

# 2019 CropLife/Purdue Precision Agriculture Dealer Survey: More Moves Toward Decision Agriculture

*Bruce Erickson, Education and Distance Outreach Director,  
Agronomy Department, Purdue University*

*James Lowenberg-DeBoer, Elizabeth Creak Professor of Agri-Tech Applied Economics,  
Harper Adams University*

**CropLife**<sup>®</sup>

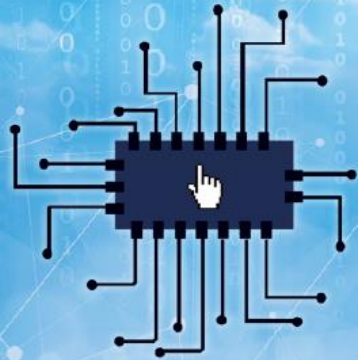
**PURDUE**  
AGRICULTURE

# Precision Dealer Survey Specs

- Conducted yearly 1997 to 2009, then every other year.
- Topics:
  - Precision technologies used by the retailers in their business
  - Precision products and services offered to customers
  - Retailers' estimation of farmer use of precision practices
  - Profitability, technology investment, constraints to adoption
  - Added more data questions in 2017
- Use U.S. CropLife magazine contact list
- Respondents include cooperatives, independents, multi-location regional companies

COVER STORY

CropLife magazine-Purdue University Precision Agriculture Dealership Survey



# More Moves Toward Decision Agriculture

2019 RETAILER SURVEY

BY BRUCE ERICKSON AND JAMES LOWENBERG-DEBOER

THE 2019 Precision Agriculture Dealership survey shows further steps toward a future in which crop management decisions will be increasingly guided by data collected from their farmer-customer's fields. Sensing-technology services, such as grid/zone soil sampling, satellite and unmanned aerial vehicle (UAV) imaging, and yield mapping, all showed steps up compared to the 2017 results. Corresponding were increases in all variable-rate services — for fertilizers,

lime, prescriptions for variable-rate seeding, and even for pesticides, although that remains relatively small.

After longer than a decade during which only around half of dealers were offering grid and zone soil sampling, this increased to 67% of dealers offering in 2015 to 82% in 2017 and now at 89% (Figure 1). Dealers offering satellite imagery — a possible foundation for creating management zones or guiding site-specific decisions — increased from 48% in 2015 to 59% in 2017 and 70% now. Similar increases were seen for dealers offering UAV services to customers and for dealers of-

fering yield monitor analysis services.

Added to the survey this year were questions about dealers offering grid or zone tissue sampling, at 67%, and electronic records/field maps, at 43%. It should be noted that the data represents the percent of dealers offering these services, not the percentage of acres in which these services were applied. The 2022 results are what dealers anticipate they will offer in three years. Among dealers who do not currently offer, the largest increases identified will be in UAV/drone imagery and precision plant tissue sampling. Variable-rate technology (VRT),

weed recognition and the targeting of individual weeds. In contrast to the data-intense technologies that underlie decision agriculture is a set of automated practices that does not depend on a field's agronomic characteristics, only a field's size and shape and where the machine has been. The economic benefits of reducing overlaps and skips, allowing drivers to work longer hours

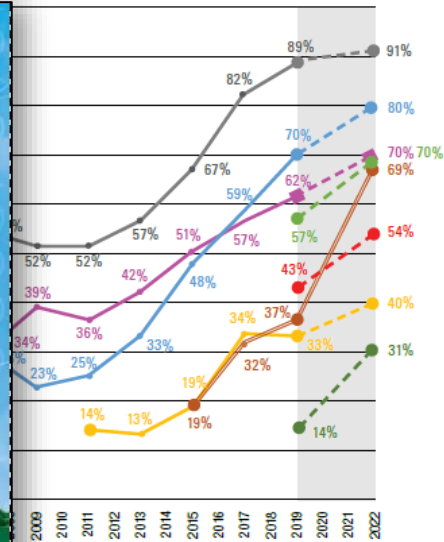
weed recognition and the targeting of individual weeds.

In contrast to the data-intense technologies that underlie decision agriculture is a set of automated practices that does not depend on a field's agronomic characteristics, only a field's size and shape and where the machine has been. The economic benefits of reducing overlaps and skips, allowing drivers to work longer hours

Continued on p.10

FIGURE 1

Strong gains in sensing-based precision services vs. the 2017 survey, with more expansion expected by 2022.



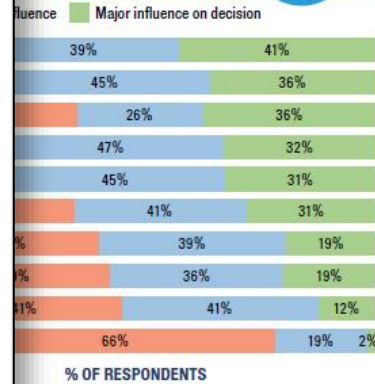
EC mapping  
 Drone imagery  
 Zone plant tissue sampling

Wired or wireless sensor networks  
 Electronic records/mapping for traceability

July 2019

FIGURE 4

Decision making, and seed selection.



tion adds value more subtly by helping to reduce over- and under-application rates vs. reducing doubling-up and skips. There are more dealers using telemetry to exchange information among applicators or to/from office locations and more dealers using GPS fleet management for vehicle logistics and tracking the locations of vehicles.

The biggest news for 2019? The impact of crop management decisions from pooled data. A new question in 2017 asked dealers to gauge the influence of data shared among farmers on a variety of factors related to crop management decisions (Figure 4). The 2019 survey showed a dramatic increase overall in the influence of pooled data — this would be data aggregated from multiple farms, either managed within the dealership or as part of an outside offering. For crop nutrient decisions, 80% of dealers said phosphorus and potassium decisions were at least somewhat influenced by pooled data, up from 43% just two years ago, and 79% saying nitrogen decisions were being influenced, up from 39% in 2017. Eighty percent of dealers (up from 39%) indicated pooled data had at least some influence for overall hybrid/variety placement, and 62% (30% in 2017) said it was influencing variable hybrid or variety placement in fields. Fifty-eight percent said pooled data was informing variable planting rate prescriptions, up from 30% in 2017. As mentioned before, some of this is likely driven by an increasing presence of data service pro-

Continued on p.16

- Highlights published in July CropLife magazine
- Full reports posted online: <http://agribusiness.purdue.edu/precision-ag-survey>

# 2019 Headlines:

- Automated technologies are in a maturing market in North America—this isn't news;
- Knowledge intense technologies to sense, inform, and react are making gains but still lag—this isn't news either!
- Dealers see big promise for UAVs in future.
- Dealers see big promise in precision pest management.
- Big uptick in using on-farm data for decision making.

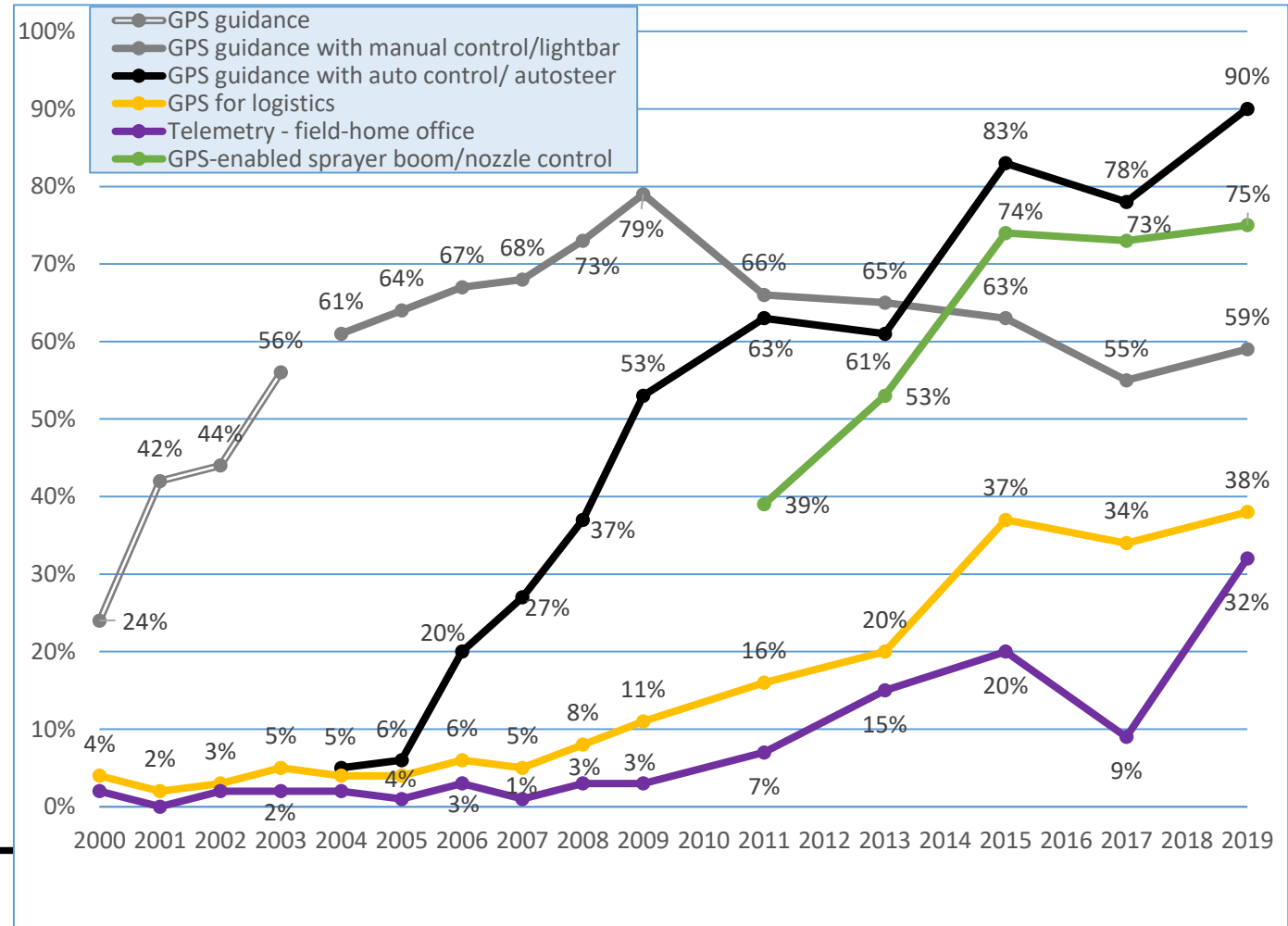
# Retailer Use of Precision Technology in 2019

- GPS Guidance and sprayer section control is standard practice
- Satellite and aerial imagery used by two thirds for internal purposes.

