UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
ESCOLA DE ADMINISTRAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO
DOUTORADO EM ADMINISTRAÇÃO

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HOW COMMUNICATION AFFECTS THE ADOPTION OF TECHNOLOGIES IN SOYBEAN PRODUCTION: A COMPARATIVE STUDY BETWEEN BRAZIL AND THE UNITED STATES

Porto Alegre

2022

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Ph.D. thesis presented to the Postgraduate Program in Business Administration at the Federal University of Rio Grande do Sul as a final requirement to obtain the Ph.D. in Business Administration.

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Porto Alegre

2022

CIP - Catalogação na Publicação

Colussi, Joana
How communication affects the adoption of technologies in soybean production: a comparative study between Brazil and the United States / Joana Colussi. -- 2022.
124 f.
Orientador: Antônio Domingos Padula.

Coorientador: Gary Donald Schnitkey.

Tese (Doutorado) -- Universidade Federal do Rio Grande do Sul, Escola de Administração, Programa de Pós-Graduação em Administração, Porto Alegre, BR-RS, 2022.

1. Adoção de Tecnologias. 2. Mídia de Massa. 3. Mídia Social. 4. Relações Interpessoais. 5. Agricultural Digital. I. Domingos Padula, Antônio, orient. II. Donald Schnitkey, Gary, coorient. III. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

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I dedicate this Ph.D. thesis to everyone who supported me on this fascinating journey, especially to my dear parents, my lovely husband, and my inspiring advisors in Brazil and the United States.

ACKNOWLEDGEMENTS

The Ph.D. was one of the most extraordinary experiences I have ever had. I have grown professionally and personally during these four years, with the fantastic help of many people:

Firstly, I would like to extend my sincere thanks to my advisor at the Federal University of Rio Grande do Sul, Dr. Antônio Padula, and my host advisor at the University of Illinois Urbana-Champaign, Dr. Gary Schnitkey. Thanks for always being there when I needed their support.

Special thanks to Dr. Steve Sonka for providing unique insights into agribusiness and farm management. Thanks also for all the guidance, support, and outstanding feedback.

We gratefully the Department of Agricultural and Consumer Economics at the University of Illinois and the National Council for Scientific and Technological Development (CNPq) from Brazil for supporting this research.

I am also grateful for the statistical support of Lourdes Odete dos Santos and Dr. Paulo Waquil, both from the Federal University of Rio Grande do Sul.

My thanks should also go to my committee members for helping me to improve this research.

Many thanks to all my colleagues and friends in Brazil and the United States. Sarah Sellars, Maria Gervani, Tatiani Secretti, Gisele Loeblein, and Aline Jansen you are like sisters at this time.

I am forever grateful to my parents João Colussi e Terezinha Marchese for always supporting me throughout my life. I always had the blessing of being able to count on you.

Finally, I could not have undertaken this journey without my lovely husband, Fernando Pellenz. You played an essential role during all these years. My love for you grows stronger every day.

****

I am thankful to people and associations/universities that helped to distribute the survey in Brazil: the Brazilian Association of Soybean Growers, Brazil's National Supply Company, Union and Organization of the Cooperatives of the State of Parana, Federation of Agriculture and Livestock in Mato Grosso, Federation of Agriculture in Rio Grande do Sul, Federation of Agriculture in Paraná, Federation of Agriculture in Goiás, Brazilian Soybean Strategic Committee, Sustainable Agriculture Associated Group, and Aquarius Project from the Federal University of Santa Maria.

Thanks also to people and associations/universities that helped to spread the survey in the United States: Farmdoc/University of Illinois; Illinois Farm Business Farm Management Association; Illinois Soybean Association; Illinois Farm Bureau; Iowa Soybean Association; Nebraska Soybean Board; North Dakota Soybean Growers Association; Ohio Soybean Association; Ohio State University; Missouri Soybeans; and Minnesota Soybean Growers Association.

"Find a group of people who challenge and inspire you, spend a lot of time with them, and it will change your life." (Amy Poehler)

ABSTRACT

The digitalization of agriculture is one of the areas widely given importance in recent years as it could be the next agricultural revolution. This transformation is crucial in agribusiness because it leads to more informed decisions, higher efficiency, and easier knowledge sharing. In addition to increasing economic efficiency, more extensive use of precision technologies will be important in advancing societal goals relating to environmental impacts and climate change mitigation. However, studies have shown that the lack of ability to use these tools and the shortage of knowledge about the most appropriate technologies contribute to current farmer unease regarding digital technology. Information plays a relevant role in the technology adoption process in agriculture. This study investigates the influence of communication channels (mass media, social media, and interpersonal meetings) on farmers' adoption, decision-making, and benefits obtained concerning the use of precision and digital technologies. The study uses data from 461 soybean farmers in Brazil and 340 soybean farmers in the United States, the two largest producers and exporters of soybeans worldwide. The comparative study was conducted in Brazil's top five soybean-producing states and the United States' top nine soybean-producing states. These states provide approximately 75% of soybean production in each country. The strength of association between the communication channels and the level of adoption of technologies showed variations and similarities between Brazil and the United States. LinkedIn had the highest positive correlation in Brazil, with a strong relationship for seven precision and digital technologies among eight analyzed. In the United States, YouTube had the highest positive correlation with four of eight precision and digital technologies analyzed. The overall influence attributed to social media among Brazilian farmers was much higher than among American farmers. The relationship between communication channels and the perceived benefits of using technologies on-farm showed a higher association with mass media channels in the United States than in Brazil. Regarding making decisions and communication channels, the study showed a relevance of interpersonal meetings in Brazil and the United States. The results reinforce that superior knowledge and information are decisive in the process of adopting technologies in agriculture. Findings in the two countries enable farmers and agribusiness managers to use communication channels more effectively in evaluating and adopting precision technologies.

Key words: Technology adoption; mass media; social media; interpersonal meetings; digital agriculture.

RESUMO

A digitalização da agricultura se tornou uma das áreas de maior importância nos últimos anos, com potencial de se tornar a próxima revolução agrícola. Essa transformação é muito importante no agronegócio porque leva a decisões mais conscientes, aumenta a eficiência produtiva e facilita o compartilhamento de conhecimento. O uso mais extensivo de tecnologias de precisão é importante também para o avanço das metas sociais relacionadas aos impactos ambientais e à mitigação das mudanças climáticas. No entanto, muitos estudos empíricos e científicos têm mostrado que a falta de habilidade para usar essas ferramentas e a escassez de conhecimento sobre as tecnologias mais adequadas contribuem para o desconforto atual do agricultor em relação às tecnologias digitais. E nesse processo de adoção e implementação de novas tecnologias na agricultura, a informação desempenha um papel fundamental. Essa pesquisa investiga a influência dos canais de comunicação (mídia de massa, mídias sociais e relações interpessoais) na adoção, tomada de decisão e benefícios obtidos pelos agricultores com o uso de tecnologias. O estudo coletou dados com 461 produtores de soja no Brasil e 340 produtores de soja nos Estados Unidos, países líderes na produção e exportação de soja. O estudo comparativo foi realizado nos cinco principais Estados brasileiros produtores e nos nove principais Estados americanos produtores. Esses Estados representam aproximadamente 75% da produção de soja em cada país. Os resultados que mediram a associação entre os canais de comunicação e a adoção de tecnologias mostraram variações e semelhanças entre os dois países. O LinkedIn apresentou a maior correlação positiva no Brasil com sete tecnologias de precisão e digital entre oito analisadas. Nos Estados Unidos, o YouTube teve a maior correlação positiva com quatro das oito tecnologias digitais e de precisão analisadas. A influência geral atribuída às mídias sociais entre os agricultores brasileiros foi muito maior do que entre os agricultores americanos. A relação entre os canais de comunicação e os benefícios percebidos com o uso de tecnologias nas fazendas teve maior associação com a mídia de massa nos Estados Unidos do que no Brasil. Em relação à associação entre tomada de decisões e canais de comunicação, o estudo mostrou relevância das relações interpessoais no Brasil e nos Estados Unidos. Os resultados reforçam que conhecimento e informação são fatores decisivos no processo de adoção de tecnologias na agricultura. As descobertas desta pesquisa permitirão que agricultores e gestores usem os canais de comunicação de forma mais eficaz na avaliação e adoção de tecnologias de precisão.

Palavras-chave: Adoção de tecnologia, mídia de massa, mídia social, relações interpessoais, agricultura digital.

FIGURES

TABLES

LIST OF ABBREVIATIONS

ABMRA – Brazilian Association of Rural Marketing and Agribusiness

AI – Artificial Intelligence

ANOVA – Analysis of Variance

APROSOJA – Brazilian Association of Soybean Growers

CONAB – National Supply Company

EC – Electrical Conductivity

EMBRAPA – Brazilian Agricultural Research Corporation

FAO – Food and Agriculture Organization of the United Nations

GNSS – Global Navigation Satellite Systems

ICTs – Information and Communication Technologies

IoT – Internet of Things

IS – Information System

IT – Information Technology

NPK – Nitrogen, Phosphorus, Potassium

SPSS – Statistical Package for Social Science

US – United States

USDA – United States Department of Agriculture

UTAUT – Theory of Acceptance and Use of Technology

WHO – World Health Organization

SUMMARY

1. INTRODUCTION

Technology adoption has contributed to developing efficient food production throughout the history of modern agriculture. In the last decades, several technologies have positively affected yields globally, and, more recently, digital solutions are leading the way. Adopting digital systems in agriculture is essential to address the challenges in terms of profits, environmental impact, food safety, and sustainability (Kamilaris, Kartakoullis, and Prenafeta-Boldú, 2017).

There is a tendency for rapid growth in generating, transferring, and storing data in agriculture along with mobile technology and data management software for the collection, generation, and dissemination of information (Jain, Kumar, and Singla, 2014). Various studies suggest that the availability of sensors, mapping technology, and tracking technologies have changed many farming systems and the management of the food system as it flows from producers to consumers (Coble et al., 2018).

In the context of the Sustainable Development Goals from the Food and Agriculture Organization of the United Nations (FAO), digital agriculture has the potential to deliver economic benefits through increased agricultural productivity, cost efficiency and market opportunities, social and cultural benefits through improved communication and environmental benefits across optimized resource use as well as adaptation to climate change (Trendov, Varas, and Zeng, 2019).

This digital transformation is crucial in agribusiness because it leads to more informed decisions, higher efficiency, and easier knowledge sharing. Some studies suggest there has been an informational revolution in the agricultural sector (Dyer, 2016), with the adoption of digital technologies by farmers increasing for a decade. This trend will likely continue at an accelerated pace, given the increased venture capital devoted to developing these technologies (Boehlje and Langemeier, 2021).

The development of digital technologies is stimulated by large agricultural and information companies as well as start-ups, which collectively have invested hundreds of millions of dollars in technologies that use data on soil types, seed variety, and climate to help farmers increase productivity (Faulkner, Cebul, and McHenry, 2014). Currently, the pressure to adoption digital technology on the farm emanating from end-use consumers also is mounting. One motivation for that pressure is the desire for more sustainable cropping systems.

The integration of information technology (IT) with agriculture and food production has shown remarkable progress in improving productivity and aiding farming to make informed decisions. A good example of this is the introduction to precision agriculture (Sridhar et al., 2022). Precision agriculture is a farming management concept that provides a systematic approach to managing the spatial and temporal crop and soil variability within a field to increase profitability, optimize yield and quality, and reduce costs and environmental impacts (Aubert, Schroeder, and Grimaudo, 2012; Reichardt and Jürgens, 2009; Stafford, 2000). Precision agriculture has become mainstream in commercial agriculture production, and many agree it is “the way we farm today” (Pope and Sonka, 2020).

Digital agriculture has been developing at a rapid pace, especially in countries such as the United States and Brazil, leaders in food production in the world, as evidenced by the widespread adoption of precision agriculture over the past two decades (Thompson, Widmar, and Mintert, 2019; Shockley, Dillon, and Stombaugh, 2012). Brazil and the United States are the two largest producers and exporters of soybeans worldwide (USDA, 2022a).

Although the adoption of precision agriculture is increasing, many empirical and scientific studies have shown that the lack of ability to use these tools and the shortage of knowledge about the most appropriate technologies contribute to current farmer unease about digital technology adoption (Pope and Sonka, 2020; Bolfe et al., 2020; Gelb and Voet, 2009). Much of this discontent is the result of uncertainty regarding the real benefits of the new digital solutions. Understanding the value of technology is increasingly essential in an environment of narrow crop margins when deploying technologies to optimize returns is critical, especially around agricultural commodities (Pope and Sonka, 2020).

The gradual adoption pattern results from the gradual flow of information and gradual change of farmers’ perceptions of new technology. Furthermore, a gradual adoption process is complicated if we consider farmers’ forward-looking behavior (Ma and Shi, 2015). For example, a producer can adopt a new technology even if this adoption is not ideal for the current time period, believing that experience will give her valuable information on the new technology to assist her in making better future decisions (Ma and Shi, 2015).

The literature documenting determinants of adoption of precision agriculture practices is broad. Many studies have examined factors such as farmer age, farm size, the cost and complexity of technology, and level of farmer education (Pivoto et al., 2019; Paustian and Theuvsen, 2017;

Lambert et al., 2014; Reichardt and Jürgens, 2009; Roberts et al., 2004) and their influence and relationship with the adoption rate of technologies in agriculture. However, this study presents a multidisciplinary analytical approach to investigate the impact of communication in adopting digital technologies in agriculture.

There are several ways to disseminate information to farmers about new technologies, such as mass media (newspaper, magazine, radio, television, and website/blog), social media (WhatsApp, Facebook, YouTube, Twitter, Instagram, LinkedIn, etc.), and interpersonal meetings (field days, conferences, retailers, extension agents, peer groups, and conversations with neighbors, etc.). Various stakeholders spread relevant information, such as technology firms, research centers, private consultants, and farmer unions (Paustian and Theuvsen, 2017). The communication channel is closely related to how the information can be distributed to farmers.

Social media, for example, set a "revolutionary" context of online communication for agricultural stakeholders as it widens the scope of peer-to-peer communication, farmer-industry networking, engaging consumers, and building relationships with agri-business and agricultural entrepreneurs (Chowdhury and Odame, 2014). Participation in social networks also is essential to share information and experiences between farmers and other agents of the agroindustry chain (Carrer, Filho, and Batalha, 2017). At the same time, mass media remains essential to the agriculture industry because many consumers still receive information about agriculture from sources such as newspapers and television (Haller, Specht, and Buck, 2019).

Therefore, based on the premise that diffusion is the process by which an innovation is communicated over time among the participants in a social system (Rogers, 2003), this investigation concentrates on one of the main elements influencing the spread of an innovation: communication channels. In other words, the information is a determinant variable in the process of adopting innovations. Although there is a consensus that information is essential to adopting digital technology, there is no common understanding of which are the most efficient communication channels to influence soybean farmers' decision-making regarding technologies in Brazil and the United States.

1.1 Problem Statement and Justification

Brazil and the United States were chosen because of their agricultural potential and the role of technology in increasing productivity and soybean production in both countries. The combined share of the two countries in world soybean production was 70% of the 2021/22 harvest (USDA, 2022a). Exports to China are a significant component of the demand for soybeans produced in both the United States and Brazil. China’s soybean imports are driven by demand for animal protein and edible oils, two important components of a diversifying Chinese diet that reflect rising living standards. The predominance of the United States and Brazil as exporters reflects the emergence of soybeans as major crops in those countries during the 20th century (Gale, Valdes, Ash, 2019).

In 2018, Brazil surpassed the United States as the world’s largest soybean producer. From 1993 to 2022, the number of planted hectares in Brazil increased from 10.7 million to 40.9 million hectares, a 282% increase (Conab, 2022a). In the same period, the planted area in the United States rose 46%, from 24.3 million hectares in 1993 to 35.6 million hectares in 2022 (USDA, 2022b). In the future, Brazil's soybean production is projected to exceed that of the United States.

The Brazilian agricultural sector has modernized since the 1960s. The first step for the country’s green revolution was given in the 1970s with the creation of the Brazilian Agriculture Research Corporation government (Embrapa). The institution is credited with transforming the Cerrado (the Brazilian savannah) from an unsuitable region for agriculture into one of the world's most productive regions for grain and cattle. Therefore, Brazil successfully transitioned from a net food importer in the 1960s to a strategic worldwide producer (Vieira Filho, 2014).

In the United States, a 1929 bulletin from the University of Illinois Extension is one of the earliest examples of grid soil sampling, with step-by-step instructions on variable rate application of lime based on soil test criteria (Linsley and Bauer 1929). Geospatial referencing of soil samples first became available to farmers in the early 1990s with the global positioning system (GPS), providing even more precise information about site-specific soil nutrient needs (Torbett et al., 2008). So, the introduction of precision agriculture technologies in the United States tended to precede the corresponding introduction in Brazil.

Despite the early adoption in the United States, Brazil had an increasing adoption rate of precision agriculture in the last decade (Say et al., 2018). But what does it mean in terms of using Information and Communication Technologies (ICTs)? And what are the most relevant communication channels to diffuse information about new technology in these two countries? These questions are essential because any innovation's successful diffusion depends upon the communication channels available (Littlejohn, Foss, and Oetzel, 2021).

Information plays a crucial role in agriculture's technology adoption. The dramatic growth in knowledge and information about agricultural production’s chemical, biological, and physical processes is one type of information. Second, the “food business” has become an increasingly sophisticated and complex business in contrast to the primary emphasis on producing commodities in the past (Boehlje and Langemeier, 2021). In addition, information and communications technologies are playing an increasingly important role in keeping farmers and rural entrepreneurs informed about agricultural innovations, weather conditions, input availability, financial services and market prices, and connecting them with buyers (FAO, 2017).

Therefore, our main research question is: **what are the most effective communication channels to influence the adoption of new technologies in soybean production in Brazil and the United States? And what are the precision/digital technologies most used by farmers and the decisions and realizing benefits through them?**

To answer this research question, we gathered information through an online survey with soybean farmers about the adoption and implementation of digital technologies in Brazil (460 respondents) and the United States (340 respondents). This comparative study was conducted in Brazil's top five soybean-producing states and the United States' top nine soybean-producing states. This study is classified as a descriptive study with a quantitative approach (Cooper and Schindler, 2016).

Findings in the both countries will enable farmers and agribusiness managers to use communication channels more effectively in evaluating and adopting precision technologies. In addition, this study supports new research in agricultural communication, an area still lacking data in Brazil and the United States.

1.2 General Objective

The study aimed to measure the influence of communication channels (mass media, social media, and interpersonal meetings) on farmers' adoption, decision-making, and benefits obtained through the use of precision and digital technologies.

1.3 Specific Objectives

From the general objective of this thesis, the following specific objectives were defined:

- To identify the precision/digital technologies most used by soybean farmers in the

United States and Brazil and the decisions and realizing benefits through these technologies.

- To offer insights into current farmers' behavior regarding adopting new technologies, helping analyze strategies for the generation and dissemination of information about digital technologies on agriculture.
- To enable farmers and agribusiness managers to use communication channels more effectively in evaluating and adopting precision technologies.

The thesis is organized into five main sections. The first is this introduction with the research context, justification, and general and specific objectives. Secondly, the theoretical framework with historical and recent advances in precision and digital agriculture is addressed. In the same section, we presented the determinants of acceptance and use of innovations under various theoretical perspectives, such as the Theory of Diffusion of Innovations (Rogers, 1962, 2003) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003). In sequence, the main channels of communication to spread information about new technologies in agriculture are described. Afterward, we presented our multidisciplinary analytical approach to analyze the influence of different communication channels in adopting digital agriculture by soybean farmers. Section 3 explained the methodological procedures, encompassing the study area, survey instrument, data collection, and data analysis.

The results and discussion are shown in section 4. First, we presented our study's demographic characteristics: age, educational level, farm size, and cooperative membership. Afterward, we compared the level of use of technologies on-farm in two countries and the level of their influence in making decisions and realizing benefits. In addition, we reported the results regarding the influence of mass media, social media, and interpersonal meetings on their decision to adopt precision and digital technology. Still, in this section, we compared the relationships between the demographic characteristics and the adoption of precision agriculture technologies of interest in this study. Last but not least, the results and discussion section presented the association between the communication channels and the adoption of technologies in Brazil and the United States.

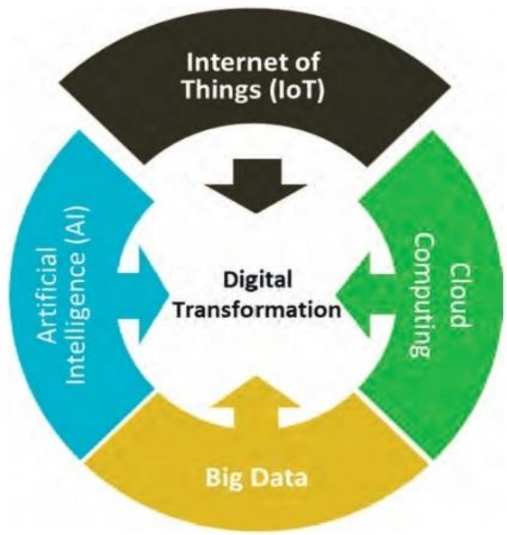
Finally, the last section summarized the main results and presented the theoretical and practical contributions. Moreover, we discuss the limitations of the study and further studies.

2. THEORETICAL FRAMEWORK

2.1 Advances in Digital Agriculture

Digital transformation is one of the most game-changing revolutions in recent history. Some studies suggest we have moved to an informational revolution in the agricultural sector (Dyer, 2016). On the other hand, digital transformation has become one of our most misunderstood buzz phrases. The collective confluence of the Internet of Things (IoT), big data, accessible cloud computing, and advances in artificial intelligence (AI) have been presented as a driver for digital transformation, according to Figure 1 (Siebel, 2019).

Figure 1. Confluence of four powerful technologies



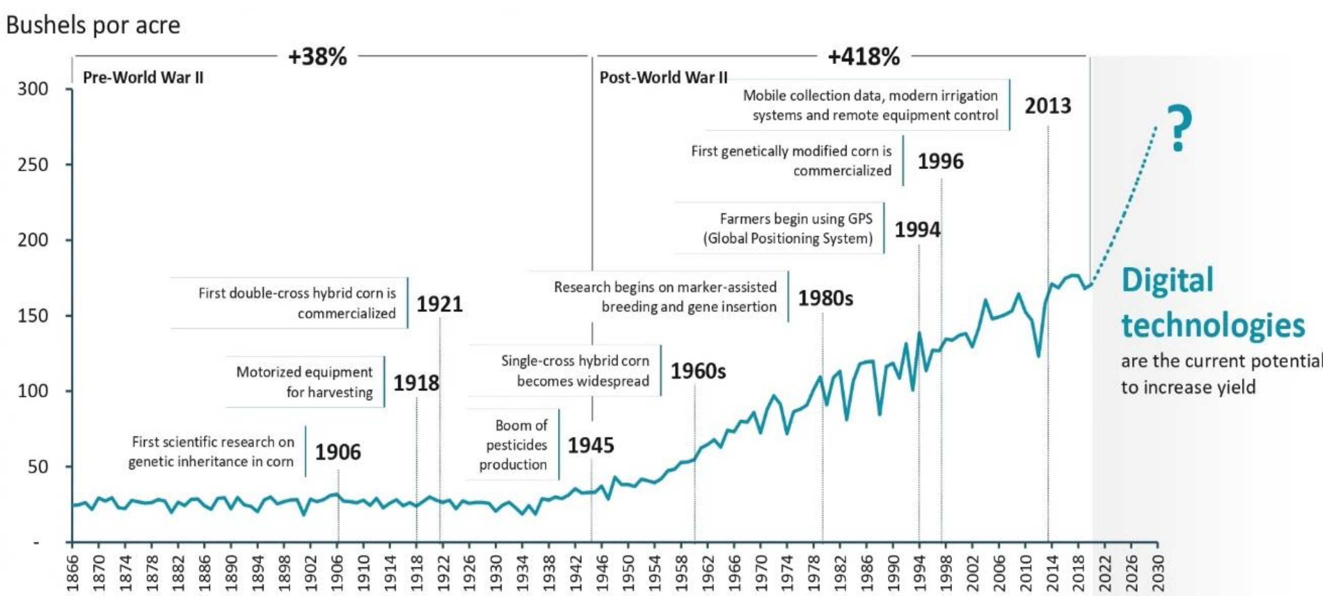
Source: Based on Siebel, T.M. Digital Transformation. Rosetta Books. New York. 2019.

Individually, these technologies are already being employed throughout the economy. The increasingly routine availability of individual technologies fosters innovation that can exploit powerful interactive effects as they are used in novel applications. The expected result of these developments is a digital transformation across society (Siebel, 2019).

Generally, we consider digital technology encompassing electronic devices, automatic systems, and technological resources that generate process, or store information. Included are tools such as websites, smartphones, blockchain technology, artificial intelligence, cloud computing, robotics, drones, video streaming, etc. (Salmons and Wilson, 2008). In agriculture, the digital concept includes scientific knowledge, techniques, and equipment from precision agriculture starting in the 1990s (Wolf and Buttel, 1996). In summary, digital technology in agriculture (1) employs sensors and technologies to capture digital data and operating machines that use digital information to apply inputs differentially; and (2) uses digital tools and techniques to summarize, analyze, synthesize, and communicate digital and other information to improve decision making (Sonka, 2020).

Over the history of modern agriculture, technology adoption has contributed to developing efficient agriculture and food. In the last decades, several technologies have positively impacted yield on a global scale. The next cutting-edge is digital technologies, as shown in Figure 2 in graphic technology evolution and yield improvement for corn, just as an example that could apply to soybeans too (Markstrat, 2020).

