DOI: 10.5902/19834659 69430

DECISION-MAKING IN AGRIBUSINESS BASED ON ARTIFICIAL INTELLIGENCE

Tomada de decisão no agronegócio baseada em inteligência artificial

Submission: March 1, 2022
Accept: October 29, 2022

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ABSTRACT

Purpose: Artificial Intelligence (AI) tools have become popular in the most diverse contexts of use. This research sought to investigate how AI tools were applied in agribusiness by assisting producers in decision-making.
Design / methodology / approach: To this end, online and semi-structured interviews were conducted with managers and rural producers who use this type of technology on their properties.
Findings: AI was found to be present in machinery, software, and other applications applied for crop monitoring, soil quality verification, and management in general. Users are quite optimistic with the results, especially in decision support during planting period. These differences are perceived before and after technologies utilization. However, interviewers still believe that the human presence is fundamental in the farming.
Research limitations / implications: As limitations, it is highlighted the schedule for conducting the interviews, as well as the fact that they were performed online. Despite this, it was possible to verify the importance of the use of technology for the agribusiness sector, serving as support for the management of rural properties.
Originality / value: In the Information Systems studies field to relate the use of AI and decision-making in a sector such as agribusiness is something recent and innovative.

Keywords: Decision Making; Agribusiness; Artificial Intelligence.

RESUMO

Finalidade: As ferramentas de Inteligência Artificial têm se popularizado nos mais diversos contextos de uso. A presente pesquisa busca investigar como as ferramentas de IA são aplicadas no agronegócio auxiliando o produtor na sua tomada de decisão.
Desenho / metodologia / abordagem: Para tal, foram realizadas entrevistas online e semiestruturadas com gestores e produtores rurais que utilizam este tipo de tecnologia nas propriedades.
Descobertas: Descobriu-se que a IA está presente no maquinário, softwares e outros aplicativos utilizados para monitoramento da lavoura, verificação da qualidade do solo e manejos em geral. Os usuários mostram-se bastantes otimistas com os resultados encontrados, principalmente no apoio à decisão durante o período de plantio. Essas diferenças são percebidas no antes e depois do uso das tecnologias. Contudo, os entrevistados ainda creem que a presença do humano é fundamental na lavoura.
Limitações / implicações da pesquisa: Como limitações, destaca-se o cronograma de execução das entrevistas, bem como o fato destas terem sido realizadas de maneira online. Apesar disso, foi possível verificar a importância do uso da tecnologia para o setor de agronegócio, servindo como suporte ao gerenciamento das propriedades rurais.
Originalidade / valor: No campo dos estudos em Sistemas de Informação, relacionar o uso da Inteligência Artificial e da tomada de decisão em um setor como o agronegócio é algo recente e inovador.

Palavras-chave: Tomada de Decisão; Agronegócio, Inteligência Artificial

1 INTRODUCTION

Agribusiness has been presented as the sector with the greatest contribution to the national Gross Domestic Product (GDP) as well as the main responsible for generating a surplus in the trade balance since it is the sector that most exports non-manufactured primary food products (Breitenbach, 2014). According to data from the Centro de Estudos Avançados em Economia (CEPEA), the agribusiness sector is responsible for 21.4% of the national GDP, increasing approximately 3.81% compared to the previous year (CEPEA, 2020).

This growth has driven the development and commercialization of agricultural technologies, making the agro-sector more digital (Talaviya, Shah, Patel, Yagnik & Shah, 2020). By these means, the use of artificial intelligence (AI) tools has been gaining space and starting to play an important role in rural producers lives, expanding their perceptions and helping them to change the environment in which they are inserted. Incorporating the use of these technologies improves insights from data collected in the field and allows agricultural practices to be designed systematically with minimal manual work (Subeesh & Mehta, 2021).

Thus, it can be said that AI technologies are important for this sector, due to the uncertainty that surrounds it. These tools help rural producers to understand why unforeseen phenomena are occurring (Smith, 2018), as well as they guide them on which cultivars should be planted and the best dates to do so (Eli-Chukwu, 2019). In this sense, being able to rely on AI-based decision support systems is interesting for the producer (Prabakaran, Vaithiyanathan, & Ganesan, 2020).

