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Evaluation of farmer's perception of precision agriculture: A case study in the municipality of Guaíba, Rio Grande do Sul state

Avaliação da percepção do agricultor sobre a agricultura de precisão: Um estudo de caso no município de Guaíba, Rio Grande do Sul

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ABSTRACT

Purpose: The main objective of the work was to investigate the perception of rural producers in the municipality of Guaíba, Rio Grande do Sul state, in relation to the implementation of precision agriculture (PA), in order to verify the difficulties and benefits of the implementation of this practice in rural life.

Originality/value: PA technology is increasingly present in the planting process, enabling productivity improvement, lower environmental impact, and rural development, an area of fundamental economic importance for the country. Understanding the perception of the farmers in relation to PA can generate important insights, allowing for successful implementations of that technology.

Design/methodology/approach: The research was carried out based on semi-structured interviews. Thus, information was obtained on the perceptions of each farmer in the face of digital transformation in the field and the obstacles encountered in the practices of such technology. Data collection was carried out with five farmers in the municipality of Guaíba. Subsequently, the data were analyzed using the content analysis technique, in its variant of propositional discourse analysis.

Findings: The results show that, despite all the technological apparatus, there are challenges to be overcome in the face of the implementation of digital agriculture. Among the difficulties mentioned, the complexity of the systems – a fact not yet reported in theory –, lack of qualified personnel, cost of machinery, dependence on the climate, and difficulties in accessing the internet stand out. Benefits of the implementation of PA were also pointed out, such as the lower use of inputs, the better harvest yield, the improvement in the farmer's technical knowledge, and the possibility of adapting the existing machinery, which, contradictorily, was also pointed out as being a difficulty.

Keywords: precision agriculture, innovation in the field, rural development, difficulties in implementing PA, benefits of implementing PA

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RESUMO

Objetivos: O objetivo central do trabalho foi investigar a percepção dos produtores rurais do município de Guaíba, Rio Grande do Sul, em relação à implantação da agricultura de precisão (AP), de modo a verificar as dificuldades e os benefícios percebidos com a implementação dessa prática na vida rural.

Originalidade/valor: A tecnologia de AP está cada vez mais presente no processo de plantio. Essa tecnologia possibilita a melhoria da produtividade, menor impacto ambiental e o desenvolvimento rural, área de fundamental importância econômica para o país. Entender qual é a percepção do agricultor em relação à AP pode gerar importantes *insights*, possibilitando implantações bem-sucedidas da referida tecnologia.

Design/metodologia/abordagem: A pesquisa foi realizada a partir de entrevistas semiestruturadas. Assim, foram obtidas informações sobre percepções de cada agricultor diante da transformação digital no campo e dos obstáculos encontrados nas práticas da tecnologia. A coleta de dados foi realizada com cinco agricultores do município de Guaíba. Posteriormente, os dados foram analisados utilizando-se a técnica de análise de conteúdo, em sua variante análise proposicional do discurso.

Resultados: Os resultados apontam que, apesar de todo o aparato tecnológico, existem desafios a serem superados na implantação da agricultura digital. Entre as dificuldades apontadas pelos participantes, destacam-se a complexidade dos sistemas – fato ainda não relatado na teoria –, a falta de pessoal qualificado, o custo do maquinário, a dependência do clima e as dificuldades de acesso à internet. Também foram apontados benefícios na implantação da AP, sendo eles a menor utilização de insumos, o melhor rendimento da colheita, a melhoria no conhecimento técnico do agricultor e a possibilidade de adaptação do maquinário existente, que, contraditoriamente, foi também apontada como uma dificuldade.

Palavras-chave: agricultura de precisão, inovação no campo, desenvolvimento rural, dificuldades na implantação da AP, benefícios da implantação da AP

INTRODUCTION

The role of agriculture in the world has been going through a much-needed transformation, and, to obtain better results, precision agriculture (PA), along with technological innovation, has become the farmer's ally in the expectation of better returns while improving deficiencies and highlighting potentialities. Technological innovation is, in fact, a key element in the search for new market opportunities. In agriculture, it consists of machinery, equipment, pesticides, fertilizers, and the use of biotechnology, in addition to PA tools (Cirani et al., 2010; DeLay et al., 2022).

The implementation of PA was only possible after the advent of the global navigation satellite system (GNSS) – better known as global positioning system (GPS) – in the year 1978 in the United States, which made it possible to use microprocessors in carrying out a survey of the data on soil and climate. However, its use in agriculture only took place after 1990, with the production of the first productivity map, derived from a performance monitor coupled to the GPS (Inamasu & Bernardi, 2014).

