**Brazilian Journal of Agriculture** **v.98, n.2, p. 108 – 118, 2023**
DOI: 10.37856/bja.v98i2.4320

# ADOPTION OF 4.0 TECHNOLOGIES IN AGRICULTURE: PROPOSITION OF A PROCESS BASED ON CASE STUDIES IN BRAZIL

Isabela Gaya Santos[1], Bruno Jorge Soares[2], Eduardo Mario Dias[1], Maria Lídia Rebello Pinho Dias Scoton[1], José Henrique Videira Menezes[1], Diego Humberto de Oliveira[1]

[1]Universidade de São Paulo, São Paulo State, Brazil. E-mail: isabelagaya@gmail.com, emdias@pea.usp.br, lidiadias@pea.usp.br, josemenezes45@gmail.com, diegohagro@gmail.com
[2]Agência Brasileira de Desenvolvimento Industrial, Federal District, Brazil. E-mail: bjotadf@gmail.com

## ABSTRACT

In Brazil, recent research showed that around 50% of farmers adopt precision agriculture technologies, indicating opportunities for diffusion in the country. 4.0 technologies have been adopted in several sectors, such as the agricultural sector. This work aimed to identify a process flow for the adoption of 4.0 technologies in agriculture, based on a case study carried out in 14 pilot projects of the Agro 4.0 Program of the Brazilian Agency for Industrial Development carried out in Brazil between 2020 and 2022. The study was carried out through questionnaires and interviews with those responsible for the projects and in the consolidation of a flowchart. As a result, it was possible to understand elements that characterize the context of 4.0 technologies adoption, such as motivations, challenges and critical factors, and identify processes and sub-processes for this challenge.

**Keywords**: Technologies; adoption of technology; agriculture.

## INTRODUCTION

The fourth industrial revolution is a movement that originated in 2011 in Germany, with the term Industry 4.0. According to Schwab (2016), this revolution comprises technological innovations that allow the fusion of physical, digital and biological domains, which include artificial intelligence, robotics, the internet of things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, energy storage and quantum computing. It stands out for the speed, breadth and depth of its applications.

The application of 4.0 technologies initially took place in the manufacturing industry. Industry 4.0 involves the concepts of being hyperconnected, intelligent and autonomous, characterized by high adaptability and optimal use of resources, which can offer enormous benefits for the productivity and profitability of the productive sector (BECKER et. al, 2017). These technologies have already been adopted in several sectors, such as the agricultural sector. 4.0 technologies have a high potential to enable the development of the agricultural sector, significantly reshape value chains and contribute greatly to more productive, resilient and transparent food systems (FAO, 2009).

Considering the increase in world demand for food, there is a global expectation of increased productivity in the sector. By 2050, the world's population will reach 9.1 billion, 34% more than today. To feed this more significant, more urban and wealthier population, food production must increase by 70%. Annual cereal production will need to increase to around 3 billion tonnes from 2.1 billion today and annual meat production will need to increase by over 200 million tonnes to reach 470 million tonnes (FAO, 2009).

In Brazil, agribusiness represents almost 30% of the Gross Domestic Product (GDP) (27.5% in 2021) (CEPEA et. al., 2021). Brazil is one of the main exporters of agricultural products, which shows the country importanceleading as a significant global food provider.

Among the most illustrative indicators of the recent trajectory of Brazilian agriculture are production numbers and productivity gains. Between 1975 and 2017, grain production, which was 38 million tons, grew by more than six times, reaching 236 million, while the planted area only doubled. Increases in production and productivity were also achieved in livestock: the number of cattle in the country more than doubled in the last four decades, while the area of pastures had little progress. There have been significant advances in poultry, consolidating Brazil as the world's largest exporter of the product, and in pig farming, with the country now being one of the largest producers and exporters of the product. The agricultural sector became the main responsible for the Brazilian trade balance surplus. Between 1990 and 2017, the country agrarian balance increased almost tenfold, reaching US$ 81.7 billion, which contributed to the balance of the country's external accounts (EMBRAPA, 2018).

