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Improving Pathways to Adoption: Putting the Right P’s in Precision Agriculture

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Abstract

On-the-go yield monitors, proximal plant-canopy and electromagnetic soil sensors, and airborne/satellite remote sensing have all been introduced into mainstream agriculture practice under the auspices of precision agriculture. While these technologies have been shown to provide production and environmental benefits, widespread adoption has been slow. In many cases, new technologies have been produced through developer push rather than user pull. Insufficient attention is paid to well-known technology adoption paradigms and as a consequence, the adoption of precision agriculture technologies is not as great as it could and should be. In precision agriculture there is often a large knowledge gap between developers and users, and not enough effort is being spent on closing this gap. By paying attention to developing of protocols and realistic performance criteria, developers can exert a stronger, positive influence on the rate and breadth of adoption.

Keywords: Precision Agriculture; Decision Support; Management Tool
1. Introduction

Since the introduction of relatively low-cost global positioning systems (GPS) technologies and field-robust data loggers, there has been an explosion in the breadth of precision agriculture activities. Initially, synonymous with on-the-go yield mapping, precision agriculture (PA) is now as much about the development of new sensors and data management processes themselves, as it is about the need to collect geo-referenced information necessary to monitor or manage spatially-variable agricultural fields. As far as the industry-wide adoption of PA is concerned, it could be asked “just who is driving whom?” In many cases our ability to collect data has exceeded our ability to understand and apply this data in a meaningful way. In this discussion we assert that developers rather than users have stifled the adoption of PA technologies. Developers and users both have mantras that involve “P’s”, although they are different. For developers the P’s are Positioning, Product, Pricing (hence Profit), Placement and Promotion and for users they are Preparation, Protocols, Performance (hence Profit) and Perception. Whilst developers tend to focus on Perception, effective, rapid adoption requires developers pay as much attention to Protocols and Performance. Through the introduction of two main innovation-adoption paradigms, we offer a focal point for considering future development of PA technologies.
2. **The processes of adoption**

The process of PA is succinctly summarized by the continuous cycle of “observe – interpret – evaluate – implement” (Cook and Bramley, 1998). Whilst PA has been in existence since the mid eighties; it has been driven forward primarily by researchers wishing to characterize subfield-scale production environment and performance more accurately. The slow adoption of PA (Dobermann et al., 2004) has been attributed to the lack of functioning decision support tools (McBratney et al., 2005). Notwithstanding this key enabling component, the adoption process remains impeded by a gap between the actual capabilities and user expectations.

The adoption of PA can be examined by following the theory of Diffusion of Innovations (Rogers, 2003). Rogers (2003) suggests that adopters of any new innovation can be categorized into five groups; innovators, early adopters, early majority, late majority and laggards (Figure 1).

(*Figure 1 near here*)

From the initial appearance of an innovative product or concept, the ‘technocratic’ minority (~3%) who first take it up are those who are generally: proactive in seeking information; avail themselves of information from a multitude of sources; and are often risk-takers. These are followed by a larger Early Adopter group (~13%) of leading farmers who are often more highly educated, or fill a local/regional leadership role. The subsequent Early Majority are more deliberate in their consideration of the risks and benefits than the Late Majority (~34%) who are generally more skeptical, and finally
there are the Laggards (~16%) who rely generally on informal, ‘over-the-fence’ contact with developments.

The application of PA in Australia’s grape and wine industry (precision viticulture - PV) is a good illustration of the distribution outlined in Figure 1. Precision viticulture is relatively new, having only formally emerged in 1999 following a significant investment in research and development by the newly formed Cooperative Research Centre for Viticulture. In a survey of PV attitudes conducted seven years later, the statement “the benefits of PV [precision viticulture] are justified by the costs” was put to 56 personnel from across the Australian winegrape industry. The response was as follows: 4% strongly agree, 35% agree, 53% didn’t know and 7% disagree (Proffitt et al., 2006a). If the assumption is made that the innovators and early adopter are likely to agree, most likely having already adopted some elements of PV, the early and late majority remain uncommitted and the laggards remain unconvinced, then the relative distribution of responses is consistent to the distribution of Figure 1. If we consider a specific example of a PA-related activity, namely remote sensing which is often considered a first entry point for many potential adopters (Proffit et al., 2006b), a 2003 phone survey of remote sensing providers throughout Australia indicated that less than 1% of Australian vineyards were imaged in 1999-2000 grape growing season, but in 2002-3 over 20% were imaged by some form of remote sensing (Lamb, 2003). If we consider the time-domain of Figure 1, this would place remote sensing within the early adopter/majority stages of Figure 1.
Few innovations and technologies progress beyond the Early Adopter level and this is the case with PA. Moore (2002) attributes this to a ‘chasm’ between the Early Adopters and Early Majority. Early Adopters rely more on primary sources of information, direct from the provider of the technology (Ryan and Gross, 1943) and are willing to piece together the whole product (Moore, 2002), often by assuming roles in the research and development phases of product development. The Majorities tend to rely on ‘word of mouth’ (Ryan and Gross, 1943) which often takes with it the added security of ‘hard-lessons learned’ by others. If the hard lessons are many and the message is overly cautious, then the uptake process is stalled. Many developers, having worked with Innovators risk forming an unrealistic view of the needs, skills and knowledge base of the mainstream (early majority plus late majority in Figure 1) market who mostly expect ‘turn-key’ solutions.