The expansion of PA was also driven by advances in technology, with an important step being the use of GPS satellites. These enabled agriculture to benefit from data storage, production mapping, variable rate application of input, and minimized damage to the environment, with less application of pesticides, allowing for more sustainable production (Laursen & Meijboom, 2021; Sasaki et al., 2021). According to Bhakta et al. (2019), data analysis allows for the optimization of the use of agricultural inputs, enabling economic gains for the farmer and reducing the environmental impact of the activity. The focus of PA has, therefore, been the management of the spatial variability of production and the factors involved in it, carried out by means of recent technologies adapted to the agricultural environment, with the objective of enabling a reduction in the use of inputs and the impact on the environment (Cirani et al., 2010).

For Reetz and Fixen (1999), PA technologies have always demanded more developed agronomic production tools, but the success of their application depends on the agronomic understanding of the production system that is administered. In this case, agronomic knowledge and common sense make all the difference. According to Batchelor et al. (1997), PA can improve harvest yields and profits, provide information to make more informed management decisions, provide more detailed and useful farm records, reduce fertilizer costs, reduce pesticide costs, and even reduce pollution. In this context, according to Capra (2006), farming ought to be understood as a

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huge industry in which decisions are made by agricultural scientists and transmitted to agricultural administrators, agronomic technicians or former farmers through a chain of agents and salespeople. The development of smart agriculture, therefore, becomes crucial to achieving future food security goals (Food and Agriculture Organization – FAO, 2010).

PA is indeed a very important topic for our country and has been widely used in the world to increase production, improve economic returns, and reduce environmental impacts (Griepentrog et al., 2003; Thompson et al., 2019), being linked not only to technological and agricultural investment but also to the management of inputs and making it increasingly sustainable and competitive in the market.

Thus, there is much evidence of the efficiency of PA, especially for producers who have enough capital to fund such system – from its implementation to the results – and the capacity to take risks with the possibility of failure in its implementation (Santos, 2014; Thompson et al., 2019). PA technology has still a lot to improve besides the resolution of problems such as the lack of specialized labor, high implementation costs, and the lack of compatibility between computational applications and machines and equipment (Soares & Cunha, 2015).

For Thompson et al. (2019), the benefits generated by the adoption of several different types of PA technology vary, and it is necessary to understand the decision, or the lack of decision, of the farmer regarding the adoption of any of them. Thompson et al. (2019) also state that examining the adoption of PA from a simple financial perspective reduces the understanding of the phenomenon and does not address issues such as improvements in the field and training of farmers. Additionally, Bhakta et al. (2019) list a series of limitations that the technologies normally used in PA face, some of them being the difficulties of implementation in small farms, the use of specialized and high-cost instruments, and the need for training or specialists for handling the equipment.

The reasons why farmers adopt or do not adopt PA is still under research (Tamirat et al., 2018; Ofori & El-Gayar, 2021). This article, thus, aims to conduct a study on the perceptions of the process of implantation of PA among farmers in the municipality of Guaíba, in the state of Rio Grande do Sul, by reporting on what is found in theory in relation to the difficulties encountered and the benefits of this innovation in the field, and by comparing the same with the perceptions of the research participants. To this end, following this introduction, a discussion on the topics of sustainable development, PA, methodological procedures, and results are presented below. Finally, there is the conclusions section.

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SUSTAINABLE RURAL DEVELOPMENT

The history of agriculture dates back to at least 10,000 years ago (Mazoyer & Roudart, 2001). Over the centuries, we have noticed the evolution of agriculture and different production systems: the ones that have enabled the development of new techniques and different forms of cultivation and food supply, from the improvements seen in the 20th century that boosted agriculture 1.0; the use of animal traction and the arrival of combustion engines; to agriculture 2.0, which marked a major revolution in the planting process. Over the years, agriculture 3.0 has also been developed with the arrival of GPS. Finally, agriculture 4.0 has incorporated connectivity and automation into the planting process. For the next revolution, the promise is the incorporation of cutting-edge robotics, algorithms, and software, so that more is produced in this area.

Almeida (1995) states that the first farmers, through their link with nature, had very broad knowledge about vegetables and had already acquired some understanding of environmental factors, such as soil, climate, seasons, and others related to agricultural practices – for instance, the role of seeds in plant reproduction, timing of planting and harvesting, and some other technical handling operations.

