FACTORS RELATED TO ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN SOUTHERN BRAZIL

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ABSTRACT

Brazil plays an important role as a supplier of agricultural products. The adoption of technologies as precision agriculture (PA) is a requirement to increase food production with improving quality and to reduce environmental footprints. Therefore, more detailed information about the dynamics of PA adoption process in Brazil is required. The objective of this study was to investigate the adoption of different PA tools by farmers in Rio Grande do Sul State (southern Brazil) and the factors involved in adoption decision. Here we analyzed the attributes of PA technology using adoption theory, characterize the users and document some of our personal observations in interacting with farmers, service providers, and researchers working on precision agriculture. An online survey was sent to 715 farmers from August to October 2011. The main motivations for adopting precision agriculture were the increase of crop productivity and the reduction of cost production. On the other hand, equipment high price and lack of staff skills/training were the most frequent limitations reported. The gateway to adopted PA by grain-producing farmers in southern Brazil was based on grid soil sampling. Outsourcing services in PA play a key role in diffusion of this technology. Yield map and variable rate seeding are the preferable tools among current adopters in order to expand the use of PA technologies. PA adopters frequently cultivate large areas; have an innovative profile and a high education level. Engagement with PA is 4.3 years on average. Technological factors explained 48% of farmer's satisfaction with PA technologies. Furthermore, impact of PA did not meet farmer's expectation at the time of adoption. In this sense, rate of PA adoption should increase as more benefits of this technology are proven.

Keywords: Precision agriculture users; innovation diffusion; survey; precision farming; Brazil

INTRODUCTION

Adoption of high efficiency technologies is a requirement to increase production, food quality and to reduce footprints of agriculture activity in the environment. The demand for agricultural products has been boosting development of technological innovations for farmers. Precision agriculture (PA) was established as a series of tools in order to assist on crop management, increase crop yield by manage spatial and temporal field variability and therefore improving economic return and reduce environmental impact (Swinton and Lowenberg-Deboer, 1998; Molin, 2001, Blackmore et al*.,* 2003). However, diffusion of PA technologies has been slower than expected (Swinton and Lowenberg-Deboer, 1998; McBratney et al., 2005; Aubert et al., 2012). In this sense, it is important to study the factors that influence adoption of PA by farmers (Aubert et al., 2012).

This work addresses the adoption of PA by applying Roger's approach to the attributes of PA technology. Technologic attributes ("relative advantage", "compatibility", "ease of use", "observability" and "trialability") are part of the persuasion phase in the decision-making process of innovation and can represent between 49% to 87% of the variability in adoption rates (Rogers, 2003). Likewise, socioeconomics characteristics of the decision maker (farmer) also influence the adoption process. Associating the perception of each technology with farmer's socioeconomics characteristics may improve the understanding about the process that will guide the adoption of precision agriculture (Rogers, 2003; Aubert et al., 2012).

Two conceptual models are often used to interpret the course in adopting innovation. The model described by Rogers (2003) discusses an innovation that has a normal distribution curve over time. The conceptual model described by Fenn and Linden (2005), called "Gartner Hype Cycle", relates to an innovation cycle with asymmetric distribution over time. In this concept, the normal adoption cycle is interrupted by a frustration of adopters regarding the performance of technology and, in consequence, adoption rates decrease. This period called "trough of disillusionment" is caused by excess of expectation, unrealistic projections and some few success cases. The resumption of adoption occurs when researches weigh risks and benefits, which were initially undetectable, and start to generate a better understanding of the technology (Fenn and Linden, 2005). In this stage of technology maturity, technological packages should be commercially available to facilitate precision agriculture adoption (Lamb et al., 2008).

In Brazil, research has been focused on technical and economical aspects of applying PA tools. More studies need to be performed about the dynamics of the adoption process of PA and the factors that influence farmer's decision.

For other countries, large farming systems show higher rates of PA adoption (Daberkow and McBride, 2003; Adrian et al., 2005). In the U.S., users of PA technologies are characterized by having large areas and few leaseholders, and management of the farm is done by full-time farmers (English et al., 2005). The main barriers to the adoption of PA have been the lack of agronomical knowledge and technical ability. Furthermore, the compatibility between hardware and a not user friendly software are the most important obstructions pointed out by farmers in order to establish PA (Fountas et al., 2005).