However, despite these revolutions caused by technology, farmers technical knowledge lack to operate this machinery becomes a challenge within the ecosystem (Subeesh & Mehta, 2021). Knowledge related to drones, sensors, telemetry systems, internet of things, precision agriculture, AI system, among others, is necessary for these workers and, the best way to deal with this, is keeping the user in mind during the development of these technologies (Liu, Ma, Shu, Hancke & Abu-Mahfouz, 2020).

Therefore, based on this argument, it is understood that it is relevant to understand this issue: how AI can be used to support decision-making in agribusiness? To answer this question, the following objectives were outlined: a) identify AI technologies used by the agro sector to support decision-making; b) present the purposes for which the AI was adopted; and c) analyze how AI supports studied agribusiness organizations-making.

For this purpose, this article is structured in six sections, starting with the introduction, followed by a brief review of the literature on the subject, then the section on methodology, analysis and discussion of the results, final considerations, and, finally, the references used are presented.

2 DECISION MAKING, ARTIFICIAL INTELLIGENCE, AND AGRIBUSINESS

The Brazilian agricultural sector is constantly looking for adjustments related to products and processes that best suit the international reality of low costs and superior quality products. Therefore, rural producers need to have a high degree of specialization and professionalism, demanding greater managerial capacity from their rural establishments. For this, the producer must be able to acquire and manage raw data in addition to other information related to his production area, counting on technology to assist him in this process (Borth, Iacia, Pistori & Ruviaro, 2014).

In this sense, decision-making in agribusiness involves issues that concerns which crops should be planted, the quantity needed, the best time to plant, who will participate in this process, for whom the establishment is producing, and how these processes will be conducted (Araujo, 2005). As a result, these decisions become essential to determining what are the priorities for the business, seeking to increase production efficiency (Ostaev, Shulus, Mironova & Smolin, 2020).

However, it is observed that producers usually choose their cultivars based on their knowledge and previous experiences, which does not always lead to an assertive decision (Ranganathaswamy & Shankar, 2021). Therefore, it is understood that, in the context of agribusiness, the decision-making process is surrounded by uncertainties, because the information is not exactly accurate. The producer is subject to issues such as weather conditions, reduced soil fertility, and post-harvest price changes, which create obstacles to achieving higher productivity (Ogunu-Ebiye & Ogunu, 2021). Thus, using technology to improve or even facilitate the choice of producer becomes interesting (Borth, Iacia, Pistori & Ruviaro, 2014).

Previously restricted to the industrial sector, technology has transformed several sectors, including agriculture. AI, for example, has been gaining ground in rural areas in recent years (Jha, Doshi, Patel & Shah, 2019). Although its use is considered new in the agricultural sector, Bannerjee, Sarkar, Das and Ghosh (2018) highlight that the idea of introducing this type of technology in the field was first proposed in the mid-1980s to manage crop management.

The basic concept of AI is to develop technology that works like a human brain (Parekh, Shah, D. & Shah, M. 2020), considering the way the brain thinks, how humans learn, make decisions, and work to identify the best way to solve a problem (Talaviya, Shah, Patel, Yagnik & Shah, 2020). From these studies, software and intelligent systems are developed, and later, they are fed with data to start generating useful information. In the agricultural sector, AI main applications are in crop management, pests, diseases, seeds, land use, irrigation, and harvest prediction (Bannerjee, Sarkar, Das & Ghosh, 2018). Therefore, producers in their daily activities can find AI support to face the adversities imposed by the environment, whether related to pests and diseases or climatic factors that are not under their control (Ogunu-Ebiye & Ogunu, 2021).

Despite still being an emerging theme in this environment, AI advantages have already been perceived by users (Wang, Huang, Wu & Xu, 2007). Properties that use automated systems such as agricultural robots and drones have stood out in the agribusiness sector (Liakos, Busato, Moshou, Pearson & Bochtis, 2018; Talaviya, Shah, Patel, Yagnik & Shah, 2020), demonstrating their benefits in managing agricultural operations and harvesting (Cook & O'Neill, 2020). Furthermore, these intelligent decision-making systems can lead to a significant reduction in human intervention in various agricultural tasks, even surpassing producers decisions in terms of precision (Subeesh & Mehta, 2021).

