Implementing the 4R framework in the field often results in the question, “What are the specific 4R practices I should do?” Precision ag practices, like GPS mapping, grid or zone soil sampling, yield monitors, variable-rate nutrient applications, and split nutrient applications, are all recognized as 4R practices (Snyder, 2016; Bruulsema, 2017). Selecting the right suite of 4R practices for site-specific characteristics can result in increased crop uptake of nutrients for greater productivity and return on investment and decreased loss of nutrients to air and water.

Understanding trends in practice adoption by farmers and agricultural dealers helps CCAs know where there are opportunities to increase implementation and what information is key when interacting with producers. Recently, surveys were conducted to evaluate the adoption rate and the economics linked to precision ag practice adoption. Earn 0.5 CEUs in Nutrient Management by reading this article and taking the quiz at www.certifiedcropadviser.org/education/classroom/classes/512

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Farmer adoption

In 2016, the USDA Economic Research Service (ERS) published a report using data from the USDA Agricultural Resource Management Survey of field crop producers...
evaluating adoption trends and farm profitability for specific precision ag technologies (Schminelpfennig, 2016). The report focused on the use of GPS mapping systems (including yield monitors and soil or yield mapping), guidance or auto-steer systems, and variable-rate technology (VRT).

Yield monitors had the highest rate of adoption on corn and soybean farms though the creation of yield maps was only half of that value (Table 1), pointing to a gap in the use of data collection and analysis tools on the farm. Use of GPS soil maps and VRT had the lowest reported rate of adoption per farm (Table 1). This level of implementation by individual farms represents 70% of corn acres and 69% of soybean acres with yield monitor recording versus only 28% of corn and 34% of soybean acres implementing VRT (Schminelpfennig, 2016).

When results were assessed based on acres farmed, implementation level increased with farm size. On corn farms more than 3,800 ac, GPS mapping systems had an 84% adoption rate, followed by guidance systems (80%), and VRT (40%) (Schminelpfennig, 2016). However, the rate of adoption of each practice as farm size increased was different. The use of GPS mapping increased the most between the farm sizes of under 600 ac to between 600 and 1,000 ac, with a 22% increase (Schminelpfennig, 2016). Guidance system adoption increased the most between the acreage range of 1,300 to 1,700 ac and 1,700 to 2,200 ac, at a 20% increase (Schminelpfennig, 2016). The use of VRT saw the largest increase in adoption in the highest acreage ranges, 2,900 to 3,800 ac to more than 3,800-ac farms, when it increased to 40% (Schminelpfennig, 2016). These adoption trends reflect the impact of expense and availability of precision ag technologies to smaller farms. For example, the adoption VRT for nutrient application requires the purchase of specialized equipment by the producer or an extra charge from an applicator and the time to compile and interpret the data collected.

The USDA survey information was also used to calculate precision ag technology impacts on the farms’ total net return. Overall, implementing a precision technology increased net returns on U.S. corn farms participating in the 2010 USDA survey (Schminelpfennig, 2016). The highest increase was for GPS mapping (1.8%), followed by guidance systems (1.5%), and then VRT (1.1%). Additionally, the 4R practice of using soil testing to determine nutrient deficiencies had a positive effect on adoption across the three precision ag technologies (Schminelpfennig, 2016). Adopting 4R practices can be profitable for a farm. Encouraging farms to use simple practices like soil testing at a field level can increase the likelihood of that farm continuing to adopt advanced practices.

Similar levels of practice adoption were reported in a Kansas Farm Management Association member survey, with only 26% adopting VRT and 40% adopting GPS yield monitors (Griffin et al., 2016). The survey also assesses the use of grid soil sampling and found 42% of farms had adopted the practice. Less than 4% of the farms reported abandoning these precision ag technologies after adopting them (Griffin et al., 2016). By collecting data from the same farms in multiple years, this survey could also evaluate the probability of additional practice adoption based on those previously adopted by the farm. Farms that reported using VRT had a 92% likelihood of adopting precision soil sampling (Griffin et al., 2016). Precision soil sampling is a major component of a VRT program. And, farms reporting use of variable-rate seeding and GPS yield monitors had a 75 and 69 percent likelihood of also adopting precision soil sampling (Griffin et al., 2016). This indicates, again, that as a farm increases management precision in one area, it is more likely to continue to improve precision in others.

### Service availability

In some cases, the ability of farms to adopt precision 4R practices depends on the rate of service and equipment adoption by agricultural retailers. Purdue University administers a survey every other year on the precision

### Table 1. Rate of adoption of precision ag technologies on corn (2010) and soybean (2012) for all reporting farms (Schminelpfennig, 2016).

<table>
<thead>
<tr>
<th>Farm type</th>
<th>Yield monitor</th>
<th>Yield map</th>
<th>GPS soil maps</th>
<th>VRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>48%</td>
<td>25%</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Soybean</td>
<td>51%</td>
<td>21%</td>
<td>16%</td>
<td>26%</td>
</tr>
</tbody>
</table>
consulting and application services offered by agricultural dealers. From 2011 to 2017, the rate of adoption of soil sampling with GPS, field mapping with GPS, yield monitor data analysis, and soil electrical conductivity mapping increased (Erickson and Lowenberg-Deboer, 2017). Soil sampling with GPS consistently has the highest adoption rate relative to other dealer precision services. In 2017, 78% of dealers reported offering soil sampling with GPS, followed by field mapping with GPS at 75% (Erickson and Lowenberg-Deboer, 2017).

As determined in the two farmer surveys, increased adoption of VRT- and GPS-based soil sampling are linked. Between 2011 and 2017, retailer-provided VRT fertilizer services increased from 54 to 78% (Erickson and Lowenberg-Deboer, 2017).

To gain understanding of 4R practice use, The Fertilizer Institute surveyed retail consultants previously recognized as 4R Advocates (www.nutrientstewardship.com/advocates). Grid or zone soil sampling and analysis was the most used practice when making a recommendation to a producer. Post-harvest yield monitoring and end-of-season nutrient use efficiency assessment were also recognized as key tools for making nutrient recommendations.

Return on investment

Dealers and farmers are both concerned with practice profitability when selecting and implementing the discussed technologies and services. As reported in the ERS research, there is a positive effect of adopting precision ag technologies on the net return to the farm for GPS mapping systems, guidance systems, and VRT. Similarly, the dealers surveyed by Purdue University reported VRT fertilizer application, VRT fertilizer and lime prescriptions, and grid or zone soil sampling services as being profitable for the dealer (Erickson and Lowenberg-Deboer, 2017). The 4R Advocates surveyed also reported these practices as being profitable for their firms.

Conclusions

Precision ag practices, like GPS mapping, grid or zone soil sampling, yield monitors, and VRT applications, are recognized as 4R practices that can improve nutrient use and reduce environmental risk. These recent producer and agricultural dealer surveys also indicate these practices have a positive impact on farm and dealer profitability. There is significant room to expand the use and availability of these practices on farms and by dealers, with less than 30% of farms using VRT and 78% of dealers offering VRT fertilizer services and application.

Reference section is omitted here due to space constraints but can be viewed online at dx.doi.org/doi:10.2134/cs2017.50.0507.

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