The objective of this study was to investigate the adoption of precision agriculture tools and the factors that led farmers from Rio Grande do Sul State (southern Brazil) to make such adoption decisions. This region stands out as the pioneers on farm mechanics, representing 46.1% of the national production of agricultural equipment (ANFAVEA, 2011) along with a significant production of grains (mainly soybean, maize and wheat). We applied Roger's approach to the attributes of PA technology, characterized the users and documented some of our personal observations by interacting with farmers, service providers, and researchers working on precision agriculture.

MATERIAL AND METHODS

Analytical framework and data collection

An online survey was sent to 715 PA adopters of Rio Grande do Sul State from August to October 2011. Seventy-five valid questionnaires were returned (10.5%) mainly from the northern part of the state, where grain producing farms are concentrated (Figure 1). PA adopters were considered as the farmers who adopt at least one of the following PA tools: georeferenced grid soil sampling (SS), variable rate fertilization (VR), variable rate seeding (VRS), lightbar (LB), auto pilot (AP), yield map (YM) or remote sensing technologies (RS) (i.e., satellite-based and aerial images and/or optical canopy sensors).

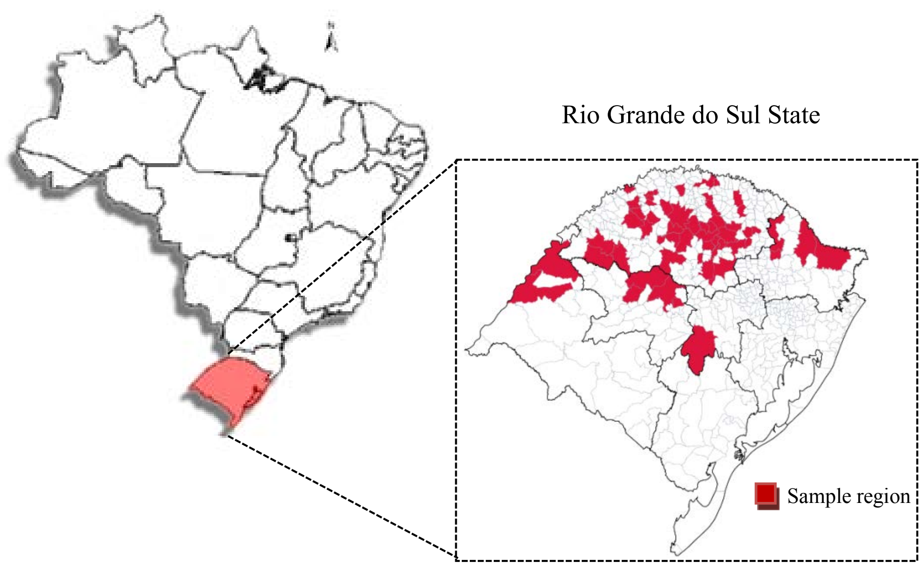

Figure 1. Grain producing region in Rio Grande do Sul State, southern Brazil, surveyed for precision agriculture adoption.

Farmers were randomly selected from a previous survey database. This survey was created by farm input companies (machinery, implements, seeds, fertilizers) as well as by PA service providers. A prior contact with farmers (decision makers) was made by telephone, and subsequently a formal electronic mail containing the questionnaire was sent to them. A preliminary questionnaire test was carried out with farmers and professionals of PA sector.

A questionnaire with multiple choice questions was structured in five main sections: 1) Technological factors derived from Diffusion Innovation Theory of Rogers (2003); 2) Farmer’s socioeconomic characteristics; 3) Motivation to adopt PA tools; 4) Problems/limitations related to PA adoption; and 5) Impacts of PA adoption.

Observed factors

In the "farmer’s socioeconomic characteristics" section, the farmers who took the survey were classified by the following attributes: total farm area, area cultivated using PA technologies, owned or leased land, type of cultivated crops, time engaged with a PA tool, intention to adopt other PA technology in the upcoming two years, PA outsourcing services, sources of information, amount and sources of income, age, formal education level and level of satisfaction with PA technology.

The review of technological factors (“relative advantage”, “compatibility”, “observability” and “trialability”) were adapted from Rogers (2003) theory to fit into the context of precision agriculture. The factor “ease of use” was adapted from Benbasat and Moore (1991). Questions related to these attributes were adapted from Moore and Benbasat (1991). The perception of users regarding the attributes was measured by Likert scale of five points, where 1 (one) means "strongly disagree" and 5 (five) "strongly agree".