Through bioinformatics, nowadays, it is possible to carry out analyses at different levels of complexity from data sets that reveal aspects of the complex organization of biological systems through studies in genomics, transcriptomics, proteomics, and metabolomics to a wide range of phenotypic analyses of the most varied organisms (Varshney et al., 2014). Another technology is genomic editing, which allows for precise and specific genetic modifications to be made in DNA strands or to generate genomic rearrangements to improve characteristics such as disease resistance and drought tolerance (Vasconcelos & Figueiredo, 2015).

Once the data are stored in the cloud, great analysis capacity is required, using artificial intelligence tools to process their large volume and extract relevant knowledge, which not only helps in decision-making in the management of the property and production but also conducts the performance of autonomous machines in the field (Saiz-Rubio & Rovira-Más, 2020).

In this context, Wolford (2021) states that the substitution of traditional agriculture (TA) for modernized agriculture represented the opening of important channels for the expansion of the business of large economic corporations, both in the supply of modern machinery and inputs, as well as in global marketing and the industrial transformation of agricultural products, besides the financing of countries that adhered to the modernization process.

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At the end of the Second World War, a broad macroeconomic process emerged, and, with it, an intense worldwide development took place. High-growth rates generated a cycle of economic expansion that lasted until the mid-1970s. This cycle was led by the United States and brought about the emergence, reconstruction, or economic resuscitation of European nations affected by the war, as well as that of Japan, integrating these nations into the group of wealthy capitalist countries (Navarro, 2001; Santos & John, 2018).

The concept of sustainable development was coined in the 1970s and was reinforced in the 1980s and 1990s. Its definition emerged from the World Commission on Environment and Development (1987), created by the United Nations to discuss and propose ways of harmonizing two objectives: economic development and environmental conservation. Sustainability was defined based on a long historical process, as well as awareness of environmental problems, economic crises, and social inequalities. And, since then, it has been a complex and continually-defining concept. Different approaches emerged as attempts to understand and explain sustainability (Sartori et al., 2014).

In order for the development of agriculture and the production process to be in line with sustainability, the precision of inputs and soil care are part of an agricultural system that is not unbalanced and vulnerable. For Gliessman (2001), the questioning of the sustainability of the models of modern agricultural production gave rise to several alternative models of production and distribution, which aimed to increase the ecological, economic, and social sustainability of agriculture.

For the global scenario at the time of the 1970s, the relationship between sustainability and development was a novelty, mainly because of the industrial revolution, which was accompanied by technological advances, the appearance of machines, and, consequently, more fossil fuel consumption. The objective of sustainable agriculture was, therefore, the maintenance of agricultural productivity with minimum environmental impact and adequate economic and financial returns, which would reduce poverty and meet the social needs of the population (Ehlers, 2017).

With regard to agricultural practices and the use of natural resources, many definitions include reduction in the use of agrochemicals and soluble synthetic fertilizers, erosion control, crop rotation, crop-livestock integration, and search for new sources of energy (Ehlers, 2017). Thus, it becomes evident that, for progress in agriculture, there is a need for concern with natural resources and, in general, the incorporation of agriculture into the economy, society, and sustainability. This is the objective of sustainable agriculture, besides maintaining the environment and the production process,

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while preserving non-renewable sources, which would be a catalyst for efficiency and competitiveness in the market.

PRECISION AGRICULTURE

Even before the industrial revolution and the mechanization of agricultural activity, farmers were already able to recognize the spatial variability of certain physical-chemical and biological characteristics of cultivated areas. The division of these areas into plots reflects this capacity for discernment. Until then, the use of manual labor and/or animal traction allowed farmers to treat more or less fertile areas, and even those with infestation of pests, diseases, and weeds in a different way (Fraisse, 1998).

PA dates back to the early 1920s, when it was recommended to producers to map soil acidity, for the application of limestone, identifying the spatial variability of the field where they produced. Thus, there was a need for management of the field, in order to remedy the non-uniformity of planting lands, minimizing costs and helping to produce in a more sustainable manner. The foundations of modern PA, according to the literature, emerged in 1929, in the United States, and were described by Linsley and Bauer in Circular no. 346 of the Agricultural Experimental Station of the University of Illinois (Franzen & Mulla, 2015).