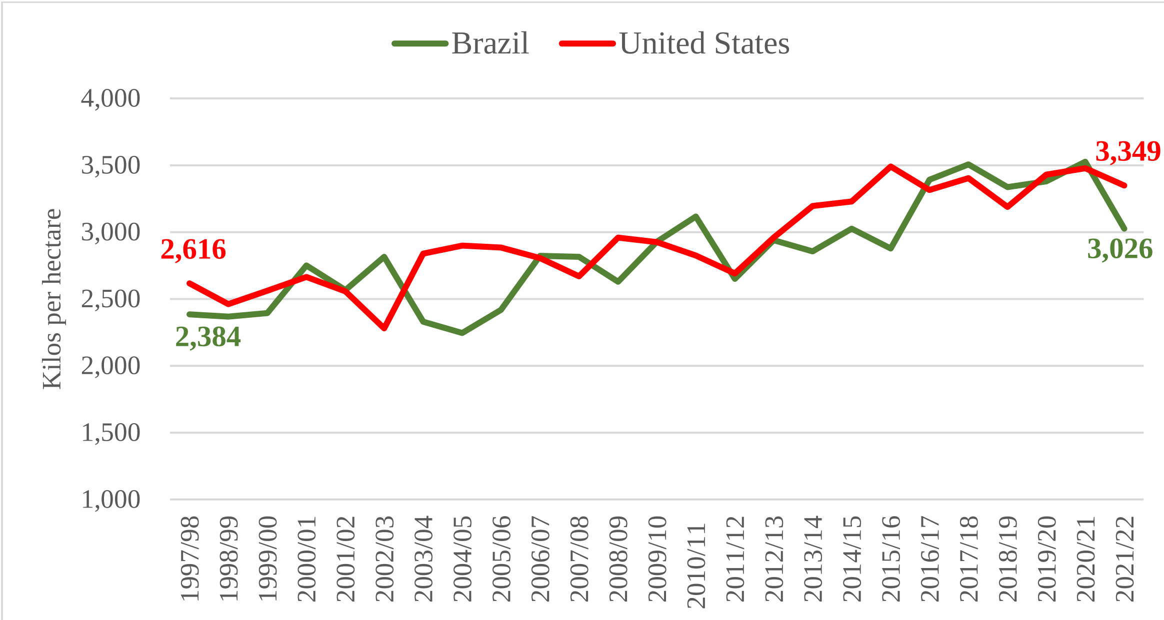
Figure 2. Agricultural technology evolution and yield improvement



Source: Cargill; John Deere; National Academy of Engineering; USDA and Markestrat analysis

Similar to the United States, soybean yields have increased in Brazil in the past 25 years. From the 1997/98 season to the 2021/22 season, the average soybean yield increased 27% in Brazil, from 2,384 kilos per hectare to 3,026 kilos per hectare, according to National Supply Company (Conab). In the same period, the soybean yields in the United States rose 28%, from 2,616 kilos per hectare in 1998 to 3,349 kilos per hectare in 2022, according to USDA (Figure 3).

Figure 3: Soybean yields in Brazil and the United States 1998-2022



Source: Conab (Brazil) and USDA (United States)

Over the past decade, numerous agriculture technology companies have emerged, offering products and data services. Many providers collect and utilize large amounts of environmental, production, and management data from farmer fields and analyze that data to provide various recommendations or services. For example, precision agriculture and information technologies (soil and yield maps, automated guidance systems, and variable rate input applications) allow farmers to optimize their production practices (Schimmelpfennig, 2016). Soil and yield maps, automated guidance systems, and variable-rate input applications positively impact net returns and operating profits. Precision agriculture technologies can also promote stewardship or best management practices Schimmelpfennig, 2016).

As intelligent machines and the use of sensors grow in quantity and relevance on farms, agricultural processes become increasingly oriented by data (Wolfert et al., 2017). In addition to increasing economic efficiency, more extensive use of precision technologies will be important in advancing societal goals relating to environmental impacts and climate change mitigation. Therefore, digital transformation can contribute to solving a complex equation with economic, social, and environmental variables.

The rapid development of the internet and, consequently, the number of devices and instruments connected to the network, has increased the amount of data produced and collected daily. The new data generation's volume, variety, and speed draw attention to developing new techniques and processing tools to add value to available information (Witkowski, 2017). Big data analysis, for example, has received a lot of attention from academia and industry, as the demand for understanding trends in massive data sets grew. Therefore, various technological advances have created opportunities for big data (Sonka, 2015).

Nowadays, there are three main differences from the past: (a) volume – more data cross the internet every second than was stored across the Internet for 20 years; (b) speed – real-time information makes it possible for a company is much more agile than its competitors; (c) variety – most sources of the big data are relatively new, such as social networks, sensor readings and GPS signals (McAfee et al., 2012). This approach by defining the data in terms of volume, velocity, variety, and veracity, with “volume” referring to the size of the data, “velocity” measuring the flow of data, “variety” reflecting the frequent lack of structure or design to the data, and finally “veracity” reflecting the accuracy and credibility of the data (Coble et al., 2016).

As data quantity, variety and speed increases, so does the inherent uncertainty, leading to a lack of confidence in the resulting analysis process and the decisions taken (Hariri, Fredericks, and Bowers, 2019). The dissemination process involves a certain degree of uncertainty and perceived risk, and the individual can reduce this degree of uncertainty by obtaining information about the solution innovation in question (Rogers, 2003).

An important factor in understanding big data's potential is that it is not just numbers. The current characteristics of the information emphasize that the data include an impressive variety of phenomena. Furthermore, it is essential to consider the power of analysis, where discoveries and insights are obtained from various sources that differ in structure and original purpose (Sonka, 2016).

Big data provides predictive insights for agriculture's future results, driving real-time operational decisions and reinventing business processes for faster and more innovative action (Devlin, 2012). Recent developments in sensor networks, cyber-physical systems, and the IoT have increased data collection enormously. Consequently, technological and knowledge advances have become the main conditions for improvements in agricultural production, with a particular focus on increased productivity and reduced costs (O'Donoghue and Heanue, 2018).

Modern digital solutions for agriculture are implemented in large rural properties, where we work with intelligent irrigation systems, IoT, precision agriculture, big data, and artificial intelligence (Bonneau et al., 2017). The increase in the adoption of digital technologies in agriculture is primarily because large rural producers perceive the increase in productivity that these solutions bring to your business (Pivoto et al., 2019). Even small farmers are collecting information through precision agricultural equipment, and many producers use data to make property decisions (Bronson and Knezevic, 2016).

Using this information in agriculture can contribute to both economic gain and reduction of environmental impact. Combined with advanced analysis, prediction from several sources promises to create value for decision-makers in the sector and society (Sonka, 2016). Farmers seek ways to improve profitability and efficiency, reducing their costs and getting better prices for their products. Therefore, they need to make better decisions and optimize and enhance management control (Wolfert et al., 2017).

In this context, the role of the farmer is no longer limited to producing food, but also doing data management. The producer assumes the role recommended by the Classical Management Theory: to organize, plan, coordinate, direct, and control (Fayol and Dores, 1978). Basic management functions are detection and monitoring of the actual performance of the farm's processes, analysis, and decision making when comparing the results with the desired performance and intervention to correct the performance of agricultural operations (Verdouw et al., 2015). In addition, it is essential to note that large data applications in agriculture do not strictly focus on primary production, but also on improving the efficiency of the entire supply chain and alleviating food security (Chen, Mao and Liu, 2014).

Although recent advances in data generation, with the growing demand for information technology to extract value from this information, developed agricultural countries like Brazil and the United States still have a long way to go in advancing digital agriculture. Several factors determine farmers' acceptance and use of innovations, which will be discussed in the next section.

2.2 Determinants of Acceptance and Use of Innovations

The acceptance and use of new technologies have been the subject of much research since the 1960s. In recent decades in academic disciplines such as psychology, communication, and sociology, numerous theoretical models have been developed to predict and explain user acceptance of information technology (IT) or information system (IS). Various theoretical perspectives inform studies on the adoption of innovations.

Among the main theoretical structures to explain user acceptance is the theory of the Diffusion of Innovations (Rogers, 2003). More recently, the Unified Theory of Acceptance and Use of Technology (Venkatesh, 2003) includes variables of these approaches and others. We examine the literature specifically linked to the information spread by several communication channels as a determinant variable in adopting innovations, influenced by moderators that affect technology usages, such as age, level of education, and experience.

The advent and adoption of digital technologies offer the profound potential to enhance the effectiveness and profitability of crop farming. Even though some digital and precision technologies have been available for some time, adoption surveys suggest increased adoption rates of the various forms of these tools (Schimmelpfennig and Ebel, 2016). Communication channels are needed to adopt innovative technology for farmers (Bakhtiar and Novanda, 2018).

In farms, for example, the most significant limitation for using technologies is that producers still lack the ability to use information and communication technologies. Research on adoption in rural properties in European countries and the United States, for example, found that farmers' most significant challenge to using digital technologies is the lack of ability to use these tools (Gelb and Voet, 2009)

A survey carried out in Brazil by Embrapa showed the difficulties of accessing and using technologies in digital agriculture. Among more than 500 farmers interviewed, 41% responded that the lack of knowledge about the most appropriate technologies is one of the main barriers. In the same survey, 47% of the more than 200 technology companies interviewed replied that the training of farmers is the main limitation for selling their products (Bolfe et al., 2020). Superior knowledge and information will enable producers to more successfully obtain the physical resources of land, labor, and capital and efficiently combine them. Thus, the role of knowledge and information for success in the farming sector and agricultural industry is more critical today than ever before (Boehlje and Langemeier, 2021)

One of the main theories on the adoption of innovations in societies originates from Everett Rogers and his colleagues. A professor of Communication Studies, he popularized this theory in his book Diffusion of Innovations, published in 1962 and today is in its fifth edition (2003). This theory explains how the invention and diffusion of new technologies and ideas impact societies over time (Littlejohn, Foss, and Oetzel, 2021). Rogers (2003) argues that diffusion is how innovation is communicated over time among the participants in a social system. This theory was critical as it was one of the first to insert information as a determinant variable in adopting innovations.

Rogers and his colleagues argue that four main elements influence the spread of a new idea: the innovation itself, communication channels, time, and a social system. It is critical to understand the effects of these attributes as they largely influence the adoption decisions of any innovation (Kapoor, Dwivedi, and Williams, 2014). First, innovation characteristics include the following: (1) the relative advantage that an innovation will provide users; (2) the degree of compatibility that an innovation will have with the values and experiences of users; (3) the complexity of the innovation; (4) whether users can try out the innovation prior to adoption (trialability); and (5) the degree to which users can observe others using the innovation (Littlejohn, Foss, and Oetzel, 2021). Second, time is a key element that impacts diffusion. Innovations take time to diffuse throughout society, so one common goal of organizations is to decrease the amount of time this takes. A third important element impacting diffusion is the social system in which the diffusion takes place. The social system includes many facets, but two important considerations are the participants in society, such as opinion leaders, and the organizational structures that lead to innovation. The final element, and the topic of this study, focuses on the communication channels through which an innovation is diffused. Successful diffusion of any innovation depends upon the types of communication channels available. In general, there are interpersonal, mass media, and social media channels (Littlejohn, Foss, and Oetzel, 2021).

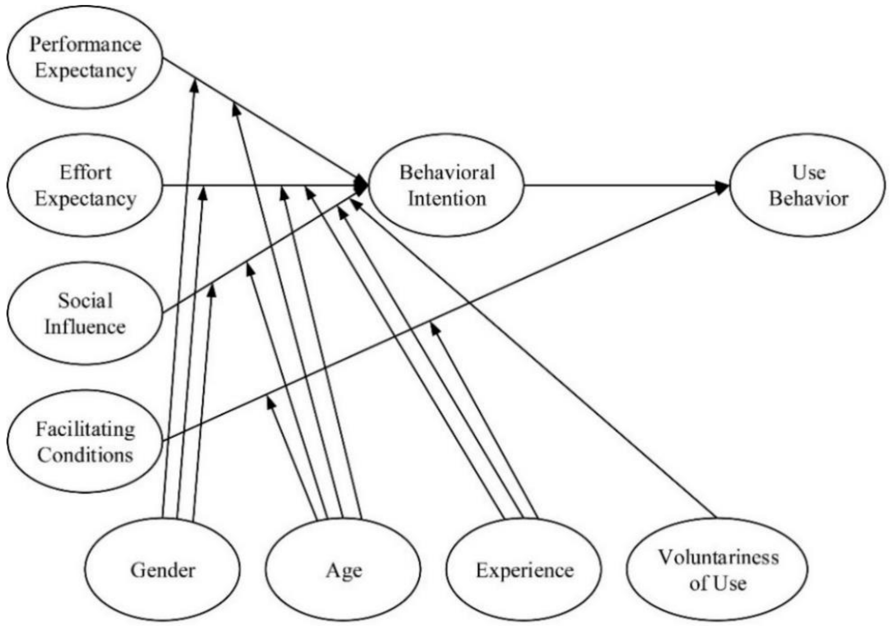
The impact of these communication channels varies depending on users and the social and cultural context in which diffusion is occurring. One of the most significant contributions of this theory is its explanation of diffusion stages in terms of users. These stages are based on innovators, early adopters, the early majority, the late majority, and laggards. Diffusion does not occur at a similar rate but rather resembles an “S” curve in terms of adoption (Dearing and Cox, 2018; Rogers, 2003). Important to the relationship between channel and user is Rogers’ distinction between homophily and heterophily. Homophily refers to the degree of similarity that users perceive with an innovator, whereas heterophily refers to the degree of difference perceived (Littlejohn, Foss, and Oetzel, 2021). A communication source with high degrees of homophily may generate more trust in innovation. A communication source with high degrees of heterophily may generate interest and exposure to novel ideas and technologies. The latter may be particularly impactful in the early stages of adoption.

The theory of Diffusion of Innovations has been widely applied across multiple disciplines. It has been particularly impactful within agricultural extension (Pathak, Brown, and Best, 2019). Other theoretical frameworks have been proposed to explain how adoption occurs within different groups.

While the theory of Diffusion of Innovations is critical in identifying critical features associated with technology adoption, another essential theory considered in this study is the Unified Theory of Acceptance and Use of Technology (UTAUT), which is a comprehensive synthesis of prior technology acceptance research. Venkatesh et al. (2003) examined eight behavioral intention models used in previous technology acceptance contexts to search for a more comprehensive IT acceptance model. The researchers then applied the UTAUT model to unify the existing theories regarding how users accept technology (Venkatesh et al., 2003; Venkatesh and Morris, 2000).

UTAUT has four essential determining components: performance expectancy, effort expectancy, social influence, and facilitating conditions. Performance expectancy refers to a user's perception that a technology will ultimately benefit the user. Effort expectancy refers to a user’s perception of the ease of use. Both performance and effort expectancy help explain the complexity of innovations as discussed in the theory of diffusion of innovation. Social influence refers to the degree to which adoption of a technology will increase a user’s social capital, while the facilitating conditions refer to the broader social system that might impact a particular adoption decision. These components influence the behavioral intention to use technology. The underlying premise of UTAUT is that an individual’s intentions to engage in post-adoptive behavior are the best predictors of that individual’s actual post-adoptive behaviors (Venkatesh et al., 2003). Besides these four essential determining components, the UTAUT model contains four moderators that affect technology usage: sex, age, experience, and voluntariness of use (Figure 4).

Figure 4. Theory of acceptance and use of technology (UTAUT) model



Source: Venkatesh *et al.* (2003)

These constructs and definitions from UTAUT to the consumer technology acceptance and use context were adapted years later. So, (1) *Performance expectancy* became defined as the degree to which using a technology will provide benefits to consumers in performing certain activities; (2) *Effort expectancy* is the degree of ease associated with consumers' use of technology; (3) *Social influence* is the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology; and (4) *Facilitating conditions* refer to consumers' perceptions of the resources and support available to perform a behavior (Venkatesh, Thong & Xu, 2012). Therefore, the Theory of Diffusion of Innovations and UTAUT will be the main theories used to analyze channel communication's role in adopting digital technologies in soybean farms in the United States and Brazil.

2.3 Communication Channels to Spread Information

Over the past decade, there has been a growing public fascination with the complex connectedness of modern society. This connectedness is found in many incarnations: in the rapid growth of the Internet, in the ease with which global communication takes place, and in the ability of news and information as well as epidemics and financial crises to spread with surprising speed and intensity (Easley and Kleinberg, 2010).

One decade late, this sentence above is very appropriate nowadays. Digital advancement is increasingly present in rural areas and has become indispensable for work and personal relationships due to the coronavirus. The use of digital solutions among farmers increase in Brazil in 2020 during the pandemic. Highlight to use of the internet to search for information related to field activities (Bolfe et al., 2020).

The communication process refers to how actors share information with other individuals to achieve mutual understanding (Rogers, 2003). In this context, electronic communications brought greater speed to the exchange of information, which previously took longer and was less effective. In addition, there was a gradual reduction in costs for the operation of communication, which had radio as its initial tools in the 1890s and television in the 1930s. Afterward, with the evolution of electronic innovations, there was an advance toward the use of computers, one of the most revolutionary technical innovations of the 20th century (Freeman and Soete, 1997).

After advancing in the communications sector, information technologies were being developed, going through several stages until the well-known Information and Communication Technologies (ICTs) were reached. In summary, ICTs are considered the current long wave experienced by the capitalist system, which has gone through different techno-economic paradigms (Freeman and Perez, 1988). ICTs involve all the technical means used to transmit information and assist in communication, including network and computer hardware and software. These tools were designed to enable individuals to perform activities in which the human brain is not very efficient, such as handling mass information and solving scientific calculations (Jain, Kumar, and Singla, 2014).

In agribusiness, using ICTs can include agronomic, zootechnical, and administrative controls, through various digital solutions. In addition, ICTs facilitate communication between actors in the production chain and the market, such as the commercialization of agricultural products, the creation links with the consumer market and the reduction of geographical limitations and tracking goods. There is a gain in agility and cost reduction in using these communicative processes (O'Donoghue and Heanue, 2018). In summary, the ICTs play a crucial role in agriculture as they allow farmers to improve the production chains, the management and marketing of the production, and the management of land and its natural resources (Csótó, 2015; da Cruz, Vieira, and Marques, 2015).

Within the digital universe, the tool that has become the most popular is the cell phone (Kabbiri et al., 2018). Through it is possible to have access to several sites and applications that provide data and facilitate the exchange of information. The price reduction in telecommunications services, mainly with the incorporation of the internet in cell phones, has emerged as a relevant factor in the accelerated increase in the adoption of these devices in emerging countries such as India, China, and Brazil (Jain, Kumar, and Singla, 2014).

Many mass media studies have indicated that the Internet has created new sources of newsroom information and opened the door for amateurs to contribute content, thereby decreasing the role of the editing room. Furthermore, creating content from sources other than the newsroom is now possible. Therefore, the general public, who used to be mere receivers of content, can now create their own news platforms based on new online technologies such as e-papers and blogs or by publishing content on their mobile phones (Chao-Chen, 2013). The proliferation of new media has allowed more people to participate in content creation, thus expanding the sources of news content (Chao-Chen, 2013). This led John Herbert (1999) to state that journalism is in a state of upheaval.

However, some studies argue that the use of news content in traditional and new media reflects complementarity in media consumption. The search for news information in a specific content area drives the consumption of particular news types across different media outlets and categories. In other words, the underlying motive that drives the individual to seek out content information in traditional media also drives them toward consuming online media in the same content domain. Complementarity between new and traditional media was demonstrated in the areas of sports, politics, business and finance, science and health, entertainment, international, and local news (Dutta-Bergman, 2004).

Besides mass media, the use of social media is rising and provides an opportunity for networking, extension, and adoption (Newman, Levy and Nielsen, 2015). The increase of mobile computing in the early 2000s promoted the first widely used social media platforms. For example, Facebook began as a social media platform in 2004, Twitter in 2006, and Instagram in 2010.

The opportunity to create alternate communities of interest via social media is already here as evidenced by the smartphone's uptake, enabling farmers to access information during their workday. The online environment provides a new opportunity as a digital blended learning tool to create one-to-one extension experiences for adoption using websites, webinars, Facebook, Instagram, and Twitter to share information, conversations, and more (Casey et al., 2016). Social media platforms and other new technologies support the communication of many topics, both beneficial and controversial, to the development of the agriculture industry. Agricultural communicator's use of these platforms is critical for engaging with stakeholders and communicating information helpful to agriculture (Hawley et al., 2018).

In addition to mass and social media, another communication channel is essential in agriculture: interpersonal meetings or social networks. This point can include field days, discussion events (conferences, forums, seminars, etc.), retailer from companies, extension agents, peer groups (both formal and informal), and conversation with neighbors. As we saw before, participation in social networks is essential to share information and experiences between farmers and other agents of the agroindustry chain (Carrer, Souza Filho, and Batalha, 2017). But identifying and measuring the effects of social networks on technology adoption is not a trivial matter (Manski, 1993).

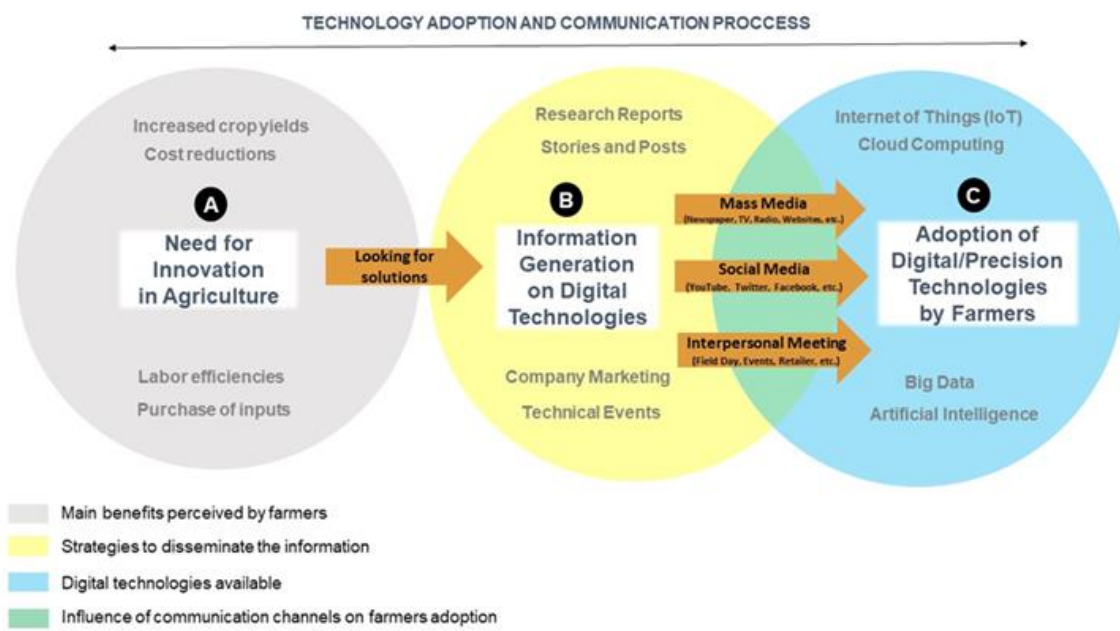
The problem, in this case, is that the individual will be unable to condition for differences between his own and his neighbors' characteristics when learning from their experiences. In general, investing in more concentrated external information programs may be necessary when social information flow is restricted (Munshi, 2004). Social learning breaks down if unobserved or imperfectly observed, individual characteristics are important determinants of neighbors' outcomes (Ellison and Fudenburg, 1993).

Connections and visits to farms by specialists, for example, help disseminate innovative technologies. Agricultural extension services can impact technology acceptance because of the delivery of consultancy and education services (O'Donoghue and Heanue, 2018; Deichmann, Goyal, and Mishra 2016). Economists increasingly appreciate the vital role social networks play in mediating the diffusion of agricultural innovations. But this literature remains underdeveloped. Several essential areas need attention, such as the influence of communication channels on the adoption of technologies in agriculture, which the study proposes advances in the next section.

2.4 Multidisciplinary Analytical Framework

Based on the main elements that influence the diffusion of innovation (Rogers, 2003) and the essential determining components of acceptance and use of technology (Venkatesh et al., 2003), this study will propose advancements in the role of communication in the adoption of digital technologies among soybean farmers in Brazil and the United States. Figure 5 presents a multidisciplinary analytical framework to achieve this goal (Colussi et. al, 2022):

Figure 5. Flowchart of the dissemination of information about digital technologies



Source: Elaborated by the author

The analytical structure (Figure 5) stems from the farmers' need to look for innovations in agriculture and its benefits, such as increased crop yields, cost reductions, and labor efficiencies (A). The need for innovation leads the farmer to seek solutions developed by the market. Consequently, the information is generated by research reports, stories and posts, company marketing, and technical events (B). This information is distributed through different communication channels, divided into mass media, social media, and interpersonal meetings. All of which indicate an intersection between B and C. Therefore, information consumption helps farmers adopt digital technologies that may involve precision agriculture, the Internet of Things (IoT), cloud computing, big data, and artificial intelligence (C).

Therefore, this study aimed to measure the influence of communication channels (mass media, social media, and interpersonal meetings) on farmers' adoption, decision-making, and benefits obtained through the use of precision and digital technologies. Findings will enable farmers and agribusiness managers to use communication channels more effectively in evaluating and adopting precision technologies.