Using a five level scale measurement (1 for "not relevant" and 5 for "extremely relevant"), we are able to evaluate the following characteristics: the farmers’ perception before and after PA adoption, in terms of: increasing crop yield, improving management and working conditions, reducing costs and preserving the environment. The same scale was used to measure the barriers of PA adoption. The investigated characteristics were: high cost of equipment, lack of appropriate finance sources, after-sale deficiency assistance, as well as lack of qualified staff, lack of information about the technologies, adequate external technical services and lack of output and efficiency of PA tools.

Data analysis

Descriptive statistics were used to analyze the attribute “farmer’s socioeconomic characteristics”. Technological factors were analyzed by exploratory factor analysis. The new variables obtained with factor scores were used to run the stepwise multiple linear regression to explain variation of "farmer satisfaction with PA". The adequacy of the sample was checked by Kaiser-Meyer-Olkin (KMO) test. The consistency of the constructs was evaluated by Cronbach's alpha (Hair et al., 2006).

RESULTS AND DISCUSSION

Farmer's socioeconomic characteristics

Precision agriculture technologies are initially adopted by farmers who cultivate large areas. The average cultivated area with PA is 688 hectares, while only 2% of the farms in Rio Grande do Sul State have areas larger than 500 hectares. Total farm area and area cultivated with PA were highly correlated ($r=0.89$, $P<0.01$), thus corroborating to the earlier work of Pedersen et al. (2004) and McBride and Daberkow (2003). Also, farmers with larger areas are more likely to implement PA technologies in the whole cultivated area. Scholar educational level of PA adopters was above average for the state of Rio Grande do Sul in 88% of cases. This demonstrates that PA adopters have differentiated training compared to other farmers. McBride and Daberkow (2008) pointed out that the education level plays an important role in the adoption of PA tools. The average age of farmers which adopt PA was 41 years, similar to PA adopters in Denmark and USA, with 43 and 46 years, respectively (Fountas et al., 2005). These farmers have access to various information sources (internet, conferences, technical seminars, consulting companies, neighbors, suppliers of agricultural machinery as well as equipment companies), in order to minimize uncertainties of the decision-making process. A summary of farmer's socioeconomic characteristics are shown in Table 1.

Table 1. Socioeconomic characteristics of precision agriculture adopters in Rio Grande do Sul State, southern Brazil.

Variables	Average (n=75)
Satisfaction level with PA results	
(Likert scale where 5 means "strongly satisfied" and 1 means "strongly dissatisfied)	4
Time engaged with PA (years)	4.3
Number of PA tools adopted	3 to 4
Farmers who intend to increase the use of PA in the coming two years (%)	61.3
Farm size (number of farmers)	
Greater than 500 ha	54
Between 50 and 500 ha	43
Less than 50 ha	3
Farm size (ha)	979
PA is implemented area (ha)	688
Ownership	
Owner land only (%)	32
Leased land only (%)	1
Owner with leased land (%)	67
Schooling	
Graduated or up (%)	56
High school or undergraduate student (%)	32
Primary school (%)	12
Cultivated crops:	
Soybean (%)	99
Corn (%)	82
Wheat (%)	79

PA adoption characterization

Engagement with PA is 4.3 years on average. However, there are farmers who have adopted PA technologies for the last 11 years and others who have adopted for just a year ago. Likewise there is a large difference between tools adoption rates. Georeferenced grid soil sampling (SS) are the most used type of tool (91% of adoption), followed by variable rate application of fertilizers (VR) (85% of adoption). Lightbar (LB) (68% of adoption) was the most adopted tool in the early 2000s (Figure 2). On the other hand, for the sugarcane industry in São Paulo State, SS and VR are only the fourth and fifth most widespread PA tools. In this sector, PA adoption was based on remote sensing (airborne and satellite imagery) and auto guidance due to the structure of the industrial system, where the average area cultivated by sugar mills is around 20000 hectares (Silva et al., 2011).

