A Worldwide Perspective on Precision Agriculture Adoption

Is Precision Agriculture Adoption Linked to Farm Field Size?

Just in case you are wondering about Harper Adams University:

- Harper Adams is a British public agricultural research and teaching university established in 1901
- 200 km northwest of London in Shropshire
- 5000 students in Agri-business, Ag Engineering, Food Science, Animal Science and Veterinary Science.
- Campus within a 550 hectare working farm
Objectives:

1) Summarize worldwide Precision Agriculture adoption.

2) Develop hypotheses to understand PA adoption patterns.

3) Discuss key adoption challenges in the next decade.

Source: Lowenberg-DeBoer, SAE, 1998
Sparse Data Warning:

- No country systematically collects official data on use of precision ag technology.
- Only a few governments (i.e. USA, Australia, UK) sporadically do surveys of PA adoption. Alternative sampling methods may not provide representative data.
- Manufacturers and PA dealers usually do not reveal sales data – proprietary information!
- Our knowledge of PA adoption comes from piecing together data from sporadic and geographically dispersed surveys.
- It is essential to look at adoption by specific practice or technology. PA is a toolbox. Farmers choose what is useful.
Retailers Adopted GPS Guidance Rapidly for Internal Business Use (% of Retailers)

- Lightbars rapidly adopted starting in late 1990s.
- Both are easy to use and have short run benefits.
Retailers Slower to Adopt Sensing Technologies

- Return for sensing technologies more complicated—no return until data is turned into a decision
- Percent of retailers - Note % scale compared to previous slide
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 over 50% offer satellite imagery
- 2020 numbers are their projections
Dealer Offerings of Variable Rate Technologies

• % of Retailers
• VRT is the action side of data technologies for data-driven farming
• Most dealers offer VRT services.
• Farmer uptake of VRT has been slower
• 2020 are projections
Farmer Adoption of GNSS Guidance in the USA

- USDA ARMS data has an irregular survey cycle with different crops each year, but it is probably the best data available.
- Easy to imagine that the cloud of data points forms a classic “S” shaped adoption curve for GNSS guidance.
- Other data suggests that sprayer boom control, seeder row shut offs and other GNSS guidance related technology has been adopted rapidly by farmers as well as dealers.

Farmer Adoption of Variable Rate Technology (VRT)

- Farmer use of VRT on cereals and oilseeds rarely exceeds 20% anywhere.
- In spite of widespread availability of VRT services, intense publicity, and subsidies in some counties and states, VRT use by US farmers shows only a slight upward trend.
- The >20% adoption of VRT in the 2010-12 period was during a period of high grain prices. Evidence suggests that farmers have cut back on VRT since to reduce costs.

VRT is adopted in some niches where it is highly profitable and were technical support is available

- In 2016 53% of the sugar beet acreage in the Red River Valley was managed with VRT N (Franzen, 2016).
- The percentage of area grid soil sampled was greater, but in some cases judged not variable enough to justify VRT.
- Fertilizer dealers in the Valley equipped to provide VRT services.
- Crop consultants invested in soil sampling equipment and mapping technology.
- University of Minnesota and North Dakota State University provide research support for VRT N.

Sugar Beet Yield and Quality Improve with VRT Nitrogen in the Red River Valley of the North, USA.

<table>
<thead>
<tr>
<th>Study</th>
<th>Tons/Acre Advantage</th>
<th>Increase in Sugar Content</th>
<th>Increase in Price per Ton*</th>
<th>Net Return to VRT per Acre**</th>
</tr>
</thead>
<tbody>
<tr>
<td>U of M 1994</td>
<td>1.2</td>
<td>0.33</td>
<td>£ 1.37</td>
<td>£ 48.00</td>
</tr>
<tr>
<td>U of M 1995</td>
<td>0.9</td>
<td>0.40</td>
<td>£ 1.07</td>
<td>£ 32.00</td>
</tr>
<tr>
<td>NDSU 1995</td>
<td>1.2</td>
<td>0.10</td>
<td>£ 1.13</td>
<td>£ 34.00</td>
</tr>
<tr>
<td>American Crystal Sugar 1995</td>
<td>0.4</td>
<td>0.53</td>
<td>£ 2.07</td>
<td>£ 34.67</td>
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</tbody>
</table>