3. METHODOLOGICAL PROCEDURES

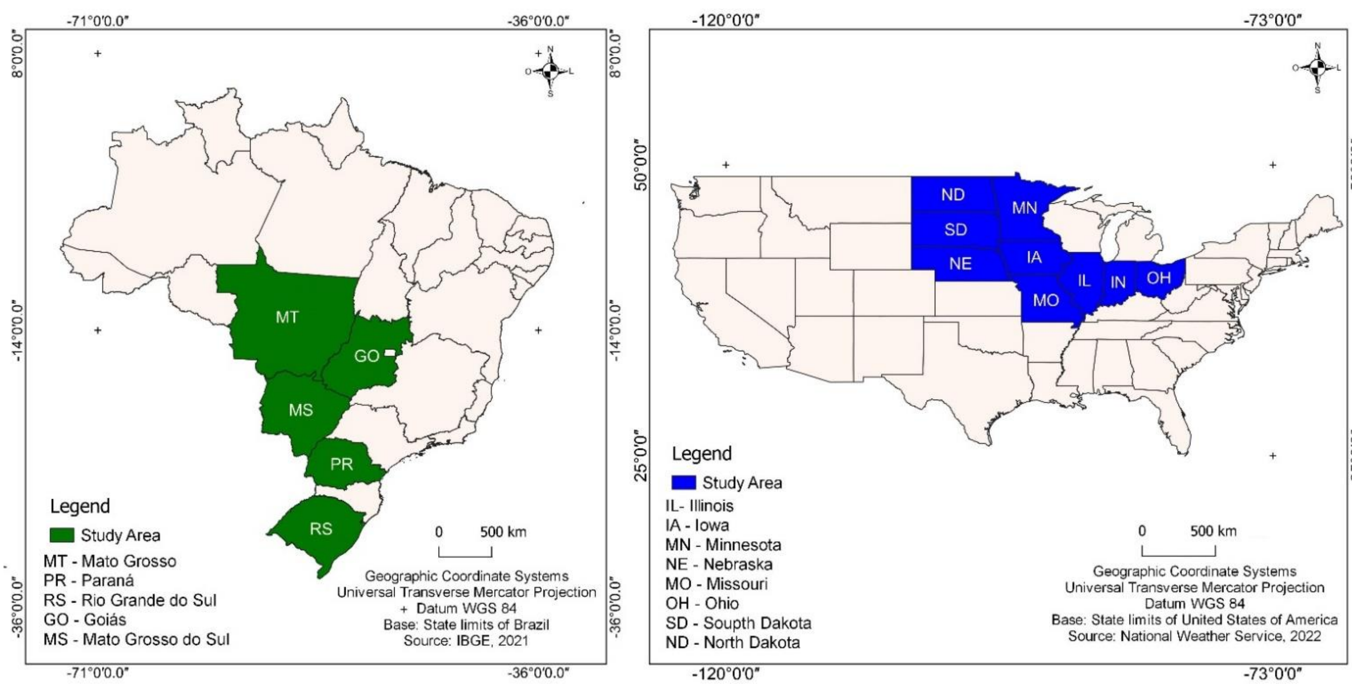
This section presents the methodological procedures regarding study area, survey instrument, data collection and data analysis. This study is classified as a descriptive study with a quantitative approach (Cooper and Schindler, 2016).

3.1 Study Area

This study was conducted in Brazil's top five soybean-producing states (Mato Grosso, Paraná, Rio Grande do Sul, Goiás and Mato Grosso do Sul) and in the United States' top nine soybean-producing states (Illinois, Iowa, Indiana, Minnesota, Nebraska, Ohio, Missouri, North Dakota, and South Dakota) (Figure 6). These states provide approximately 75% of soybean production in each country. Completed surveys were obtained from 461 farmers in Brazil and 340 farmers in the United States.

Brazil and the United States are the two largest producers and exporters of soybeans in the world. The combined share of these two countries in world soybean production was 70% of the 2021/22 harvest (USDA, 2022a).

Figure 6. Maps of the study area in Brazil and the United States



Source: IBGE, 2021 and National Weather Service, 2022

The United States became the top soybean producer during the 20th century. Beginning in the 1940s, demand from the U.S. processing industry and livestock farms encouraged growth in soybean production. Brazil's more recent expansion of soybean output has been critical to supporting China's rising imports. Commercial Brazil's soybean production began during the 1960s and grew rapidly as cultivation spread to the country's interior regions and as yields improved. Brazil's soybean output surpassed China's in the 1970s and caught up with U.S. output in 2012 (Gale, Valdes, Ash, 2019).

Historically, soybean production in Brazil originated in Rio Grande do Sul and Paraná, southern states that have a sub-tropical climate. Following the introduction of the crop, the Brazilian Agricultural Research Corporation (EMBRAPA, the acronym in Portuguese) started to develop seeds suited to the tropical climate of the savanna. Consequently, in the 1970s and 1980s, soybean production migrated first to the Midwest: Mato Grosso do Sul, Mato Grosso, and Goiás. That was possible thanks to the development of cultivars well adapted to the low latitude of the region as the new cultivars were less sensitive to the length of daylight (Cattelan and Dall'Agnol, 2017). In the 1990s and 2000s, soybean production migrated to the Brazilian North and Northeast, especially in the Matopiba, a region formed by the Brazilian state of Tocantins and parts of the states of Maranhão, Piauí and Bahia. Despite this recent expansion, 75% of soybean production in Brazil remains concentrated in the South and Midwest regions (Conab, 2022b).

The study area in the United States comprises a significant portion of its Midwestern states. It is known for its fertile land and agricultural prominence, with about 75% of the area's cropland planted to corn and soybeans (USDA, 2020). The Midwest represents one of the most intense areas of agricultural production in the world and consistently affects the global economy (USDA, 2020). The U.S. Midwest is a region with large farms, where the adoption and implementation of precision agriculture technology has the potential to contribute to on-farm economic and environmental benefits as well as off-farm benefits, such as ecosystem protection, by reducing non-point source water pollution (Kolady et al. 2021).

3.2 Sampling

The data was treated as probability sampling from an infinite population. The most critical requirement of probability sampling is that everyone in your population has a known and equal chance of getting selected. Treating the sample as infinite random provides more conservative dependability estimates and ensures that such estimates can be generalized beyond the observed sample of participants (Shavelson, Webb, Rowley, 1989). The following formula of the sampling from an infinite population was used to calculate the number of elements of the sample according to the level of confidence and margin of error:

$$n = 4.p.q / E^2$$

n = number of elements in the sample;
p = probability of finding the phenomenon studied in the population;
q = probability of not finding the phenomenon studied in the population; and
E = margin of error.

Results gathered with 461 farmers in five Brazilian states reached a 95.3% confidence level and a margin of error of 4.6%. In the United States, 340 farmers were interviewed in nine American states, getting a confidence level of 94.5% and a margin of error of 5.5%.

3.3 Survey Instrument

Based on a review of the literature and previous research focused on precision agriculture adoption, we designed the questionnaire survey sent to soybean farmers across the top five soybean-producing states in Brazil and across the United States' top nine soybean producing states. The online survey was prepared in English and Portuguese, the official languages in the United States and Brazil, respectively. The survey instrument was hosted on the Qualtrics virtual platform. The survey is comprised of three main sections: (1) use of digital technologies, (2) influence of communication channels, and (3) demographic information. Both English and Portuguese surveys are presented in their entirety in Appendix A and B.

The first section's four questions one to four, asked about the precision and digital technology tools used on the farm, the decisions influenced by use of these tools, and the perceived benefits of use of the tools. The variables in each question were selected and adapted from the Precision Agriculture Dealership Survey conducted by CropLife magazine and the Departments of Agricultural Economics and Agronomy at Purdue University. The Purdue/CropLife survey is the longest-running, most widely used survey that chronicles the development and adoption of precision agriculture (Erickson & Lowenberg-Deboer, 2019).

The CropLife survey is extensive, so we adapted it to cover key precision agriculture technologies. We chose the technologies with the highest percentages of use in the results of the 2017 and 2019 Purdue/CropLife Precision Agriculture Dealer Surveys (Erickson and Lowenberg-Deboer, 2019; Erickson, Lowenberg-Deboer and Bradford, 2017). In addition, we adapted the definitions from English to Portuguese to make the questions understandable to Brazilian farmers. After that, experts in precision agriculture reviewed the choices and definitions, which led to minor revisions.

The second section, questions five to seven, investigated the level of influence of mass media, social media, and interpersonal meetings on the decision to adopt a new digital technology on the farm. In the questionnaire applied in Brazil, the variables regarding social media were based on Brazilian Association of Rural Marketing and Agribusiness (ABMRA, São Paulo, Brazil) reports, the most relevant study of farmers' media habits and participation in events in Brazil. The ABMRA study considered nine social media platforms (WhatsApp, Facebook, YouTube, Messenger, Instagram, LinkedIn, Skype, Snapchat, and Twitter). Our study chose the top six platforms in terms of use according to their results in 2017. Restrictions apply to the availability of these data. Data were obtained from ABMRA and are available from the corresponding author with the permission of the ABMRA board.

In the questionnaire employed in the United States, the variables regarding social media were based on the Social Media Use in 2021 from the Pew Research Center (Pew Research Center, 2021a). The Center conducts public opinion polling, demographic research, content analysis, and other data-driven social science research, such as U.S. journalism, media, internet, science, and technology studies. The report considered 11 social media platforms (YouTube, Facebook, Instagram, Pinterest, LinkedIn, Snapchat, Twitter, WhatsApp, Tik Tok, Reddit, and Nextdoor). We chose the top seven to investigate in our research.

The last section, questions nine to thirteen, focused on the demographic profile of the respondents. In both countries, we collected data such as the number of hectares planted, age group, level of education, and participation in agricultural cooperatives. The questionnaire also asked whether the coronavirus pandemic has made farmers more willing to adopt digital technologies. This question was added because the data were collected during the COVID-19 pandemic.

Soybean farmers in both countries were invited to weigh the use of eight precision and digital technologies on interval scales in numeric format, from 1 being "never use" to 5 being "always use", and to weigh the influence of different types of communication channels, on interval scales in numeric format, from 1 being "not at all influential" to 5 being "extremely influential". The scale's reliability was validated with the help of a pilot survey of 10 respondents in Brazil and 8 in the United States and leading to minor alterations in the final questionnaire.

3.4 Data Collection

Online surveys were distributed to soybean farmers in both countries. In Brazil, the data were collected through an online questionnaire (in Portuguese) available to the farmers from March to June 2021. In the United States, data were collected through an online questionnaire (in English) open to the farmers from July 2021 to April 2022. In both countries, participants were recruited by random sampling. Members of the target population meet specific practical criteria, such as easy accessibility, geographical proximity, availability at a given time, or the willingness to participate (Etikan, Musa, and Alkassim, 2016). It is also referred to the researching subjects of the population that are easily accessible to the researcher (Given 2018).

In Brazil, the online survey was distributed with help from the Brazilian Association of Soybean Growers (Aprosoja Brasil, Brasilia, Brazil), National Supply Company (Conab, Brasilia, Brazil), state associations of rural producers, and agricultural cooperatives. In the United States, the online survey was spread primarily among *Farmdoc* subscribers. *Farmdoc* is an extension program of the University of Illinois. In the last 20 years, it has become the premier online source of economic analysis and market information for commercial producers in the Midwestern United States. In addition, state associations of rural producers, such as Illinois, Iowa, Ohio, Minnesota, Indiana, Missouri and North Dakota Soybean Associations, helped distribute the survey.

In both countries, these organizations were responsible for sending information about the study, including a link to the survey, to farmers. An invitation message was sent to explain the objectives to those interested in voluntarily participating in this online survey. In some cases, the direct participant spread the study further to other farmers as potential research participants. In Brazil, the WhatsApp (instant messaging app) was the primary distribution tool, followed by Facebook, Instagram, and e-mail lists. In the United States, the e-mail lists from Farmdoc and the state associations were the primary distribution tool, followed by social media.

The data were collected during the COVID-19 pandemic. After the first report in Wuhan, China in December 2019, the virus began to spread quickly to other parts of the world, and COVID-19 outbreak was classified as a pandemic by the World Health Organization on March 11, 2020. As of first half of 2022, the WHO has reported over 569 million confirmed cases, with over 6 million deaths due to COVID-19 globally (WHO, 2021). During this period, many digital tools supported on-farm production by providing online advice and facilitating access to inputs and machinery services.

3.5 Data Analysis

The data obtained for each question were consolidated in a Qualtrics platform report, exported in CSV, and imported into a spreadsheet. The data were analyzed using descriptive statistics, Spearman rank correlation (ρS), and one-way analysis of variance (ANOVA). We used the Statistical Package for Social Science (SPSS), Version 18.0 for Windows, to analyze data with a minimum level of statistical significance of $p < 0.05$.

The Spearman rank correlation determined the significance of correlations between different variables. Spearman correlation is recommended when data follow a non-normal distribution and for ordinal variables. The first section, "use of digital technologies", and its three questions were correlated with the second section, "influence of communication channels", and its three questions. However, it is essential to point out that these relationships do not imply causality, but a level of association/correlation. In addition, we used ANOVA to identify statistically significant differences in demographics profile (age, education, and farm size) in relation to the use of technologies and influence from mass media, social media, and interpersonal meetings on farmers' decisions. In summary, ANOVA compares the means of different groups and shows if there any statistical differences between the means.

Before the analysis, the reliability of the scales used to measure the variables was investigated using Cronbach's α coefficient. A Cronbach's α coefficient higher than 0.7 indicates that the different items can be summed and that the median can be used to represent these constructs. In Brazil, the Cronbach’s α indicated that all the scales used for precision and digital technologies ($\alpha = 0.83$), making decisions ($\alpha = 0.87$), perceived benefits ($\alpha = 0.88$), mass media ($\alpha = 0.78$), social media ($\alpha = 0.76$), and interpersonal meetings ($\alpha = 0.77$) were within the acceptable limit. In the United States, the Cronbach’s α also indicated that all the scales used were within the acceptable limit, as follows: precision and digital technologies ($\alpha = 0.80$), making decisions ($\alpha = 0.85$), perceived benefits ($\alpha = 0.86$), mass media ($\alpha = 0.78$), social media ($\alpha = 0.75$), and interpersonal meetings ($\alpha = 0.78$).

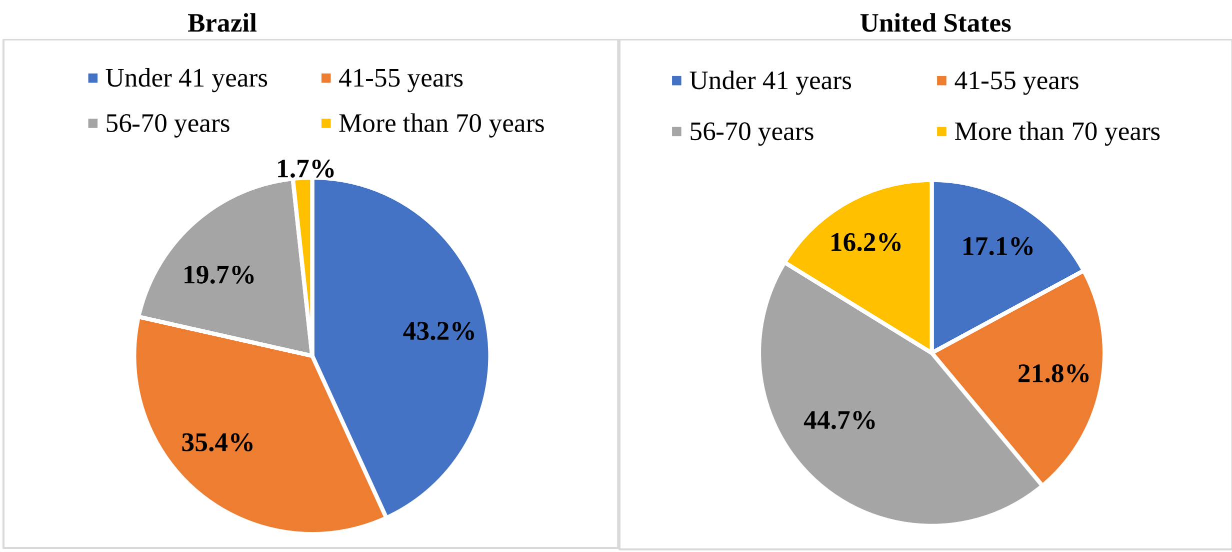
4. RESULTS AND DISCUSSION

This section compares Brazil's and the United States' findings regarding using precision and digital technology tools on-farm, making decisions, and the benefits realized. We also report and analyze the influence of mass media, social media, and interpersonal meetings on farmers' adoption of new technology. Moreover, this section compared the relationships between the demographic characteristics and the adoption of precision agriculture technologies of interest in this study. Last but not least, the results and discussion section presented the association between the communication channels and the adoption of technologies in Brazil and the United States.

4.1 Sample Characteristics

Our study's demographic characteristics were age, educational level, farm size, and cooperative membership. It is possible to see differences in the farmer's profile in Brazil and the United States. Among the farmers who participated in the survey in Brazil, for example, 43.2% are under 41 years old. Conversely, only 17.1% are under 41 years old in the United States. Another significant difference is regarding the senior group: in Brazil, 21.4% are more than 56 years old, while in the United States, 61% are more than 56 years old (Figure 7).

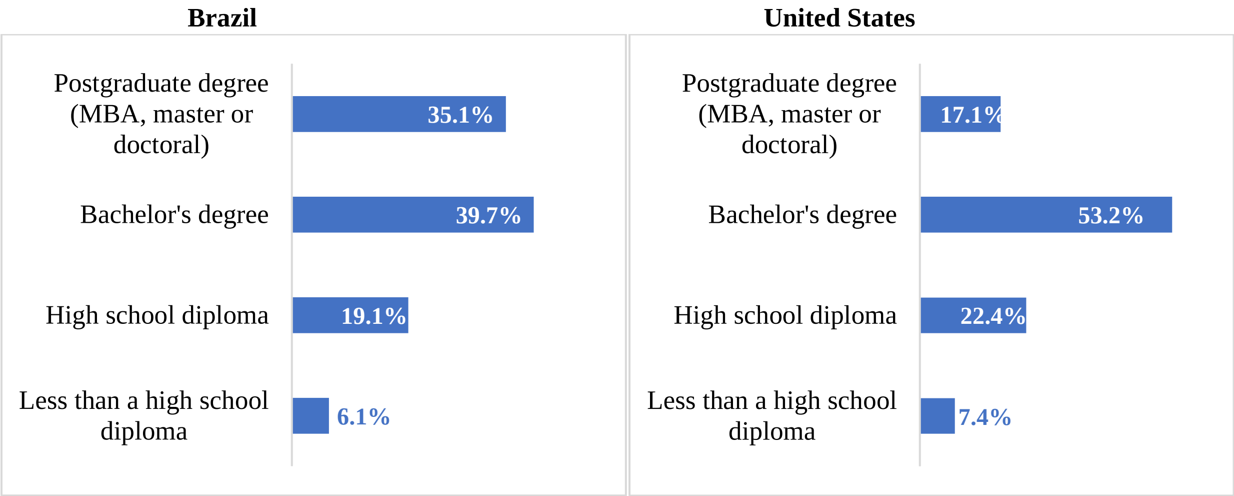
Figure 7. Age group of survey's respondents in Brazil and the United States



Source: elaborated by the author

Figure 8 shows the respondents' level of education in each country. For participants with a high school diploma or less, the proportions of the respondents are very similar in both Brazil and the United States. However, the mix of education levels beyond high school differed substantially. Relative to the bachelor's degree: 39.7% of the respondents in Brazil have obtained that degree while 53.2% of the respondents have done so in the United States. Moving beyond the bachelors, in Brazil, 35.1% of respondents have a postgraduate degree (MBA, master's, or doctorate). In the United States, however, the corresponding percentage is only 17.1%.

Figure 8. Level of education of survey's respondents in Brazil and the United States

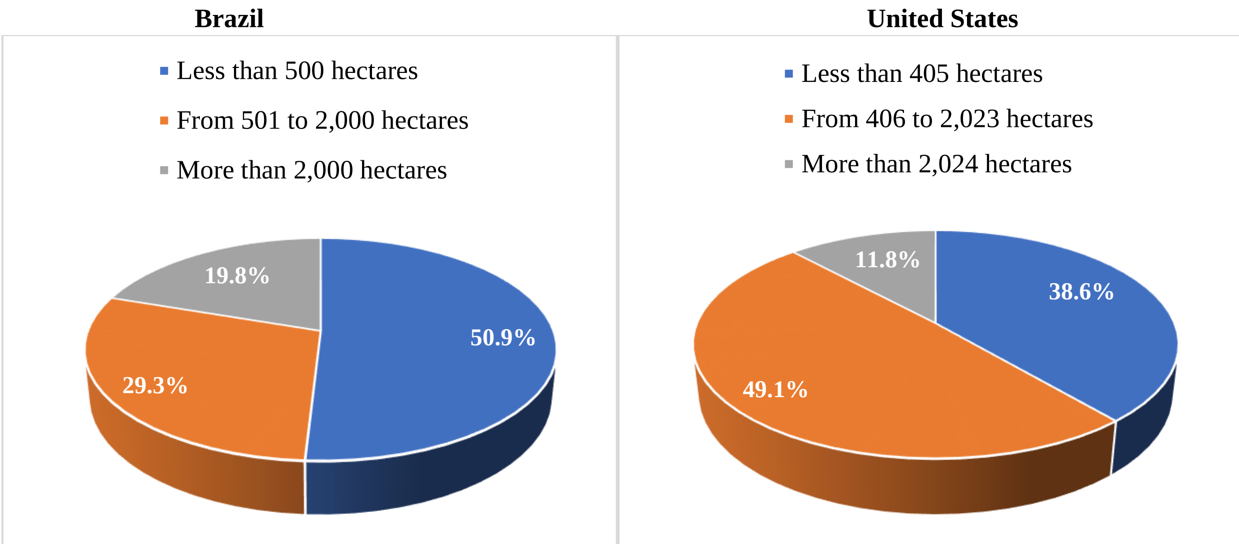


Source: elaborated by the author

Figure 9 shows the respondents' farm size in both countries. In Brazil, 50.9% of the soybean producers' respondents farm less than 500 hectares. Meanwhile, in the United States, 38.6% farm less than 405 hectares. The percentage of respondents who farm more than 2,000 hectares in Brazil is almost double that of the United States.

Note that the farm size categories are not identical because of the difference between metric and imperial systems. Whereas most countries, such as Brazil, use the metric system, which includes measuring units of meters and grams, in the United States, the imperial system is used where things are measured in feet, inches, and pounds. To minimize the chance of confounding the respondents, we used hectares in Brazil and acres in the United States. One hectare is equal to 10,000 square meters or 2.471 acres. Fortunately, it was possible to create three categories that are roughly similar to compare the answers in both countries.

Figure 9. Farm size of survey's respondents in Brazil and the United States



Source: elaborated by the author

Finally, survey respondents were asked about their membership in cooperatives that offer technical support. The result was very similar in both countries. Among the respondents in Brazil, 56% are members of a cooperative, and 44% are not members of any cooperative that provides technical support. In the United States, 55.3% are cooperative members, and 44.7% are not members of any cooperative. Farmer's involvement with external groups, such as cooperatives, provides a source of information and knowledge exchange that can stimulate interest in new technologies and encourage trial and adoption (Hasler et al. 2017, Roberts et al. 2004).

4.2 *Technology Adoption On-Farm, Decisions, and Benefits*

The survey in Brazil and the United States asked about the level of the use of precision and digital technology tools on-farm on an interval 5-point scale, from 1 = Never use to 5 = Always use. Table 1 shows the mean responses for each technology in both countries.

Table 1. Level of the use of precision and digital technologies on-farm

	Brazil	**United States**
Use of Precision and Digital Technologies	**Means**	**Means**
Guidance/Autosteer	3.56	4.23
Yield monitors	2.92	4.31
Satellite/drone imagery	2.99	2.94
Soil electrical conductivity mapping	1.50	1.81
Wired or wireless sensor networks	2.10	2.36
Electronic records/mapping for traceability	2.09	3.26
Sprayer control systems	1.98	3.93
Automatic rate control telematics	2.11	3.36

Regarding the use of precision and digital technology tools on-farm, a higher adoption rate generally was reported by respondents in the United States. This was the case for seven of the eight precision and digital technologies analyzed in our study (Table 1). In the United States, two technologies reached an average of over 4 points: Guidance/Autosteer (M: 4.23) and Yield monitors (M: 4.31). However, that in Brazil, no technology had a mean above 4 points and only one technology had a mean exceeding 3 points: Guidance/Autosteer (M: 3.56).

In the early 1990s, Global Navigation Satellite Systems (GNSS) technology enabled the beginning of precision agriculture in the world. Since then, the technology has supported increasing activities and generated countless benefits in rural areas (Bolfe et al., 2020). The combination of GNSS-enabled soil sampling, variable rate fertilizer applications, and yield monitoring was the "classic precision agriculture" package in the 1990s and some adoption studies focus on whether that classic package has been adopted (Lowenberg-DeBoer and Erickson, 2019). Not by coincidence, Yield monitors had the highest mean in our survey in the United States, and the third-highest mean in Brazil (Table 1). GNSS-enabled yield monitors have been widely available for combines since the beginning of precision agriculture worldwide.

The introduction of Guidance/Autosteer systems trailed adoption of the classic precision agriculture package. However, today, those systems are the most common precision technology among farmers surveyed in both the United States and Brazil. Autosteer has many benefits, including less operator fatigue, more time focused on the operating equipment, and less waste of applied inputs (Erickson, Lowenberg-Deboer, and Bradford, 2017).

The adoption levels were also higher in the United States than in Brazil in Electronic records/mapping for traceability, Sprayer control systems and Automatic rate control telematics (Table 1). Although adoption rates are on average higher in the United States than in Brazil, our study showed similarities between the two countries. For example, the means of use of Satellite/drone imagery were 2.94 in the United States and 2.99 in Brazil. The development of new remote sensors in satellites and drones for agriculture has significantly enhanced the potential in recent years (Mogili and Deepak, 2018; Mulla, 2013). Agricultural drone applications include remote sensing farmland for variable rate seeding, fertilization, and crop protection, deterring birds, identifying wildlife, and spraying pesticides in locations difficult to reach (Lowenberg-DeBoer, 2022).