At that time, the authors had observed the existence of great variations in the need for liming in a certain area and that the application of limestone should respect this variability. This philosophy, however, was passed over due to the development of mechanical traction equipment, which facilitated the application of inputs at uniform rates. The resurgence and dissemination of PA, as it is known today, occurred only in the 1980s, when microcomputers, sensors, and terrestrial or satellite tracking systems were made available, allowing for the diffusion of techniques and the use of technologies known as *smart farm technologies* (Ofori & El-Gayar, 2021).

In Brazil, the first research actions in the area were carried out at the Higher School of Agriculture "Luiz de Queiroz" (Escola Superior de Agricultura "Luiz de Queiroz" [Esalq]) of the University of São Paulo (Universidade de São Paulo – USP) in 1997, where a pioneering work with the culture of corn resulted in the first map of harvest variability in Brazil (Balastreire et al., 1997).

Nowadays, PA is presented as a set of tools capable of helping rural producer to identify the strategies to be adopted to increase efficiency in the

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management of agriculture (DeLay et al., 2022). That is, PA is not only linked to state-of-the-art agricultural implements and great technological investments, but also to the use of the land as a whole, aiming at an increase in its yields, producing more, and fulfilling the demands that the world currently needs to meet. According to Thompson et al. (2019), PA has the advantage of enabling a better knowledge of the production field, thereby ensuring better-informed decision-making. In addition, there are greater capacity and flexibility for the distribution of inputs in those places and at a time when they are most needed, minimizing production costs; uniformity in productivity is achieved by correcting the factors that contribute to its variability, thereby obtaining an overall increase in productivity; the localized application of the necessary inputs to sustain high productivity contributes to the preservation of the environment since these inputs are applied only in the necessary places, quantities, and time.

In 2012, the Brazilian Ministry of Agriculture, Livestock, and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento – Mapa), when establishing the Brazilian Commission for Precision Agriculture (Comissão Brasileira de Agricultura de Precisão – CBAP), defined PA as an agricultural management system based on the spatial and temporal variation of the productive unit aimed at increasing economic return and sustainability and minimizing the effects on the environment (Brasil, 2012, p. 6). In 2019, the Brazilian Commission for Precision and Digital Agriculture (Comissão Brasileira de Agricultura de Precisão e Digital – CBPAD) was established, determining that the commission is responsible for spreading the importance of precision and digital agriculture for agricultural development and the promotion of socioenvironmental sustainability, in addition to supporting professional updating, training, and qualification programs, encouraging the implementation of public policies, identifying the demands and trends of the sector, among other attributions.

The 2019-2020 season came to an end with a sown area of 65,911.4 thousand hectares. Soy, corn, wheat, sorghum, and cotton were the main products with an increase in area. It is noteworthy to remember that Brazil is a country of continental proportions, with a wide climatic and land variety, which, thanks to the cultivation techniques implemented – from soil management, through seed technology, to execution with modern machines –, in addition to qualified labor, makes it a country that is able to produce up to three-grain crops, using the same area (Companhia Nacional de Abastecimento – Conab, 2020).

In the literature, there are several benefits that can be linked with the use of techniques associated with PA, with improvement in crop productivity

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having received the highest praise (Koenig et al., 2015; Thompson et al., 2019). Reduction in the use of agricultural implements is also cited as one of the benefits provided by PA (Bhakta et al., 2019; Thompson et al., 2019; Ofori & El-Gayar, 2021). However, as highlighted by Thompson et al. (2019), considering the improvement in harvesting and reduction in the use of inputs as the only way of not using PA seems to minimize the technology's potential. For the authors, PA has the ability to increase the farmer's convenience, reduce fatigue and improve the producer's capabilities.

Regarding the disadvantages, the high costs associated with the implementation of PA systems is a point constantly mentioned (Bhakta et al., 2019; Ofori & El-Gayar, 2021), which may make it impossible to implement these systems in the properties of small businesses (Daberkow & McBride, 1998, 2003; Griffin & Lowenberg-DeBoer, 2005; Ofori & El-Gayar, 2021). Another important issue that surfaces in the literature is the need for qualified personnel. In this regard, Bhakta et al. (2019) carried out a systematic mapping in which they presented the technologies used in PA. The authors point out that, out of the seven technologies used in PA, six require qualified personnel, and the seventh still requires further studies so that it can be better understood. Another problem that has been raised is that of the unavailability of a favorable climate. Environmental changes make the farmer insecure due to the risk of losing the investment made in the acquisition of machinery and, consequently, postpone the decision to invest in it (Ofori & El-Gayar, 2021).