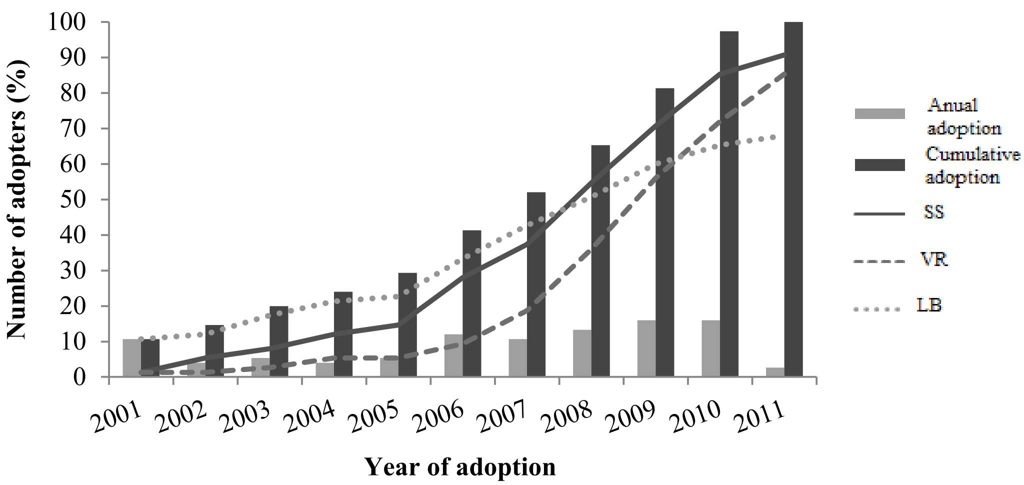

Figure 2. Adoption behavior of PA tools used by grain producers in Rio Grande do Sul State, southern Brazil, between 2001 and 2011.

The gateway to PA in Brazil to manage variability was based on grid soil sampling (SS) and variable rate fertilization (VR). This behavior is strongly influenced by specialized PA outsource capable of diffusing these practices. For these two PA tools, SS and VR, farmers do not require specific knowledge about the processes, as well as data collection and mapping. Also the acquisition of specific machinery is not required. This is because all processes are performed by outsourcing services. Furthermore, farmers can easily realize about soil nutrient content to trace a strategy management applying VR fertilizer in order to improve crop productivity. An outsourcing role is highly important in this kind of adoption and diffusion process. The services with the highest percentage of outsourcing are generation of maps (97%), georeferenced soil sampling (89%) and variable rate application of fertilizers (56%). These results reflect the dependence of users on outsourcing services.

Other PA tools with lower adoption rates are autopilot (AP) (22%), yield maps (YM) (21%), remote sensing (RS) (12%) and variable rate seeding (VRS) (6%). About "intention of use" in the upcoming two years, 61.3% of farmers plan to increase the use of precision agriculture in their farms. In this regard, YM as well as VRS were the most frequently tools listed by farmers who intend to increase the adoption of PA technologies. It is worth noting the potential market for yield maps once this tool holds important information about field spatial and temporal variability, which are essential to PA management.

Factors of adoption of PA technologies

Factor analysis resulted in five factors that accounted for 69.4% of variation from the original variables. The factors grouped the same original variables established by Moore and Benbasat (1991) to represent "relative advantage", "compatibility", "ease of use", "trialability" and "observability". This result shows the effectiveness of the methodology used to identify the perceptions of farmers regarding technological factors of PA. The main factor was the "relative advantage", which explained 22.3% of the variance observed in the set of original variables.

The multiple linear regression model revealed that 48.2% of satisfaction with PA adoption was explained by four technological factors: "relative advantage", "compatibility", "trialability" and "observability". The factor "ease of use" was not statistically significant to explain satisfaction (Table 2).

Table 2. Regression analysis to the set of technological factors associated to farmer's satisfaction with precision agriculture.

Independent variables (Factors)	Standardized Beta coefficient
Relative advantage	0.461**
Observability	0.442**
Compatibility	0.274*
Trialability	0.179*
Ease of use	0.037^{ns}
Standardized value for the set of technological factors (R^2)	0.482**

Note: Dependent variable was farmer's satisfaction with PA technology. **: $p<0.01$. *: $p<0.05$. ns: no significant

No significant associations between socioeconomic variables and satisfaction were found. Therefore, satisfaction of PA adopter depends on the technological factors "relative advantage", "compatibility", "trialability" and "observability", and not on farmer's socioeconomic characteristics such as age, school education level, time of use and farm size of area, among others.

The "relative advantage" factor had a greater weight in the regression analysis and had the best explanatory power of variation in "farmers satisfaction" (β=0.461). This result demonstrates that the more advantage the innovation offers, the more prone is the farmer to adopt it (Rogers, 2003). Farmers need to realize the benefits generated by precision agriculture tools as being advantageous over previously adopted technologies. If the relative advantages are small or difficult to be proven, the technology will take longer to be adopted.

The marketing of PA has instigated the expectation of farmers to save inputs and increase crop yield, although these effects actually are not always observed. We know that results in PA depend on each case and fundamentally on existing field variability. When the expected level of results is not confirmed by the adopter, it leads to initial frustrations that can retard the adoption process (Lamb et al., 2008). Therefore, uncertainties surrounding the evidence of relative PA advantages remain a constraint to adoption and undermine the confidence of farmers who have not yet adopted PA technologies (Robertson et al., 2012).