The technology with the lowest mean in the United States (M:1.81) and Brazil (M:1.50) was the same one: Soil electrical conductivity (E.C.) mapping. This technology is newer and unproven in its capabilities when compared to the more established ones. One of the challenges in quantifying the economic benefits of precision and digital technology adoption is that farmers lack tools and methods that enable comprehensive analysis (Pope and Sonka, 2020).

In summary, our study shows a higher adoption level in the United States than in Brazil in seven of eight precision and digital technologies analyzed. This result in adoption level is consistent with the time that these precision agriculture technologies have been available in each country. Technology adoption is a process that occurs over time among the participants in a social system (Rogers, 2003). Introduction of precision agriculture technologies in the United States tended to precede the corresponding introduction on Brazil. The United States is not the only developed country which aggressively adopted precision agriculture technologies. Other developed countries with significant adoption levels include Australia, Canada and European countries. Developing countries, such as Argentina and Brazil, have had an increasing adoption rate in the last decade (Say et al., 2018).

Many studies have been conducted on the adoption rate of precision agriculture technologies in the United States and Brazil. Although results among these studies vary, adoption rates have generally increased over the last two decades, despite behind what many researchers expected. In the United States, the overall adoption rates rarely overcome 50% of farms or even

50% of planted areas (Pathak, Brown, and Best 2019; Schimmelpfennig and Ebel, 2016). Although precision agriculture is already a reality for professional and rural producers in Brazil, there are still significant gaps in the adoption process (Bolfe et al. 2020, Anselmi et al., 2014). A study conducted in 2021 by IHS Markit – Business Intelligence showed an adoption rate of 34% among soybean farmers in Brazil (IHS Markit, 2021).

Respondents in Brazil and the United States also indicated the influence of the use of digital technology and precision tools on making decisions, on an interval 5-point scale, from 1 = Not at all influential to 5 = Extremely influential. Table 2 shows the mean responses for each technology in both countries.

Table 2. Level of influence of the use of digital technology and precision tools in making decisions on-farm

	Brazil	**United States**
Making decisions	**Means**	**Means**
Nitrogen, phosphorus, potassium (NPK) fertilization and liming application	3.64	3.93
Overall hybrid/variety selection	3.49	3.53
Overall crop planting rates	3.44	3.45
Variable seeding rate prescriptions	2.38	2.72
Pesticide selection (herbicides, insecticides or fungicides)	3.26	2.91
Cropping sequence/rotation	3.12	2.69
Irrigation	2.02	1.41

Regarding the influence of precision and digital technologies in making decisions, the results in the United States and Brazil are relatively similar (Table 2). For example, the Nitrogen, phosphorus, potassium (NPK) fertilization and liming applications had the most significant influence among the respondents both in the United States (M:3.93) and in Brazil (M: 3.64). One of the benefits of precision agriculture is applying nutrients where they can be most profitable based on soil test results and analysis of prior yield data. Agricultural retailers' willingness and ability to provide variable rate application of various fertilizers has grown over time but follows an adoption path similar to GNSS-based soil sampling (Minter et al., 2016).

The Overall hybrid/variety selection and Overall crop planting rates decisions had means exceeding 3 points in both countries. The Variable seeding rate prescriptions also had means similar among Americans (M: 2.72) and Brazilians (M: 2.38) farmers. These decisions involve crop management according to field variability and site-specific conditions. Decisions that are better than those that would be made with conventional agricultural practices can boost the efficient use of resources, reduce input costs, and improve yields (Tey and Brindal, 2012).

The means in Brazil were higher than in the United States regarding three decisions: Pesticide selection (herbicides, insecticides or fungicides), Cropping sequence/rotations decisions and Irrigation (Table 2). These results can be understood by the more intensive use of agricultural land in some regions of Brazil, where two crops can be grown in one year. The tropical environment there allows pest populations to go through multiple generations per year on crops, consequently increasing selection pressure (Fatoretto, 2017). In addition, decisions regarding Cropping sequence/rotation tend to be more sensitive in Brazil than in the United States, which have just one crop per year due the temperate climate.

Irrigation was the decision with the lowest mean in both countries. It may also be associated with the smaller number of farmers using these technologies in relation to the other groups of technologies evaluated. For example, in Brazil less than 5% of the total soybean area harvested was irrigated in 2020, according to data from Embrapa and Conab. In the United States, this percentual is less than 10%, higher than in Brazil but still low regarding the total area (USDA, 2020). Although registering a lower mean, the mean for irrigation decision was higher in Brazil. Again, this likely can be linked to the practice of having two crops per year in some regions of Brazil.

Another aspect of the survey investigated the benefits obtained through the adoption and use of precision and digital technologies as perceived by the farmer respondents. Table 3 shows the mean responses for each technology in both countries, from 1 = Not at all influential to 5 = Extremely influential.

Table 3: Level of influence of using precision and digital tools on-farm in the benefits obtained

	Brazil	United States
Benefits	**Means**	**Means**
Increased crop productivity/yields	3.70	3.92
Cost reductions	3.63	3.78
Purchase of inputs	3.38	3.40
Marketing choices	3.31	2.96
Time savings (paper filing to digital)	3.51	3.17
Labor efficiencies	3.57	3.30
Lower environmental impact	3.34	2.99
Autosteer (less fatigue/stress)	3.54	4.18

The results (shown in Table 3) in the United States and Brazil regarding benefits obtained were generally similar. Autosteer (less fatigue/stress) had the highest mean among the respondents in the United States (M: 4.18). In Brazil, the highest mean was reported for Increased crop productivity/yields (M: 3.70). In both countries, the second highest mean was Cost reduction, a constant concern in a commodity market with thin profit margins.

Regarding the benefit of achieving Lower environmental impact, the mean was higher in Brazil (M: 3.34) than in the United States (M: 2.99). This result may be because of the considerable concern focused on potential environmental impacts of soybean production in Brazil's Midwest and North. Soybean production and its supply chain depend highly on land, fertilizer, fuel, machines, pesticides, and electricity (Da Silva, 2010). The pressure to adopt digital technology on the farm emanating from end-use consumers is mounting. One motivation for that pressure is the desire for more sustainable cropping systems. It is necessary to produce more food with less natural resources and inputs.

The use of technology varies from farmer to farmer. Still, the decision to invest in technology is commonly tied to the potential for increased efficiency and profitability (Pope and Sonka, 2020). It is important to note that farmers are heterogeneous in their perceptions of precision farming technologies, and their perceptions are also affected by the technologies they use (Thompson, Widmar, and Mintert, 2019). Therefore, our results suggest that farmers perceive substantial benefits from using technologies in soybean production in Brazil and the United States, especially regarding the potential for increases in efficiency and profitability, as well less fatigue and time savings.

4.3 Level of Influence from Mass Media, Social Media, and Interpersonal Meetings

Soybean farmers in the United States and Brazil also were asked to report on the level of influence of mass media, social media, and interpersonal meetings on their decision to adopt precision and digital technology on an interval 5-point scale, from 1 = Not at all influential to 5 = Extremely influential. Table 4 shows the means regarding each question in both countries:

Table 4. Level of influence of mass media, social media and interpersonal meetings in farmer's adoption decision

	Brazil	**United States**
Mass Media	**Means**	**Means**
Newspaper	1.75	2.11
Magazine	2.11	2.78
Radio	2.17	2.40
Television	2.15	2.10
Website and blog	3.38	3.41
Pay television	2.41	1.55
Social Media	**Means**	**Means**
YouTube	3.17	2.52
WhatsApp	3.65	-
Facebook	2.40	1.74
Twitter	-	1.89
LinkedIn	2.03	1.47
Instagram	2.61	1.26
Snapchat	-	1.26
Messenger	1.71	-
Interpersonal Meetings	**Means**	**Means**
Field Days	3.87	3.51
Conferences, forums, seminars	3.86	3.53
Extension Agents	3.63	3.50
Retailers	3.20	3.50
Peers groups	3.42	3.41
Conversations with neighbors	3.62	3.40

* The blank (-) means that this option was not included in one of the countries following the criteria described in the methodology.

In relation to the mass media group, Website and blog had the highest and similar average in both the United States and Brazil, 3.41 and 3.38, respectively (Table 4). This was the only channel that reached a mean above 3 points within the mass media group. The result is in line with the rapid growth of the Internet, the ease with which global communication takes place, and the ability of news and information to spread with surprising speed and intensity (Easley and Kleinberg, 2010).

The respondents indicate that radio remains relevant to farmers in the United States (M:2.40) and Brazil (M: 2.17), despite the proliferation of new media. This can be explained by the radio's immediacy and by its accessibility. For example, the radio can be accessed in cars, trucks, while operating agricultural equipment via cell phones. The radio also usually brings local news that interests the producer, such as weather forecasts.

The newspaper and magazine channels had higher levels of influence among the respondents in the United States than in Brazil, but still below 3 points. Due to a weakened newspaper industry and reduced resources, an accurate understanding of consumer demand for digital news products is more important than ever (Chyi and Ng, 2020). Meanwhile, Pay television had the second-highest mean among Brazilian respondents (M: 2.41), in the United States had the lowest mean among the mass media group (M: 1.55).

Interestingly, there is a noticeable difference in the level of influence attributed to social media overall between the Brazilian and United States respondents. For each channel for which respondents in both countries could respond, the level of influence reported in Brazil exceeded that reported among U.S. respondents. It can be linked to the age groups interviewed in both countries, younger groups in Brazil than in the United States.

WhatsApp stands out among Brazilian farmers as the most influential in soybean farmers' decision making among social media group, with a 3.65 average. WhatsApp is a cross-platform online instant messaging service for mobile devices. As of 2021, WhatsApp is the most popular mobile messenger app worldwide with approximately two billion monthly active users (Statista, 2021). This outranks Facebook Messenger at 1.3 billion users and WeChat at 1.2 billion users (Statista, 2021). As noted in the methodology section, WhatsApp was not listed in this survey of American soybean produces because WhatsApp was not cited among the most popular social media in the United States (Pew Research Center, 2021a).

YouTube reached the highest social media mean among American farmers, with a 2.52 average. YouTube had the second-highest average among the respondents in Brazil (M: 3.17). The number of YouTube viewers amounted to 1.86 billion in 2021, up from 1.47 billion in 2017 (Statista, 2021). While many social media proved to be ephemeral, YouTube continues to expand rapidly and has become the second most visited website globally (Arthurs, Drakopoulou, and Gandini, 2018). YouTube was the only social media that reached an average above 2 points among American farmers. The second-highest average among the respondents in the United States was Twitter, with an average of 1.89, followed by Facebook with 1.74.

In Brazil, the third-highest average within the social media group was Instagram (M: 2.61). It started as a photo-sharing platform in 2010, growing in popularity to attract a large crowd of followers, which led to its creative use by bloggers and marketers. Instagram has moved from photo sharing to video and live streaming (Adekunle and Kajumba 2021). On the other hand, the Instagram and Snapchat had the lowest mean among American farmers respondents.

There was a slight variation in survey results in the United States and Brazil regarding the interpersonal meeting group. Means for all eight channels in this question (Field days, Conferences, forums and seminars, Extension agents and retailers, Peer groups, and Conversations with neighbors) exceeded 3 on a 5-point scale. The two types of interpersonal meetings with the highest means in both countries were Field days and Conferences. These events typically provide educational opportunities for producers seeking knowledge in crop production, farm management, land use, and other issues. Besides, these are opportunities to share information and experiences among farmers and other agents of the agroindustry chain. This result reinforces the notion that a social network effect is still important in agriculture.

The influence of Extension agents had similar results in the United States (M: 3.50) and Brazil (M: 3.63). Connections and visits with farms by specialists, for example, help disseminate innovative technologies. Agricultural extension services can affect technology acceptance because of the delivery of consultancy and education services (O'Donoghue and Heanue, 2018; Deichmann, Goyal, and Mishra, 2016).

The categories Peer groups and Conversations with neighbors also had similar means in both countries. Peer groups are facilitate sharing specific context-sensitive knowledge that makes intuitive, practical sense (Littlejohn and Foss, 2010). With respect to influence from neighbors, a typical model assumes that farmers learn by observing others' experimentation (Maertens and

Barrett, 2013). Farmer-to-farmer knowledge sharing is an essential source of information. Economists increasingly appreciate the critical role that social networks play in mediating the diffusion of agricultural innovations.

4.4 Demographic Profile and Adoption Level of Technologies

Certain demographic characteristics historically have been felt to affect the pace of technology adoption. In this study data were collected on three of those characteristics, farmer age, farmer education and farm size. This section reports on the relationships between these three characteristics and adoption of the eight precision agriculture technologies of interest in this study. The one-way ANOVA was used to quantify strength of relationship. Appendix C contains all numeric results for all characteristics and technologies. To conserve space, in this section only data for relationships that were found to be statistically significant will be presented and discussed.

One of the key characteristics often discussed in the agricultural economics literature is farmers' age, which is expected to influence technology and innovation adoption to a great extent (Ghadim and Pannell, 1999). The effect of age on precision agriculture adoption is unclear (Tey and Brindal, 2012). Some researchers have reported that older farmers are likely to be more risk-averse than younger farmers, less willing to innovate and have shorter planning horizons. They are more reluctant to engage with new technologies owing to the reduced likelihood of paying off investments (Paustian and Theuvsen, 2017; Hasler et al., 2017; Kutter et al., 2009). However, some authors have reported that older farmers correlate positively with precision agriculture adoption (Torbett et al., 2007).

In our study, as shown in Figure 3, nearly half (43.2%) of respondents in Brazil were younger than 40 years of age. Meanwhile, nearly half (44.7%) of respondents in the United States were 56–70 years old. The age difference is consistent with the average age of producers in both countries. For example, 62% of U.S. farm producers are older than 55 years old, according to the US Census of Agriculture (USDA, 2017). In Brazil, the percentage of farmers more senior than 55 years old is 46%, according to data from the Census of Agriculture in Brazil (IBGE, 2017).

According to our findings, the higher average age among American farmers did not appear to be a significant factor in adopting digital technologies. We used one-way ANOVA to compare the effect of eight independent variables on three dependent variables – under 41 years, 41-55 years old, and more than 56 years old (see Appendix C). And the results showed that the age groups' means are not significantly different statistically for all eight technologies analyzed (at a 95% confidence level). This suggests that there is no difference in farmers' behavior regarding adopting technologies among the different age groups interviewed in the United States.

On the other hand, in Brazil, the results of the one-way ANOVA (Table 5) disclosed a difference among the three ages relative to four technologies – Guidance/Autosteer ($F = 7.394$; $df = 2, 458$; $p < 0.05$), Satellite/drone imagery ($F = 5.849$; $df = 2, 458$; $p < 0.05$), Wired or wireless sensor networks ($F = 4.720$; $df = 2, 458$; $p < 0.05$), and Electronic records/mapping for traceability ($F = 5.726$; $df = 2, 458$; $p < 0.05$). The ANOVA shows at least one age group mean differs significantly from the overall mean of the dependent variable.

Table 5: Age groups and use of technologies in Brazil, using one-way ANOVA

Guidance/Autosteer	**N**	**Mean**	**Std. Deviation**
Under 41 years	199	3.72	1.382
From 41 to 55 years	163	3.68	1.422
More than 56 years	99	3.06	1.713
Total	461	3.56	1.493
Satellite/drone imagery	**N**	**Mean**	**Std. Deviation**
Under 41 years	199	3.05	1.228
From 41 to 55 years	163	3.15	1.283
More than 56 years	99	2.61	1.384
Total	461	2.99	1.295
Wired or wireless sensor networks	**N**	**Mean**	**Std. Deviation**
Under 41 years	199	2.29	1.405
From 41 to 55 years	163	2.07	1.443
More than 56 years	99	1.77	1.211
Total	461	2.10	1.391
Electronic records/mapping for traceability	**N**	**Mean**	**Std. Deviation**
Under 41 years	199	2.22	1.370
From 41 to 55 years	163	2.18	1.333
More than 56 years	99	1.70	1.147
Total	461	2.09	1.325

Therefore, soybean farmers' age appears as a significant factor on the adoption of some digital technologies on farms in Brazil. Younger farmers are likely more highly educated and, therefore, more willing to innovate (Tey and Brindal, 2012). A high education level provides the knowledge and skills needed to understand the technologies, make farmers want to experiment, and enable them to adopt them (Paustian and Theuvsen, 2017). However, in our study, higher-level education did not appear to be a significant factor in adopting digital technologies among American soybean farmers. The results of the one-way ANOVA did not show a significant difference among the four-level education groups regarding all eight precision and digital technologies at the 95% confidence level. Therefore, the analyze discloses that none of the levels of education group means are significantly different from the overall mean.

Conversely, the results of the one-way ANOVA in Brazil showed a significant difference among the three-level education groups regarding the use of two technologies: Satellite/drone imagery ($F = 5.363$; $df = 2, 458$; $p < 0.05$) and Electronic records/mapping for traceability ($F = 4.682$; $df = 2, 458$; $p < 0.05$). The statistical test shows that at least one group differs significantly from the overall mean of these two technologies (Table 6). Note that among farmers with postgraduate the means are higher than the average.

Table 6: Level of education and use of technologies in Brazil, using one-way ANOVA

Satellite/drone imagery	**N**	**Mean**	**Std. Deviation**
Less than a bachelor's degree	116	2.74	1.333
Bachelor's degree	183	2.92	1.229
Postgraduate (MBA, master or doctoral)	162	3.23	1.307
Total	461	2.99	1.295
Electronic records/mapping for traceability	**N**	**Mean**	**Std. Deviation**
Less than a bachelor's degree	116	1.95	1.278
Bachelor's degree	183	1.96	1.257
Postgraduate (MBA, master or doctoral)	162	2.35	1.402
Total	461	2.09	1.325

Another farm characteristic also felt to influence technology adoption is farm size. Larger farms are more likely to adopt precision agriculture technologies owing to increased awareness and the ability to absorb costs and associated risks. Some precision agriculture technologies, such as variable-rate technologies and remote sensing, are likely unsuitable for small farms (Hasler et al., 2017; Schimmelpfennig and Ebel, 2016; Tey and Brindal, 2012; McBride and Daberkow, 2003). For the U.S. respondents of our study, the results of the one-way ANOVA showed a significant difference among the four-level farm size groups regarding the use seven technologies analyzed. The exception was Soil electrical conductivity. Seven technologies reached means higher than the overall mean among respondents who farm more than 2,000 hectares (Table 7).

Table 7: Farm size and use of technologies in the United States, using one-way ANOVA

Guidance/Autosteer	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	3.25	1.479
From 203 to 405 hectares	75	3.95	1.283
From 406 hectares to 2,023 hectares	167	4.56	.716
More than 2,023 hectares	40	4.75	.543
Total	339	4.23	1.130
Yield Monitors	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	3.72	1.521
From 203 to 405 hectares	75	4.19	1.291
From 406 hectares to 2,023 hectares	167	4.51	1.046
More than 2,023 hectares	40	4.50	1.038
Total	339	4.31	1.224
Satellite/drone imagery	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	2.56	1.310
From 203 to 405 hectares	75	2.76	1.282
From 406 hectares to 2,023 hectares	167	3.05	1.155
More than 2,023 hectares	40	3.35	1.292
Total	339	2.94	1.245
Wired or wireless sensor networks	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	2.11	1.398
From 203 to 405 hectares	75	1.84	1.274
From 406 hectares to 2,023 hectares	167	2.56	1.459
More than 2,023 hectares	40	2.85	1.511
Total	339	2.36	1.451
Electronic records/mapping for traceability	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	2.49	1.465
From 203 to 405 hectares	75	2.92	1.609
From 406 hectares to 2,023 hectares	167	3.53	1.484
More than 2,023 hectares	40	3.78	1.441
Total	339	3.25	1.561

Spray control systems	N	Mean	Std. Deviation
Less than 202 hectares	57	3.26	1.598
From 203 to 405 hectares	75	3.33	1.663
From 406 hectares to 2,023 hectares	167	4.28	1.232
More than 2,023 hectares	40	4.53	.877
Total	339	3.93	1.456
Automatic rate control telematics	**N**	**Mean**	**Std. Deviation**
Less than 202 hectares	57	2.63	1.566
From 203 to 405 hectares	75	2.69	1.627
From 406 hectares to 2,023 hectares	167	3.75	1.466
More than 2,023 hectares	40	3.98	1.230
Total	339	3.36	1.589

In Brazil, the results of the one-way ANOVA also showed a significant difference among the four-level farm size groups regarding all but one of the technologies analyzed. The exception in Brazil was Spray control systems. Seven technologies reached higher means among the more than 2,000 hectares group than the overall mean for all farm size groups (Table 8).

Table 8: Farm size and use of technologies in Brazil, using one-way ANOVA

Guidance/Autosteer	N	Mean	Std. Deviation
Less than 100 hectares	117	2.56	1.567
From 101 to 500 hectares	118	3.18	1.523
From 501 hectares to 2,000 hectares	135	4.19	1.033
More than 2,000 hectares	91	4.42	.895
Total	461	3.56	1.493
Yield Monitors	**N**	**Mean**	**Std. Deviation**
Less than 100 hectares	117	2.40	1.427
From 101 to 500 hectares	118	2.42	1.416
From 501 hectares to 2,000 hectares	135	3.36	1.412
More than 2,000 hectares	91	3.58	1.300
Total	461	2.92	1.488

Satellite/drone imagery	N	Mean	Std. Deviation
Less than 100 hectares	117	2.56	1.296
From 101 to 500 hectares	118	2.79	1.313
From 501 hectares to 2,000 hectares	135	3.16	1.227
More than 2,000 hectares	91	3.55	1.128
Total	461	2.99	1.295
Soil electrical conductivity mapping	**N**	**Mean**	**Std. Deviation**
Less than 100 hectares	117	1.44	.923
From 101 to 500 hectares	118	1.25	.776
From 501 hectares to 2,000 hectares	135	1.67	1.112
More than 2,000 hectares	91	1.64	1.131
Total	461	1.50	1.004
Wired or wireless sensor networks	**N**	**Mean**	**Std. Deviation**
Less than 100 hectares	117	1.76	1.229
From 101 to 500 hectares	118	1.95	1.267
From 501 hectares to 2,000 hectares	135	2.15	1.406
More than 2,000 hectares	91	2.66	1.551
Total	461	2.10	1.391
Electronic records/mapping for traceability	**N**	**Mean**	**Std. Deviation**
Less than 100 hectares	117	1.79	1.121
From 101 to 500 hectares	118	1.80	1.106
From 501 hectares to 2,000 hectares	135	2.19	1.394
More than 2,000 hectares	91	2.73	1.491
Total	461	2.09	1.325
Automatic rate control telematics	**N**	**Mean**	**Std. Deviation**
Less than 100 hectares	117	1.72	1.195
From 101 to 500 hectares	118	1.78	1.192
From 501 hectares to 2,000 hectares	135	2.30	1.367
More than 2,000 hectares	91	2.75	1.561
Total	461	2.11	1.379

Our survey results in Brazil and the United States are consistent with other studies that analyzed the relationship between farm size and adoption. Larger farms are more likely to adopt new technologies for crop production for several reasons. Precision agriculture requires investment in different types of equipment, and the capital cost of equipment applies to a greater crop-producing area on larger farms (Schimmelpfennig, 2016). Therefore, our findings reinforce that farm size is one of the most important demographic factors in favor of the adoption of precision agriculture technologies.

4.5 Relationship Between the Adoption and Communication Channels

Spearman's correlation was applied to measure the strength of the association between the communication channels and the level of adoption of technologies in soybean production in the United States and Brazil. In both countries, the results depict a positive correlation between eight precision and digital technologies and several mass media, social media, and interpersonal meetings. Table 9a shows the three communication channels with the highest correlation coefficients for each of the eight technologies.

Table 9a. Relationship between use of precision and digital technologies and communication channels

	Brazil	**United States**
Precision and digital technologies	**Communication Channels (Spearman's rank correlation coefficient ρS)**	**Communication Channels (Spearman's rank correlation coefficient ρS)**
Guidance/Autosteer	1st Conversation with neighbors (ρS 0.209)	1st YouTube (ρS 0.208)
	2nd Conferences, forums, seminars (ρS 0.120)	2nd Twitter (ρS 0.159)
	3rd Field Days (ρS 0.096)	3rd Website and blog (ρS 0.154)
Yield monitors	1st LinkedIn (ρS 0.178)	1st YouTube (ρS 0.181)
	2nd Conversation with neighbors (ρS 0.170)	2nd Peer groups (ρS 0.163)
	3rd Pay Television (ρS 0.145)	3rd Website and blog (ρS 0.145)
Satellite/drone imagery	1st LinkedIn (ρS 0.253)	1st Website and blog (ρS 0.225)
	2nd Conferences, forums, seminars (ρS 0.246)	2nd Twitter (ρS 0.180)
	3rd Instagram (ρS 0.226)	3rd YouTube (ρS 0.165)
Soil E.C. mapping	1st LinkedIn (ρS 0.228)	1st Pay Television (ρS 0.199)
	2nd Instagram (ρS 0.183)	2nd YouTube (ρS 0.163)
	3rd Messenger (ρS 0.182)	3rd Peer Groups (ρS 0.141)
Wired or wireless sensor networks	1st LinkedIn (ρS 0.261)	1st Instagram (ρS 0.271)
	2nd Instagram (ρS 0.208)	2nd YouTube (ρS 0.231)
	3rd Conferences, forums, seminars (ρS 0.183)	3rd Twitter (ρS 0.209)
Electronic records/mapping for traceability	1st LinkedIn (ρS 0.224)	1st Website and blog (ρS 0.252)
	2nd Instagram (ρS 0.180)	2nd YouTube (ρS 0.190)
	3rd Conferences, forums, seminars (ρS 0.148)	3rd Facebook (ρS 0.158)

	Brazil	United States
Precision and digital technologies	**Communication Channels (Spearman's rank correlation coefficient ρS)**	**Communication Channels (Spearman's rank correlation coefficient ρS)**
Sprayer control systems	1st LinkedIn (ρS 0.221) 2nd Subscription Television (ρS 0.189) 3rd WhatsApp (ρS 0.151)	1st YouTube (ρS 0.165) 2nd Website and blog (ρS 0.164) 3rd Retailers and Extension agents (ρS 0.133)
Automatic rate control telematics	1st LinkedIn (ρS 0.246) 2nd Instagram (ρS 0.186) 3rd Peer groups (ρS 0.135)	1st YouTube (ρS 0.238) 2nd Website and blog (ρS 0.204) 3rd Facebook (ρS 0.145)

To summarize the results from the Spearman's correlation between use of technologies and communication channels, we show in Table 9b only the communication channels listed in Table 9a and the number of times they are listed. Channels are listed from most to least cited within their category (mass media, social media, and interpersonal meetings).