The “Gartner Hype-Cycle” (Fenn and Linden, 2005) is an alternative model that describes the adoption process over time. Depicted in Figure 2, the Hype Cycle describes the key stages of product utilization in a market.

(Figure 2 near here)

With the initial appearance of a new technology (Technology Trigger) often comes media and industry hype which generates heightened levels of expectations (Peak of Inflated Expectations) in the form of unrealistic projections during which a flurry of publicized activity by technology leaders results in some successes. The point at which practical, in-field, operational experience provides a realistic picture of what the technology can really offer users is generally associated with a level of initial disillusionment (Trough of
Disillusionment), but detailed, painstaking experimentation by an increasingly diverse range of investigators provides an insight into the real applicability of the technology, associated risks, and often unforeseen benefits. Commercial, off-the-shelf methodologies and tools become available to ease the development process. Following an extension phase, the uptake stabilizes into a Plateau of Productivity; the final height of this plateau varies according to whether the technology is broadly applicable or only benefits a niche market. The Trough of Disillusionment coincides with Moore’s Chasm (the gap between the Early Adopters and Early Majority categories of Figure 1) (Moore, 2002) since both are related to the mismatch between the developer’s understanding of mainstream user markets, and user expectations. Very few technologies associated with PA have reached the end of the Hype Cycle, primarily since they are in their early stages of uptake.

One exception is satellite imagery in agriculture. It has worked its way through most of the Hype Cycle. In the seventies, satellite imagery was expected to make a significant contribution to agriculture. However, by the late 80s following almost two decades of Landsat imagery, there was a perception that remote sensing had simply failed to fulfil its promise (Johnston and Barson, 1990; Bryceson and Marvanek, 1998). The problem was that the early satellite systems (Landsat and SPOT) were not developed specifically for agricultural applications, rather they were medium-resolution systems designed broadly to provide landscape-scale natural resources inventory information. In term of Figures 1 and 2, the Chasm was broad and the Trough was deep. After a further fifteen years of goals-focused research using high-resolution airborne sensors, the appearance of high-resolution satellite systems such as Quickbird and IKONOS and the establishment of
small-medium enterprises (SMEs) that focus on generating, processing, and distributing farm-scale data, satellite remote sensing is returning to mainstream agriculture.

3. Right tools for the trade

In any sphere of business, failure rates amongst new products can range from 30% to 60% (Boulding et al., 1997). Often, pressure is on to get the product in the market and claim the ‘turf’ associated with a particular activity or technology, primarily to acquire market resilience to the rapid imitation of competitors (Bayus et al., 1997; Chaney et al., 1991). This pressure may tempt producers to bypass systematic tests, like concept and product testing, in order to fast-track products onto the shelf.

Later adopters (Figure 1) use earlier adopters from their professional and social networks as key referents in making adoption decisions. The reputation of a technology is most easily damaged during the very early stages of adoption. Failure to adequately field-test equipment in the rush to get to market can have negative ramifications in the Early Adopter segments. Worse still, seeking low-cost manufacture or component options to encourage greater market penetration in the mainstream market through lower pricing could lead to product failure at the operational level if a new round of comprehensive field tests are not carried out on the components from the new manufacturer.

An example is the components used on-the-go yield mapping; one of the more widespread PA technologies in use today. A yield mapping system relies on three main components: a yield monitor; differential GPS (DGPS); and map making software. A yield monitor is a device that periodically measures the mass of harvested product during
the harvesting operation. When these harvested mass data are linked to an accurate location given by the DGPS a series of points that link field position to local yield is created. These data are then processed and analysed via mapping software. Harvesting is considered by growers as one of the most stressful times of the year. Peripheral activities, those not immediately concerned with ‘getting in the crop’, are generally given low priority. Consequently, yield mapping per se needs to be fool-proof as machine operators have little time or energy to invest in trouble-shooting equipment or post-processing data during harvest. A process as simple as following the correct sequence in removing data cards from yield monitoring hardware can be overlooked by fatigued operators. Once lost, yield mapping data can never be re-collected (Figures 3 and 4).