Precision Ag Technology	2017	2019
GPS guidance systems with automatic control (autosteer) for fertilizer/chemical application	78%	86
Auto sprayer boom section or nozzle control	73%	72
GPS guidance systems with manual control (light bar) for fertilizer/chemical application	55%	56
Satellite/aerial imagery for internal dealership purposes	52%	65
Smart scouting using an app on a mobile device to record field situations and locations	44%	44
Field mapping with GIS to document work for billing/insurance/legal purposes	43%	46
UAV or drone for internal dealership purposes	34%	38
GPS to manage vehicle logistics, tracking locations of vehicles, and guiding vehicles to the next site	34%	36
Telematics to exchange information among applicators or to/from office locations	24%	30
Sprayer turn compensation	22%	22
Y drops on fertilizer applicators	19%	25
Other soil sensors for mapping, mounted on a pickup, applicator or tractor (example: pH sensor)	9%	9
Chlorophyll/greenness sensors mounted on a pickup, applicator or tractor (CropSpec, GreenSeeker, OptRx, etc.)	9%	7

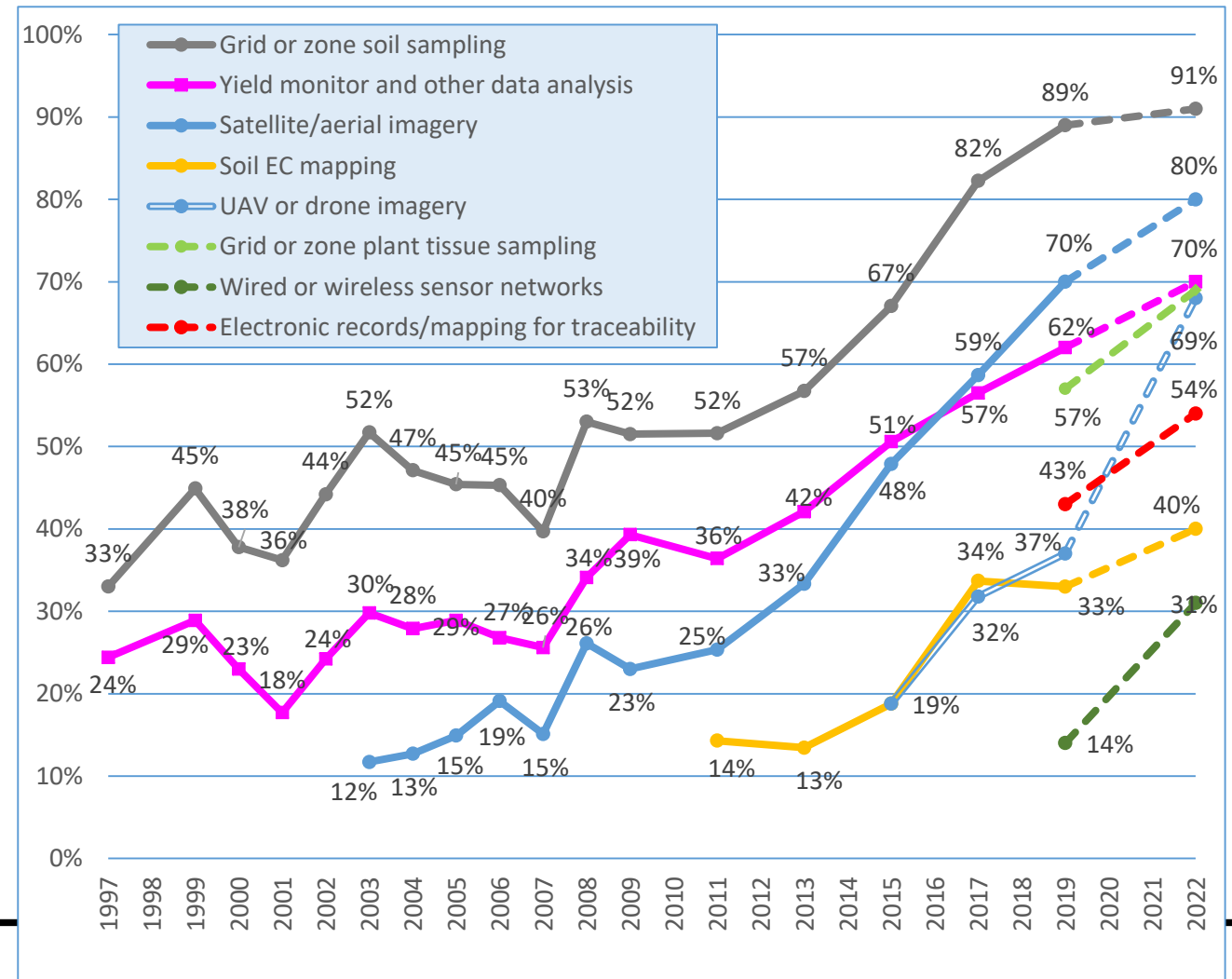
# Retailers Adopted GPS Guidance Rapidly for Internal Business Use (% of Retailers)

- Lightbars rapidly adopted starting in late 1990s
- Autosteer rapidly adopted starting in about 2004
- Both are easy to use and have short run benefits



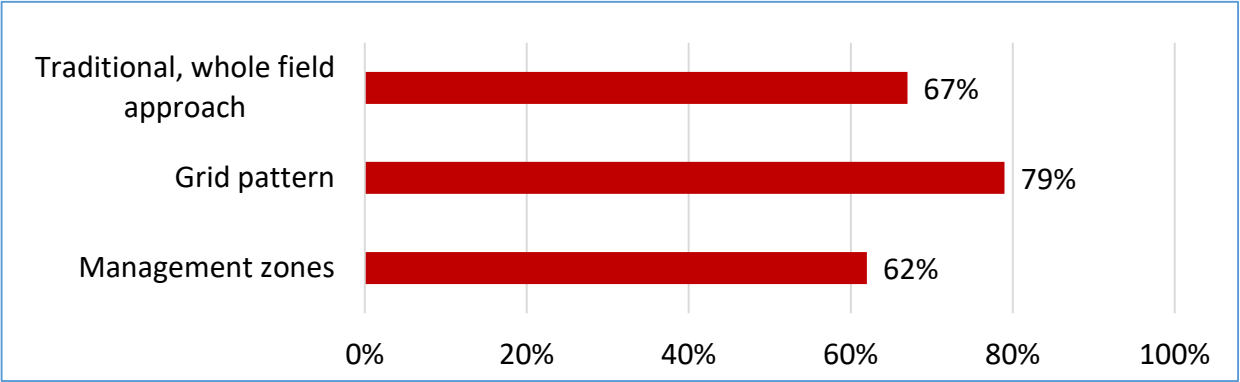
# Ag Retailers Slower to Offer Data Gathering Technologies to Customers (% of Retailers)

- Data collection technologies are foundation of data-driven farming
- Intensive soil sampling services have become almost standard practice.
- After many years 70% offer satellite imagery
- Big future plans for UAV services
- 2022 numbers are their projections

