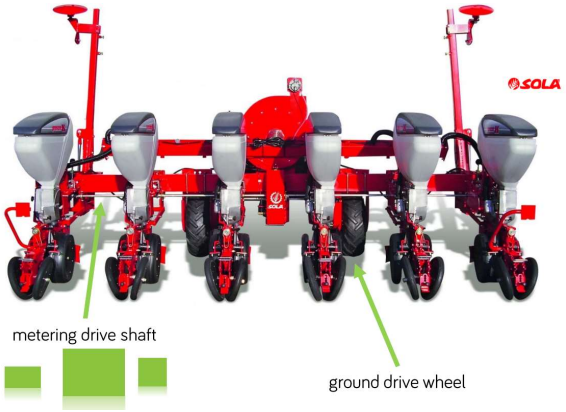


Maps for the variables ECa (A) and Clay (B) used in the decision tree and grain yield (GY) (C)



Conventional Seeding

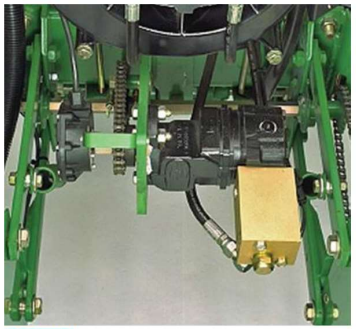




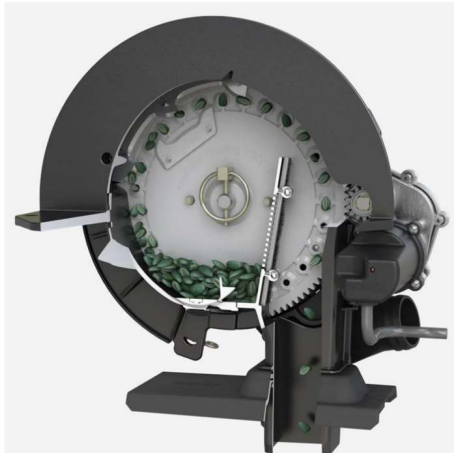
https://sparkle-project.eu/moodle/pluginfile.php/101/mod_resource/content/4/A2_L6_1_VRT%20Intro%20and%20Seeding.pdf

VRT Seeding

❑ Hydraulic Motor Drive



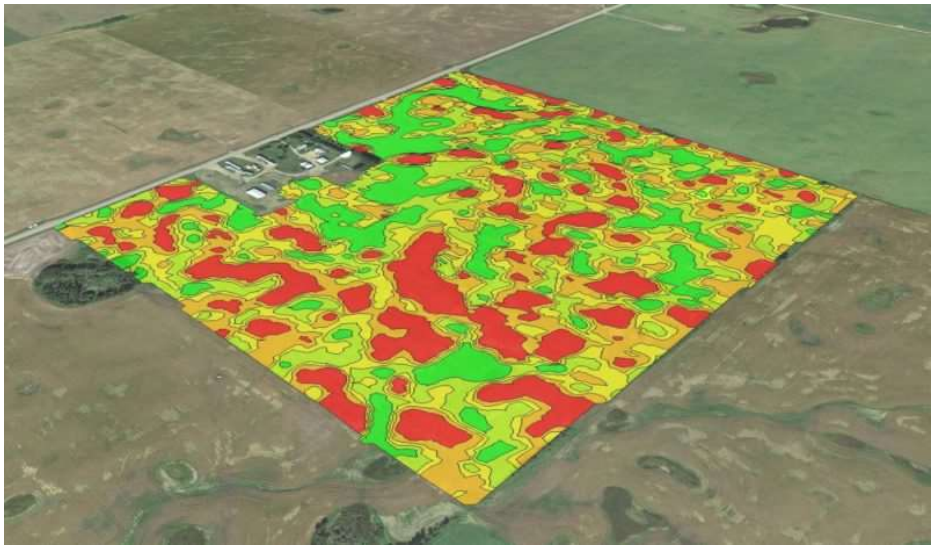
Kit to convert ground driven drills to hydraulic drive variable rate



https://sparkle-project.eu/moodle/pluginfile.php/101/mod_resource/content/4/A2_L6_1_VRT%20Intro%20and%20Seeding.pdf

VRT for Variable Rate Fertilizer Application

Variable Rate Fertilizer Application is the practice of adjusting the rate of fertilizer application across different zones of a field based on real-time or pre-mapped data on soil nutrient levels, crop needs, and environmental conditions.



VRT for Variable Rate Fertilizer Application

Variable Rate Fertilizer #1020 (Air Date 10-22-17)

Benefits and Challenges of VRT

Benefits

- Lower usage of fertilizers, pesticides, and water
- Maximizes plant health by applying the right amount of inputs
- Reduces nutrient runoff, protects water sources, and improves soil health

Challenges

- Advanced equipment and technology investments
- Learning new software and data management skills
- Requires storage, processing, and interpretation of large datasets

Emerging Trends in VRT

- AI and Machine Learning algorithms to analyze data and make more accurate recommendations
- Internet of Things (IoT) for real-time data collection from interconnected devices
- Centralized data storage and processing for enhanced VRT accuracy
- Automated VRT machinery guided by machine learning models and IoT sensors

Next Lecture

- Soil and Crop Health Monitoring I