Regarding these technologies use for decision support, Baird and Maruping (2021) point out that the technologies will relate to a certain type of decision-making agent. The authors mention that agents can be reflexive, responding to stimuli; supervisory, which are those whose decisions involves improving some aspect or returning it to normality; anticipatory, that is, acting before the need for or the desire for action; and, finally, prescriptive, whose role is to function as substitutes for decision-making based on behaviors or results. Table 1 shows some examples of these agents:

Table 1. Decision-making agents

Agents	Examples
Reflective	Detection, action or alerting agents; virtual assistants that react to queries;
Supervisory	Decision support systems, environmental intelligence, guidance systems, such as those that observe human behavior and remind them of process steps, with visual cues, for example.
Anticipatory	Searching, filtering and presenting content, compiling digital content, augmented reality agents that anticipate needs;
Prescriptive	Bots, autonomous vehicles, legal agents, autonomous agents

Source: adapted from Baird and Maruping (2021)

From the agribusiness perspective, these agents presented by Baird and Maruping (2021) can be related to the AI technologies used by producers in the field. Awasthi (2020) brings some examples of these technologies: automated tractors are able to free the producer from the activity of driving, identify the furrows in the field, and deflect people and other creatures from irrigation systems while performing other tasks. The AI presented in this machinery is capable of programming threshold points for the operation using commands developed from algorithms based on *machine learning* (Waleed, Um, Kamal, Khan & Iqbal, 2020). Thus, in view of these characteristics, this type of machinery could be classified as a prescriptive agent, for example. Robots that help recognize the nature of the harvest, collect yields at a better rate than humans, check for the presence of weeds, among others (Awasthi, 2020), could be classified as supervisory.

In addition, applications developed with AI which can be accessed via smartphone help producers combat crop insects and, through satellite images, to verify if the insects are moving to other plantation areas (Awasthi, 2020). These applications can be classified as reflective agents because they react to consultations conducted by the producers. Another example comes from Zhou et al. (2019), whose study presented a platform based on AI able to control agricultural equipment operation and management, with location and status of agricultural work information, fault detection during the process, and agricultural machinery trajectory while assisting manager's decision-making.

Thus, as previously mentioned by Ogunu-Ebiye and Ogunu (2021), there are several challenges encountered during crops planting and management. Jha, Doshi, Patel and Shah (2019) corroborate and list pest infestations in crops, lack of adequate storage for harvesting, pesticide control, weed management, and irrigation and drainage installation lacks in plantations as the main obstacles to property management. In this sense, being able to rely on AI in the agribusiness sector, supporting the producer in decision-making and supporting sustainable actions, increases yields and reduces production costs (Linaza et al. 2021).

3 METHODOLOGICAL PROCEDURES

This article is an exploratory research with qualitative approach (Flick, 2008), whose data collection was conducted through semi-structured interviews. The instrument's key questions were developed based on a literature review and addressed the types, functions, applications, and use of AI technologies for rural properties decision-making and management. This investigation target audience were three managers and two rural producers who use AI in their daily lives, whether participating in the development of this AI or managing it during the production process. Due to the Covid-19 pandemic, the interviews were conducted online (Schmidt, Palazzi & Piccinini, 2020) during the month of June 2021. Platforms such as Google Meet and video calls via WhatsApp were essential to realize this study. Below, in Table 2, the interviewees selected for this work are presented.

Table 2. Identification of Respondents

Interviewee	Occupation	Main products	Location
E1	Farmer and rancher	Soy, corn, barley, sheep	Ernestina-RS
E2	Coordinator in Mechanization	Grains in general	Porto Alegre-RS
E3	Manager Technician in Production	Grains in general	Porto Alegre-RS
E4	Coordinator of Digital Agriculture	Grains in general	Luís Eduardo Magalhães - BA
E5	Farmer and rancher	Soy, corn, cattle of cut	Carazinho-RS

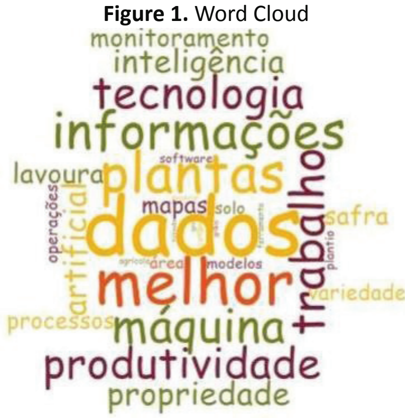
Source: research data

The interview script was divided into three blocks: the first, aimed at knowing the profile of the interviewee; the second, related to the use and management of AI; and the third, questions focused on the use of AI and decision-making, totaling 17 questions. The interviews were recorded and lasted approximately 40 minutes. After data collection, following Bardin (2011), audios were transcribed into text files, which totaled approximately 20 pages. In the next step, the data were coded and organized into three categories supported by NVivo® software to get data better interpretation (Bardin, 2011). It is noteworthy that the data collected were analyzed in a qualitative way and original excerpts from the interviewees' speeches were used to illustrate the results (Ferreira et al. 2022).