(Figure 3 near here)

(Figure 4 near here)

4. Right trade for the tools

Innovation need not be confined to new products or practises per se; it can also be the application of one existing product to another existing practice. In the early stages of adopting any innovation, there is a natural tendency to experiment. To what extent this activity is incumbent on the producer rather than the consumer of a technology or practice is at the heart of the issue; producers nowadays seem less inclined to analyze the environment in which the potential adopter is expected to use the technology (Tessmer, 1990). Inappropriate application of a technology or practice can do as much harm to adoption as product failure (Rogers, 2003).
Industry-wide protocols can go a long way to alleviate the risk to adopters. One good example relates to the measurement of apparent soil electrical conductivity \((E_{Ca})\) of the soil as this parameter is related to the basic physical and chemical structure (including ion and water content). On-the go \(E_{Ca}\) sensors based on resistive or electromagnetic induction (EMI) techniques are becoming a widely used PA tool. Field-portable EMI soil sensors such as EM38 (Geonics, Ontario Canada) work on the principle of detecting electrical current flow induced in underlying soil in response to an oscillating ‘primary’ magnetic field. The amount of current flowing is related to soil conductivity. In response to increasing calls for standardization of practice, groups in Australia and the United States have recently produced guidelines or standards for EMI mapping in agricultural crops (for example, Corwin, 2005; Corwin and Lesch, 2005; O’Leary and Peter, 2006). However, these guidelines deal primarily with issues of instrument calibration, operational check-listing, data interpretation and/or map production. It still remains largely up to the user to decide on issues of suitable environment within which to apply the technique or technology. One typical example is with the use of on-the-go EMI soil survey techniques in established (trellised) vineyards (Lamb et al., 2005). EMI survey techniques have been used in Australian vineyards for about 10 years (Lamb and Bramley, 2001). Numerous users of the technology in vineyards, especially those containing steel trellis posts, have observed edge-effects appearing in the resulting maps (for example, Figure 5) and many had assumed this to be a result of regular irrigation or soil cultivation activities. However, Lamb et al. (2005) subsequently demonstrated that this effect was the result of mutual inductance occurring between the EMI instrument’s
transmitter coil and the nearby, highly-conductive, current loops comprising the horizontal trellis wires and the vertical steel posts. It was subsequently demonstrated that a systematic, artefactual along-row modulation in the EC_a values can occur for a row spacing less than 3 m and that any side-to-side deviation of the sensor from the mid-row position while conducting a survey would also alter the measured EC_a values. In this case, users were advised not to conduct surveys in vineyards with row spacings less than 3 m, and to date no method of correcting for such artefacts has been reported in the literature.

(Figure 5 near here)

5. Conclusion: Closing the Chasm and Flattening the Hype Cycle - Putting the Right P’s in Precision Agriculture

The ultimate goal in facilitating the adoption of PA is to close the Chasm and flatten the Hype Cycle and this can only be achieved by paying attention to each and every component of the PA cycle and its relevance to end-users. In many cases, product or process developers work closely with farmers during the development or evaluation phase. However, impediments to uptake occur, not with the early innovator class of adopters but with the mainstream segment of the market. Engaging a broader cross-section of potential users, both in attitudes and their respective agricultural systems, during the development or evaluation phases of any new product may alleviate this rate-determining step in the uptake process. The development phase must also include comprehensive operational protocols as these play just as much of a role in the success of
a technology as those associated with data processing, map production and decision support.

In order to avoid the chasm between the early adopters and the mainstream market, manufacturers of PA technologies need to understand the changing expectations of end-users as their product moves through the adoption cycle. Evaluation programs and the feedback loop from the users of PA technology must be a continuous cycle over time in direct response to how the technology is being used in the field. The PA technology can then be developed so that it is compatible with the needs of those ‘next-in-line’ to adopt. It cannot be assumed that PA technologies will be self-sustaining in their adoption once they have past the critical mass of early adopters without a commitment to continuous improvement by manufacturers, and an ongoing process of consultation across the broad spectrum of users. By including Protocols and Performance in their earliest planning stage, developers will go a long way to dealing with the rate-determining step in adoption of PA - Perception.

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References


**Figure Captions**

Fig. 1. Bell-curve illustrating distribution of adopter categories based on innovativeness (Adapted from Rogers, 2003).

Fig. 2. The 5 key stages of the Gartner Hype Cycle (adapted from Fenn and Linden, 2005)

Fig. 3. The ‘trappings’ of product failure. An example of a raw grape yield map where yield monitor failure resulted in patchy coverage of a field. Unfortunately, like many PA data acquired by direct sampling, yield maps can only ever be collected once.

Fig. 4. How NOT to spend an evening harvesting white winegrapes. Failure of inappropriately-rated load cells within this harvester-borne yield monitor cost the owner significant time delays in their harvesting operation; and valuable data. The load cell rating was not specified by the commercial provider of the yield monitor. Inset: Photograph of the offending load cell showing visible corrosion (at cable input) from repeated wash-downs conducted after each harvesting operation. Moisture infiltration resulted in de-lamination of the load transducer.
Fig. 5. Two-dimensional EM38 survey map of an 11 ha vineyard (superimposed on a grey-scale aerial image of the vineyard) comprising vertical-shoot-positioned canopy wires and steel trellis posts. The trellising covers the full extent of the EC<sub>a</sub> map (white boundary) within the image. The EC<sub>a</sub> values increase by approximately 15 mS/m when moving 5 m inside of the trellis boundary.