* Assumes that in 1994-1995 - UK£1 ~ US$1.50
** Net return to VRT minus grid soil testing and VRT service
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
- 2020 are projections
Farmer VRT Adoption Estimated by Retailers

• % acres, not % farmers, in the retailer’s market area
• Substantially higher estimates than USDA and other sources
• Farmer interest in VRT seeding remarkable
• 2020 are projections
Nutrient Management and Hybrid/Variety Selection Dominate Decisions Based on Farm Data

- 58% of retailers manage and/or archive yield, soil test and other data for farmers.
- 17% pool that data within their customer base.
- 10% pool that data beyond their customers
- Only 13% of retailers do not help customers with farm data
Profitability of Precision Service Offerings

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

<table>
<thead>
<tr>
<th>Service Offerings</th>
<th>Don’t know</th>
<th>Not breaking even</th>
<th>Breaking even</th>
<th>Making a profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field mapping (with GIS)</td>
<td>11%</td>
<td>13%</td>
<td>45%</td>
<td>31%</td>
</tr>
<tr>
<td>VRT fertilizer or lime presc</td>
<td>6%</td>
<td>5%</td>
<td>21%</td>
<td>68%</td>
</tr>
<tr>
<td>VRT fertilizer appl</td>
<td>5%</td>
<td>4%</td>
<td>11%</td>
<td>80%</td>
</tr>
<tr>
<td>VRT lime appl</td>
<td>7%</td>
<td>4%</td>
<td>20%</td>
<td>69%</td>
</tr>
<tr>
<td>VRT pesticide appl</td>
<td>27%</td>
<td>6%</td>
<td>25%</td>
<td>42%</td>
</tr>
<tr>
<td>VRT seeding presc</td>
<td>19%</td>
<td>9%</td>
<td>32%</td>
<td>39%</td>
</tr>
<tr>
<td>Yield monitor sales/support</td>
<td>19%</td>
<td>9%</td>
<td>37%</td>
<td>35%</td>
</tr>
<tr>
<td>Yield monitor and other data analysis</td>
<td>17%</td>
<td>14%</td>
<td>39%</td>
<td>31%</td>
</tr>
<tr>
<td>Satellite/aerial imagery</td>
<td>26%</td>
<td>16%</td>
<td>36%</td>
<td>22%</td>
</tr>
<tr>
<td>UAV</td>
<td>30%</td>
<td>16%</td>
<td>29%</td>
<td>22%</td>
</tr>
<tr>
<td>Guidance/autosteer sales and support</td>
<td>23%</td>
<td>12%</td>
<td>27%</td>
<td>38%</td>
</tr>
<tr>
<td>Grid or zone soil sampling</td>
<td>17%</td>
<td>20%</td>
<td>27%</td>
<td>38%</td>
</tr>
<tr>
<td>Soil EC mapping</td>
<td>22%</td>
<td>8%</td>
<td>33%</td>
<td>38%</td>
</tr>
<tr>
<td>Chlorophyll/greenness sensors</td>
<td>31%</td>
<td>0%</td>
<td>42%</td>
<td>27%</td>
</tr>
<tr>
<td>Precision planter equip sales</td>
<td>23%</td>
<td>6%</td>
<td>27%</td>
<td>44%</td>
</tr>
<tr>
<td>Telematics equip sales</td>
<td>29%</td>
<td>20%</td>
<td>27%</td>
<td>24%</td>
</tr>
<tr>
<td>Profit/cost mapping</td>
<td>26%</td>
<td>10%</td>
<td>44%</td>
<td>20%</td>
</tr>
</tbody>
</table>
PA Adoption by Medium and Small Scale Farmers in the USA

• The initial wave of PA technology was designed mainly for large scale, mechanized grain producers.

• Not surprisingly, PA adoption has been concentrated among those large scale producers.

• As PA technology prices decline with mass production and the technology becomes easier to use, the expectation is that it will be used by all mechanized farms.

USDA ARMS data is collected by crop. Analysis focused on the smallest 15% of farms by crop. What is considered small differs by crop.