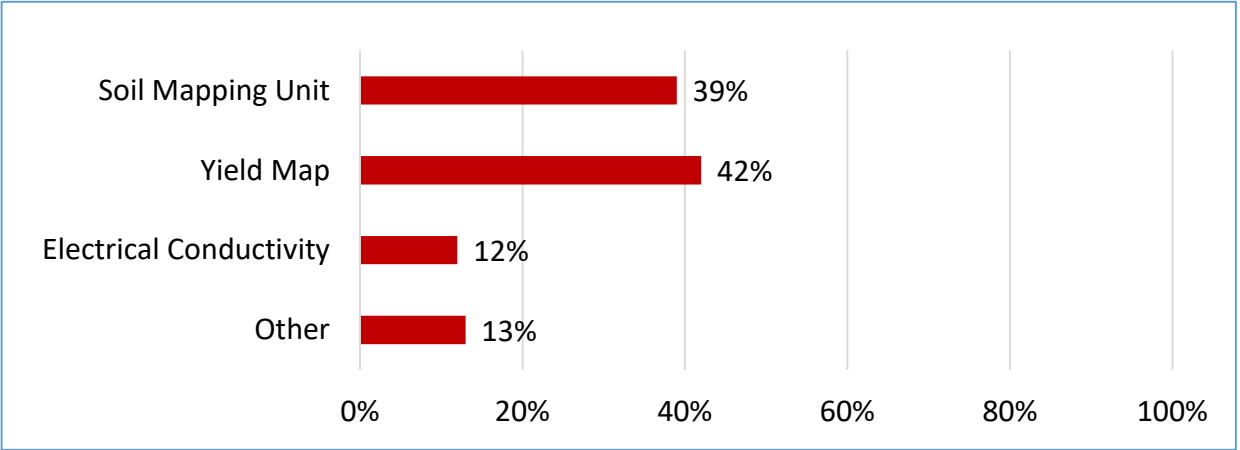


# Soil Sampling

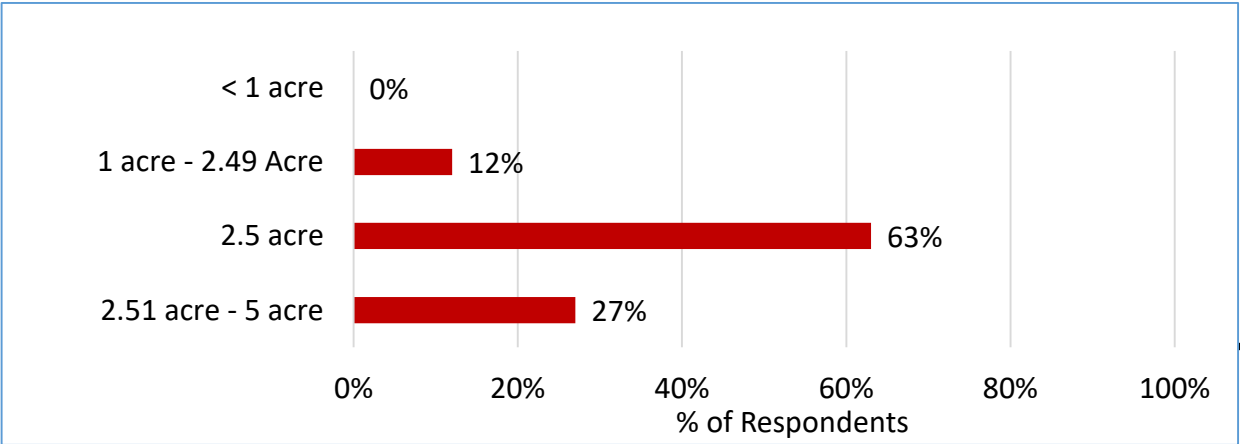
← More dealers sample in grids than zones



← If zones, soil mapping units or yield maps most common method for delineation

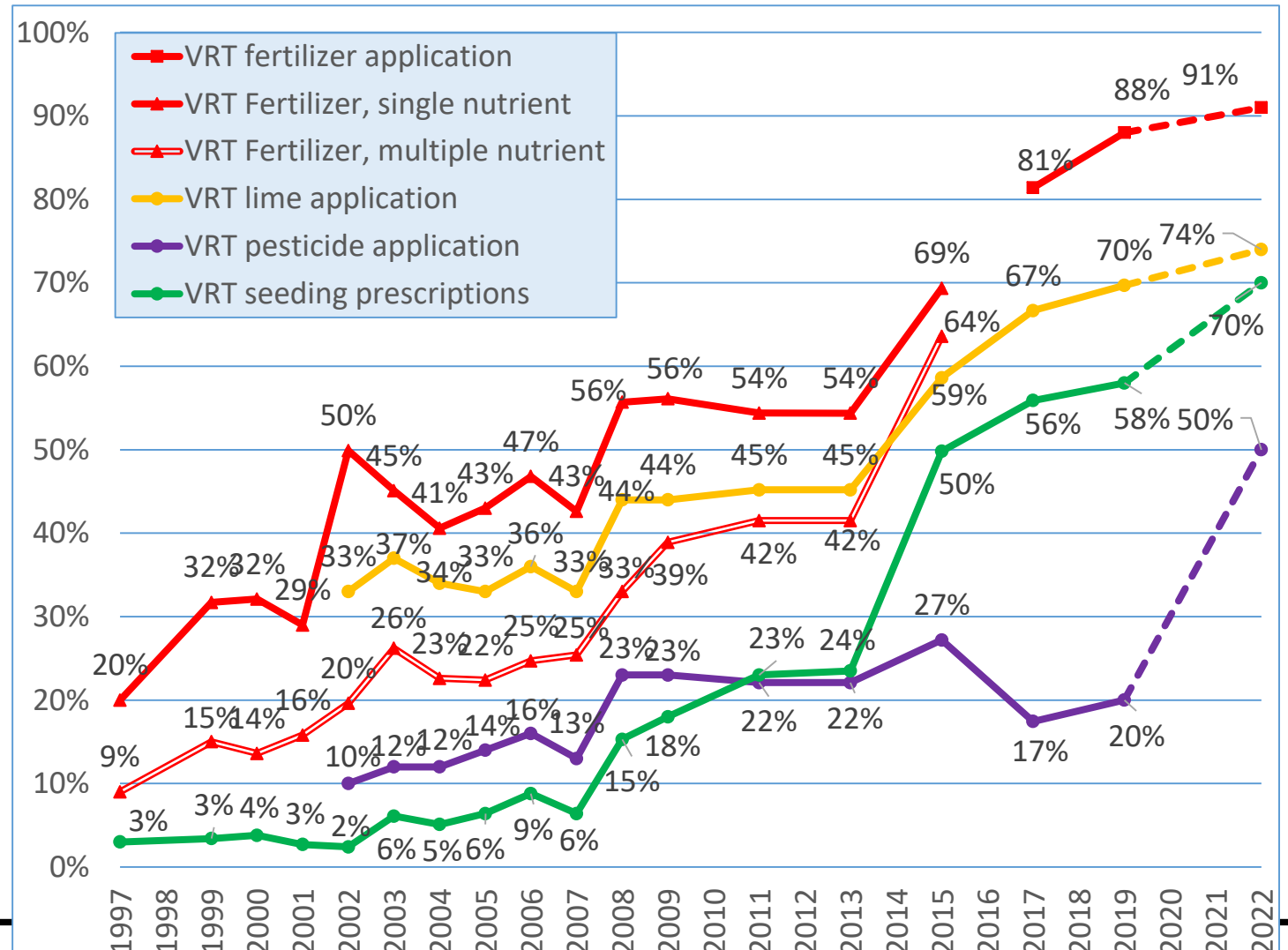


← If grids, 2.5 acres most common size



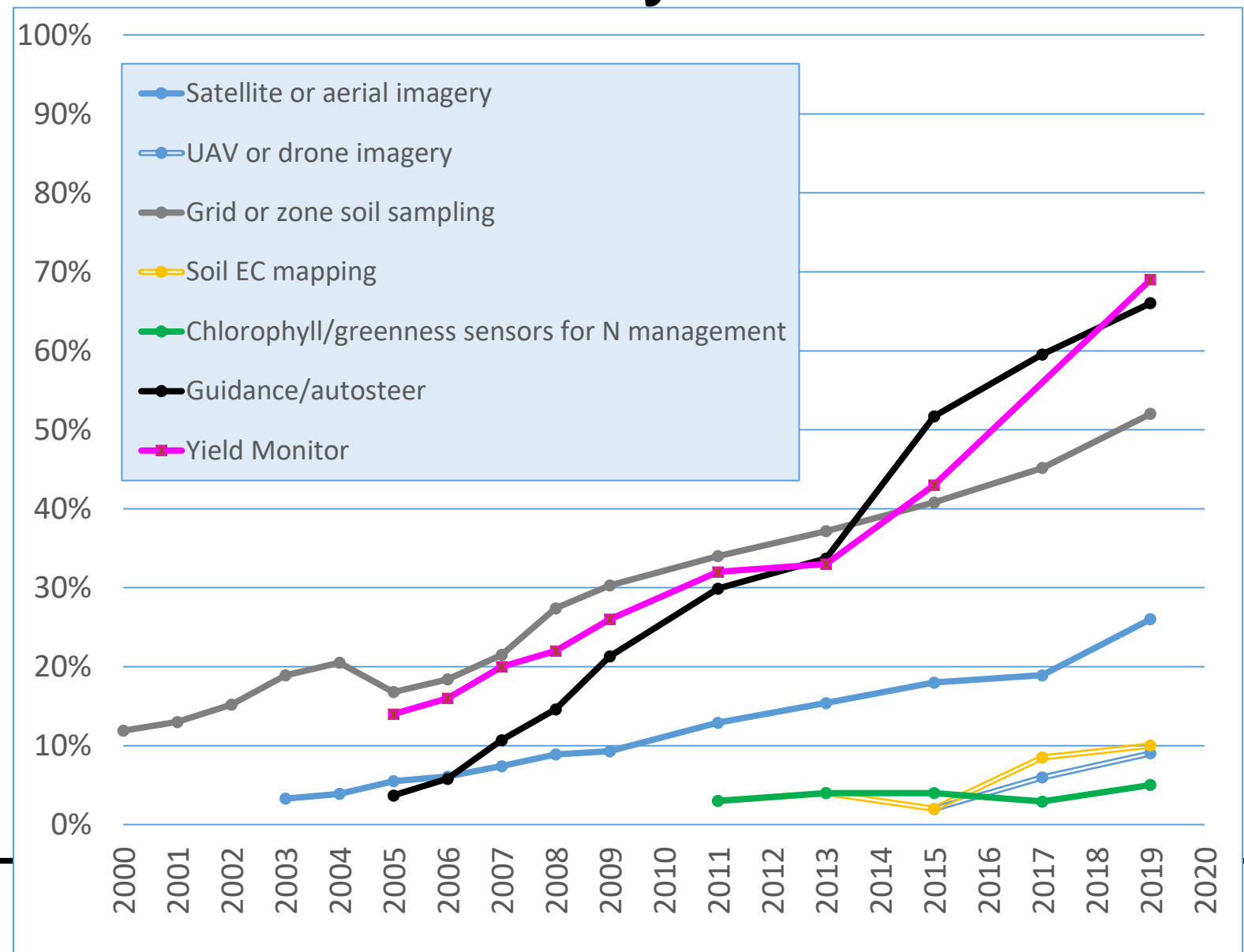
# Dealer Offerings of Variable Rate Technologies