It is, thus, possible to summarize the advantages and disadvantages found in the literature for the implementation of PA (Daberkow & McBride, 2003; Rogers et al., 2003; Griffin & Lowenberg-DeBoer, 2005; Fragalle & Fonseca, 2011; Shockley et al., 2011; Costa & Guilhoto, 2012; Tey & Brindal, 2012; Koenig et al., 2015; Bhakta et al., 2019; Thompson et al., 2019; Ofori & El-Gayar, 2021) as follows:

- Advantages:
  - better crop productivity;
  - less use of inputs;
  - benefits related to producer capacity.
- Disadvantages:
  - high costs;
  - lack of qualified personnel;
  - climate dependency.

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METHODOLOGICAL PROCEDURES

This section addresses the methodological procedures that were used in order to achieve the proposed objective. The research was carried out through a qualitative approach, being of an exploratory nature. Lakatos and Marconi (2006, p. 190) explain that exploratory studies are investigations of empirical research whose objective is to formulate questions or a problem. According to Terence and Escrivão (2006), qualitative research was initially used in anthropology and sociology from the 1960s onwards and was then incorporated into other areas, such as administration, especially, organizational studies.

Seeking analysis of crop management, knowledge of available technological innovations, and solutions adopted by farmers participating in this study were undertaken. Data collection was performed using a semi-structured instrument. According to Andrade (2010), planning of research includes an execution plan and the instruments that will be used in the data collection, such as questionnaires, forms, interview scripts, etc.

The field research was carried out with medium-sized farmers, in the municipality of Guaíba, in the metropolitan region of Rio Grande do Sul. Guaíba has unique logistical conditions for projects that aim to serve the Southern Common Market (Mercado Comum do Sul – Mercosul) with products and services of international quality. According to Calcanhotto (2001), Guaíba is characterized by having a historical tradition in rural activity, with an important socioeconomic contribution to the generation of employment and income, and it is this feature that has led it to be chosen for the present study.

Five farmers participated in the research, for which they fit the desired profile. The research subjects were landowners who had a strategic and decision-making role in crop management and were chosen initially for convenience, but, later, by using a snowball-like technique (Handcock & Gile, 2011). According to the National Institute for Colonization and Land Reform (Instituto Nacional de Colonização e Reforma Agrária – Incra, 2019), the tax module served as a parameter for classifying rural property in terms of size, in the form of Law no. 8,629, of February 25, 1993, which stated the classification as follows: 1. small property: the rural property of an area comprising of between one and four fiscal modules; 2. medium property: rural property with an area greater than four and up to 15 tax modules; and 3. large property: rural property with an area greater than 15 tax modules.

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The interviews were conducted in November 2020. According to Fontanella et al. (2008, p. 17), information saturation could be defined as the suspension of the inclusion of new participants when the data obtained starts to present, in the researcher's evaluation, a certain redundancy or repetition, and it is not considered relevant to persist in the collection of information.

Subsequently, the classification and aggregation of the data were performed, choosing the theoretical or empirical categories, responsible for specifying the theme (Bardin, 2011). Thereafter, inferences and interpretations were made, interrelating them with the theoretical framework designed initially or by being open to other new theoretical and interpretive dimensions, as suggested by reading the material (Minayo, 2000).

The present study was carried out by analyzing multiple cases which, according to Yin (2001, p. 68), must follow a logic of replication and not that of sampling, as mentioned below:

> It requires the operational calculation of the universe or the entire group of potential respondents and, therefore, the statistical procedure for selecting the specific subset of respondents who will participate in the survey. [...] Case Studies, in general, should not be used to assess the incidence of phenomena [...] a Case Study would have to deal with both the phenomenon of interest and its context, producing a large number of potentially relevant variables.

Furthermore, according to Prodanov and Freitas (2013), exploratory studies are, in general, of a qualitative approach, using tools such as bibliographic surveys, case studies, interviews, and analyses of examples. Thus, the assembly of the collection instruments was made, based on open questions, as previously performed by Silva et al. (2018), by allowing the subject participants freedom in the answer.

Structured interviews are conducted using a fully-structured questionnaire, that is, a questionnaire in which the same questions are presented in exactly the same order. The main reasons for its adoption are the possibility of comparison, given the same set of questions, and the fact that divergences should reflect differences between the respondents and not between the questions asked (Lakatos & Marconi, 2006).