Table 9b. Frequency of communication channels listed in Table 9a

	Brazil	United States
Mass Media	**Number of times listed**	**Number of times listed**
Website and blog	0	6
Pay Television	2	1
Total	2	7
Social Media	**Number of times listed**	**Number of times listed**
YouTube	0	8
LinkedIn	7	0
Instagram	5	1
Twitter	0	3
Facebook	0	2
WhatsApp	1	0
Messenger	1	0
Total	14	14
Interpersonal Meetings	**Number of times listed**	**Number of times listed**
Conferences, forums, seminars	4	0
Conversation with neighbors	2	0
Peer groups	1	2
Field days	1	0
Retailers and Extension agents	0	1
Total	8	3

Note that there are variations and similarities between both countries in Table 9b. For example, mass media channels appeared seven times in the U.S. results, in Brazil, these channels appeared only twice among the communication channels with the highest correlation coefficients. Meanwhile, interpersonal meetings channels showed up eight times in Brazil and only three times in the United States. Meanwhile, among the social media channels, the total in both countries was 14 times, with a highlight to LinkedIn in Brazil and YouTube in the United States (Table 9b).

LinkedIn had the highest positive correlation in Brazil with seven precision and digital technologies among eight analyzed technologies (Table 9a). This result can be questioned because the social media for business professionals had a low mean (M: 2.03 points) among the farmers that indicated the level of influence in their decision-making to adopt new technology on the farm. Indeed, the low mean showed that fewer farmers use this channel, but still, LinkedIn may have the highest association with producers using these technologies. In other words, farmers who responded that LinkedIn influences decision-making tend to have the highest levels of on-farm technology adoption.

In addition, respondents' education level may have influenced the results around LinkedIn. Among the farmers surveyed in Brazil, 39.7% have a bachelor's degree and 35.1% have postgraduate degree (MBA, master's, or doctorate). The results of the one-way ANOVA showed a significant difference among the three-level education groups regarding the use of LinkedIn at the 95% confidence level ($F = 15.260$; $df = 2, 450$; $p < 0.05$). Among farmers that have a postgraduate degree, for example, LinkedIn had a mean of 2.46. Meanwhile, among farmers that have a bachelor's degree, the mean was 1.88, among farmers with a high school diploma, the mean was 1.77, and among the farmers with less than a high school diploma, the mean was 1.33 (Table 10). People with higher levels of education are more likely to be LinkedIn users than those with lower levels of education, according to the Social Media Use in 2021 report (Pew Research Center, 2021a).

Table 10. Level education and use of LinkedIn in Brazil, using one-way analysis ANOVA.

	N	Mean	Std. Deviation
Less than a bachelor's degree	113	1.66	1.057
Bachelor's degree	182	1.88	1.186
Postgraduate degree (MBA, master or doctorate)	158	2.46	1.461
Total	453	2.03	1.300

In second place in Brazil, behind LinkedIn, Instagram also showed a positive association with the use of Satellite/drone imagery (ρS = 0.226; $p < 0.05$), Wired or wireless sensor networks (ρS = 0.208; $p < 0.05$), Automatic rate control telematics (ρS = 0.186; $p < 0.05$), Soil EC mapping (ρS = 0.183; $p < 0.05$), and Electronic records/mapping for traceability (ρS = 0.180; $p < 0.05$). Similar to YouTube, Instagram appears to have gained relevance during the pandemic. This scenario led to the surge of live events with guests remotely located, which was not common before COVID-19.

In addition, Instagram is the main platform used by digital influencers and digital media content creators who use their media platforms to influence audience behavior. Influencers in agriculture, including producers, agronomists, communicators, and other professionals, began to gain strength in the last five years. Therefore, there is little public data to measure the real impact on companies investing in influencers as marketing tools. Instagram appeals more to the younger generation than other social media platforms, making it more popular among the youth than Facebook, which remains widespread among older generations (Adekunle and Kajumba, 2021).

Among the farmers who participated in the survey in Brazil, for example, 43.3% were under 40 years of age or younger. The results of the one-way ANOVA showed a significant difference among the three-age groups regarding the use of Instagram at the 95% confidence level ($F = 21.694$; $df = 2{,}454$; $p < 0.05$). Among farmers under 41 years of age, for example, Instagram had a mean of 3.02. Meanwhile, among farmers from 41 to 55 years old, the mean was 2.50, and among producers more than 56 years old, the mean was 1.98 (Table 11).

Table 11. Age groups and use of Instagram in Brazil, using one-way ANOVA

	N	Mean	Std. Deviation
Under 41 years	198	3.02	1.342
From 41 to 55 years	161	2.50	1.309
More than 56 years	98	1.98	1.201
Total	457	2.61	1.359

In the United States, the communication channels most associated with using technologies are quite different than in Brazil. YouTube had the highest positive correlation with four of eight precision and digital technologies analyzed among American farmers (Table 9a). Note that the four technologies with the highest positive correlation with YouTube – Automatic rate control telematics ($\rho S = 0.238$; $p < 0.05$), Guidance/Autosteer ($\rho S = 0.208$; $p < 0.05$), Yield monitors ($\rho S = 0.181$; $p < 0.05$), and Spray control systems ($\rho S = 0.165$; $p < 0.05$) – are the same ones that reached the highest means in relation to the use of precision and digital technologies tools on farm. The results suggest an association among adopters of these long-used technology, present since the beginning of the implementation of precision agriculture, with YouTube.

YouTube was the only social media that reached an average above 2 points among American farmers (M: 2.52). YouTube is the most used online platform in the Pew Research Center survey, and there is evidence that its reach is growing. Fully 81% of Americans say they have ever used the video-sharing site in 2021, up from 73% in 2019. During the pandemic, YouTube saw the most significant growth of any social media app among American users (Pew Research Center, 2021a). Farmers typically use YouTube to seek information about agricultural innovations, upcoming technologies, and specialized skills. The live streaming service is also popular among producers, especially younger Internet users. The results of the one-way ANOVA show a difference among the four-age groups in the use of YouTube ($F = 3.214$; $df = 3, 333$; $p < 0.05$) in the United States. Among farmers under 41 years of age, for example, YouTube had a mean of 2.97. Meanwhile, among farmers more than 70 years, the mean was 2.37 (Table 12).

Table 12. Age groups and use of YouTube in the U.S., using one-way ANOVA

	N	Mean	Std. Deviation
Under 41 years	58	2.97	1.184
From 41 to 55 years	73	2.49	1.180
From 56 to 70 years	152	2.41	1.182
More than 70 years	54	2.37	1.431
Total	337	2.52	1.237

Second to YouTube in the United States, Website and blog also showed a positive association with six of eight precision and digital technologies analyzed (Table 9a). The result is in line with the answers from respondents that indicated Website and blog as the most influential mass media in their decision to adopt precision and digital technology on-farm. In addition, the channel was the only one that reached mean above 3 points among the respondents within the mass and social media groups, at the same level at the interpersonal meetings (Table 4).

Another difference between Brazil and the United States pointed out in our findings is the interpersonal meetings most associated with the use of technologies. In Brazil, Conversation with neighbors and Conferences, forums, seminars had the highest correlations with the use of technologies. In contrast, Peer groups and Retailers and Extension agents appear as the most influential interpersonal meeting in the United States.

Therefore, regardless of the nature of the interpersonal meetings, our results reinforce the role of social networks in influencing the adopter's propensity for innovation adoption. This component of the innovation adoption process ranges from the nature of social networks that the adopter engages with to planned dissemination programs such as agricultural extension activities to promote use of the innovation (Pathak, Brown, and Best 2019). The social system, that includes opinion leaders and organizational structures, lead to innovation (Rogers, 2003).

4.6 Relationship Between Benefits and Communication Channels

We also applied Spearman's Correlation to measure the association between communication channels and the perceived benefits of using technologies on-farm. The results depict a positive correlation between eight perceived benefits and several mass media, social media, and interpersonal meetings. Again, we discussed only the three communication channels with the highest correlation coefficients (Table 13a).

Table 13a: Relationship between perceived benefits of using technologies on-farm and communication channels

	Brazil	**United States**
Perceived Benefits	**Communication Channels (Spearman's rank correlation coefficient ρS)**	**Communication Channels (Spearman's rank correlation coefficient ρS)**
Increased crop productivity/yields	1st Field Days and Conferences, forums, and seminars (0.312) 2nd Websites e blogs (0.274) 3rd WhatsApp (0.240)	1st Website and blog (0.305) 2nd Field Days (0.304) 3rd Conferences, forums, seminars (0.281)
Cost reductions	1st Conferences, forums, and seminars (0.344) 2nd Field Days (0.280) 3rd WhatsApp (0.245)	1st Website and blog (0.224) 2nd Retailers and Extension Agents (0.199) 3rd Twitter and Conferences, forums and seminars (0.198)

	Brazil	United States
Perceived Benefits	**Communication Channels (Spearman's rank correlation coefficient ρS)**	**Communication Channels (Spearman's rank correlation coefficient ρS)**
Purchase of inputs	1st WhatsApp (0.262)	1st Website and blog (0.280)
	2nd Conferences, forums, seminars (0.260)	2nd Field Days (0.274)
	3rd Websites and blogs (0.244)	3rd Television (0.257)
Marketing choices	1st WhatsApp (0.311)	1st Television (0.332)
	2nd Websites and blogs (0.227)	2nd Magazine (0.266)
	3rd Conferences, forums, seminars (0.204)	3rd Website and blog (0.251)
Time savings (paper filing to digital)	1st Conferences, forums, seminars (0.343)	1st Website and blog (0.308)
	2nd Websites and blogs (0.269)	2nd Twitter (0.236)
	3rd Field Days (0.249)	3rd YouTube (0.203)
Labor efficiencies	1st Conferences, forums, seminars (0.351)	1st Website and blog (0.265)
	2nd Field Days (0.270)	2nd YouTube (0.204)
	3rd Extension Agents (0.260)	3rd Facebook (0.191)
Lower environmental impact	1st Conferences, forums, seminars (0.340)	1st Website and blog (0.239)
	2nd Field Days (0.279)	2nd Twitter and Snapchat (0.199)
	3rd Extension Agents (0.269)	3rd Television (0.171)
Autosteer (less fatigue/stress)	1st Conferences, forums, seminars (0.240)	1st Website and blog and YouTube (0.201)
	2nd Conversation with neighbors (0.231)	2nd Retailers and Extension Agents (0.175)
	3rd Instagram (0.184)	3rd Twitter (0.164)

To simplify the results from Spearman's correlation between perceived benefits of using technologies on-farm and communication channels, we show in Table 13b only the communication channels listed in Table 13a and the number of times they are listed. Channels are listed from most to least cited within their category (mass media, social media, and interpersonal meetings). There are many differences between both countries. For example, mass media channels appeared 11 times in the United States and only 4 times in Brazil among the communication channels with the highest correlation coefficients. Meanwhile, interpersonal meetings channels appeared 15 times in Brazil and only 6 times in the United States. Among social media channels, the results were similar in two countries: 5 times in Brazil and 7 times in the United States.

Table 13b. Frequency of communication channels listed in Table 13a

	Brazil	United States
Mass Media	**Number of times listed**	**Number of times listed**
Website and blog	4	8
Television	0	2
Magazine	0	1
Total	4	11
Social Media	**Number of times listed**	**Number of times listed**
YouTube	0	2
Twitter	0	3
WhatsApp	4	0
Instagram	1	0
Snapchat	0	1
Facebook	0	1
Total	5	7
Interpersonal Meetings	**Number of times listed**	**Number of times listed**
Conferences, forums, seminars	8	2
Field days	5	2
Retailers and Extension Agents	2	2
Total	15	6

Conferences, forums, and seminars had the highest positive correlation with six perceived benefits of using technologies on-farm among the eight analyzed in the study in Brazil (Table 13a). The educational role played by these events can help to understand the result. Understanding the value of technology is increasingly essential in an environment of narrow crop margins when deploying technologies to optimize returns is critical, especially for agricultural commodities, such as soybeans (Pope and Sonka, 2020).

In relation to Increased crop productivity/yields, for example, Conferences, forums, and seminars had a similar positive correlation as Field days ($\rho S = 0.312$; $p < 0.05$). Regarding Cost reductions benefit, Conferences ($\rho S = 0.344$; $p < 0.05$) and Field days ($\rho S = 0.280$; $p < 0.05$) also had the highest association in the study. Both channels prioritize the interaction and collaboration between farmers and researchers to promote innovation and knowledge exchange, reducing costs and increasing yields. Increased productivity is one of the most relevant drivers of the significant increase in Brazilian agricultural production and exportable surpluses in the 21st (Gasques, 2014; Fuglie, Wang, and Ball, 2012).

Still, regarding Conferences, the highest association was with Labor efficiencies ($\rho S = 0.351$; $p < 0.05$) and Time savings ($\rho S = 0.343$; $p < 0.05$). Brazilian agriculture underwent a quick process of technical and structural change. In recent decades, the trend toward a reduction in the use of labor has been linked with an increase in farm machinery capital stock (Da Silva et al., 2010). In the case of soybeans, the production organization model and the available technological package have evolved to favor gains in scale and increased the capital-labor ratio, which also contributes to growing per capita income in agriculture, reducing the number of workers. Conferences also had a positive correlation with Lower environmental impact ($\rho S = 0.340$; $p < 0.05$). Soybean production and its supply chain depend highly on land, fertilizer, fuel, machines, pesticides, and electricity. In recent decades, the expansion of this crop in Brazil has generated concerns about its environmental impacts (Da Silva et al., 2010).

WhatsApp had the highest association with marketing choices ($\rho S = 0.311$; $p < 0.05$) and purchase of inputs ($\rho S = 0.262$; $p < 0.001$). We expected this result because of the increase in this mobile messaging app for these activities, especially during the pandemic. The lockdown and social distancing created a situation where WhatsApp became even more important to farmers in communicating with suppliers (to buy the agricultural inputs) and with traders and cooperatives (to sell the soybean production). It is important to highlight that, unlike Instagram and LinkedIn, the results of the one-way ANOVA did not show a significant difference among the three age groups in the use of WhatsApp and among the three-level education groups. The table with all the results of the one-way ANOVA is presented in Appendix C. In other words, the behavior regarding the use of WhatsApp does not change according to the interviewed producers' age or level of education in Brazil.

When we look at the results among the farmers surveyed in the United States, the findings are distinct from those in Brazil. Website and blog had the highest positive correlation with seven among eight perceived benefits of using technologies analyzed in the study (Table 13a). This result is in line with the answers from respondents that indicated Website and blog as the most influential mass media in their decision to adopt precision and digital technology on-farm. In addition, the channel was the only one that reached mean above 3 points among the respondents within the mass and social media groups, at the same level at the interpersonal meetings (Table 4).

The influence of Websites and blogs can also be explained by the wide internet access in rural areas in the United States. Roughly seven-in-ten rural Americans (72%) say they have a broadband internet connection at home, according to a Pew Research Center survey of U.S. adults conducted from January 25 to February 8, 2021. Rural residents had seen a nine-percentage point rise in home broadband adoption since 2016, when 63% reported having a high-speed internet connection at home (Pew Research Center, 2021b).

Still regarding the Website and blog, the highest positive association among perceived benefits of using technologies were with Increased crop productivity/yields ($\rho S = 0.305$; $p < 0.05$) and Time savings ($\rho S = 0.308$; $p < 0.05$). Farmers can find information regarding machinery, seeds, chemicals, management, and innovations on the Website and blog. Access to this information can help producers achieve better results regarding yields and efficiency. Greater information availability would influence early adoption. Different sources of information are important at different stages of the adoption process. For instance, mass media such as Website and blog are important in the awareness phase, whereas technical know-how provided by service providers is important in decision-making (Watcharaanantapong, 2014, McBride and Daberkow, 2003).

The second channel most associated with the benefits Increased crop productivity/yields ($\rho S = 0.304$; $p < 0.05$) and Purchase of inputs ($\rho S = 0.274$; $p < 0.05$) was Field days – usually promoted by service providers. In addition, Retailers and extension agents appeared associated with Cost reductions ($\rho S = 0.199$; $p < 0.05$) and Autosteer ($\rho S = 0.175$; $p < 0.05$). Some studies have considered the role of farmer relationships with influential actors in the wider precision agriculture innovation ecosystem as they may impact adoption. The more cohesive these social networks, the higher the adoption rates (Busse et al., 2014).

Our results also show an interesting difference in the channels most associated with Purchase of inputs and Marketing choice. Whereas WhatsApp was the most associated with these benefits in Brazil, in the United States, Purchase of inputs has the highest association with Website/blog ($\rho S = 0.280$; $p < 0.05$) and Marketing choices with Television ($\rho S = 0.332$; $p < 0.05$). Television also showed an association with Purchase of inputs ($\rho S = 0.257$; $p < 0.05$). The relevance of Television in the United States could be attributed to the role played by this channel in enhancing the capacity of farmers by broadcasting different agricultural related programs. These programs disseminate scientific and agricultural knowledge to farmers and provide the latest information via discussion of agriculture experts.

4.7 *Relationship Between Making-Decisions and Communication Channels*

Finally, we also applied Spearman's Correlation to measure the association between communication channels and the use of technologies on-farm in making decisions. The results in both countries depict a positive correlation between decision-making and mass media, social media, and interpersonal meetings. Again, as in the two previous subsections, we present the three communication channels with the highest correlation coefficients (Table 14a).

Table 14a: Relationship between making decisions and communication channels

	Brazil	**United States**
Making Decisions	**Communication Channels (Spearman's rank correlation coefficient ρS)**	**Communication Channels (Spearman's rank correlation coefficient ρS)**
Nitrogen, phosphorus, potassium (NPK) and liming decisions	1st Conferences, forums, seminars (0.284) 2nd Peer groups (0.247) 3rd Field Days (0.244)	1st Retailers and Extension Agents (0.218) 2nd Website and blog (0.208) 3rd Conferences, forums and seminars (0.184)
Overall hybrid/variety selection	1st Field Days and WhatsApp (0.263) 2nd Conferences, forums and seminars (0.260) 3rd Websites and blogs (0.238)	1st Website and blog (0.286) 2nd YouTube (0.205) 3rd Conferences, forums and seminars (0.201)
Overall crop planting rates	1st WhatsApp (0.230) 2nd Field Days (0.218) 3rd Websites and blogs (0.186)	1st Website and blog (0.316) 2nd YouTube (0.265) 3rd Pay Television (0.210)
Variable seeding rate prescriptions	1st LinkedIn (0.209) 2nd Retailers (0.205) 3rd Pay Television (0.175)	1st Snapchat (0.229) 2nd Website and blog (0.211) 3rd Twitter (0.207)
Pesticide selection (herbicides, insecticides or fungicides)	1st WhatsApp (0.270) 2nd Field Days (0.260) 3rd Pay Television (0.234)	1st Television (0.273) 2nd Instagram (0.269) 3rd Pinterest (0.256)
Cropping sequence/rotation decisions	1st WhatsApp (0.244) 2nd Pay Television (0.238) 3rd Conferences, forums, seminars (0.234)	1st Television (0.279) 2nd Radio (0.253) 3rd Pay Television (0.225)
Irrigation	1st LinkedIn (0.220) 2nd Magazines (0.213) 3rd Radio (0.190)	1st Pay Television (0.199) 2nd Snapchat (0.195) 3rd Facebook (0.191)

To summarize the results from the Spearman's correlation above between making decisions and communication channels, we show in Table 14b only the communication channels listed in Table 14a and the number of times they are listed. Channels are listed from most to least cited within their category (mass media, social media, and interpersonal meetings).

Table 14b. Frequency of communication channels listed in Table 14a

Mass Media	Number of times listed	Number of times listed
Website and blog	2	4
Pay television	3	3
Television	0	2
Radio	1	1
Magazines	1	0
Total	7	10
Social Media	**Number of times listed**	**Number of times listed**
WhatsApp	4	0
YouTube	0	2
LinkedIn	2	0
Snapchat	0	2
Facebook	0	1
Twitter	0	1
Total	6	6
Interpersonal Meetings	**Number of times listed**	**Number of times listed**
Conferences, forums, seminars	3	2
Field Days	4	0
Retailers/Extension Agents	1	1
Peer groups	1	0
Total	9	3

Note that there are variations and similarities between both countries in Table 14b. For example, whereas mass media channels appeared 10 times in the U.S. results, in Brazil, these channels appeared seven times among the communication channels with the highest correlation coefficients. Among social media channels, the total in both countries was 6 times, primarily WhatsApp in Brazil (Table 14b). And interpersonal meetings channels were more relevant in Brazil (9 times) than in the United States (3 times).

The three highest correlation coefficients in Brazil regarding Nitrogen, phosphorus, potassium (NPK) fertilization and liming applications, for example, were interpersonal meetings channels: Conferences (ρS = 0.284; $p < 0.05$), Peer groups (ρS = 0.247; $p < 0.05$), and Field days (ρS = 0.244; $p < 0.05$). In the United States, the channel most influential regarding NPK fertilization and liming applications was Retailers and extension agents (ρS = 0.218; $p < 0.05$). The result reinforces the idea that adopters of established decisions regarding precision agriculture, like NPK fertilization, tend to prioritize in-person connections.

The degree to which users can observe others using the innovation, indicated as a characteristic that will influence the rate of adoption (Rogers, 2003), is higher in more established technologies and decisions. The performance expectancy, degree to which using a technology will provide benefits to consumers in performing certain activities (Venkatesh et al., 2003), in more established technologies/decisions is widely known and proven by previous users. Farmers' initial acceptance of a mobile digital platform for farm management is shaped by social influence, which mediates the impact of performance and effort expectancy (Fox et al., 2021).

Within the mass media group, Pay television showed a positive correlation with three types of decisions among Brazilian farmers: Cropping sequence/rotation decisions (ρS = 0.238; $p < 0.05$), Pesticide selection (ρS = 0.234; $p < 0.05$), and Variable seeding rate prescriptions (ρS = 0.175; $p < 0.05$). All these decisions require particular knowledge in precision agriculture, typically spread by specialized channels, and normally available on Pay television.

The role of Television also showed up in the results in the United States. The Television stands out as the most influential communication channel regarding Pesticide selection (ρS = 0.273; $p < 0.05$) and Cropping sequence/rotation decisions (ρS = 0.279; $p < 0.05$). In addition, Pay television had the highest association with Irrigation decisions among American farmers interviewed (ρS = 0.199; $p < 0.05$).

The behavior regarding using Television and Pay television does not change according to the interviewed producers' age in both countries. The results of the one-way ANOVA did not show a significant difference among the different age groups in the use of Open and Pay television in Brazil and the United States. The table with all the results of the one-way ANOVA is presented in Appendix C. Therefore, the Television facility to transfer related and timely information helps make decisions to use resources productively and profitably (Ekbia and Evans, 2009). Farmers can get information easily by watching agriculture-related programs or advertisements on Television (Chhachhar et al., 2014, Murty and Abhinov, 2012).

Despite the relevance of mass media and interpersonal meetings, social media channels are increasingly important to Brazilian farmers. The Overall hybrid/variety selection decision had WhatsApp ($\rho S = 0.263$; $p < 0.05$) and Field days ($\rho S = 0.263$; $p < 0.05$) with the highest correlation coefficients in Brazil. Both communication channels had the highest association also with Overall crop planting rates and Pesticide selection (herbicides, insecticides, or fungicides).

The results suggests that in-person activities still have relevance for soybean farmers in Brazil, but social media, has been growing in importance to farmers. Note that LinkedIn showed up with the highest association with Variable seeding rate prescriptions ($\rho S = 0.209$; $p < 0.05$) and Irrigation ($\rho S = 0.220$; $p < 0.05$). The connections in these social media are essential to help farmers in several kinds of decision-making.

In the United States, the Website and blog had the highest correlation with Overall hybrid/variety selection decision ($\rho S = 0.286$; $p < 0.05$) and Overall crop planting rates ($\rho S = 0.316$; $p < 0.05$) decisions. The result reinforces other insights from our survey that showed a higher relevance from mass media in the United States than in Brazil. Mass media remains essential to the agriculture industry because many consumers still receive information about agriculture from sources such as newspapers and television (Haller, Specht, and Buck, 2019). Meanwhile, social media has been growing in importance to American farmers too.

4.8 Impacts of the COVID-19 Pandemic

The increasing digitalization of the agricultural sector has become even more indispensable in the past two years due to the COVID-19 pandemic. During this period, many digital tools supported on-farm production by providing online advice and facilitating access to inputs and machinery services. Therefore, could the pandemic thus accelerate a digital revolution in agriculture?