4 ANALYSIS AND DISCUSSION OF RESULTS

This section is developed based on interviewees' reports. As a way of illustrating the main terms, figure 1 was created to show the most frequent words.

Figure 1. Word Cloud



Source: research data

It can be seen that the words "*dados*" and "*informação*" are highlighted, as the main assets used by AI in decision-support; "*melhor*", "*produtividade*" and "*plantas*", are producers objectives when using AI: to enhance their productive areas choosing the best culture. The words "*monitoramento*" and "*processos*" are the functions sought by respondents when choosing to deploy AI; "*safra*" and "*variedade*" are mentioned because AI recommendations deal with this topic. The main findings of the interviews are discussed below.

4.1 AI Deployment

Considering agribusiness sector growth (CEPEA, 2020) and the demand for rural properties managerial capacity by technology (Borth, Iacia, Pistori & Ruviaro, 2014), respondents were asked which technological tools were used in their establishments. It was found that the AI tools used by them to support decision-making include weather forecasting software, such as Climate Field View; intelligent machinery used in the field, such as sprayers; image surveillance, as NDVI; and software jointly developed with companies.

Respondents were also asked about the main functions of the AI software they use on their properties. E1 comments that "it *is used a lot for part of the climate, crop projection, insect population*"; and E3 corroborates, reporting that his tool is able to save the crop based on climate information because "*it gives an indication if the next crop will be a moderate or strong La Niña or El Niño [...] If it is better this year to plant in the November window instead of planting in late December.*". Another interviewee mentions a technique that is essential in the estimation of recommendations "*the various models, through a technique called Ensemble, recommend productivity and estimate the best variety to be planted*" (E3). E5 points out that AI is able to assess soil quality, to inform plants health based on satellite images, which for the farmer is important considering that his production and harvest are at stake. These recommendations are made by the tools when issuing "*alerts to the user and performing the monitoring and recording of some operations*", as reported by E2.

In order to understand the reasons why the phenomena are occurring, producers have resorted to technological tools to measure and monitor agricultural systems with greater precision (Smith, 2018). As a result, respondents were asked why the interest in deploying AI arose. E5 answer indicates that it arose from an interest in seeking a technology that "*added profitability and productivity to the family's property, through monitoring, fertilization, and variable rate*", which helped to apply it in the right place and amount, even generating products savings. In the same direction, E2 comments, “*this technology was sought to improve the performance of activities with a focus on cost reduction, increased productivity, and lower environmental impact”.*

For E4, the interest arose from a question that the agricultural planning sector did not have the answer to: how to recommend the best varieties for each crop? Soon he states that “*we could not solve this issue by the old methods such as analysis of spreadsheets in Excel; we felt the need to hire a service and develop our own*”.

4.2 AI Perception

It is undeniable that AI use brings facilities and advantages to its users, especially in rural areas, where it has been gaining ground (Jha, Doshi, Patel & Shah, 2019). By analyzing soil management sources, for example, AI systems are able to provide predictive information about which crop to plant in a given year and what are the optimal dates to sow and harvest in a specific area (Eli-Chukwu, 2019). Such evidence is reported by E1: “*It (AI) is a good indicator of how your soil is doing, because it indicates high productivity zones and low productivity zones […]. We know where to irrigate more. It is a good indicator of several things*”. E5 complements the fact that AI facilitates production planning for the following year, as the data generated allow producers making diagnoses about which regions of the soil productivity have decreased and will need special attention during next sowing.

Another point mentioned by the interviewees is the agricultural processes operationalization. E1 comments that automatic pilot utilization in the agricultural machine made it easier for the operator: “*taking care of the spray boom and still driving is a complex process. The amount of product varies with the amount you walk […] then you have to drive, make sure you are on the right track, and maintain speed, so having the autopilot to do this for you already helps.*” Fountas et al. (2020) comment that this automation has brought several benefits to agriculture, among them those mentioned by the interviewee.