Based on the above, the study's data collection instrument was a structured interview that comprised of the following set of six questions:

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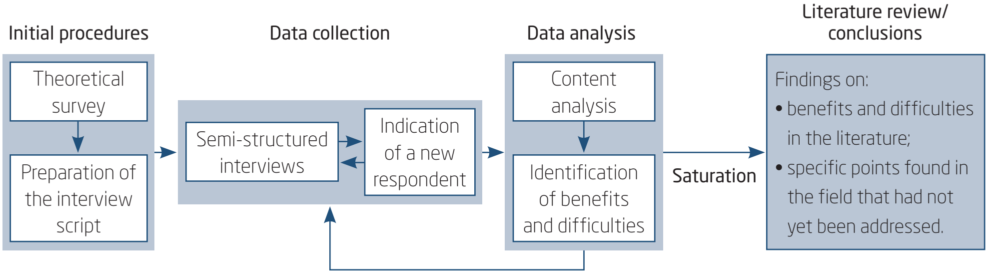
- PA has been present in Brazil since the 1970s, when the GPS system was available. In this regard, how do you define it? (Inamasu & Bernardi, 2014).
- With regard to agriculture technology, do you use any climate-monitoring application or similar technology, to obtain data for planting? If so, what has the process of deploying this application been like? What were the difficulties faced and the lessons learned? (Esperidião et al., 2019).
- Regarding equipment that allows for PA, taking into account costs (sustainability and productivity), what efforts, in terms of resources, were necessary to make the implementation of PA on your property viable? (Knob, 2006).
- With regard to planting, we can focus on either the traditional method or the technological innovations that make it possible to plant with PA. In your opinion, what are the advantages and disadvantages of each method? (Antonini, 2016).
- What is your opinion regarding the availability of trained professionals to put into practice all the technological apparatus that is currently available on the market? (Inamasu & Bernardi, 2014).
- In your opinion, for the implementation of PA, is it necessary for the farmer to have knowledge of information technology? How has that process been for you? (Inamasu & Bernardi, 2014).

Data analysis was performed through the content analysis technique, considering the aspect of propositional discourse analysis (Bardin, 2011). From the questions presented above, it was possible to identify the farmers' knowledge about PA, crop management, and tools used for decision-making. The research protocol is summarized in Figure 1.

Figure 1

Research protocol



Source: Elaborated by the authors.

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RESULTS

The main motivation for applying the interview protocol was to understand the disadvantages encountered by farmers and the benefits that PA could bring to the field and observe its impact on different economic agents, such as: producers, qualified professionals, technology, and costs involved.

In terms of disadvantages encountered, according to Daberkow and McBride (2003), it was mainly the location of the property, the fertility of the soil, and the level of access to information that influenced the adoption of technologies such as PA. Bhakta et al. (2019) also reported challenges in terms of financial difficulties, especially experienced by smallholder farmers. Such problems were reported by interviewee B, as follows:

> I do not use applications because I believe that these resources are financially unfeasible for the farmer. I simply use the resources offered by the internet, for example, weather applications, often err and hinder the forecast. These errors hinder the proper progress of planting or harvesting.

Costa and Guilhoto (2012) argue that, although there were existing technologies that were applied to agriculture, they were still hardly being used in the country, but their effects, mainly under the Brazilian conditions, still needed to be better evaluated. According to Shikuku et al. (2019), the dissemination of knowledge required time and effort. Interviewee A, in fact, reported on the difficulty in having resources and knowledge. They said: "At the moment I do not have these precision agriculture resources. The support I receive to improve productivity in agriculture is from Emater/RS and the suppliers of inputs". And, as reported by interviewee C: "Another disadvantage of implementing precision agriculture is the difficulty of accessing the internet in rural areas".

Griffin and Lowenberg-DeBoer (2005) reported that the economic returns of using this tool had not yet been well established. Interviewee E reported their concern about the climate and that PA depended on natural resources in order to be efficient. They stated vehemently: "Precision farming depends on the climate, on the rain… If there is no irrigation, and this can bring profit or loss".

Tey and Brindal (2012) believed that the probability of adopting PA would be greater if there were greater profits for the producer. With regard to trained professionals, interviewees A, B, C, D, and E reported difficulties in finding qualified personnel – a factor reported by Bhakta et al. (2019), as

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well as Ofori and El-Gayar (2021). Another important factor, undoubtedly, was the increasing mechanization of activities that reduced the importance of the employment of unskilled labor, as cited by interviewee C:

> I believe that precision agriculture is more advantageous than traditional agriculture, but I am not fully aware. The cost of implementing the precision farming system and qualified people to carry out this type of activity, I consider it a disadvantage, while the traditional is the more accessible.