The results of the survey carried out in Brazil show that it can. Among the Brazilian farmers interviewed, 66% answered that the pandemic made them more willing to adopt digital technologies. Conversely, the results in the United States show the opposite. Among the American respondents, 73% answered that the pandemic did not make them more willing to adopt digital technologies.

This result can be associated with the higher adoption rate generally reported by respondents in the United States compared to Brazil. A producer who is already a heavy adopter tends to respond that the pandemic has not changed his behavior at all. Another hypothesis to try to understand this result is the higher average age among American farmers compared to Brazilian farmers interviewed. Although the effect of age on precision agriculture adoption is unclear, some studies have reported that older farmers are likely to be more risk-averse than younger farmers and less willing to innovate (Paustian and Theuvsen, 2017; Hasler et al., 2017; Kutter et al., 2009).

The timing of data collection also may have influenced the results in the two countries. For example, the data was collected in Brazil between March to June 2021. After the first wave in 2020, when the virus spread around the globe, the COVID-19 death toll in Brazil steadily rose in March 2021, reaching a peak in April 2021. This period was characterized by an upsurge in total cases, with a peak between February and June 2021 (Giovanetti, 2022). Moreover, many people were not covered with the vaccine's first and second shots. In the United States, data were collected from July 2021 to April 2022. In this period, the number of disease cases was controlled by the higher vaccination coverage coupled with natural immunity acquired following prior infections.

Therefore, at least regarding Brazil and based on our results, we can indicate that after COVID-19, agricultural digitalization will lead to a transformation in farming over the coming years. The result is consistent with another survey conducted in Brazil that indicated that the use of digital solutions among farmers increased during the pandemic, mainly to search for information related to field activities (Bolfe et al., 2020).

The pandemic crisis can push the digital revolution in the agricultural industry with tools and information to make the correct decision in time and improve yield productivity (Haggag, 2021). The advent of digitalization and the growth of digital marketing would allow customers to order and deliver any item to their doorstep (Sridhar et al., 2022). Digital advancement is increasingly present in rural areas and has become indispensable for work and personal relationships because of the SARS-CoV2 virus.

5. CONCLUSIONS AND IMPLICATIONS

This section summarizes the main results from this study, guided by general and specific objectives. In addition, we present the theoretical and practical contributions from the findings in Brazil and the United States. Finally, we discuss the study's limitations and further studies to complement our results.

5.1 Main Findings

This study analyzed relationships among communication channels and the precision and digital technologies most used by soybean farmers in Brazil and the United States. Our primary purpose was to measure the influence of each communication channel on farmers' decision-making regarding these technologies. Then, we revealed farmer respondents' perceptions of the most effective communication channels to influence the adoption of new technology in soybean production in the world's two largest producers and exporters of soybeans.

Based on the survey data of 461 soybean farmers in Brazil and 340 soybean farmers in the United States, we found differences and similarities in Brazilian and American producers' behavior regarding the adoption of technologies. The descriptive results showed a higher adoption level in the United States than in Brazil in seven of eight precision and digital technologies analyzed. This result is consistent with the length of time that these precision agriculture technologies have been available in each country. Regarding the influence of precision and digital technologies in making decisions and in perceiving benefits, the results in the United States and Brazil are relatively similar. Our results also suggest that farmers perceive substantial benefits from using technologies in soybean production in Brazil and the United States, especially regarding the potential for increases in efficiency and profitability.

Conversely, there is a noticeable difference in the overall influence attributed to social media between the Brazilian and United States respondents. For each channel for which respondents in both countries could respond, the level of influence reported in Brazil exceeded that reported among U.S. respondents. This result could be linked to the age groups interviewed in both countries, younger groups in Brazil than in the United States. In relation to the mass media group, the Website and blog category had the highest average in both the United States and Brazil. Based on a statistical comparison of means, there was a slight variation in survey results in the United States and Brazil regarding the interpersonal meeting groups.

We also report on the relationships between demographic characteristics and adoption of the precision agriculture technologies of interest in this study. Our analysis demonstrates that the higher average age among American farmers did not appear to be a significant factor in adopting digital technologies. The level education also did not appear to be a significant factor among farmers interviewed in the United States. On the other hand, the results in Brazil disclosed a difference among the ages and education level relative to technology adoption. In line with the literature, farm size appears to be a significant factor in adopting digital technologies in both countries.

The strength of association between the communication channels and the level of adoption of technologies showed variations and similarities between Brazil and the United States. LinkedIn had the highest positive correlation in Brazil with a strong relationship for seven precision and digital technologies among eight analyzed. Farmers who responded that LinkedIn influences decision-making tend to have the highest levels of on-farm technology adoption. In the United States, YouTube had the highest positive correlation with four of eight precision and digital technologies analyzed. Farmers typically use YouTube to seek information about agricultural innovations, upcoming technologies, and specialized skills.

The results regarding the relationship between communication channels and the perceived benefits of using technologies on-farm showed a higher association with mass media channels in the United States than in Brazil. Website and blog had the highest positive correlation with seven among eight perceived benefits of using technologies analyzed in the United States. Farmers can find information regarding machinery, seeds, chemicals, management, and innovations on this channel. In Brazil, Conferences had the highest positive correlation with six perceived benefits of using technologies on-farm among the eight analyzed in the study. The educational role played by these events can help to understand the result.

Lastly, one important finding concerns the link between making decisions and communication channels. This study showed a higher relevance for interpersonal meetings in Brazil than in the United States, yet interpersonal meetings are still important in a U.S. context. Indeed, interpersonal meetings had the highest means among all communication channels in both countries. The findings may suggest that adopters of established decisions regarding precision agriculture tend to prioritize in-person connections. In contrast, adopters of emergent technologies tend to prefer social media. In the United States, Website and Pay television stand out as the highest correlation coefficients. Despite the relevance of mass media, social media channels are increasingly important to American farmers.

5.2 Theoretical and Practical Contributions

The theoretical foundation for this study included aspects from both the diffusion of innovations (Rogers, 2003) and the UTAUT model (Venkatesh et al., 2003). While these theories speak to the adoption of technologies or other innovations, our study focused specifically on the role that communication channels play in the adoption. As such, the diffusion of innovation theory discusses this specifically, yet with little empirical support. Here, we show that the relative influence of a specific channel impacts decision making differently in two different national contexts. We also show that the influence of communication channel is impacted by various moderating factors as articulated in the UTAUT model. This points to several key research initiatives moving forward. For example, it is important to understand the role of social media in shaping the performance and effort expectancy dimensions as discussed within the UTAUT model. This would provide a richer explanation of how the various components of the model's impact decision making regarding digital precision agriculture.

The study findings present valuable information to understand how mass media, social media, and interpersonal meetings affect the decision to adopt digital technologies in soybean production in Brazil and the United States. The survey results offer essential insights into current farmers' behavior regarding adopting new technologies, helping analyze strategies for generating and disseminating information about digital technologies in agriculture. In addition, a better understanding of the role of communication around technologies continues to be necessary, especially because new agriculture technologies have become available, such as blockchain, traceability, robotics, artificial intelligence, etc.

The study contributes practically to increasing knowledge about the best use of communication channels and supports new research in agricultural communication, an area still lacking data in the United States and Brazil. The survey results could help inform the go-to-market strategies of input and machinery suppliers, trading companies, financial institutions, and technology providers, among others. Realizing the full potential of digital farming will require collaboration of all players in the agricultural value chain.

Findings reinforce that superior knowledge and information are decisive in the process of adopting technologies in agriculture. Therefore, our results suggested that agricultural companies, farmers, policymakers, and stakeholders focus on the vital role of communication in disseminating new technologies. Superior knowledge based on information is the first step toward spreading all-new technology in agriculture. If information about a new product does not reach the farmer clearly and accurately, it is less likely to be adopted.

5.3 Limitations and Further Studies

Several limitations of the study should be noted. It is crucial to remember that results are contingent upon our sample, representing 461 soybean farmers in Brazil's top five soybean-producing states and 340 in the United States' top nine soybean-producing states. Therefore, caution should be exercised when extrapolating or generalizing the results presented here to all soybean farmers in these countries. Another limitation is data collection, which was carried out entirely online due to the pandemic period. So, the results may have a bias influenced by the profile of online respondents, who are usually more adept at innovations.

In addition, our study identified communication channel categories in general terms, such as magazines and newspapers. However, the results could be different if we included agricultural-specific magazines, newspapers, and radio. Also, many media providers have offerings that cut across channels – a magazine (or its brand), has a website with blogs, and is active in one or more social media channels, besides realizing public events. Therefore, the use of mass media, social media, and interpersonal meetings should reflect complementarity in consumption. The underlying motive that drives the individual to seek out content information in mass media also goes toward the consumption of social media or interpersonal meetings in the same content domain.

The presented study did not analyze the difference between heavy and light users of technologies. Future research could fill this gap by providing insights on how their communication channels differ from those with the same demographics profile but differ in extent of use. Moreover, the study did not evaluate the causal relationship between the use of technologies and the level of influence of communication channels. Further research could expand to a deeper analysis of soybean farmers' behavior regarding technology adoption and the influence of communication channels.

Finally, the study should be repeated in agricultural developing countries, such as South Africa, Nigeria, and Zambia – the top three soybean producers on the African continent. The behavior of the individual actors may differ, which is essential to enable agribusiness managers to be more effective in the evaluation and potential adoption of precision technologies in these regions – where an increase of technology adoption likely could materially advance agricultural development.

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APPENDIX A

Influência dos canais de comunicação na adoção de tecnologias digitais na agricultura

Introdução

Pesquisadores da Universidade Federal do Rio Grande do Sul (Brasil) e da Universidade de Illinois (EUA) estão desenvolvendo uma pesquisa multidisciplinar para analisar o papel da comunicação na adoção de tecnologias digitais na agricultura brasileira e americana. O estudo conta com o apoio oficial da Associação Brasileira dos Produtores de Soja (Aprosoja Brasil), da Companhia Nacional de Abastecimento (Conab), da Federação da Agricultura e Pecuária de Mato Grosso (Famato) e do Sistema Ocepar.

Objetivos

Mensurar o impacto de diferentes canais de comunicação – veículos de massa, mídia social e relações interpessoais – na tomada de decisão sobre a adoção de novas tecnologias no campo. Esta pesquisa é focada em produtores de soja dos cinco principais Estados no Brasil: MT, PR, RS, GO e MS. Os resultados subsidiarão novas pesquisas e contribuirão para o aumento do conhecimento sobre os canais de comunicação mais eficientes para disseminar tecnologias digitais na agricultura.

Privacidade e Informação

Sua privacidade será respeitada e seus dados mantidos de forma confidencial. Não haverá despesas pessoais ou compensações financeiras para a sua participação. No final do questionário você poderá incluir o seu endereço de email para receber os resultados da pesquisa. Para mais informações, por favor contate jcolussi@illinois.edu ou antonio.padula@ufrgs.br.

Tempo estimado

Cinco a sete minutos para ler e responder todas as questões.

Q1 **Bloco 1 - Uso de Tecnologias Digitais**

1. Indique o grau de utilização das **tecnologias de precisão e digital** que você usa em sua fazenda. Utilize a escala variando de 1 até 5, sendo 1 = Nunca utilizo até 5 = Utilizo sempre.

	1	2	3	4	5
Piloto automático guiado por GPS	○	○	○	○	○
Mapeamento de produtividade	○	○	○	○	○
Imagens de satélite/drones	○	○	○	○	○
Mapeamento de condutividade elétrica do solo	○	○	○	○	○
Redes de sensores com ou sem fio	○	○	○	○	○
Registros eletrônicos / mapeamento para rastreabilidade	○	○	○	○	○
Sistemas de pulverização localizada	○	○	○	○	○
Sistemas de telemetria das operações	○	○	○	○	○

Q2 **2**. Indique o grau de influência do uso de ferramentas de tecnologia digital e de precisão em sua fazenda na **tomada das seguintes decisões**. Utilize a escala variando de 1 até 5, sendo 1 = Sem influência até 5 = Extremamente influente.

	1	2	3	4	5
Decisões de aplicação de fertilizantes (NPK) e corretivos de solo	○	○	○	○	○
Seleção de variedades e híbridos	○	○	○	○	○
Escolha da populacao média de plantas	○	○	○	○	○
Semeadura em taxa variável	○	○	○	○	○
Escolha da data de semeadura	○	○	○	○	○
Seleção de agroquímicos (herbicidas, inseticidas ou fungicidas)	○	○	○	○	○
Rotação de culturas	○	○	○	○	○
Uso de irrigação	○	○	○	○	○

Q3 **3**. Indique o grau de influência do uso de tecnologias digitais em sua fazenda nos **seguintes benefícios**. Utilize a escala variando de 1 até 5, sendo 1 = Sem influência até 5 = Extremamente influente.

	1	2	3	4	5
Aumento da produtividade	○	○	○	○	○
Redução de custos	○	○	○	○	○
Compra de insumos agrícolas	○	○	○	○	○
Comercialização da produção	○	○	○	○	○
Economia de tempo (arquivos de papel para o digital)	○	○	○	○	○
Eficiências de trabalho	○	○	○	○	○
Menor impacto ambiental	○	○	○	○	○
Piloto automático (menos cansaço/stress)	○	○	○	○	○

Q4 **4**. Indique o grau de utilização desses **softwares de suporte** para tomar decisões em sua fazenda. Utilize a escala variando de 1 até 5, sendo 1 = Nunca utilizo até 5 = Utilizo sempre.

	1	2	3	4	5
Fieldview (Climate/Bayer)	○	○	○	○	○
Xarvio (Basf)	○	○	○	○	○
Strider (Syngenta)	○	○	○	○	○
Farmers Edge	○	○	○	○	○
Aegro	○	○	○	○	○
Agrosmart	○	○	○	○	○
Solinftec	○	○	○	○	○
Outro. Qual?	○	○	○	○	○

Q5 Bloco 2 - Influência dos Canais de Comunicação

5 - Indique o grau de influência de **veículos de massa** na decisão de adotar uma nova tecnologia digital na sua lavoura. Utilize a escala variando de 1 até 5, sendo 1 = Sem influência até 5 = Extremamente influente.

	1	2	3	4	5
Jornal impresso	○	○	○	○	○
Revistas	○	○	○	○	○
Rádio	○	○	○	○	○
Televisão aberta	○	○	○	○	○
Televisão por assinatura	○	○	○	○	○
Websites e blogs	○	○	○	○	○

Q6 **6** - Indique o grau de influência de **redes sociais** na decisão de adotar uma nova tecnologia digital na sua lavoura. Utilize a escala variando de 1 até 5, sendo 1 = Sem influência até 5 = Extremamente influente.

	1	2	3	4	5
WhatsApp	○	○	○	○	○
Facebook	○	○	○	○	○
Youtube	○	○	○	○	○
Instagram	○	○	○	○	○
Messenger	○	○	○	○	○
LinkedIn	○	○	○	○	○

Q7 **7** - Indique o grau de influência de **relações interpessoais** na decisão de adotar uma nova tecnologia digital na sua lavoura. Utilize a escala variando de 1 até 5, sendo 1 = Sem influência até 5 = Extremamente influente.

	1	2	3	4	5
Dias de campo	○	○	○	○	○
Discussões em eventos (conferências, fóruns e seminários)	○	○	○	○	○
Extensionistas técnicos	○	○	○	○	○
Representantes de empresas	○	○	○	○	○
Grupos formais e informais	○	○	○	○	○
Troca de informações com vizinhos	○	○	○	○	○

Q8 **8**. A pandemia de **coronavírus**, e consequente necessidade de distanciamento social, tornou você mais disposto a adotar tecnologias digitais na agricultura?

○ Sim

○ Não

Q9 **Bloco 3 - Perfil Demográfico**

9. Em quais desses **Estados brasileiros** você cultiva soja?
(Por favor escolha todas as opções que se aplicam)

- ☐ Mato Grosso
- ☐ Paraná
- ☐ Rio Grande do Sul
- ☐ Goiás
- ☐ Mato Grosso do Sul

Q10 **10**. Quantos **hectares** de soja você cultiva? (Por favor escolha apenas uma das opções)

- ○ De 0 a 100 hectares
- ○ De 100 hectares a 500 hectares
- ○ De 501 hectares a 2.000 hectares
- ○ De 2.001 hectares a 10.000 hectares
- ○ Mais de 10.000 hectares

Q11 **11**. Qual é a sua **faixa etária**?
(Por favor escolha apenas uma das opções)

- ◯ Até 24 anos
- ◯ De 25 a 40 anos
- ◯ De 41 a 55 anos
- ◯ De 56 a 70 anos
- ◯ Mais de 70 anos

Q12 **12**. Qual é a sua **escolaridade**?

- ◯ Ensino Fundamental incompleto (antigo 1° grau)
- ◯ Ensino Fundamental completo (antigo 1° grau)
- ◯ Ensino Médio incompleto (antigo 2° grau)
- ◯ Ensino Médio completo (antigo 2° grau)
- ◯ Ensino Superior incompleto
- ◯ Ensino Superior completo
- ◯ Pós-graduação (MBA, mestrado ou doutorado)

Q13 **13**. Você é vinculado a alguma **cooperativa agropecuária** que presta suporte técnico?

- ◯ Sim
- ◯ Não

MAIL **Você deseja receber os resultados da pesquisa por e-mail?**

- ◯ Sim. Qual email? ____
- ◯ Não

APPENDIX B

Influence of communication channels on the adoption of technologies in agriculture

ILLINOIS
College of Agricultural, Consumer & Environmental Sciences

Introduction
A team of economists from the College of Agricultural, Consumer and Environmental Sciences (ACES) of the University of Illinois at Urbana-Champaign are analyzing the role of communication in the decision to adopt digital technologies in agriculture in the Midwest. This research is supported by Farmdoc. **We need your help**.

Research objective
We intend to measure the impact of each communication channel – mass media, social media, and interpersonal meetings – on farmers' decision-making to adopt a new digital technology. This survey is focused on soybean producers in these states: Illinois, Iowa, Minnesota, Indiana, Nebraska, Missouri, Ohio, South Dakota, and North Dakota. The results will support new research and contribute in a practical way to increase knowledge about the most efficient communication channels for the dissemination of digital agriculture technologies.

Privacy and Information Your privacy will be respected and your data kept confidential. There will be no personal expenses or financial compensation for participation. At the end of the questionnaire, you can include your email address to receive the survey results. For more information, please email jcolussi@illinois.edu or schnitke@illinois.edu.

To complete survey
Five to eight minutes.

Q1 **Block A – Use of Digital Technologies**

1. Indicate the level of the use of these **precision and digital technologies tools** on your farm. Consider the scale of 5 points, from 1 = Never use to 5 = Always use.

	1	2	3	4	5
Guidance/Autosteer	○	○	○	○	○
Yield monitors	○	○	○	○	○
Satellite/drone imagery	○	○	○	○	○
Soil electrical conductivity mapping	○	○	○	○	○
Wired or wireless sensor networks	○	○	○	○	○
Electronic records/mapping for traceability	○	○	○	○	○
Sprayer control systems	○	○	○	○	○
Automatic rate control telematics	○	○	○	○	○

Q2 **2**. Indicate the level of influence of the use of digital technology and precision tools on your farm in **making the following decisions**. Consider the scale of 5 points, from 1 = Not at all influential to 5 = Extremely influential.

	1	2	]3	4	5
Nitrogen, phosphorus, potassium (NPK) and liming decisions	○	○	○	○	○
Overall hybrid/variety selection	○	○	○	○	○
Overall crop planting rates	○	○	○	○	○
Variable hybrid or variety placement	○	○	○	○	○
Variable seeding rate prescriptions	○	○	○	○	○
Pesticide selection (herbicides, insecticides or fungicides)	○	○	○	○	○
Cropping sequence/rotation decisions	○	○	○	○	○
Irrigation decisions	○	○	○	○	○

Q3 **3**. Indicate the level of influence of using precision and digital tools on your farm in the **following benefits**. Consider the scale of 5 points, from 1 = Not at all influential to 5 = Extremely influential.

	1	2	3	4	5
Increased crop productivity/yields	○	○	○	○	○
Cost reductions	○	○	○	○	○
Purchase of inputs	○	○	○	○	○
Marketing choices	○	○	○	○	○
Time savings (paper filing to digital)	○	○	○	○	○
Lower environmental impact	○	○	○	○	○
Labor efficiencies	○	○	○	○	○
Autosteer (less fatigue/stress)	○	○	○	○	○

Q4 **4**. Indicate the level of the use of these **support technologies** to make decisions on your farm. Consider the scale of 5 points, from 1 = Never use to 5 = Always use.

	1	2	3	4	5
Agrible (supply chain)	○	○	○	○	○
Encirca (analytics)	○	○	○	○	○
Farmer's Business Network (analytics)	○	○	○	○	○
Farmlogs (management system)	○	○	○	○	○
Fieldview (management system)	○	○	○	○	○
Granular (management system)	○	○	○	○	○
Other. Which?	○	○	○	○	○

Q5 **Block B - Influence of Communication Channels**

5. Indicate the level of influence of these **mass media** in your decision to adopt a new digital technology on your farm. Consider the scale of 5 points, from 1 = Not at all influential to 5 = Extremely influential.

	1	2	3	4	5
Newspaper	○	○	○	○	○
Magazines	○	○	○	○	○
Radio	○	○	○	○	○
Television	○	○	○	○	○
Websites and blogs	○	○	○	○	○
Pay television	○	○	○	○	○

Q6 **6.** Indicate the level of influence of these **social media** in your decision-making to adopt a new digital technology on your farm. Consider the scale of 5 points, from 1 = Not at all influential to 5 = Extremely influential.

	1	2	3	4	5
YouTube	○	○	○	○	○
Facebook	○	○	○	○	○
Pinterest	○	○	○	○	○
Instagram	○	○	○	○	○
Twitter	○	○	○	○	○
Snapchat	○	○	○	○	○
LinkedIn	○	○	○	○	○

Q7 **7**. Indicate the level of influence of these **interpersonal meetings** in your decision-making to adopt a new digital technology on your farm. Consider the scale of 5 points, from 1 = Not at all influential to 5 = Extremely influential.

	1	2	3	4	5
Field Days	○	○	○	○	○
Conferences, forums and seminars	○	○	○	○	○
Retailers and extension agents	○	○	○	○	○
Peer groups (formal or informal)	○	○	○	○	○
Conversation with neighbors	○	○	○	○	○

Q8 **8**. Has the **coronavirus pandemic** made you more willing to adopt digital technologies in agriculture?

- ☐ Yes
- ☐ No

Q9 **Block C – Demographic Information**

9. Which of the following **state(s)** do you farm in?
(Please choose all that apply)

- ☐ Illinois
- ☐ Iowa
- ☐ Minnesota
- ☐ Indiana
- ☐ Nebraska
- ☐ Missouri
- ☐ Ohio
- ☐ South Dakota
- ☐ North Dakota

Q10 **10**. How many **acres** do you farm?
(Please choose only one of the following options)

- ☐ From 0 to 100 acres
- ☐ From 101 acres to 500 acres
- ☐ From 501 to 1.000 acres
- ☐ From 1.001 acres to 5.000 acres
- ☐ More than 5.000 acres

Q11 **11**. What is your **age group**?
(Please choose only one of the following options)

- ☐ Under 25 years
- ☐ 25-40 years
- ☐ 41-55 years
- ☐ 56-70 years
- ☐ More than 70 years

Q12 **12**. What is the highest **level of education** you have completed?
(Please choose only one of the following options)

- ☐ Less than a high school diploma
- ☐ High school diploma
- ☐ Some college (no degree) or Associate's degree
- ☐ Bachelor's degree
- ☐ Postgraduate degree (MBA, masters or doctoral)

Q13 **13**. Are you a member of any **cooperative** that offers technical support?