Maximum Area by Crop for Each Farm Size, hectares

Source: Schimmelpfennig, IaDB, 2017
Like larger farms, small and medium farms in the US are adopting guidance

The smallest US rice farms are bigger than the smallest corn and soybean farms and consequently are adopting guidance.
Precision Agriculture In the UK

• Overall, UK adoption of PA is modest, % of farms in 2012:
  • GPS - 22%
  • Soil Mapping – 20%
  • VRT – 16%
  • Yield Mapping – 11%

• As almost everywhere PA adoption is greater on larger farms and on those specialized in cereals and oilseeds.

• UK pattern similar to rest of the world, but UK has more smaller livestock and mixed farms, and fewer large arable farms which lead PA adoption everywhere.

Source: DEFRA 2012 Farming Practices Survey
In UK data farm size defined by number of workers:
• Small <2 workers
• Medium - 2 or 3 workers
• Large – over 3 workers
• Strong interest in PA for sugar cane driven by economics & environmental concerns.
• Public sector research in PA for viticulture and some adoption of selective harvest.
• Australia led development of GPS guidance in part motivated by soil compaction and profitability of controlled traffic.
• CSIRO adoptions studies show:
  o As in USA, GPS guidance widely used.
  o Many have yield monitors, but do not use data.
  o Note – “Vary Fertilizer Rates” includes manual variation.
  o Lack of technical support identified as key constraint.

Source: Llewellyn & Ouzman, CSIRO, 2014
Precision Agriculture in Argentina

- Larger farms in Latin America have been part of PA from the early 1990s.
- Argentine data collected in terms of number of machines.
- Rapid growth in GPS guidance.
- Variable rate fertilizer is less than 20% of crop area.

Sources: Ricardo Melchiori, INTA, Parana, Argentina.
Precision Agriculture in Brazil

- Strong interest in Precision Ag for sugar – both guidance and VRT
- Growth in use of GPS guidance
- Interest in VRT fertilizer, but often very coarse resolution (e.g. 5 ha grids).
- Adoption slowed by:
  - High cost of technology – in part due to taxes and import tariffs
  - “No Frills” preference because of high capital costs and composition of the labor force
  - Has been more profitable to bring new land into farm production than to intensify on existing land
Forty Five% of Brazilian grain farmers in 2013 used something from the PA toolbox.

Based on Kleffmann Group telephone interviews with 992 large scale farmers in 2013.

Source: J. P. Molin, INFO AG, 2015
Largely because of high soil testing costs Brazilian farmers use very large soil test grid sizes.

In the 2013 survey 14% used larger than 9 ha.

Almost 50% used larger than 4 ha.

The grid size used by these Brazilian farmers is larger than the average field size on many European farms.
Rethinking Precision Agriculture in Africa

- Use of GNSS guidance and classic PA technology on farms in South Africa and on some large scale estates elsewhere.
- Traditional African agriculture is very site-specific, but manual, so PA technology from the Americas and Australia does not solve their problems.
- Rethinking PA for African smallholder farmers to identify uses that solve African problems. Some ideas:
  - Handheld soil nutrient sensors.
  - Using cell phones to communicate remote sensing and other sensor based weather & pest management information.
- In most areas little or no ag inputs supply infrastructure, so no PA services or support.
Precision Agriculture in Europe

• PA technology developed in the Americas or Australia often not a good fit, in part because of smaller farm size.
• European PA adoption estimates are “soft” because only the UK government collects random sample data. In other countries number are based on on-line survey and other methods
• Interest in GNSS guidance growing especially in areas with relatively large farm size such as eastern Germany
• Use of on-the-go sensing for fertilizer application probably highest in the world because:
  o Relatively higher N prices
  o Higher grain prices
  o Environmental regulation limits N use in some countries
  o Government support for N sensor use
• Growing interest in PA technologies that fit European farming, including:
  o Controlled traffic
  o Precision livestock, especially robotic milking
  o Precision horticulture and viticulture
European Farmers Taking Time to find PA Technology that Fits Their Needs

“The most successful example of PA on arable land is the use of Controlled Traffic Farming (CTF), which has been able to reduce machinery and input costs up to 75% in some cases, whilst also increasing crop yield.” (EU Directorate-General for Internal Policies – Agriculture & Rural Dev., 2014)

Source: Lartey et al. (Computers & Electronics in Agriculture, 2011) – Survey of farmers in four European countries
• GNSS guidance being widely adopted on mechanized farms almost everywhere.