Interviewee D echoed the same sentiments:

> Qualification is low when it comes to labor. Even finding a good quality professional tractor driver is complicated. If you require technological knowledge combined with the skills of the field, operating machines, even if you cannot admit anyone to work…

Another issue identified in the study was the influence of the size of the properties on the adoption of PA, also observed by Daberkow and McBride (1998, 2003) and Ofori and El-Gayar (2021). The results also confirm the observations by Griffin and Lowenberg-DeBoer (2005) and DeLay et al. (2022) that the largest production scales tend to favor the adoption of PA technologies. Bhakta et al. (2019) also point out that the application of PA on small farms is a challenge itself. Reducing the cost of technologies adopted in PA has played an important role in accelerating innovation (World Economic Forum, 2017). Respondents A, B, and C pointed out that it is an advantage to have the technology for large properties. As stated by interviewee A, "This agriculture is advantageous for those who have a lot of lands. The equipment is expensive, and the investment takes a long time to return".

The participation of government agencies in the process of implementing PA was also discussed and brought to light what was proposed by Fragalle and Fonseca (2011), who stated that the use of various communication tools was a strategy for approaching and relating to the public. For interviewee A, communication between the agency and the producer could be beneficial in generating professional training.

> I believe that new planting systems do not accompany the training of professionals. Therefore, the difficulty of implementing other techniques. The farmer does not have the necessary knowledge to use these technologies. Emater could assist and provide courses for farmers.

Regarding the perceived advantages, all respondents agreed that the benefits could lead to lower costs. As explicitly stated by interviewee D: "I like to save, I believe it helps a lot in reducing costs… and can bring benefits to our land".

An item identified in the research that deserves to be highlighted and that had earlier been pointed out by Rogers et al. (2003) concerns the innovative profile of the farmer and the search for information and various sources. In this regard, interviewee A reported on the possibility of innovating with their own machinery, as "It is feasible… especially if we use our own work equipment, such as tractors".

Rogers et al. (2003) focused on how relative advantage could be used to evaluate the extent to which a technological innovation could offer advantages over another technology. Additionally, if the gains obtained from knowledge were greater than the price spent to obtain it, the farmer would see an advantage in this exchange and would be willing to invest (Shikuku et al., 2019). Interviewees A, C, and E were in agreement with the benefits that technical knowledge offered the farmer, as it can be noticed in the following response of interviewee A:

> Today, most people use their cell phones for various features. It would not be impossible to learn to deal with equipment, as long as they are guided. If I had to implement this precision system, I would look for courses to improve myself.

Summary of results

From the reports of the subjects participating in the research, it was possible to elaborate two tables – one of the advantages and another of the disadvantages – in the process of implementing PA. Among the disadvantages reported in theory by Bhakta et al. (2019) and Ofori and El-Gayar (2021), there were the high cost of machinery, need for qualified personnel, climate issue, and difficulties related to connectivity. These problems were also identified in the present study. However, a different point raised by the participants was the complexity of the system, which may have been due to other studies having overlooked the farmers' point of view when discussing precision farming. Table 1 shows the list of disadvantages and their respective citations by the participating subjects.

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Table 1

Disadvantages of the implementation of PA

Disadvantages	A	B	C	D	E
Complex system	x	x			
Lack of qualified personnel	x	x	x	x	x
High cost of machines	x		x	x	x
Climate dependency	x	x			x
Low internet access			x		

Source: Elaborated by the authors.

Regarding the benefits mentioned in the literature, the improvement in productivity, with a reduction in planting costs (Koenig et al., 2015; Thompson et al., 2019), was presented as an important factor in the farmers' perception. PA plays an important role in optimizing the use of fertilizers and is in line with what was proposed by Berry et al. (2003) and corroborated by Thompson et al. (2019) in relation to precision conservation, which they defined as the use of precision technologies and procedures, through spatial and temporal variability, to achieve conservation objectives.

Shockley et al. (2011), in a comparative study of TA and PA, adopted a system of direct planting for the cultivation of soybeans and corn and, thereby, demonstrated a cost reduction of around 2.4%, 2.2%, and 10.4% for seeds, fertilizers, and fuels, respectively, in the production process with the innovation system.