Despite the benefits and advantages perceived with the use of AI, producers face barriers and challenges for its implementation, as data quality, for example. There is a limited amount of data available, and its quality can be questionable, which hinders AI projects implementation (Kshetri, 2020). This is perceived in E3’s answer, who highlights one of the great challenges for AI the information collected about the producer’s plantation. According to the interviewee, for the AI system to produce a better result it is necessary to send customer data, thereby, generating with more precision the indications of variety for planting. E4 also demonstrates difficulties with the data; “t*he great difficulty for this was correcting the databases. [...] problems that there were in the historical series, removing data that had some kind of conflict or that jeopardized the analysis*”.

In addition, structural and institutional barriers are evidenced in the use of these technologies in various regions (Tzachor, 2021). Interviewee E5 comments that the internet signal is still a problem in his establishment: “*If you move or take a dip, something like that, the connectivity is gone*”. E1, on the other hand, reports that the main difficulty is managing the tool: “*It fixes one thing and another one ruins it. And to regulate is a more complex process.*” The interviewee reports that the implementation cost must also be considered, because, to obtain operation better results in terms of precision it is necessary a great investment in these field technologies, which is not always possible, depending on establishments size. AI would make it possible to increase productivity, but costs are still an obstacle in this sector.

In addition to the external barriers reported by the interviewees, other reports mention the user’s difficulty with the AI operation. For E1, the main point is the fact that the machine in which it is present is idle for a good part of the year, which makes the operator forget how it works: “*As* *the machine is used once or twice and the rest of the months it stays still, when you go back to use it again, you don't remember how it was. So, it is practically a video game... it's quite complex*". The process of adapting to the AI was also reported as a difficulty, due to users resistance such as reports E2: "*The adaptation process had at the beginning, a little resistance on the part of the operators, either because of difficulty in understanding the processes or even in handling the equipment*". E3 corroborates E2's speech and adds that this happens because the agricultural sector is very conservative when it comes to new technologies.

4.3 Users and AI

Considering that in agribusiness the information is not accurate, mainly because the producer is subject to issues such as weather, post-harvest price changes, etc. (Ogunu-Ebiye & Ogunu, 2021), decision-making about property management is done in an environment of uncertainty. Respondents commented that, despite the producer's expertise, he does not know every corner of the crop precisely, so, having AI support managing the property is important (E1). E2 even points out that the differences are evident in the comparison between before and after the technology adoption.

Thus, from the answers, it is clear that being able to rely on technology is an advantage, as AI is able to provide more and better information about a situation in the rural establishment, allowing producer to look, to analyze, and to decide which management actions to take (Smith, 2018). E5, for example, says that based on an AI indication, he managed to adjust some points of concern so that the problem would not be repeated in the following harvest;

> "*soil pathogens, so in that sense we have already [...] unpacked the soil in this region and will see if we will need to use any chemical or biological in these areas, but we already think, [...] 'ah such cultivar is susceptible', so we have already identified this part and in these plots we will end up opting for several cultivars resistant to this pathogen and will be working with susceptible ones in other places.*" (E5).

Another factor perceived by the interviewees is the decision on the best type of nurture for a given time, climate, or soil condition. If before the crop losing risk due to not having this information was high (E3), today, with the use of AI, it is possible to start mapping and understanding the property profile, making the producer make more assertive decisions. E3's speech illustrates this example: "*The next crop will be a crop like this, so maybe it's better to plant later [...] this one is better than this one. [...] It's not possible to plant there, the system is indicating that this year will be like this*". E4 highlights that AI is fundamental for the recommendation "*of the best varieties and productivity estimation for these varieties, among the various factors that involve such as soil, climate, and management problems that happen in the field*". This demonstrates that producers in their day-to-day activities can find in AI a support to face the adversities imposed by the environment, whether related to pests and diseases or to climatic factors that are not under their control (Ogunu-Ebiye & Ogunu, 2021).

However, fully relying on AI to make decisions for people is still not entirely safe. Thinking in the rural context and leaving the interpretation and decision to a human reduces the negative risks associated with AI systems that make the wrong decisions on their own (Smith, 2018). One of the interviewees indicates a similar situation: "*One day I got there at the farm, and she was having a different feeling than the numbers were telling me. Then we have to be very mature; you have to be very smart not to make a decision in this sense*" (E3).