Motivation, impacts and barriers of PA adoption

The main reasons given by farmers to adopt PA were increased crop yield, reduced costs and improved management (Figure 3). In USA and Germany, the increase in earnings and environmental benefits, followed by increased productivity and detailed knowledge of farming, are the main motivations of adoption for precision agriculture practices by farmers (Roberts et al., 2001; Reichardt and Jürgens, 2009).

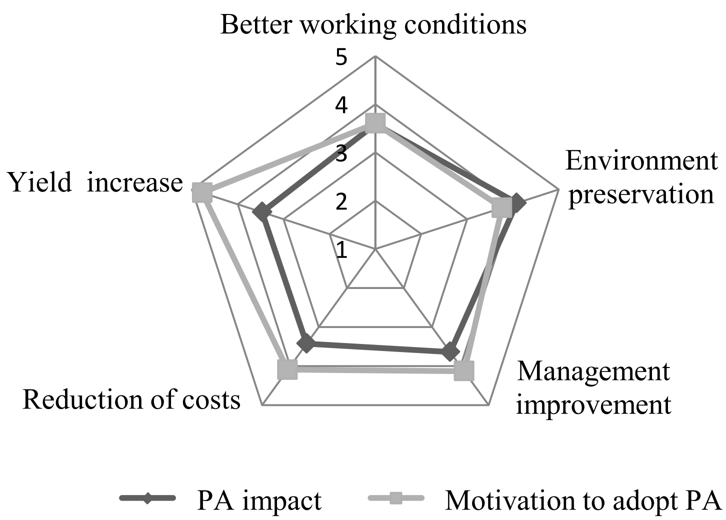

Figure 3. Gap between motivation and impact of PA adoption. (1="not relevant"; 5="strongly relevant").

Farmers assigned higher scores for adoption reasons rather than for observed impacts after PA technologies implementation. Therefore, the impact of PA did not meet the initial expectations that existed at the time of adoption. Possibly this behavior is due to excessive expectations around the technology. According to the adoption model called "Gartner Hype Cycle", when a greater gap between the effective capacity of the technology and the expectations of adopters occurs the rate of adoption can reduce dramatically (Lamb et al., 2008).

The main problems pointed by farmers who already use PA technologies were high costs of equipment (average of 4.36 in a five-point scale) and lack of staff skills (average of 3.62 in a five-point scale). These same problems were reported by Silva et al. (2011) and may prevent PA to achieve higher adoption rates.

In order to reduce PA adoption problems, industry should organize efficient technical support systems; develop quick and inexpensive methods to identify causes of spatial variability; develop simple approaches for on-farm trialing; non-complex ways for data interpretation and nonetheless provide formal training for quality work force (Robertson et al., 2012).

Another way to prevent frustration regarding PA tools adoption is the implementation of protocols. These should include regular monitoring of farmers to correct possible technology errors throughout the implementation process and not only during the initial phase of adoption (Lamb et al., 2008). These strategies are important because the improper application of technology can have a negative impact on adoption process as well as on product failure (Rogers, 2003).

From the approach taken in this work we understand that the rate of adoption of PA corresponds to a complex technology rate, agreeing with Aubert et al. (2012) and Daberkow and McBride, (2003). It is expected that a complex technology produces delayed gains and requires diffusion of complementary technologies to achieve better results (Rogers, 2003). In this way, it is reasonable to recognize precision agriculture as a system where different components (positioning system, sensor, hardware, software, data management and other mechanisms) must to be in perfect synchronicity to make work correctly to achieve satisfactory results.

CONCLUSIONS

Precision agriculture practiced by grain-producing farmers in Rio Grande do Sul State, southern Brazil, is still focused on grid soil sampling. Outsourcing services in PA play a key role in adoption and diffusion of this technology. Yield maps and variable rate seeding are the preferable tools among current adopters in order to expand the use of PA technologies. PA adopters frequently cultivate large areas and have innovative profiles.

Technological factors elucidate 48% of farmer’s satisfaction with PA adoption; while farmer’s socioeconomic characteristics were not significantly correlated. The factor “relative advantage” was the most significant factor to predict satisfaction.

Greater attention should be given to enhance technological factors (relative advantage, compatibility, observability, trialability and ease of use) and reduce frustration of PA adopters. A broaden knowledge of the above mentioned factors should accelerate PA adoption process and also studies on each specific precision agriculture tool should help to better understand the way it performs among Brazilian farmers.

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