The research participants in the present study also mentioned a decrease in the use of inputs, which had earlier been widely reported in theory (Bhakta et al., 2019; Thompson et al., 2019; Ofori & El-Gayar, 2021; DeLay et al., 2022), alongside the adaptation of existing machinery and the training of farmers to deal with the new technology. The latter aspects seem to have shed new light on the phenomenon. The possibility of improving as a professional, carrying out training, and learning more about an activity that the farmer already practiced could take the field where they worked to a new level of productivity and could also be related to the benefits that accrue from producer capacity, as pointed out by Thompson et al. (2019). In relation to the machinery and the possibility of it being adapted to the new technologies, there is a contradictory situation, since this point also appears to have been perceived to be a disadvantage in the implementation of PA. It is clear that there was apprehension about the investment necessary to

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adapt the machines, although being an investment that could generate interesting returns. The list of benefits cited by each participating subject is shown in Table 2.

Table 2

Advantages of the implementation of PA

Advantages	A	B	C	D	E
Decrease in inputs	x	x			
Increased crop yield	x	x		x	x
Possibility of adapting existing machinery	x				x
Increased technical knowledge for the farmer	x			x	x

Source: Elaborated by the authors.

CONCLUSIONS

The tools of PA allow the producer to gain better knowledge of their property, efficiently enabling better management with regard to the use of inputs and natural resources, generating a decrease in costs and enabling an increase in productivity.

The present study aimed to analyze farmers' perceptions in relation to the adoption of PA, seeking perceived advantages and disadvantages in the process. It was possible to identify the following advantages of adopting PA: the reduction of inputs, increase in crop productivity, possibility of adapting existing machinery, and improvement of the farmer's technical knowledge. Among the disadvantages, the following items were mentioned: the complexity of PA systems, need for qualified personnel, cost of machinery, dependence on climate, and need for internet connectivity.

Within the general scope of the study, it was possible to highlight that PA had a fundamental role to play in the development and transformation of agriculture. Besides keeping the interests of the farmers in mind, there were challenges to be overcome, such as the understanding of PA as management, training for PA tools, and the cost of implementing machinery and human resources necessary for the use of the technology involved in the process. Among the main advantages, we can highlight the adaptation of machinery that the producer had at their disposal, enabling technological innovation at a lower cost than purchasing new equipment. In addition, we

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can also mention the possibility of training farmers for their own development of technological knowledge.

It is, therefore, important to call attention to the observations of the participants that allowed for the identification of two contradictory elements not previously found in the literature – that of the perception of complexity that the system passes on to farmers, which can generate some reservation in the use of technology, and the possibility of improving as a professional, through training and improvement of machines used in the field. A practical opportunity can be observed here – that of farmers realizing the complexity involved in using technology but expressing willingness to understand and apply it.

Possible ways to improve the reality of farmers who do not have large properties would be through access to smaller equipment using the same technology, improvements in connectivity and internet in rural areas, and technical development initiatives for those who still face difficulties in keeping up with advances in technology.

In a more recent scenario, we are going through a pandemic in which rural workers have dealt with tremendous losses due to the difficulties encountered in this context. As such, new strategies and policies need to be undertaken so that activities aimed at rural development can resume. Prins (2020) reports that coronavirus disease 2019 (Covid-19) is directing the transformation of agricultural data in three aspects: 1. increasing digitization; 2. increasing digital collaboration; and 3. visibility, mainly due to disruptions in the value chain, which will make planning a fundamental tool in the process of supplying agricultural products. Thus, the application of PA must respect all interests directly involved in the field, as monitoring these processes, cutting-edge equipment, and management become unviable without proper public policies aimed at small-scale producers.

As a suggestion for future studies, evaluations can be cited in relation to the dichotomy found between system complexity and the possibility of adopting the technology in existing machinery. Surveys related to the type of technology that is most applicable to a particular crop, taking into account factors such as size, the profile of the producer regarding technology and availability of financial and human resources, can also be carried out. Besides, an analysis of the influence of professional training on the successful implementation of PA projects can be performed.

It is, of course, necessary to highlight some of the study's limitations. The first is related to data collection as we used a method that is similar to the snowball-sampling technique. It is also worth noting that the study was

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carried out among farmers from the municipality of Guaíba, which might represent a local bias. It is, however, also necessary to consider that the conclusions presented here were based on qualitative data analysis without statistical representation, which does not invalidate the study but corroborates the creation of a solid theoretical basis while innovating, validating, or comparing information from previous studies.

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