- % of Retailers
- VRT is the action side of data technologies for data-driven farming
- Big plans for VRT pesticides
- 2022 are projections



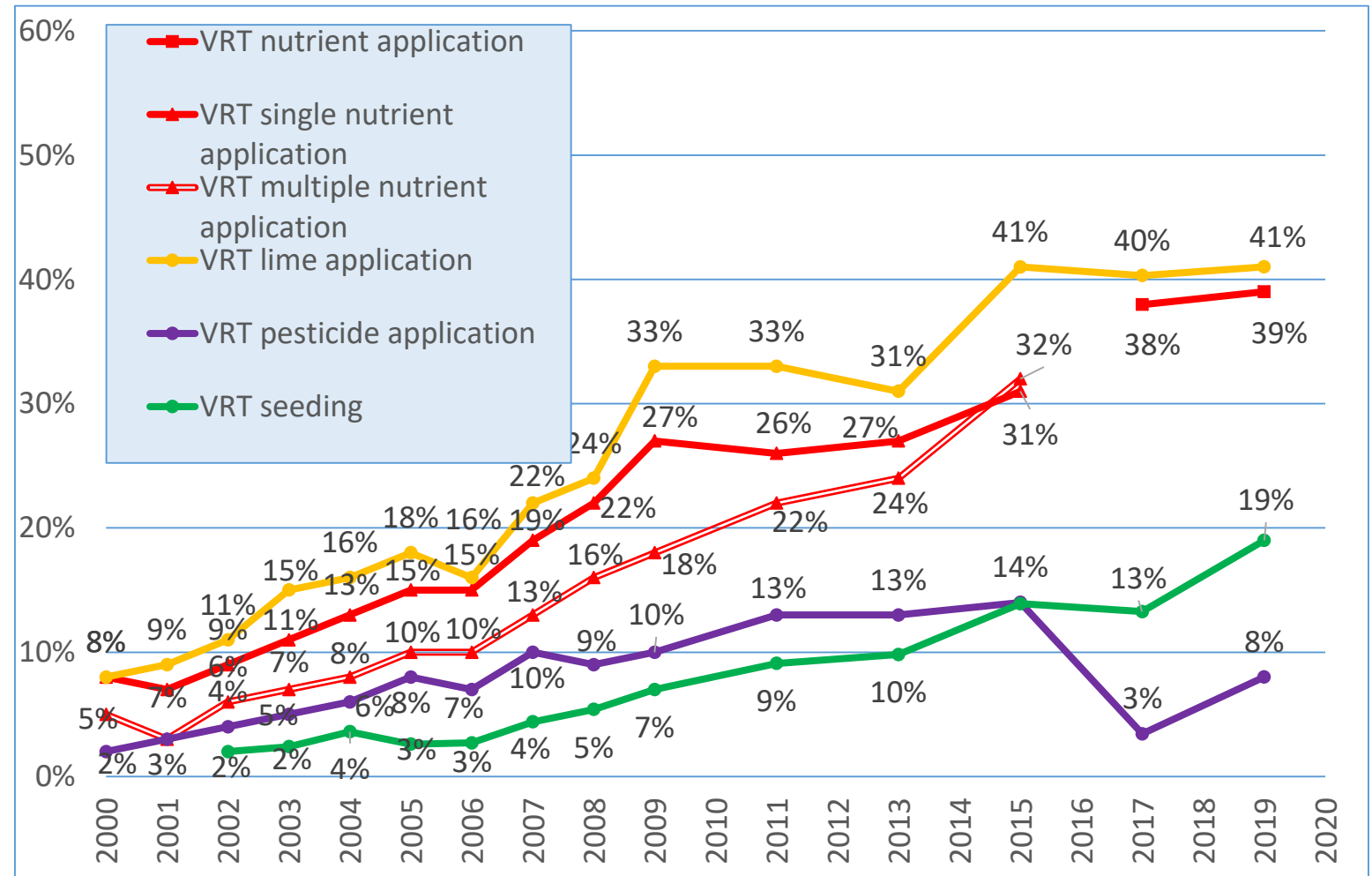
# Farmer Adoption Estimated by Retailers in their Market

- % acres in the retailer's market area, not % farmers
- GPS guidance becoming standard
- For yield monitor data always a question of use



# Farmer VRT Adoption Estimated by Retailers

- % acres, not % farmers, in the retailer's market area
- Substantially higher estimates than USDA and other sources
- VRT seeding and pesticides lag



## Setting the Record Straight on Precision Agriculture Adoption

James Lowenberg-DeBoer and Bruce Erickson\*

### ABSTRACT

There is a perception that adoption of precision agriculture (PA) has been slow. This study reviews the public data on farm level use of PA in crop production worldwide. It examines adoption estimates for PA from completed surveys that utilized random sampling procedures, as well as estimates of adoption using other survey methods, with an objective to document the national or regional level adoption patterns of PA using existing data. The analysis indicates that Global Navigation Satellite Systems (GNSS) guidance and associated automated technologies like sprayer boom control and planter row or section shutoffs have been adopted as fast as any major agricultural technology in history. The main reason for the perception that PA adoption is slow is because PA is often associated with variable rate technology (VRT)—just one of many PA technologies, one of the first adopted by many farmers, but that now rarely exceeds 20% of farms. This level of adoption suggests that farmers like the idea of VRT, but are not convinced of its value. VRT adoption estimates for niche groups of farmers may exceed 50%. The biggest gap in PA adoption is for medium and small farms in the developing world that do not use motorized mechanization.

### Core Ideas

- There is a perception that adoption of precision agriculture has been slow.
- Precision agriculture is not one technology but a toolkit from which farmers choose what they need.
- Global Navigation Satellite Systems guidance is being adopted rapidly.
- Variable rate technology adoption rarely exceeds 20% of farms.
- Use of precision agriculture technology on non-mechanized farms is almost nonexistent.

Published in *Agron. J.* 111:1–18 (2019)

doi:10.2134/agronj2018.12.0779

Available freely online through the author-supported open access option

© 2019 The author(s).

This is an open access article distributed under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

**B**ECAUSE PRECISION AGRICULTURE (PA) is considered an approach that meets production and environmental goals simultaneously, both scientists and policymakers have been investigating techniques to overcome adoption barriers (Pierpaoli et al., 2013; Silva et al., 2015; Keskin and Sekerli, 2016; Paustian and Theuvsen, 2017; Kendall et al., 2017; and Thompson et al., 2018). For example, the World Agri-Tech Summit in London, UK, Oct. 17, 2018, had a session entitled, “Tackling Adoption Barriers: What Value is Digital Agriculture Bringing to the Farm?”, and in 2015 the UK Parliament Office of Science and Technology stated, “Precision farming uses technology to improve efficiency. It offers benefits for yields, profits and the environment. However, uptake by farmers has been slow” (POST, 2015:p. 1). The Italian Ministry of Agriculture, Food, and Forestry (2015) guidelines for PA make a similar comment. These reports suggest that there is an adoption barrier, which may or may not be accurate.

In spite of high profile reports, the data tells a different story. Some aspects of PA were adopted as quickly and as widely as any technology in history, while others have lagged behind for technical and economic reasons. The objective of this study is to set the record straight on PA adoption by reviewing the available data with an eye on data reliability and to hypothesize adoption trends. Because PA adoption data collection methods vary widely from country to country, there are limitations in making direct numerical comparisons. Consequently, the methodology is impressionistic comparison that looks at the big picture, rather than making quantitative comparisons. This study will be of interest to PA researchers and educators across all the disciplines involved, to agribusinesses involved in manufacturing and selling PA tools, and policymakers concerned about agricultural productivity and the environment.

The lack of a clear definition of PA makes tracking adoption more difficult. One aspect of this problem is how to distinguish PA from other terms describing agricultural technology (e.g.,

J. Lowenberg-DeBoer, Elizabeth Creak Chair of Agri-Tech Economics, Harper Adams Univ., Newport, Shropshire UK TF10 8NB; B. Erickson, Agronomy Education Distance & Outreach Director, Purdue Univ., West Lafayette, IN 47907. Received 14 Dec. 2018. Accepted 27 Feb. 2019. \*Corresponding author (berickso@purdue.edu).

Abbreviations: ARMS, Agricultural Research Management Survey; DEFRA, Department of Food and Rural Affairs; EC, electrical conductivity; EMBRAPA, Brazilian Agricultural Research Corporation; GM, Genetically Modified; GNSS, Global Navigation Satellite Systems; GPS, global positioning system; GRDC, Grain Research and Development Corporation; ISPA, International Society of Precision Agriculture; INTA, National Institute for Agricultural Technology; KFMA, Kansas Farm Management Association; PA, Precision Agriculture; TAM, Technology Acceptance Model; VRT, Variable Rate Technology; WCA, World Census of Agriculture.

site-specific farming, smart farming, and digital agriculture). From another perspective, there is no clear definition of what technologies are included in PA. There have been many attempts to define PA. The Lleida University Research Group in AgroTIC and Precision Agriculture lists 27 definitions from the scientific literature and the Internet (Lleida University, 2018). Some focus the definition on variable rate technology (VRT). Others concentrate on application of electronic information technology. The International Society for Precision Agriculture (ISPA) solicited input from their members on a definition. After the 2018 ISPA conference in Montreal, PrecisionAg.com posted three candidate definitions of PA (Sulecki, 2018). This study will use a slightly modified version of the third proposed definition:

“Precision agriculture is a management strategy that uses electronic information and other technologies to gather, process, and analyze spatial and temporal data for the purpose of guiding targeted actions that improve efficiency, productivity, and sustainability of agricultural operations.” In this definition, “agriculture” should be broadly defined to include all types of biological production systems (e.g., arable cropping, perennial forages, forestry, orchards, vineyards, horticulture, livestock husbandry, and aquaculture). Unfortunately, adoption data for precision animal production is even more sparse than for crops. Consequently, this study focuses on crop PA, especially grain and oilseed production.