• Sprayer boom control, seed row shut offs and other technology linked to GNSS guidance being widely adopted.

• Hypothesis #1 - Investment in GPS guidance and related technologies cashflowed by reduction in overlap and more efficient field operations. Other benefits (e.g. reduced fatigue, flexibility in hiring) are unquantified side effects.

• Hypothesis #2 – GPS guidance technology is not disruptive and consequently is easily sold through existing agribusiness channels
Variable Rate Technology Adoption has Lagged

- Variable Rate Technology (VRT) being adopted in niches where it is highly profitable. For example, sugar beet growers in the USA, in the Red River Valley of the North, Minnesota and North Dakota.
- VRT adoption for all broad acre crops only rarely exceeds 20% of area or farms.
- Hypothesis #3 - Constraints to VRT adoption include:
  - High cost of site specific information (e.g. grid or zone soil sampling)
  - Cost of developing individualized prescription maps
  - Lack of demonstrated value – impact on yields and profits often hard to see
  - Cost of being wrong (and over applying) is often small because environmental impacts not measured
  - VRT is disruptive technology that would require substantial changes in agronomic practices and in business models.
Challenge #1 - On-the-go sensors & fertilizer application

• The hypothesis is that VRT fertilizer adoption has lagged for bulk commodities because of current technology is knowledge intensive, requires human intervention at several points and yields only modest benefits.
• The most likely technical solution is on-the-go fertilizer sensor and applicator combinations that embody current knowledge and reduce need for direct human intervention.
• Combining on-the-go sensors measurements with some estimate of crop response capacity (e.g. soil depth, yield maps) can fine tune the fertilizer application.
• Currently most advanced for nitrogen application, but could be developed for P, K, lime and micronutrients.
Challenge #2 – Pest management at the individual plant level

- The future of crop pest management may use conventional pesticides, but in much smaller quantities, because they are applied only to specific weeds, insects or diseased plants.
- That plant or insect specific application might be by large scale equipment or small robots.
- Robotic pesticide application could be adapted to small farms.

John Deere Blue River “see and spray” tech.

Field robot competition at Harper Adams University in June 2017
https://www.harper-adams.ac.uk/news/203084/field-robot-event-comes-to-uk-for-the-first-time
Challenge #3 - Proof of Concept for Big Data and Artificial Intelligence in Agriculture

• In theory “Big Data” gives us the opportunity to systematically learn from cropping experience, but lack objective data on distribution of benefits.

• In practice, the use of big data in agriculture are limited by the lack of a good business model for farmer data pooling. Some options:
  • Paying farmers for data in cash or discounts on inputs
  • Benchmarking relative to other farmers in their area and other analysis
  • Cooperative models that commit to sharing benefits of data pooling with farmers

• Given the transactions costs of pooling farm data, the Big Data proof of concept may come very large farms in places like the Ukraine, Kazakhstan, or Brazil, rather than pooling data from medium and small. The transactions costs would be lower.
Challenge #4 – The biggest PA market opportunity is low cost technology for small and medium farms

For example, soil or optical fertilizer sensors:

- In the developing world soil tests are expensive and not easily available.
- Smallholder farmers lack information about the type and amount of fertilizer that their crops need.
- Research has show the potential of handheld nitrogen sensors on medium and small farms, But the cost of the sensors is still too high.
- To achieve widespread use an N sensor should cost < US$10.
- To attain the required price threshold the sensor will probably be a cell phone app or accessory

Research in the Yaqui Valley of Mexico shows that use of sensor based nitrogen management can improve farm profits and benefit the environment
Take home message:

• GPS guidance and related technology is being adopted worldwide by mechanized agriculture because it is easy to use, benefits are seen quickly, and it does not disrupt agribusiness structure.

• VRT adoption for bulk commodity crops has lagged worldwide because it is more complicated, technology is not mature, and it is more disruptive.

• Precision agriculture adoption challenges in the next decade include:
  • On-the-go sensors and application for fertilizer
  • Plant level pest management
  • Proof of concept for value of Big Data and artificial intelligence in agriculture
  • Precision agriculture technology for small and medium farms