Schwab and Davis (2019) argue that AI is rapidly evolving in the performance of its cognitive functions, which were previously only attributed to humans, such as knowledge, general learning, and high-level reasoning, and are now functions of intelligent machines. When asked if they believe in the possibility of

AI completely replacing the role of human, respondents were unanimous in answering no. E5 highlights: "*I think this is part of the feeling of seeing the person eye-to-eye [...] I think there is no way to replace it yet*". E2 corroborates "*I believe that in some activities that offer a greater risk [...] it can be replaced, however, I believe that the human hand will always exist in the rest of the operations*". Smith (2018) comments that although, in some activities, this substitution is already possible, agricultural workers will continue to have important roles, whether in caring for animals or for environment. It is like E3's words: "*We have to go there to work the fields, really feel it. The idea is not to take it away; it is to improve it*".

Table 3. Synthesis from results

CATEGORY	CONCLUSIONS
Implantation of AI	The AI technologies chosen by the producers range from intelligent machines to supporting software. They serve to monitor the climate and production conditions and were implemented with the aim of improving productivity and harvest recommendations for producers.
Perceptions about the AI	Several advantages of the use of AI were pointed out, highlighting the predictive functions and the improvement in the operationalization of the day-to-day tasks of rural properties. However, disadvantages were also mentioned, such as difficulties in obtaining accurate data, internet connectivity and the handling and acceptance of these technologies in the field.
Users and the AI	AI has facilitated the decision-making process for producers. Issues that involve choosing which plants are most suitable or being able to identify how the soil condition is for the next sowing are essential for producers to position themselves on the best strategy to be adopted in the future. However, the conclusions were unanimous on delegating decisions entirely to AI. In this case, the results showed that human presence in the field is still fundamental.

Source: search results

At the end, Table 3 was prepared briefly presenting the main findings of the interviews. The framework was constructed based on the categories created during the analysis.

5 FINAL CONSIDERATIONS

Agribusiness is the sector of the economy that drives the national GDP, so technological tools development to assist decision-making in this sector becomes essential for next crops good performance and better results. From the small farmer to large exporters of agricultural commodities, AI tools have been strong allies in field evolution. For the development of this work, five professionals from the agribusiness sector were interviewed who have professional contact with AI in their work units.

From here onwards, it was possible to verify that the conclusions regarding the use of AI were positive, regardless the applicability area. In general, what can be seen is that the benefits of using this technology are known to both large and small producers. However, although the results are expressive, the reports showed that the implementation costs are still high for AI acquisition on a large scale by producers; in addition, the implementation time and the learning curve are still challenges that need to be overcome.

In addition to contributing to the literature in the area, this study demonstrates the importance of technology for agribusiness, as it indicates the potential for using AI in the field and the facilities it brings to those who use it. It contributed in a practical way as well by identifying that AI can be an excellent support for activities realized on rural properties, facilitating their management.

Based on the results, it would be interesting to expand the horizons of the analysis to other regions of the country, considering Brazilian territory geographic peculiarities, as well as exploring the use of AI in other types of crops, such as livestock and fruit farming, for example. Another interesting point would be to longitudinally follow a property that is starting to use these technologies, seeking to understand how the complete process takes place, from implementation to the final results. As well as research properties with different levels of maturity in relation to the use of AI to identify the challenges encountered and investigate the existence of an agricultural sector that fully delegated decisions involving the management of its cultivars to AI to understand the motivations and what the consequences of this delegation were.

Finally, it is relevant to comment on some limitations faced during this research development. The first one refers to the schedule to conduct the interviews, which had to be rescheduled several times due to the interviewees' unavailability, shortening the period for analysis; the second one regards to the limited number of interviewees; and to the fact that the interviews were conducted online, which may somehow influence the target audience's research perception.

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Contribution	[Author 1]	[Author 2]	[Author 3]
1. Definition of research problem	√	√	√
2. Development of hypotheses or research questions (empirical studies)	√	√	√
3. Development of theoretical propositions (theoretical work)	√	√	√
4. Theoretical foundation / Literature review	√	√	
5. Definition of methodological procedures	√	√	√
6. Data collection	√	√	
7. Statistical analysis	-	-	-
8. Analysis and interpretation of data	√	√	
9. Critical revision of the manuscript	√	-	√
10. Manuscript writing	√	√	
11. Other (please specify)	-	-	-

Conflict of Interest
The authors have stated that there is no conflict of interest.

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