Site-specific crop management is ancient, but the idea of using electronic information technology to automate that process is relatively recent. From the dawn of agriculture, farmers instinctively managed crops site-specifically. For example, some crop varieties were planted in the lowlands and others in uplands. Manure was often applied on thinner or lighter soils or where the crop was less vigorous. In the 1920s, some US university researchers advocated grid soil sampling and spot application of fertilizer and lime to optimize soil nutrient levels (Linsley and Bauer, 1929), and most soil sampling protocols noted the importance of collecting different composite soil samples from areas with different characteristics. Depending on the information provided by the farmer, fertilizer recommendations would be made for each of these areas. Farmers applying fertilizers would often manually adjust the rates as they drove across the field.

The modern age of PA is often linked to the announcement by US President Ronald Reagan in 1983 that would allow global positioning systems (GPS) for civilian use. The term GPS refers to the US system; GNSS refers collectively to GPS plus other systems in use around the world. In the 1980s, soil scientists and agribusiness researchers in the United States and Europe started to develop equipment and methods for variable rate fertilizer application (Haneklaus and Schnug, 2002; Mulla and Khosla, 2016). The first commercially successful grain yield monitors were introduced in 1992. The combination of GNSS-enabled soil sampling, variable rate fertilizer applications, and yield monitoring was the “classic precision agriculture” package in the 1990s and some adoption studies focus on whether that classic package has been adopted.

Global Navigation Satellite Systems equipment guidance was commercialized in the late 1990s, first in Australia and shortly after in North America. In Australia guidance was closely linked with controlled traffic to reduce soil compaction, where farm equipment follows the same paths for various field

operations (Quick, 2007), but in North America controlled traffic was a minor motivator for adoption. Soon after the introduction of guidance came a wave of related technology including automatic boom/nozzle control for sprayers and automatic row shut offs for planters.

During the 20th century, the technologies used to collect remote sensing information changed from visual observations of airborne individuals, to cameras mounted in planes, to high resolution satellites, to digital sensors mounted in unmanned aerial vehicles (Mulla, 2013). Use of unmanned aviation for crop monitoring began experimentally in the first years of the 21st century.

Proximal soil sensing started before the release of GNSS for civilian use (Shonk et al., 1991). Electrical conductivity (EC) was first used to measure soil salinity by USDA ARS researchers at the Riverside, CA, research site in the 1970s. On-the-go soil sensing to guide fertilizer use started with the “Soil Doctor” sensor, invented in 1982 and originally used without GPS to vary nitrogen application on the go within fields. (Colburn, 1999; Lowenberg-DeBoer, 2004). Global Navigation Satellite Systems technology was later used with EC and the Soil Doctor to create maps of the sensor readings that could be used to guide crop management decisions. Starting in the 1990s numerous optical, EC, mechanical, and ion soil sensors were developed and some have been commercialized (Adamchuk et al., 2004).

The history of proximal plant sensors is similar to that of soil sensors (Mulla, 2013). Development of optical sensors to diagnose plant conditions based on reflectance started several decades before PA was a concept (Markwell et al., 1995). With GNSS it became possible to use sensor readings to create fertilizer and pesticide application maps, or to create on-the-go sensor-algorithm-application equipment. In the mid-1990s competing research teams in Europe and North America created sensors which could guide nitrogen application. Those sensors, such as the Yara N-Sensor, CropCircle, and GreenSeeker were eventually commercialized starting in the late 1990s.

To accompany the adoption information, a timeline of PA milestones and technology introduction was developed to provide points of reference (Table 1). Determining the year of technology introduction can be complicated, as inventions can exist in an entrepreneur’s shop, a researcher’s lab, or in prototype testing for many years with little documentation. As the commercial introduction is most relevant to adoption and is often better documented, the dates in the table below for specific technologies are the approximate year they came to the market.

Over the years, several studies have tried to provide a worldwide overview of PA adoption (Zhang et al., 2002; Griffin and Lowenberg-DeBoer, 2005; Say et al., 2018). Zhang et al. (2002) focused mainly on the technical issues associated with PA adoption and cited several adoption studies from the United States, United Kingdom, and Australia. They identify the following constraints to adoption: (i) the quantity of PA data exceeds the ability of farmers to analyze and use it for management, (ii) lack of scientifically validated procedures determining variable rate application of inputs, (iii) absence of evidence for the benefits of PA, (iv) labor intensive and costly data collection, and (v) need for improved technology transfer.

Griffin and Lowenberg-DeBoer (2005) summarized the worldwide data on PA adoption, reviewed the studies of PA

# Precision Agriculture Timeline

Table I. Key precision agriculture milestones.

Year	Technology or activity†	Company/organization, product name	Reference
1983	Executive order that allowed civilian use of GPS	US government	Brustein, 2014 Rip and Hasik, 2002
1987	Computer-controlled VRT fertilizer	Soil Teq	Mulla and Khosla, 2016
1988	Handheld GNSS	Magellan	Smithsonian, 2018
1992	First conference dedicated to precision agriculture research	International Conference on Precision Agriculture	Khosla, 2010

- First InfoAg?
- Impact plate grain yield monitor?
- Autoguidance?

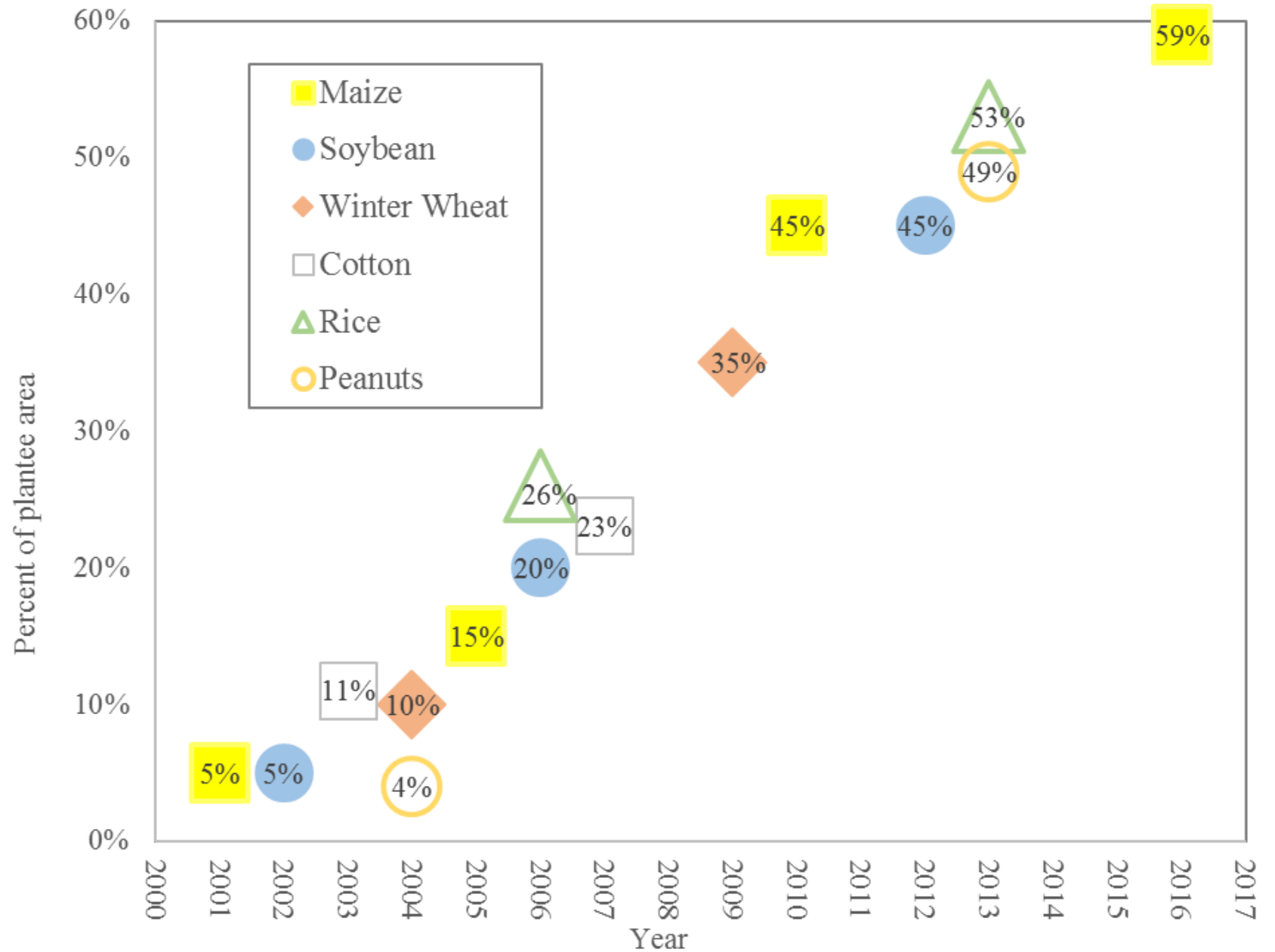
# Precision Agriculture Timeline

Table 1. Key precision agriculture milestones.