- ○ Yes
- ○ No

EMAIL Would you like to receive the survey results by email? Yes. Which email:

____

Realization: UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN   Support: farmdoc

APPENDIX C

Age groups and use of technologies in **Brazil**, using one-way ANOVA

Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Under 41 years	199	3.72	1.382	.098	3.53	3.91	1	5
From 41 to 55 years	163	3.68	1.422	.111	3.46	3.90	1	5
More than 56 years	99	3.06	1.713	.172	2.72	3.40	1	5
Total	461	3.56	1.493	.070	3.43	3.70	1	5
Under 41 years	199	2.94	1.510	.107	2.73	3.15	1	5
From 41 to 55 years	163	3.05	1.435	.112	2.83	3.27	1	5
More than 56 years	99	2.67	1.512	.152	2.37	2.97	1	5
Total	461	2.92	1.488	.069	2.78	3.06	1	5
Under 41 years	199	3.05	1.228	.087	2.87	3.22	1	5
From 41 to 55 years	163	3.15	1.283	.100	2.95	3.35	1	5
More than 56 years	99	2.61	1.384	.139	2.33	2.88	1	5
Total	461	2.99	1.295	.060	2.87	3.11	1	5
Under 41 years	199	1.49	.974	.069	1.36	1.63	1	5
From 41 to 55 years	163	1.57	1.122	.088	1.40	1.74	1	5
More than 56 years	99	1.40	.844	.085	1.24	1.57	1	5
Total	461	1.50	1.004	.047	1.41	1.59	1	5
Under 41 years	199	2.29	1.405	.100	2.09	2.48	1	5
From 41 to 55 years	163	2.07	1.443	.113	1.85	2.30	1	5
More than 56 years	99	1.77	1.211	.122	1.53	2.01	1	5
Total	461	2.10	1.391	.065	1.97	2.23	1	5
Under 41 years	199	2.22	1.370	.097	2.02	2.41	1	5
From 41 to 55 years	163	2.18	1.333	.104	1.97	2.38	1	5
More than 56 years	99	1.70	1.147	.115	1.47	1.93	1	5
Total	461	2.09	1.325	.062	1.97	2.21	1	5
Under 41 years	199	1.95	1.388	.098	1.76	2.14	1	5
From 41 to 55 years	163	2.01	1.419	.111	1.79	2.23	1	5
More than 56 years	99	1.97	1.388	.140	1.69	2.25	1	5
Total	461	1.98	1.396	.065	1.85	2.10	1	5
Under 41 years	199	2.14	1.389	.098	1.95	2.33	1	5
From 41 to 55 years	163	2.20	1.397	.109	1.99	2.42	1	5
More than 56 years	99	1.89	1.316	.132	1.63	2.15	1	5
Total	461	2.11	1.379	.064	1.98	2.23	1	5

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.074	2	16.037	7.394	.001
Within Groups	993.289	458	2.169		
Total	1025.362	460			
Between Groups	9.147	2	4.573	2.076	.127
Within Groups	1008.884	458	2.203		
Total	1018.030	460			
Between Groups	19.226	2	9.613	5.849	.003
Within Groups	752.696	458	1.643		
Total	771.922	460			
Between Groups	1.734	2	.867	.860	.424
Within Groups	461.516	458	1.008		
Total	463.249	460			
Between Groups	17.963	2	8.982	4.720	.009
Within Groups	871.446	458	1.903		
Total	889.410	460			
Between Groups	19.715	2	9.858	5.726	.003
Within Groups	788.458	458	1.722		
Total	808.174	460			
Between Groups	.355	2	.178	.091	.913
Within Groups	896.382	458	1.957		
Total	896.738	460			
Between Groups	6.420	2	3.210	1.693	.185
Within Groups	868.157	458	1.896		
Total	874.577	460			

Age groups and use of technologies in the **United States**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Guidance/Autosteer	Under 41 years	58	4.45	.841	.110	4.23	4.67	1	5
	From 41 to 55 years	74	4.24	1.108	.129	3.99	4.50	1	5
	More than 56 years	207	4.15	1.201	.083	3.99	4.32	1	5
	Total	339	4.22	1.129	.061	4.10	4.34	1	5
Yield monitors	Under 41 years	58	4.47	.995	.131	4.20	4.73	1	5
	From 41 to 55 years	74	4.30	1.258	.146	4.01	4.59	1	5
	More than 56 years	207	4.27	1.267	.088	4.10	4.44	1	5
	Total	339	4.31	1.222	.066	4.18	4.44	1	5
Satellite/drone imagery	Under 41 years	58	3.03	1.169	.154	2.73	3.34	1	5
	From 41 to 55 years	74	2.88	1.249	.145	2.59	3.17	1	5
	More than 56 years	207	2.95	1.269	.088	2.78	3.13	1	5
	Total	339	2.95	1.245	.068	2.82	3.08	1	5
Soil electrical conductivity mapping	Under 41 years	58	1.88	1.141	.150	1.58	2.18	1	5
	From 41 to 55 years	74	1.91	1.229	.143	1.62	2.19	1	5
	More than 56 years	207	1.76	1.233	.086	1.59	1.93	1	5
	Total	339	1.81	1.215	.066	1.68	1.94	1	5
Wired or wireless sensor networks	Under 41 years	58	2.34	1.371	.180	1.98	2.71	1	5
	From 41 to 55 years	74	2.38	1.440	.167	2.04	2.71	1	5
	More than 56 years	207	2.37	1.492	.104	2.17	2.58	1	5
	Total	339	2.37	1.456	.079	2.21	2.52	1	5
Electronic records/mapping for traceability	Under 41 years	58	3.59	1.298	.170	3.24	3.93	1	5
	From 41 to 55 years	74	3.24	1.569	.182	2.88	3.61	1	5
	More than 56 years	207	3.16	1.623	.113	2.94	3.39	1	5
	Total	339	3.25	1.563	.085	3.09	3.42	1	5
Sprayer control systems	Under 41 years	58	4.00	1.228	.161	3.68	4.32	1	5
	From 41 to 55 years	74	3.92	1.422	.165	3.59	4.25	1	5
	More than 56 years	207	3.91	1.528	.106	3.70	4.12	1	5
	Total	339	3.93	1.455	.079	3.77	4.08	1	5
Automatic rate control telematics	Under 41 years	58	3.28	1.461	.192	2.89	3.66	1	5
	From 41 to 55 years	74	3.51	1.492	.173	3.17	3.86	1	5
	More than 56 years	207	3.34	1.652	.115	3.11	3.56	1	5
	Total	339	3.37	1.585	.086	3.20	3.54	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Guidance/Autosteer	Between Groups	3.942	2	1.971	1.551	.214
	Within Groups	427.020	336	1.271		
	Total	430.962	338			
Yield monitors	Between Groups	1.737	2	.869	.580	.560
	Within Groups	502.741	336	1.496		
	Total	504.478	338			
Satellite/drone imagery	Between Groups	.794	2	.397	.255	.775
	Within Groups	523.353	336	1.558		
	Total	524.147	338			
Soil electrical conductivity mapping	Between Groups	1.398	2	.699	.472	.624
	Within Groups	497.894	336	1.482		
	Total	499.292	338			
Wired or wireless sensor networks	Between Groups	.042	2	.021	.010	.990
	Within Groups	716.866	336	2.134		
	Total	716.909	338			
Electronic records/mapping for traceability	Between Groups	8.077	2	4.038	1.659	.192
	Within Groups	818.106	336	2.435		
	Total	826.183	338			
Sprayer control systems	Between Groups	.387	2	.193	.091	.913
	Within Groups	714.770	336	2.127		
	Total	715.156	338			
Automatic rate control telematics	Between Groups	2.242	2	1.121	.445	.641
	Within Groups	846.401	336	2.519		
	Total	848.643	338			

Level of education and use of technologies in **Brazil**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Guidance/Autosteer	Less than a bachelor's degree	116	3.50	1.552	.144	3.21	3.79	1	5
	Bachelor's degree	183	3.49	1.493	.110	3.27	3.71	1	5
	Postgraduate (MBA, master or doctoral)	162	3.69	1.450	.114	3.47	3.92	1	5
	Total	461	3.56	1.493	.070	3.43	3.70	1	5
Yield monitors	Less than a bachelor's degree	116	2.73	1.453	.135	2.47	3.00	1	5
	Bachelor's degree	183	2.86	1.548	.114	2.63	3.08	1	5
	Postgraduate (MBA, master or doctoral)	162	3.12	1.426	.112	2.90	3.34	1	5
	Total	461	2.92	1.488	.069	2.78	3.06	1	5
Satellite/drone imagery	Less than a bachelor's degree	116	2.74	1.333	.124	2.50	2.99	1	5
	Bachelor's degree	183	2.92	1.229	.091	2.74	3.10	1	5
	Postgraduate (MBA, master or doctoral)	162	3.23	1.307	.103	3.03	3.44	1	5
	Total	461	2.99	1.295	.060	2.87	3.11	1	5
Soil electrical conductivity mapping	Less than a bachelor's degree	116	1.43	.867	.081	1.27	1.59	1	5
	Bachelor's degree	183	1.43	.910	.067	1.29	1.56	1	5
	Postgraduate (MBA, master or doctoral)	162	1.64	1.173	.092	1.45	1.82	1	5
	Total	461	1.50	1.004	.047	1.41	1.59	1	5
Wired or wireless sensor networks	Less than a bachelor's degree	116	2.02	1.396	.130	1.76	2.27	1	5
	Bachelor's degree	183	2.07	1.343	.099	1.88	2.27	1	5
	Postgraduate (MBA, master or doctoral)	162	2.19	1.443	.113	1.97	2.42	1	5
	Total	461	2.10	1.391	.065	1.97	2.23	1	5
Electronic records/mapping for traceability	Less than a bachelor's degree	116	1.95	1.278	.119	1.71	2.18	1	5
	Bachelor's degree	183	1.96	1.257	.093	1.77	2.14	1	5
	Postgraduate (MBA, master or doctoral)	162	2.35	1.402	.110	2.13	2.56	1	5
	Total	461	2.09	1.325	.062	1.97	2.21	1	5
Sprayer control systems	Less than a bachelor's degree	116	1.98	1.432	.133	1.72	2.25	1	5
	Bachelor's degree	183	1.89	1.335	.099	1.69	2.08	1	5
	Postgraduate (MBA, master or doctoral)	162	2.07	1.438	.113	1.85	2.30	1	5
	Total	461	1.98	1.396	.065	1.85	2.10	1	5
Automatic rate control telematics	Less than a bachelor's degree	116	2.04	1.392	.129	1.79	2.30	1	5
	Bachelor's degree	183	1.98	1.288	.095	1.79	2.17	1	5
	Postgraduate (MBA, master or doctoral)	162	2.30	1.454	.114	2.08	2.53	1	5
	Total	461	2.11	1.379	.064	1.98	2.23	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Guidance/Autosteer	Between Groups	4.057	2	2.028	.910	.403
	Within Groups	1021.306	458	2.230		
	Total	1025.362	460			
Yield monitors	Between Groups	11.478	2	5.739	2.611	.075
	Within Groups	1006.552	458	2.198		
	Total	1018.030	460			
Satellite/drone imagery	Between Groups	17.665	2	8.833	5.363	.005
	Within Groups	754.257	458	1.647		
	Total	771.922	460			
Soil electrical conductivity mapping	Between Groups	4.535	2	2.267	2.264	.105
	Within Groups	458.715	458	1.002		
	Total	463.249	460			
Wired or wireless sensor networks	Between Groups	2.300	2	1.150	.594	.553
	Within Groups	887.110	458	1.937		
	Total	889.410	460			
Electronic records/mapping for traceability	Between Groups	16.192	2	8.096	4.682	.010
	Within Groups	791.982	458	1.729		
	Total	808.174	460			
Sprayer control systems	Between Groups	3.071	2	1.535	.787	.456
	Within Groups	893.667	458	1.951		
	Total	896.738	460			
Automatic rate control telematics	Between Groups	9.701	2	4.850	2.569	.078
	Within Groups	864.876	458	1.888		
	Total	874.577	460			

Level of education and use of technologies in the **United States**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Guidance/Autosteer	High school diploma	25	3.88	1.333	.267	3.33	4.43	1	5
	Some College or Associate degree	76	4.26	1.075	.123	4.02	4.51	1	5
	Bachelors Degree	181	4.23	1.178	.088	4.05	4.40	1	5
	Postgraduate	58	4.33	.925	.121	4.08	4.57	1	5
	Total	340	4.23	1.128	.061	4.11	4.35	1	5
Yield monitors	High school diploma	25	4.00	1.528	.306	3.37	4.63	1	5
	Some College or Associate degree	76	4.17	1.399	.160	3.85	4.49	1	5
	Bachelors Degree	181	4.37	1.170	.087	4.20	4.54	1	5
	Postgraduate	58	4.41	.956	.125	4.16	4.67	1	5
	Total	340	4.31	1.222	.066	4.18	4.44	1	5
Satellite/drone imagery	High school diploma	25	2.52	1.358	.272	1.96	3.08	1	5
	Some College or Associate degree	76	2.67	1.290	.148	2.38	2.97	1	5
	Bachelors Degree	181	3.07	1.202	.089	2.90	3.25	1	5
	Postgraduate	58	3.09	1.218	.160	2.77	3.41	1	5
	Total	340	2.94	1.248	.068	2.81	3.08	1	5
Soil electrical conductivity mapping	High school diploma	25	1.84	1.248	.250	1.32	2.36	1	5
	Some College or Associate degree	76	1.88	1.346	.154	1.57	2.19	1	5
	Bachelors Degree	181	1.69	1.067	.079	1.53	1.84	1	5
	Postgraduate	58	2.10	1.410	.185	1.73	2.47	1	5
	Total	340	1.81	1.214	.066	1.68	1.94	1	5
Wired or wireless sensor networks	High school diploma	25	2.08	1.441	.288	1.49	2.67	1	5
	Some College or Associate degree	76	2.46	1.553	.178	2.11	2.82	1	5
	Bachelors Degree	181	2.36	1.434	.107	2.15	2.57	1	5
	Postgraduate	58	2.36	1.423	.187	1.99	2.74	1	5
	Total	340	2.36	1.456	.079	2.21	2.52	1	5
Electronic records/mapping for traceability	High school diploma	25	3.28	1.882	.376	2.50	4.06	1	5
	Some College or Associate degree	76	2.93	1.561	.179	2.58	3.29	1	5
	Bachelors Degree	181	3.43	1.539	.114	3.21	3.66	1	5
	Postgraduate	58	3.12	1.440	.189	2.74	3.50	1	5
	Total	340	3.26	1.562	.085	3.09	3.42	1	5
Sprayer control systems	High school diploma	25	4.12	1.563	.313	3.47	4.77	1	5
	Some College or Associate degree	76	3.70	1.721	.197	3.30	4.09	1	5
	Bachelors Degree	181	4.04	1.328	.099	3.85	4.24	1	5
	Postgraduate	58	3.79	1.386	.182	3.43	4.16	1	5
	Total	340	3.93	1.454	.079	3.77	4.08	1	5
Automatic rate control telematics	High school diploma	25	3.28	1.768	.354	2.55	4.01	1	5
	Some College or Associate degree	76	3.11	1.725	.198	2.71	3.50	1	5
	Bachelors Degree	181	3.57	1.521	.113	3.35	3.80	1	5
	Postgraduate	58	3.05	1.456	.191	2.67	3.43	1	5
	Total	340	3.36	1.587	.086	3.19	3.53	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Guidance/Autosteer	Between Groups	3.696	3	1.232	.968	.408
	Within Groups	427.865	336	1.273		
	Total	431.562	339			
Yield monitors	Between Groups	5.144	3	1.715	1.150	.329
	Within Groups	501.044	336	1.491		
	Total	506.188	339			
Satellite/drone imagery	Between Groups	14.287	3	4.762	3.115	.056
	Within Groups	513.652	336	1.529		
	Total	527.938	339			
Soil electrical conductivity mapping	Between Groups	8.230	3	2.743	1.874	.134
	Within Groups	491.723	336	1.463		
	Total	499.953	339			
Wired or wireless sensor networks	Between Groups	2.725	3	.908	.426	.734
	Within Groups	716.052	336	2.131		
	Total	718.776	339			
Electronic records/mapping for traceability	Between Groups	14.485	3	4.828	1.997	.114
	Within Groups	812.253	336	2.417		
	Total	826.738	339			
Sprayer control systems	Between Groups	8.463	3	2.821	1.339	.262
	Within Groups	707.843	336	2.107		
	Total	716.306	339			
Automatic rate control telematics	Between Groups	18.938	3	6.313	2.539	.056
	Within Groups	835.286	336	2.486		
	Total	854.224	339			

Farm size and use of technologies in **Brazil**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Guidance/Autosteer	Less than 100 hectares	117	2.56	1.567	.145	2.28	2.85	1	5
	From 101 to 500 hectares	118	3.18	1.523	.140	2.90	3.46	1	5
	From 501 hectares to 2,000 hectares	135	4.19	1.033	.089	4.02	4.37	1	5
	More than 2,000 hectares	91	4.42	.895	.094	4.23	4.60	1	5
	Total	461	3.56	1.493	.070	3.43	3.70	1	5
Yield monitors	Less than 100 hectares	117	2.40	1.427	.132	2.14	2.66	1	5
	From 101 to 500 hectares	118	2.42	1.416	.130	2.16	2.67	1	5
	From 501 hectares to 2,000 hectares	135	3.36	1.412	.122	3.12	3.60	1	5
	More than 2,000 hectares	91	3.58	1.300	.136	3.31	3.85	1	5
	Total	461	2.92	1.488	.069	2.78	3.06	1	5
Satellite/drone imagery	Less than 100 hectares	117	2.56	1.296	.120	2.32	2.79	1	5
	From 101 to 500 hectares	118	2.79	1.313	.121	2.55	3.03	1	5
	From 501 hectares to 2,000 hectares	135	3.16	1.227	.106	2.95	3.36	1	5
	More than 2,000 hectares	91	3.55	1.128	.118	3.31	3.78	1	5
	Total	461	2.99	1.295	.060	2.87	3.11	1	5
Soil electrical conductivity mapping	Less than 100 hectares	117	1.44	.923	.085	1.28	1.61	1	5
	From 101 to 500 hectares	118	1.25	.776	.071	1.11	1.40	1	5
	From 501 hectares to 2,000 hectares	135	1.67	1.112	.096	1.48	1.86	1	5
	More than 2,000 hectares	91	1.64	1.131	.119	1.40	1.87	1	5
	Total	461	1.50	1.004	.047	1.41	1.59	1	5
Wired or wireless sensor networks	Less than 100 hectares	117	1.76	1.229	.114	1.54	1.99	1	5
	From 101 to 500 hectares	118	1.95	1.267	.117	1.72	2.18	1	5
	From 501 hectares to 2,000 hectares	135	2.15	1.406	.121	1.91	2.39	1	5
	More than 2,000 hectares	91	2.66	1.551	.163	2.34	2.98	1	5
	Total	461	2.10	1.391	.065	1.97	2.23	1	5
Electronic records/mapping for traceability	Less than 100 hectares	117	1.79	1.121	.104	1.58	1.99	1	5
	From 101 to 500 hectares	118	1.80	1.106	.102	1.59	2.00	1	5
	From 501 hectares to 2,000 hectares	135	2.19	1.394	.120	1.95	2.42	1	5
	More than 2,000 hectares	91	2.73	1.491	.156	2.41	3.04	1	5
	Total	461	2.09	1.325	.062	1.97	2.21	1	5
Sprayer control systems	Less than 100 hectares	117	1.81	1.238	.114	1.59	2.04	1	5
	From 101 to 500 hectares	118	1.87	1.330	.122	1.63	2.12	1	5
	From 501 hectares to 2,000 hectares	135	2.05	1.478	.127	1.80	2.30	1	5
	More than 2,000 hectares	91	2.21	1.524	.160	1.89	2.53	1	5
	Total	461	1.98	1.396	.065	1.85	2.10	1	5
Automatic rate control telematics	Less than 100 hectares	117	1.72	1.195	.110	1.50	1.94	1	5
	From 101 to 500 hectares	118	1.78	1.192	.110	1.56	2.00	1	5
	From 501 hectares to 2,000 hectares	135	2.30	1.367	.118	2.07	2.54	1	5
	More than 2,000 hectares	91	2.75	1.561	.164	2.42	3.07	1	5
	Total	461	2.11	1.379	.064	1.98	2.23	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Guidance/Autosteer	Between Groups	254.206	3	84.735	50.216	.000
	Within Groups	771.156	457	1.687		
	Total	1025.362	460			
Yield monitors	Between Groups	127.911	3	42.637	21.891	.000
	Within Groups	890.119	457	1.948		
	Total	1018.030	460			
Satellite/drone imagery	Between Groups	59.069	3	19.690	12.623	.000
	Within Groups	712.853	457	1.560		
	Total	771.922	460			
Soil electrical conductivity mapping	Between Groups	13.295	3	4.432	4.501	.004
	Within Groups	449.954	457	.985		
	Total	463.249	460			
Wired or wireless sensor networks	Between Groups	44.939	3	14.980	8.107	.000
	Within Groups	844.471	457	1.848		
	Total	889.410	460			
Electronic records/mapping for traceability	Between Groups	58.895	3	19.632	11.974	.000
	Within Groups	749.279	457	1.640		
	Total	808.174	460			
Sprayer control systems	Between Groups	10.111	3	3.370	1.737	.159
	Within Groups	886.626	457	1.940		
	Total	896.738	460			
Automatic rate control telematics	Between Groups	72.879	3	24.293	13.848	.000
	Within Groups	801.698	457	1.754		
	Total	874.577	460			

Farm size and use of technologies in the **United States**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Guidance/Autosteer	Less than 202 hectares	57	3.25	1.479	.196	2.85	3.64	1	5
	From 203 to 405 hectares	75	3.95	1.283	.148	3.65	4.24	1	5
	From 406 hectares to 2,023 hectares	167	4.56	.716	.055	4.45	4.67	1	5
	More than 2,023 hectares	40	4.75	.543	.086	4.58	4.92	3	5
	Total	339	4.23	1.130	.061	4.11	4.35	1	5
Yield monitors	Less than 202 hectares	57	3.72	1.521	.201	3.32	4.12	1	5
	From 203 to 405 hectares	75	4.19	1.291	.149	3.89	4.48	1	5
	From 406 hectares to 2,023 hectares	167	4.51	1.046	.081	4.36	4.67	1	5
	More than 2,023 hectares	40	4.50	1.038	.164	4.17	4.83	1	5
	Total	339	4.31	1.224	.066	4.18	4.44	1	5
Satellite/drone imagery	Less than 202 hectares	57	2.56	1.310	.173	2.21	2.91	1	5
	From 203 to 405 hectares	75	2.76	1.282	.148	2.46	3.06	1	5
	From 406 hectares to 2,023 hectares	167	3.05	1.155	.089	2.87	3.22	1	5
	More than 2,023 hectares	40	3.35	1.292	.204	2.94	3.76	1	5
	Total	339	2.94	1.245	.068	2.81	3.07	1	5
Soil electrical conductivity mapping	Less than 202 hectares	57	1.84	1.347	.178	1.48	2.20	1	5
	From 203 to 405 hectares	75	1.57	1.117	.129	1.32	1.83	1	5
	From 406 hectares to 2,023 hectares	167	1.89	1.239	.096	1.70	2.08	1	5
	More than 2,023 hectares	40	1.93	1.071	.169	1.58	2.27	1	5
	Total	339	1.81	1.215	.066	1.68	1.94	1	5
Wired or wireless sensor networks	Less than 202 hectares	57	2.11	1.398	.185	1.73	2.48	1	5
	From 203 to 405 hectares	75	1.84	1.274	.147	1.55	2.13	1	5
	From 406 hectares to 2,023 hectares	167	2.56	1.459	.113	2.33	2.78	1	5
	More than 2,023 hectares	40	2.85	1.511	.239	2.37	3.33	1	5
	Total	339	2.36	1.451	.079	2.20	2.51	1	5
Electronic records/mapping for traceability	Less than 202 hectares	57	2.49	1.465	.194	2.10	2.88	1	5
	From 203 to 405 hectares	75	2.92	1.609	.186	2.55	3.29	1	5
	From 406 hectares to 2,023 hectares	167	3.53	1.484	.115	3.31	3.76	1	5
	More than 2,023 hectares	40	3.78	1.441	.228	3.31	4.24	1	5
	Total	339	3.25	1.561	.085	3.08	3.42	1	5
Sprayer control systems	Less than 202 hectares	57	3.26	1.598	.212	2.84	3.69	1	5
	From 203 to 405 hectares	75	3.33	1.663	.192	2.95	3.72	1	5
	From 406 hectares to 2,023 hectares	167	4.28	1.232	.095	4.09	4.47	1	5
	More than 2,023 hectares	40	4.53	.877	.139	4.24	4.81	1	5
	Total	339	3.93	1.456	.079	3.77	4.08	1	5
Automatic rate control telematics	Less than 202 hectares	57	2.63	1.566	.207	2.22	3.05	1	5
	From 203 to 405 hectares	75	2.69	1.627	.188	2.32	3.07	1	5
	From 406 hectares to 2,023 hectares	167	3.75	1.466	.113	3.53	3.98	1	5
	More than 2,023 hectares	40	3.98	1.230	.194	3.58	4.37	1	5
	Total	339	3.36	1.589	.086	3.19	3.53	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Guidance/Autosteer	Between Groups	90.572	3	30.191	29.665	.000
	Within Groups	340.938	335	1.018		
	Total	431.510	338			
Yield monitors	Between Groups	29.486	3	9.829	6.908	.000
	Within Groups	476.608	335	1.423		
	Total	506.094	338			
Satellite/drone imagery	Between Groups	19.267	3	6.422	4.265	.006
	Within Groups	504.432	335	1.506		
	Total	523.699	338			
Soil electrical conductivity mapping	Between Groups	5.753	3	1.918	1.302	.274
	Within Groups	493.539	335	1.473		
	Total	499.292	338			
Wired or wireless sensor networks	Between Groups	40.053	3	13.351	6.658	.000
	Within Groups	671.758	335	2.005		
	Total	711.811	338			
Electronic records/mapping for traceability	Between Groups	65.378	3	21.793	9.627	.000
	Within Groups	758.309	335	2.264		
	Total	823.687	338			
Sprayer control systems	Between Groups	86.834	3	28.945	15.404	.000
	Within Groups	629.467	335	1.879		
	Total	716.301	338			
Automatic rate control telematics	Between Groups	104.692	3	34.897	15.606	.000
	Within Groups	749.119	335	2.236		
	Total	853.811	338			