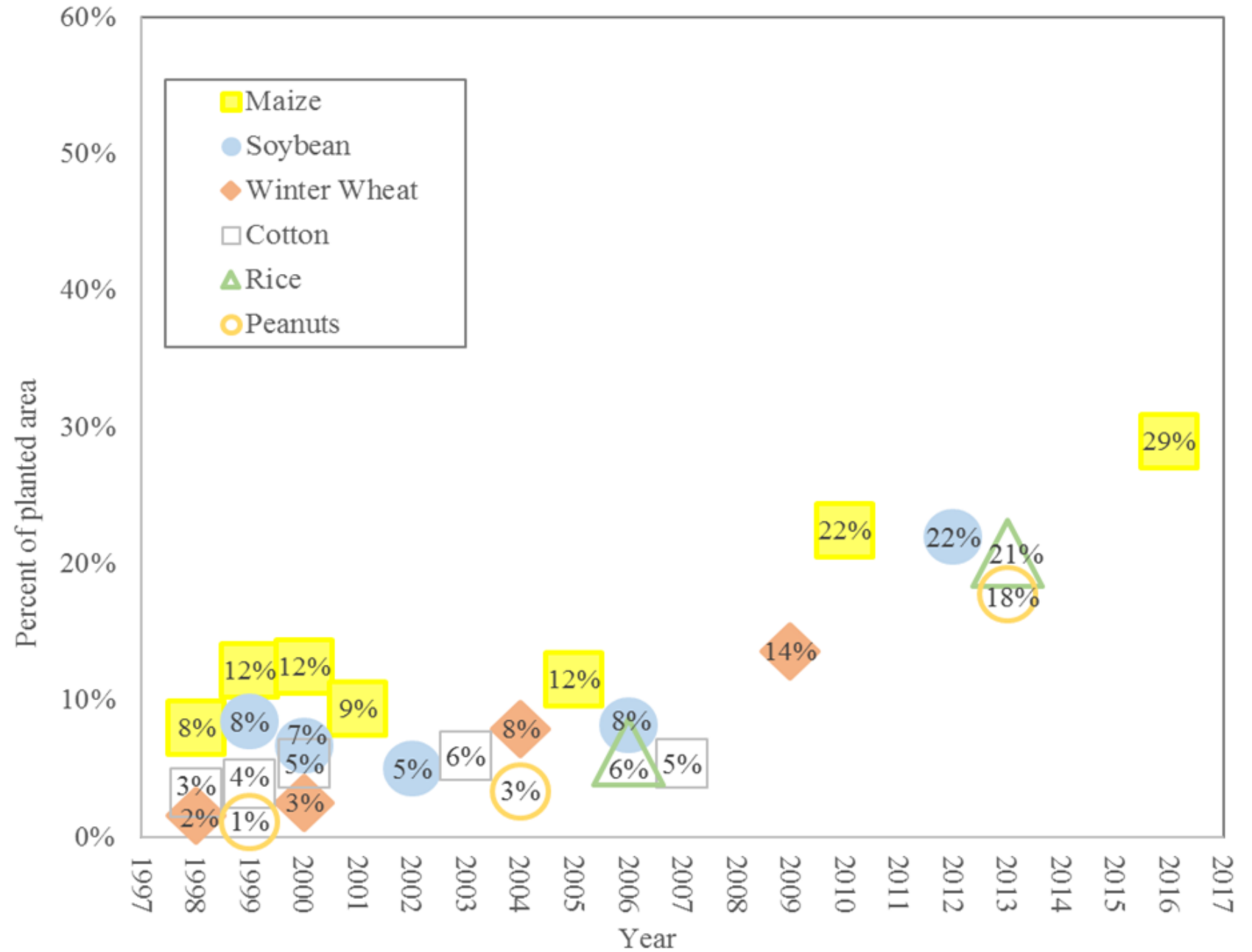
Year	Technology or activity†	Company/organization, product name	Reference
1983	Executive order that allowed civilian use of GPS	US government	Brustein, 2014 Rip and Hasik, 2002
1987	Computer-controlled VRT fertilizer	Soil Teq	Mulla and Khosla, 2016
1988	Handheld GNSS	Magellan	Smithsonian, 2018
1992	First conference dedicated to precision agriculture research	International Conference on Precision Agriculture	Khosla, 2010
1992	Impact plate grain yield monitor	Ag Leader, Yield Monitor 2000	Ag Leader, 2018
1995	First conference dedicated to precision agriculture industry	InfoAg	IPNI, 2010
1997	Auto guidance	Beeline	Rural Retailer, 2002
1997	On-the-go soil EC sensor	Veris	(Lund, E., personal communication, 13 Nov. 2018)
1997	Cotton yield monitor	Micro-Trak, Zycorn	Vellidis et al., 2003
2000	End of GNSS selective availability	US government	Coalition to Save Our GPS, 2012
2002	Integrated optical sensor and variable rate nitrogen applicator	N-Tech Industries, Greenseeker	Rutto and Arnall, 2017
2003	On-the-go soil pH sensor	Veris, Soil pH Manager (MSP)	Lowenberg-DeBoer, 2003
2006	Automated sprayer boom section controllers	Trimble, AgGPS EZ-Boom 2010	Trimble, 2006
2009	Planter row shutoffs	Ag Leader, Sure Stop	Ag Leader, 2018
2017	First fully autonomous field crop production	Harper Adams University	Hands Free Hectare, 2018

† EC, electrical conductivity; GNSS, Global Navigation Satellite Systems; GPS, global positioning system; VRT, variable rate technology.

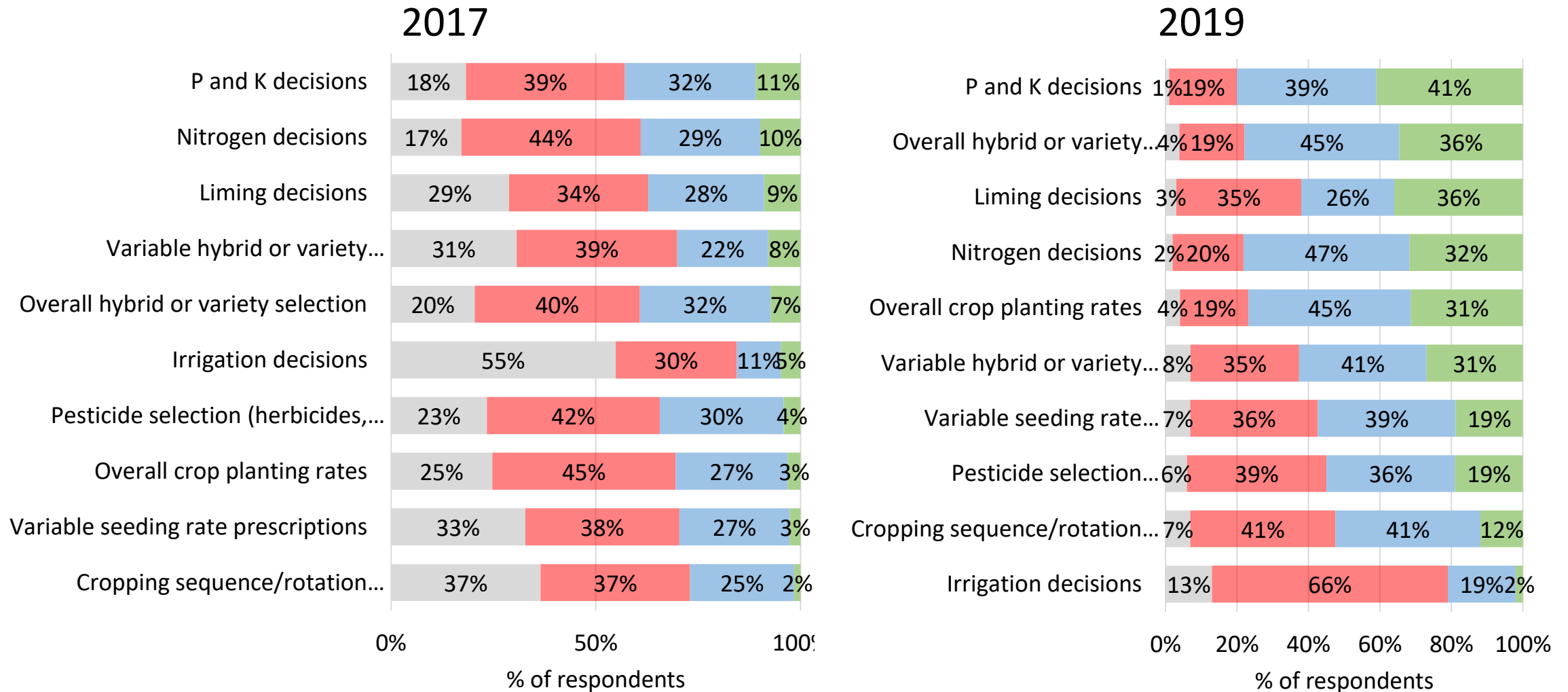
# USDA Data: Acres with Autoguidance in U.S.



# USDA Data: Acres Using Any VRT in U.S.

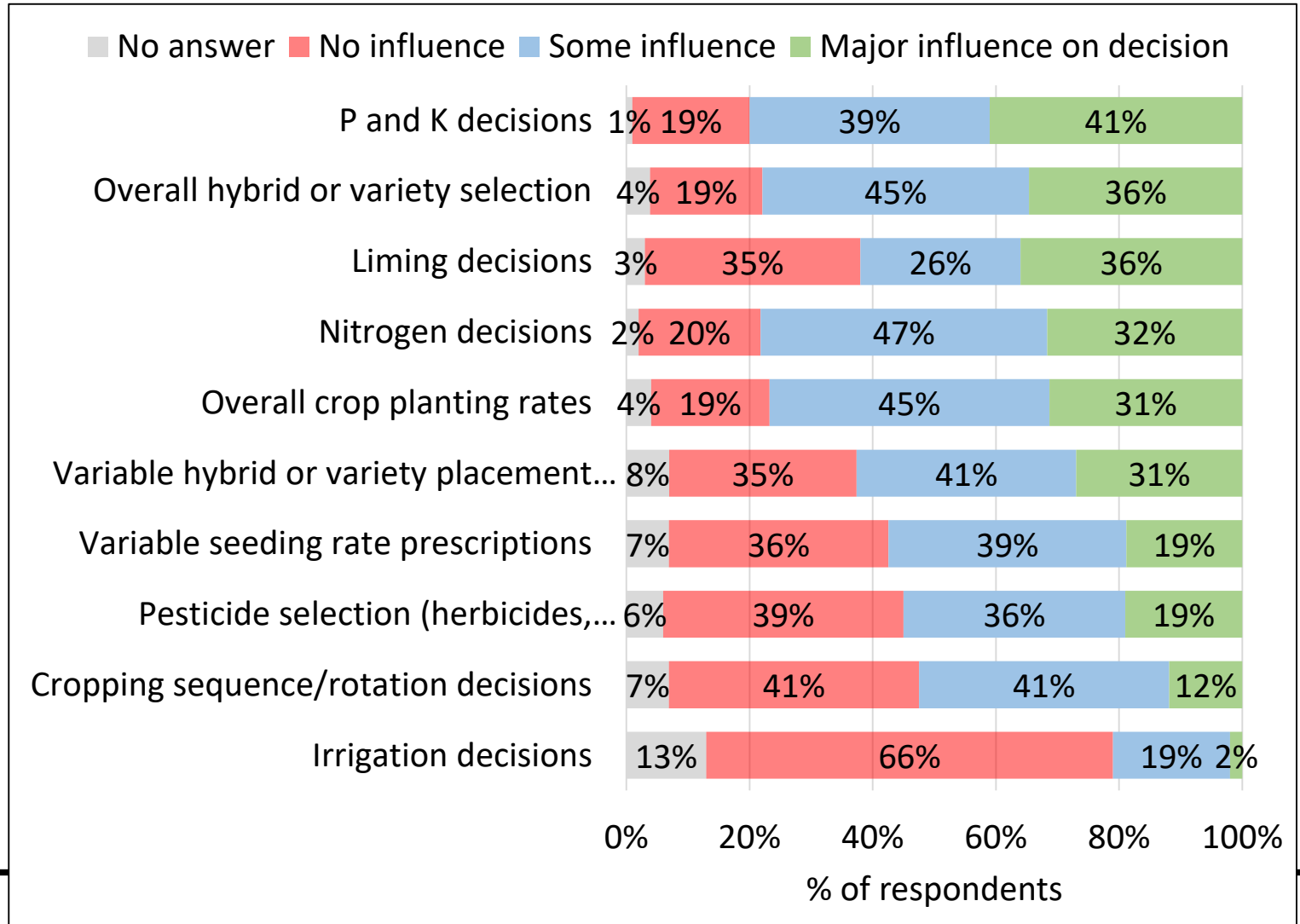


# Big Uptick in Data for Decisions



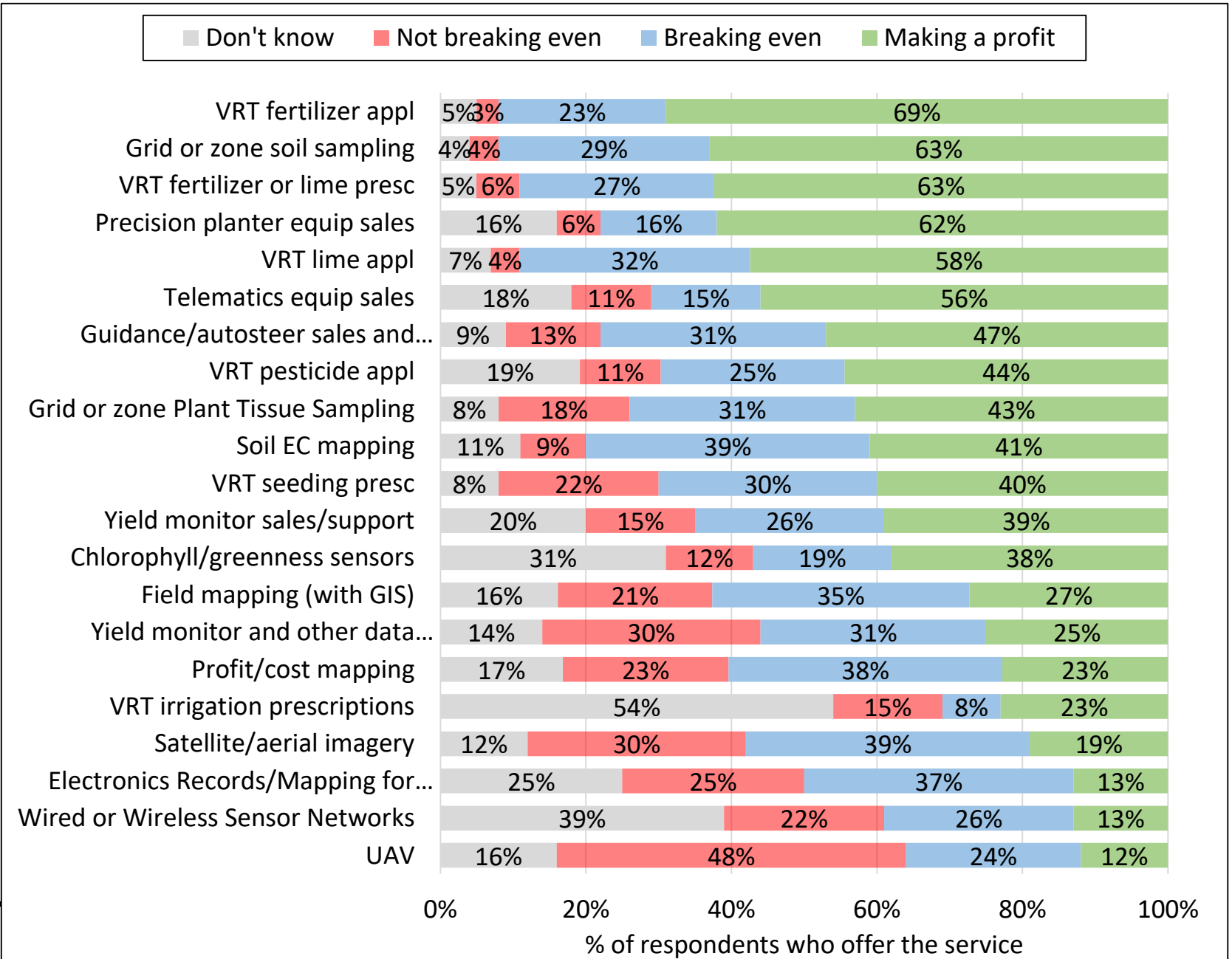
# Nutrient Mgmt. and Hybrid/Variety Selection Dominate Decisions Based on Farm Data

- 61% of retailers manage and/or archive yield, soil test and other data for farmers.
- 22% pool that data within their customer base.
- 11% pool that data beyond their customers
- Only 8% of retailers do not help customers with farm data

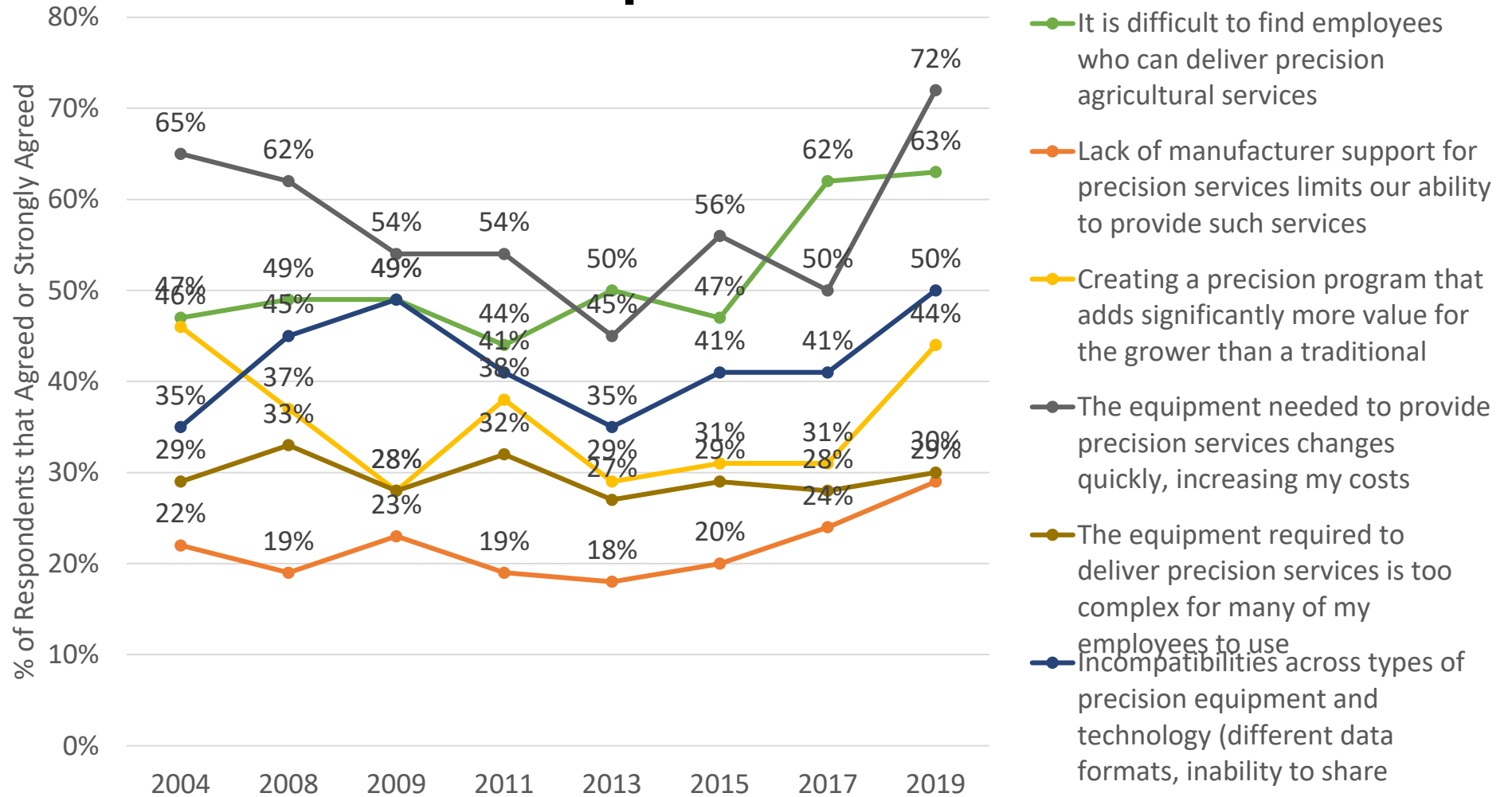


# Profitability of Offerings

- % of Retailers
- VRT fertilizer related services usually profitable
- Sensing services (e.g. UAV, satellite/aerial imagery, soil EC, chlorophyll sensors) less profitable