Level education and use of Social Media in **Brazil**, using one-way analysis ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
WhatsApp	Less than a bachelor's degree	115	3.74	1.140	.106	3.53	3.95	1	5
	Bachelor's degree	182	3.52	1.169	.087	3.35	3.69	1	5
	Postgraduate (MBA, master or doctorate)	161	3.73	1.166	.092	3.55	3.91	1	5
	Total	458	3.65	1.163	.054	3.54	3.76	1	5
Facebook	Less than a bachelor's degree	115	2.57	1.298	.121	2.33	2.81	1	5
	Bachelor's degree	182	2.34	1.263	.094	2.16	2.53	1	5
	Postgraduate (MBA, master or doctorate)	160	2.36	1.256	.099	2.16	2.55	1	5
	Total	457	2.40	1.271	.059	2.29	2.52	1	5
YouTube	Less than a bachelor's degree	114	3.01	1.293	.121	2.77	3.25	1	5
	Bachelor's degree	183	3.10	1.234	.091	2.92	3.28	1	5
	Postgraduate (MBA, master or doctorate)	160	3.37	1.180	.093	3.18	3.55	1	5
	Total	457	3.17	1.237	.058	3.06	3.29	1	5
Instagram	Less than a bachelor's degree	114	2.51	1.434	.134	2.24	2.77	1	5
	Bachelor's degree	183	2.54	1.304	.096	2.35	2.73	1	5
	Postgraduate (MBA, master or doctorate)	160	2.76	1.362	.108	2.55	2.98	1	5
	Total	457	2.61	1.359	.064	2.49	2.74	1	5
Messenger	Less than a bachelor's degree	115	1.83	1.147	.107	1.62	2.05	1	5
	Bachelor's degree	183	1.73	1.001	.074	1.58	1.87	1	5
	Postgraduate (MBA, master or doctorate)	160	1.61	.984	.078	1.46	1.77	1	5
	Total	458	1.71	1.035	.048	1.62	1.81	1	5
LinkedIn	Less than a bachelor's degree	113	1.66	1.057	.099	1.47	1.86	1	5
	Bachelor's degree	182	1.88	1.186	.088	1.71	2.06	1	5
	Postgraduate (MBA, master or doctorate)	158	2.46	1.461	.116	2.23	2.69	1	5
	Total	453	2.03	1.300	.061	1.91	2.15	1	5

ANOVA

		Squares	df	Mean Square	F	Sig.
WhatsApp	Between Groups	5.264	2	2.632	1.953	.143
	Within Groups	613.140	455	1.348		
	Total	618.404	457			
Facebook	Between Groups	4.415	2	2.207	1.370	.255
	Within Groups	731.695	454	1.612		
	Total	736.109	456			
YouTube	Between Groups	10.081	2	5.041	3.330	.037
	Within Groups	687.262	454	1.514		
	Total	697.344	456			
Instagram	Between Groups	5.761	2	2.880	1.563	.211
	Within Groups	836.909	454	1.843		
	Total	842.670	456			
Messenger	Between Groups	3.356	2	1.678	1.570	.209
	Within Groups	486.175	455	1.069		
	Total	489.531	457			
LinkedIn	Between Groups	48.497	2	24.249	15.260	.000
	Within Groups	715.070	450	1.589		
	Total	763.567	452			

Level education and use of Social Media in the **United States**, using one-way analysis ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
YouTube	High school diploma	25	2.52	1.262	.252	2.00	3.04	1	5
	Some College or Associate degree	75	2.32	1.254	.145	2.03	2.61	1	5
	Bachelors Degree	181	2.58	1.252	.093	2.40	2.76	1	5
	Postgraduate	57	2.61	1.161	.154	2.31	2.92	1	5
	Total	338	2.52	1.238	.067	2.39	2.66	1	5
Facebook	High school diploma	25	1.68	.945	.189	1.29	2.07	1	4
	Some College or Associate degree	75	1.59	.931	.108	1.37	1.80	1	5
	Bachelors Degree	180	1.82	1.022	.076	1.67	1.97	1	5
	Postgraduate	57	1.75	.912	.121	1.51	2.00	1	5
	Total	337	1.74	.979	.053	1.64	1.85	1	5
Pinterest	High school diploma	25	1.20	.577	.115	.96	1.44	1	3
	Some College or Associate degree	75	1.15	.512	.059	1.03	1.26	1	4
	Bachelors Degree	180	1.14	.530	.039	1.07	1.22	1	5
	Postgraduate	57	1.16	.368	.049	1.06	1.26	1	2
	Total	337	1.15	.504	.027	1.10	1.21	1	5
Instagram	High school diploma	25	1.16	.473	.095	.96	1.36	1	3
	Some College or Associate degree	75	1.25	.699	.081	1.09	1.41	1	5
	Bachelors Degree	181	1.27	.664	.049	1.17	1.36	1	5
	Postgraduate	57	1.28	.620	.082	1.12	1.45	1	4
	Total	338	1.26	.651	.035	1.19	1.33	1	5
Twitter	High school diploma	24	1.79	1.285	.262	1.25	2.33	1	5
	Some College or Associate degree	75	1.84	1.356	.157	1.53	2.15	1	5
	Bachelors Degree	181	1.93	1.247	.093	1.75	2.11	1	5
	Postgraduate	57	1.86	1.156	.153	1.55	2.17	1	5
	Total	337	1.89	1.256	.068	1.75	2.02	1	5
Snapchat	High school diploma	19	1.26	.933	.214	.81	1.71	1	5
	Some College or Associate degree	57	1.33	.873	.116	1.10	1.56	1	5
	Bachelors Degree	168	1.21	.630	.049	1.12	1.31	1	4
	Postgraduate	50	1.34	.745	.105	1.13	1.55	1	5
	Total	294	1.26	.722	.042	1.18	1.34	1	5
LinkedIn	High school diploma	19	1.37	1.012	.232	.88	1.86	1	5
	Some College or Associate degree	58	1.36	.873	.115	1.13	1.59	1	5
	Bachelors Degree	168	1.46	.915	.071	1.32	1.60	1	5
	Postgraduate	50	1.68	.978	.138	1.40	1.96	1	4
	Total	295	1.47	.925	.054	1.37	1.58	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
YouTube	Between Groups	4.153	3	1.384	.903	.440
	Within Groups	512.157	334	1.533		
	Total	516.311	337			
Facebook	Between Groups	2.915	3	.972	1.014	.387
	Within Groups	319.138	333	.958		
	Total	322.053	336			
Pinterest	Between Groups	.072	3	.024	.094	.964
	Within Groups	85.210	333	.256		
	Total	85.282	336			
Instagram	Between Groups	.280	3	.093	.219	.883
	Within Groups	142.326	334	.426		
	Total	142.607	337			
Twitter	Between Groups	.733	3	.244	.154	.927
	Within Groups	528.982	333	1.589		
	Total	529.715	336			
Snapchat	Between Groups	.977	3	.326	.622	.601
	Within Groups	151.857	290	.524		
	Total	152.833	293			
LinkedIn	Between Groups	3.099	3	1.033	1.210	.306
	Within Groups	248.406	291	.854		
	Total	251.505	294			

Age groups and use of Social Media in **Brazil**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
WhatsApp	Under 41 years	198	3.61	1.191	.085	3.44	3.77	1	5
	From 41 to 55 years	163	3.69	1.140	.089	3.52	3.87	1	5
	More than 56 years	97	3.66	1.154	.117	3.43	3.89	1	5
	Total	458	3.65	1.163	.054	3.54	3.76	1	5
Facebook	Under 41 years	198	2.56	1.315	.093	2.37	2.74	1	5
	From 41 to 55 years	162	2.35	1.228	.096	2.16	2.54	1	5
	More than 56 years	97	2.20	1.222	.124	1.95	2.44	1	5
	Total	457	2.40	1.271	.059	2.29	2.52	1	5
YouTube	Under 41 years	198	3.31	1.243	.088	3.14	3.49	1	5
	From 41 to 55 years	161	3.19	1.210	.095	3.00	3.37	1	5
	More than 56 years	98	2.87	1.224	.124	2.62	3.11	1	5
	Total	457	3.17	1.237	.058	3.06	3.29	1	5
Instagram	Under 41 years	198	3.02	1.342	.095	2.83	3.20	1	5
	From 41 to 55 years	161	2.50	1.309	.103	2.29	2.70	1	5
	More than 56 years	98	1.98	1.201	.121	1.74	2.22	1	5
	Total	457	2.61	1.359	.064	2.49	2.74	1	5
Messenger	Under 41 years	198	1.79	1.074	.076	1.64	1.94	1	5
	From 41 to 55 years	162	1.64	.989	.078	1.48	1.79	1	5
	More than 56 years	98	1.69	1.030	.104	1.49	1.90	1	5
	Total	458	1.71	1.035	.048	1.62	1.81	1	5
LinkedIn	Under 41 years	194	2.19	1.326	.095	2.00	2.37	1	5
	From 41 to 55 years	161	2.06	1.354	.107	1.85	2.27	1	5
	More than 56 years	98	1.67	1.082	.109	1.46	1.89	1	5
	Total	453	2.03	1.300	.061	1.91	2.15	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
WhatsApp	Between Groups	.695	2	.348	.256	.774
	Within Groups	617.708	455	1.358		
	Total	618.404	457			
Facebook	Between Groups	9.300	2	4.650	2.905	.056
	Within Groups	726.809	454	1.601		
	Total	736.109	456			
YouTube	Between Groups	13.072	2	6.536	4.337	.014
	Within Groups	684.271	454	1.507		
	Total	697.344	456			
Instagram	Between Groups	73.507	2	36.754	21.694	.000
	Within Groups	769.162	454	1.694		
	Total	842.670	456			
Messenger	Between Groups	2.111	2	1.055	.985	.374
	Within Groups	487.420	455	1.071		
	Total	489.531	457			
LinkedIn	Between Groups	17.318	2	8.659	5.221	.006
	Within Groups	746.249	450	1.658		
	Total	763.567	452			

Age groups and use of Social Media in the **United States**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
YouTube	Under 41 years	58	2.97	1.184	.155	2.65	3.28	1	5
	From 41 to 55 years	73	2.49	1.180	.138	2.22	2.77	1	5
	From 56 to 70 years	152	2.41	1.182	.096	2.23	2.60	1	5
	More than 70 years	54	2.37	1.431	.195	1.98	2.76	1	5
	Total	337	2.52	1.237	.067	2.39	2.65	1	5
Facebook	Under 41 years	58	2.03	1.008	.132	1.77	2.30	1	5
	From 41 to 55 years	73	1.82	1.085	.127	1.57	2.07	1	5
	From 56 to 70 years	151	1.58	.882	.072	1.44	1.72	1	5
	More than 70 years	54	1.76	.989	.135	1.49	2.03	1	5
	Total	336	1.74	.978	.053	1.64	1.85	1	5
Pinterest	Under 41 years	58	1.09	.283	.037	1.01	1.16	1	2
	From 41 to 55 years	73	1.16	.578	.068	1.03	1.30	1	5
	From 56 to 70 years	151	1.13	.421	.034	1.06	1.19	1	4
	More than 70 years	54	1.28	.738	.100	1.08	1.48	1	5
	Total	336	1.15	.504	.028	1.10	1.21	1	5
Instagram	Under 41 years	58	1.33	.604	.079	1.17	1.49	1	3
	From 41 to 55 years	73	1.30	.758	.089	1.12	1.48	1	4
	From 56 to 70 years	152	1.20	.587	.048	1.10	1.29	1	5
	More than 70 years	54	1.30	.717	.098	1.10	1.49	1	5
	Total	337	1.26	.651	.035	1.19	1.33	1	5
Twitter	Under 41 years	58	2.45	1.404	.184	2.08	2.82	1	5
	From 41 to 55 years	73	2.22	1.397	.163	1.89	2.55	1	5
	From 56 to 70 years	152	1.63	1.097	.089	1.45	1.80	1	5
	More than 70 years	53	1.58	1.008	.139	1.31	1.86	1	4
	Total	336	1.89	1.257	.069	1.76	2.02	1	5
Snapchat	Under 41 years	52	1.48	.918	.127	1.23	1.74	1	5
	From 41 to 55 years	64	1.50	1.054	.132	1.24	1.76	1	5
	From 56 to 70 years	126	1.12	.431	.038	1.04	1.20	1	4
	More than 70 years	51	1.10	.361	.051	1.00	1.20	1	3
	Total	293	1.26	.723	.042	1.18	1.35	1	5
LinkedIn	Under 41 years	52	1.44	.826	.115	1.21	1.67	1	4
	From 41 to 55 years	64	1.70	1.136	.142	1.42	1.99	1	5
	From 56 to 70 years	127	1.41	.885	.079	1.25	1.56	1	5
	More than 70 years	51	1.37	.799	.112	1.15	1.60	1	4
	Total	294	1.47	.926	.054	1.37	1.58	1	5

ANOVA

		Squares	df	Mean Square	F	Sig.
YouTube	Between Groups	14.466	3	4.822	3.214	.023
	Within Groups	499.658	333	1.500		
	Total	514.125	336			
Facebook	Between Groups	9.272	3	3.091	3.297	.021
	Within Groups	311.202	332	.937		
	Total	320.473	335			
Pinterest	Between Groups	1.220	3	.407	1.607	.188
	Within Groups	84.039	332	.253		
	Total	85.259	335			
Instagram	Between Groups	1.056	3	.352	.829	.479
	Within Groups	141.484	333	.425		
	Total	142.540	336			
Twitter	Between Groups	41.595	3	13.865	9.446	.000
	Within Groups	487.331	332	1.468		
	Total	528.926	335			
Snapchat	Between Groups	10.060	3	3.353	6.791	.000
	Within Groups	142.705	289	.494		
	Total	152.765	292			
LinkedIn	Between Groups	4.466	3	1.489	1.749	.157
	Within Groups	246.817	290	.851		
	Total	251.282	293			

Age groups and use of Mass Media in **Brazil**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Newspaper	Under 41 years	199	1.70	1.044	.074	1.55	1.84	1	5
	From 41 to 55 years	163	1.74	1.022	.080	1.58	1.90	1	5
	From 56 to 70 years	99	1.87	1.085	.109	1.65	2.09	1	5
	More than 70 years	461	1.75	1.045	.049	1.65	1.85	1	5
Magazines	Under 41 years	199	2.05	1.058	.075	1.90	2.20	1	5
	From 41 to 55 years	163	2.09	1.039	.081	1.93	2.25	1	5
	From 56 to 70 years	99	2.25	1.003	.101	2.05	2.45	1	5
	More than 70 years	461	2.11	1.040	.048	2.01	2.20	1	5
Radio	Under 41 years	199	2.18	1.212	.086	2.01	2.35	1	5
	From 41 to 55 years	163	2.13	1.095	.086	1.96	2.30	1	5
	From 56 to 70 years	99	2.22	1.225	.123	1.98	2.47	1	5
	More than 70 years	461	2.17	1.173	.055	2.06	2.28	1	5
Television	Under 41 years	199	2.15	1.212	.086	1.98	2.32	1	5
	From 41 to 55 years	163	2.07	1.145	.090	1.89	2.24	1	5
	From 56 to 70 years	99	2.27	1.150	.116	2.04	2.50	1	5
	More than 70 years	461	2.15	1.175	.055	2.04	2.25	1	5
Pay Television	Under 41 years	199	2.41	1.307	.093	2.22	2.59	1	5
	From 41 to 55 years	163	2.37	1.242	.097	2.18	2.56	1	5
	From 56 to 70 years	99	2.51	1.312	.132	2.24	2.77	1	5
	More than 70 years	461	2.41	1.284	.060	2.30	2.53	1	5
Website and blog	Under 41 years	199	3.44	1.225	.087	3.27	3.61	1	5
	From 41 to 55 years	163	3.44	1.202	.094	3.25	3.62	1	5
	From 56 to 70 years	99	3.17	1.178	.118	2.94	3.41	1	5
	More than 70 years	461	3.38	1.209	.056	3.27	3.49	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
WhatsApp	Between Groups	.695	2	.348	.256	.774
	Within Groups	617.708	455	1.358		
	Total	618.404	457			
Facebook	Between Groups	9.300	2	4.650	2.905	.056
	Within Groups	726.809	454	1.601		
	Total	736.109	456			
YouTube	Between Groups	13.072	2	6.536	4.337	.014
	Within Groups	684.271	454	1.507		
	Total	697.344	456			
Instagram	Between Groups	73.507	2	36.754	21.694	.000
	Within Groups	769.162	454	1.694		
	Total	842.670	456			
Messenger	Between Groups	2.111	2	1.055	.985	.374
	Within Groups	487.420	455	1.071		
	Total	489.531	457			
LinkedIn	Between Groups	17.318	2	8.659	5.221	.006
	Within Groups	746.249	450	1.658		
	Total	763.567	452			

Age groups and use of Mass Media in the **United States**, using one-way ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	Mean Lower Bound	Mean Upper Bound	Minimum	Maximum
Newspaper	Under 41 years	58	1.98	1.017	.134	1.72	2.25	1	5
	From 41 to 55 years	74	2.04	1.116	.130	1.78	2.30	1	5
	From 56 to 70 years	151	2.07	1.056	.086	1.90	2.24	1	5
	More than 70 years	54	2.46	1.224	.167	2.13	2.80	1	5
	Total	337	2.11	1.098	.060	1.99	2.23	1	5
Magazine	Under 41 years	58	2.67	1.082	.142	2.39	2.96	1	5
	From 41 to 55 years	74	2.53	1.063	.124	2.28	2.77	1	5
	From 56 to 70 years	151	2.79	1.099	.089	2.61	2.96	1	5
	More than 70 years	54	3.19	.973	.132	2.92	3.45	1	5
	Total	337	2.77	1.084	.059	2.66	2.89	1	5
Radio	Under 41 years	58	2.29	1.185	.156	1.98	2.60	1	5
	From 41 to 55 years	73	2.48	1.281	.150	2.18	2.78	1	5
	From 56 to 70 years	152	2.33	1.189	.096	2.14	2.52	1	5
	More than 70 years	54	2.57	1.207	.164	2.24	2.90	1	5
	Total	337	2.39	1.211	.066	2.26	2.52	1	5
Television	Under 41 years	58	2.00	1.060	.139	1.72	2.28	1	4
	From 41 to 55 years	73	2.10	1.108	.130	1.84	2.35	1	5
	From 56 to 70 years	152	2.05	1.082	.088	1.87	2.22	1	5
	More than 70 years	54	2.35	1.152	.157	2.04	2.67	1	5
	Total	337	2.10	1.096	.060	1.98	2.22	1	5
Website and blog	Under 41 years	58	3.57	1.045	.137	3.29	3.84	1	5
	From 41 to 55 years	73	3.37	1.208	.141	3.09	3.65	1	5
	From 56 to 70 years	152	3.26	1.120	.091	3.08	3.44	1	5
	More than 70 years	54	3.74	1.119	.152	3.44	4.05	1	5
	Total	337	3.42	1.136	.062	3.29	3.54	1	5
Pay Television	Under 41 years	52	1.46	.779	.108	1.24	1.68	1	4
	From 41 to 55 years	65	1.66	1.035	.128	1.41	1.92	1	5
	From 56 to 70 years	128	1.56	1.025	.091	1.38	1.74	1	5
	More than 70 years	51	1.41	.804	.113	1.19	1.64	1	4
	Total	296	1.54	.952	.055	1.43	1.65	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Newspaper	Between Groups	8.313	3	2.771	2.326	.075
	Within Groups	396.625	333	1.191		
	Total	404.938	336			
Magazine	Between Groups	14.272	3	4.757	4.162	.006
	Within Groups	380.588	333	1.143		
	Total	394.861	336			
Radio	Between Groups	3.518	3	1.173	.798	.495
	Within Groups	488.993	333	1.468		
	Total	492.510	336			
Television	Between Groups	4.447	3	1.482	1.236	.296
	Within Groups	399.321	333	1.199		
	Total	403.769	336			
Website and blog	Between Groups	10.758	3	3.586	2.822	.039
	Within Groups	423.082	333	1.271		
	Total	433.840	336			
Pay Television	Between Groups	2.184	3	.728	.801	.494
	Within Groups	265.330	292	.909		
	Total	267.514	295			

Level education and use of Mass Media in **Brazil**, using one-way analysis ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Newspaper	Less than a bachelor's degree	116	1.80	1.166	.108	1.59	2.02	1	5
	Bachelor's degree	183	1.72	.986	.073	1.58	1.87	1	5
	Postgraduate (MBA, master or doctorate)	162	1.75	1.023	.080	1.59	1.91	1	5
	Total	461	1.75	1.045	.049	1.65	1.85	1	5
Magazine	Less than a bachelor's degree	116	2.00	1.022	.095	1.81	2.19	1	5
	Bachelor's degree	183	2.13	1.033	.076	1.98	2.28	1	5
	Postgraduate (MBA, master or doctorate)	162	2.16	1.063	.083	2.00	2.33	1	5
	Total	461	2.11	1.040	.048	2.01	2.20	1	5
Radio	Less than a bachelor's degree	116	2.36	1.197	.111	2.14	2.58	1	5
	Bachelor's degree	183	2.09	1.180	.087	1.92	2.27	1	5
	Postgraduate (MBA, master or doctorate)	162	2.12	1.139	.089	1.94	2.29	1	5
	Total	461	2.17	1.173	.055	2.06	2.28	1	5
Television	Less than a bachelor's degree	116	2.40	1.285	.119	2.16	2.63	1	5
	Bachelor's degree	183	2.09	1.147	.085	1.93	2.26	1	5
	Postgraduate (MBA, master or doctorate)	162	2.02	1.103	.087	1.85	2.20	1	5
	Total	461	2.15	1.175	.055	2.04	2.25	1	5
Pay Television	Less than a bachelor's degree	116	2.40	1.376	.128	2.14	2.65	1	5
	Bachelor's degree	183	2.40	1.240	.092	2.22	2.58	1	5
	Postgraduate (MBA, master or doctorate)	162	2.44	1.271	.100	2.25	2.64	1	5
	Total	461	2.41	1.284	.060	2.30	2.53	1	5
Website and blog	Less than a bachelor's degree	116	3.23	1.233	.114	3.01	3.46	1	5
	Bachelor's degree	183	3.28	1.239	.092	3.10	3.46	1	5
	Postgraduate (MBA, master or doctorate)	162	3.59	1.134	.089	3.42	3.77	1	5
	Total	461	3.38	1.209	.056	3.27	3.49	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Newspaper	Between Groups	.462	2	.231	.211	.810
	Within Groups	501.850	458	1.096		
	Total	502.312	460			
Magazine	Between Groups	1.855	2	.928	.857	.425
	Within Groups	495.936	458	1.083		
	Total	497.792	460			
Radio	Between Groups	5.817	2	2.909	2.125	.121
	Within Groups	626.985	458	1.369		
	Total	632.803	460			
Television	Between Groups	10.182	2	5.091	3.730	.025
	Within Groups	625.081	458	1.365		
	Total	635.262	460			
Pay Television	Between Groups	.227	2	.114	.069	.934
	Within Groups	757.638	458	1.654		
	Total	757.866	460			
Website and blog	Between Groups	11.518	2	5.759	3.990	.019
	Within Groups	661.051	458	1.443		
	Total	672.568	460			

Level education and use of Mass Media in the **United States**, using one-way analysis ANOVA

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Newspaper	High school diploma	25	2.08	1.288	.258	1.55	2.61	1	5
	Some College or Associate degree	76	2.07	1.050	.120	1.83	2.31	1	5
	Bachelors Degree	180	2.12	1.085	.081	1.96	2.28	1	5
	Postgraduate	57	2.18	1.136	.150	1.87	2.48	1	5
	Total	338	2.11	1.097	.060	2.00	2.23	1	5
Magazine	High school diploma	25	3.00	1.354	.271	2.44	3.56	1	5
	Some College or Associate degree	76	2.70	1.046	.120	2.46	2.94	1	5
	Bachelors Degree	180	2.80	1.043	.078	2.65	2.95	1	5
	Postgraduate	57	2.72	1.146	.152	2.42	3.02	1	5
	Total	338	2.78	1.084	.059	2.66	2.89	1	5
Radio	High school diploma	25	2.60	1.555	.311	1.96	3.24	1	5
	Some College or Associate degree	76	2.39	1.132	.130	2.14	2.65	1	5
	Bachelors Degree	181	2.41	1.234	.092	2.23	2.60	1	5
	Postgraduate	56	2.27	1.087	.145	1.98	2.56	1	5
	Total	338	2.40	1.212	.066	2.27	2.53	1	5
Television	High school diploma	25	2.16	1.179	.236	1.67	2.65	1	4
	Some College or Associate degree	76	2.05	1.094	.126	1.80	2.30	1	5
	Bachelors Degree	181	2.12	1.104	.082	1.96	2.28	1	5
	Postgraduate	56	2.09	1.083	.145	1.80	2.38	1	5
	Total	338	2.10	1.099	.060	1.99	2.22	1	5
Website and blog	High school diploma	25	3.68	1.145	.229	3.21	4.15	1	5
	Some College or Associate degree	76	3.14	1.104	.127	2.89	3.40	1	5
	Bachelors Degree	181	3.51	1.138	.085	3.34	3.68	1	5
	Postgraduate	56	3.36	1.119	.150	3.06	3.66	1	5
	Total	338	3.41	1.135	.062	3.29	3.54	1	5
Pay Television	High school diploma	19	1.84	1.119	.257	1.30	2.38	1	5
	Some College or Associate degree	60	1.67	1.036	.134	1.40	1.93	1	5
	Bachelors Degree	168	1.54	.966	.075	1.39	1.68	1	5
	Postgraduate	50	1.32	.683	.097	1.13	1.51	1	4
	Total	297	1.55	.954	.055	1.44	1.65	1	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Newspaper	Between Groups	.421	3	.140	.116	.951
	Within Groups	405.307	334	1.213		
	Total	405.728	337			
Magazine	Between Groups	2.010	3	.670	.567	.637
	Within Groups	394.348	334	1.181		
	Total	396.358	337			
Radio	Between Groups	2.017	3	.672	.455	.714
	Within Groups	493.063	334	1.476		
	Total	495.080	337			
Television	Between Groups	.347	3	.116	.095	.963
	Within Groups	407.029	334	1.219		
	Total	407.376	337			
Website and blog	Between Groups	9.069	3	3.023	2.376	.070
	Within Groups	424.943	334	1.272		
	Total	434.012	337			
Pay Television	Between Groups	5.111	3	1.704	1.887	.132
	Within Groups	264.525	293	.903		
	Total	269.636	296			