# Dealer Barriers to Adoption



# CropLife-Purdue Survey Summary:

- GPS guidance technologies have been adopted rapidly by retailers
- Information-intensive technologies more complicated, adoption is slower but increasing
- Most ag retailers offering farm data management & archiving
- Big increase in use of data to make decisions
- Creating a profitable data driven ag input supply business remains a challenge for retailers

# E-Learning Academy

## PRECISION AGRICULTURE ONLINE COURSE

2018 Session Starting Dates for this 12-Week Course: January 10, June 13 and September 19

### PRECISION AGRICULTURE EDUCATION OFFERED IN A CONVENIENT FORMAT

Applying technology to crop production through mechanization, fertilizers, crop protection chemistry, genetics, and other innovations has resulted in multiple-fold gains in productivity and efficiency. Now, the application of information technology to crop production, known as precision agriculture, has transformed many aspects of crop production and promises even more.

While the capabilities of precision agriculture have progressed dramatically in recent years, the inability to understand and apply these to benefit crop production can greatly limit utility. Change has come so fast that many involved in crop production are unfamiliar with, or uncomfortable working around an often intimidating array of sensors, wires, controllers, monitors, and computer programs.

In 2017, Precision Agriculture earned Purdue's highest award for professional online courses. Precision Agriculture is a fully online course that provides knowledge from which those working in agriculture can better understand the science of site-specific agriculture to help their customers and benefit their companies. Designed for working professionals who must mix continuing education with other responsibilities, participants in the course can access content at their convenience by computer, tablet, or mobile device.

The foundation of the lessons in this course are dozens of high-definition videos featuring leaders in precision agriculture, along with supplemental reading, graphics, glossaries, and tests. Through visual and audio presentations, this course connects with all learning styles and was specifically designed to meet the needs of off-campus learners.

Successful Completion  
Earns a Certificate of  
Completion & 18 Certified Crop Adviser CEUs

*Agricultural professionals in this course will gain current knowledge of precision agriculture that will help them understand management challenges of crop production. The course will equip them to better communicate with and advise customers, helping build customer confidence and trust.*



#### Contact Us

For more information about this or other online agronomy courses designed for the needs of sales staff, farmers and other agricultural professionals:

Email: [elearn@purdue.edu](mailto:elearn@purdue.edu)  
Webpage: <http://ag.purdue.edu/agry/ADE/pages/default.aspx>  
OR <http://tinyurl.com/purdueagry>

## PRECISION AGRICULTURE ONLINE COURSE INSTRUCTORS



Bruce Erickson, PhD, CPAg  
Course Designer & Instructor  
Agronomy  
Purdue University



John Fulton, PhD  
Food, Agricultural and  
Biological Engineering  
Ohio State University



Terry Griffin, PhD, CCA  
Agricultural Economics  
Kansas State University



Derek Heeren, PhD, PE  
Biological Systems Engineering  
University of Nebraska



Josh McGrath, PhD  
Plant & Soil Sciences  
University of Kentucky



Phillip Owens, PhD  
Agronomy  
Purdue University



Dharmendra Saraswat, PhD  
Agricultural & Biological  
Engineering  
Purdue University



Tim Stombaugh, PhD  
Biosystems & Agricultural  
Engineering  
University of Kentucky

### COURSE MODULE OUTLINE

#### Introduction to Precision Agriculture

Scope and overview of the technologies and their applications

#### Global Positioning Systems

Global navigation systems used around the world, how they work, equipment, factors affecting accuracy

#### Differential Correction

Ground-based and space-based correction systems, levels of accuracy, manual guidance and autoguidance

#### Sensors

Satellite, aerial, UAV, and proximal sensing platforms; active vs. passive sensing; spectral, spatial and temporal resolution; soil, crop and weather sensors

#### Soil & Water Spatial Variability

Soil formation and change across landscapes, soil mapping technology and utility, precision land management, irrigation and drainage

#### Nutrient Spatial Variability

Grid and zone sampling approaches, developing management zones, nutrient-specific sensors, equipment for nutrient VRT

#### Crop Spatial Variability

Yield monitors for grain and non-grain crops, calibration of monitors, data cleaning, yield map interpretation, yield stability, crop quality sensors

#### Geographic Information Systems

GIS coordinate systems, map scales and standards, capture, storage, editing, analysis, display, image classification

#### Automation

Implement steering, VRT seeding, planter unit controllers, variable hybrid/variety planting, spray boom and nozzle controllers, boom leveling

#### Data Analysis

Experimental design, data quality, compatibility, privacy, interpretation and correlation, product comparisons

#### Telematics

Understanding telematics technology, wireless network applications, product comparisons

#### Precision Farming Economics and Adoption

Cost effectiveness of guidance systems, section controllers, site-specific management in various crops, regions, situations

Unit 1 - UNDERSTANDING THE LAND/FIELD PREPARATION (5 Modules) > Water and Solute Movement, Irrigation and Drainage (click to open module)

Page 3 of 8

**Table of Contents**

- Introduction
- Water and Solute Movement
- Crop Water Use**
- Irrigation
- Drainage
- Glossary
- For More Information
- Test: Water and Solute Movement in Soils, Irrigation and Drainage

**Crop Water Use**

Page 3 of 8

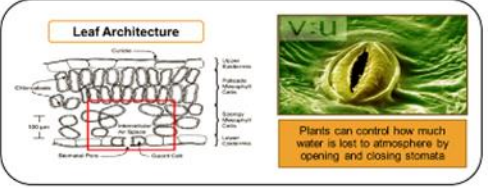
**Water Balance Equation**

$$WC_t = WC_{t-1} + IRR + RAIN - AET - DP \text{ where:}$$

- $WC_t$  Soil water content today (inches),
- $WC_{t-1}$  Soil water content yesterday (inches),
- $IRR$  Irrigation depth since yesterday (inches),
- $RAIN$  Rain since yesterday (inches),
- $AET$  Actual ET (inches), and
- $DP$  Deep percolation (inches).

**Evapotranspiration and the Water Cycle**  
Evapotranspiration is the sum of the water lost to the atmosphere from evaporation from the earth's surface and the transpiration of plants. Warm conditions, dry air, and the thickness of the plant canopy are some of the factors that can increase evapotranspiration, which is a major part of the water cycle. Openings in the leaves of plants called stomates open to allow the diffusion of CO<sub>2</sub> for photosynthesis, but also regulate transpiration, or the loss of water from plant leaves.

**Leaf Architecture**



Plants can control how much water is lost to atmosphere by opening and closing stomata.

**Plant Available Water** During part of a plant's lifecycle, precipitation may not meet its demand for water, so it will rely on irrigation or water stored in the soil. When a field is saturated, the pore space available for water and air is filled with water. Gravity will force the water to drain, leaving a layer of capillary water surrounding the solids in soil, a level called field capacity. The wilting point is reached when the remaining capillary water is so tightly held by the soil that it is unavailable to plants. A soil's plant available water is the volume of water between field capacity and the wilting point.

**Water Availability in Different Soils** Plant available water in different soil textures is related to soil particle shape and size. Water drains most quickly from sandy soils, whereas clay soils hold more water, but the tight pores between clay's small particles make it more difficult for plants to access the water. Soils that have the most plant

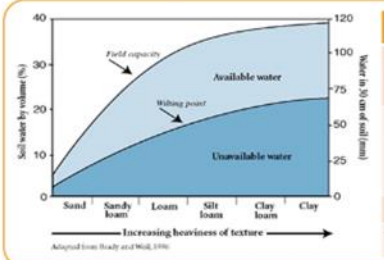
available water are loams and silt loams.

Farmers can track the water available in soils using sensors connected to irrigation systems or a formula that calculates the soil's water balance by using the previous day's water content, adding any rain or irrigation water, and subtracting evapotranspiration and water lost to ground storage.

**Presentation Slides** [Crop Water Use](#)

**Plant available water = volume of water between field capacity and wilting point**

Unit 1 | Module 2



Textures	Fraction Available Water
Sands, and loamy sands and sandy loams in which the sand is not dominated by very fine sand	< 0.10
Loamy sands and sandy loams in which very fine sand is the dominant sand fraction, and loams, clay loams, sandy clay loams, and sandy clay	0.10 - 0.15
Silty clay, and clay	0.10 - 0.20
Silt, silt loam, and silty clay loam	0.15 - 0.25

Soil texture and plant available water