All the progress made so far has resulted from various efforts, including specific policies to increase agricultural production and productivity, such as public investment in research and development, rural extension and credit, and investments in technology. When agriculture is considered a whole, technology largely explains the evolution of productivity. Between 1975 and 2015, technological advances were responsible for 59% of the growth in the gross value of agricultural production, while labor accounted for 25% and land for 16% (EMBRAPA, 2018).

In this scenario, the role of innovation becomes increasingly essential considering these opportunities for productivity and sustainability. Although Brazil historically stood out positively in the use of technologies in the agricultural sector, there are many challenges to overcome to democratize and expand technological adoption in the country.

About precision agriculture technologies, a recent survey found that about 50% of farmers already adopt or are willing to adopt agricultural technologies for their operations (MCKINSEY, 2022), showing that there is still half of the public that still does not use or consider this type of technology in its production process.

Considering these numbers and to contribute with the process of 4.0 technologies diffusion in agriculture, this research aimed to identify a flow of processes for the adoption of 4.0 technologies in this sector, based on field research and case studies carried out in 14 pilot projects of the Agro 4.0 Program of the Brazilian Agency for Industrial Development carried out in Brazil between 2020 and 2022.

## MATERIAL AND METHODS

The quest to improve efficiency and productivity must be a continuous process of innovation that involves, among several factors, the implementation of new processes and/or the improvement of processes in a company/industry/farm.

According to OCDE (1997), technological process innovation is the adoption of new or significantly improved production methods; these methods may involve changes in equipment or production organization, or a combination of these changes, and may derive from using new knowledge.

Methods may be intended to produce or deliver technologically new or improved products that cannot be created or delivered using conventional production methods or intended to increase the production or delivery efficiency of existing products.

The modeling of a company's processes allows all activities to be critically analyzed - in the way they are being performed - through the elaboration of a representative map, which demonstrates the sequence of steps for the execution of a process (VILLELA, 2000).

Miranda (2014), modeling allows mapping the critical relationships between processes and sub-processes, assessing their efficiency and deepening and optimizing these relationships, registering and disseminating the generated knowledge.

Business Process Management (BPM) is a discipline that provides a general understanding of business process management, which collaborates with the creation of more robust practices that lead to more effective, more efficient and more agile processes, which ultimately offer a greater return to stakeholders. There is a vast supply of literature on BPM, including books, articles, best practices and lessons learned (ABPMP, 2013).

BPM implies a permanent and continuous commitment of the organization to the management of its processes. This includes activities such as modeling, analysis, design, performance measurement and process transformation (figure 1) (ABPMP, 2013).


**Figure 1.** BPM lifecycle. Source: ABPMP, 2013.

The BMP defines some notations (Business Process Modeling Notation - BPMN) that represent a standardized set of symbols and rules that determine the meaning of these symbols. A typical flowchart in BPMN is represented, in general terms, with: a) rounded rectangles to represent “beginning” and “end”; b) arrows coming from one symbol and ending in another to indicate the order in the flow; c) rectangles to represent the processing steps; d) parallelograms to represent inputs and outputs; and e) diamonds to represent condition or decision, among others.

Pool swimlanes can also help organize the flowchart, representing how workflows cross functions or transfer control from one role to another (ABPMP, 2013).

There are also levels of representation of a flow, which can be at a high or lower level, representing adjacent processes and subprocesses, the latter consisting of a set of activities, which can also be formed by a group of tasks (ABPMP, 2013).

BPM is a practice guide representing a set of techniques and tools to facilitate process management, using BPMN. In the case of this research, some of them were used, being adapted to the purpose and scope of this article.

To carry out this study, we sought to use this step-by-step to identify a flowchart of processes for adopting 4.0 technologies, based on experiences in the projects selected in the first call of proposals of the Agro 4.0 Program, to enable other producers and companies to learn and identify opportunities for improvement, collaborate with the process of innovation in their business processes.

The Agro 4.0 Program is an initiative of the Brazilian Agency for Industrial Development and partners. It aims to encourage the use of technologies 4.0 in agribusiness, through public notices, events, meetings, information and other actions focused on increasing efficiency, productivity and cost reduction.

The Program's first public notice selected 14 projects in agriculture to monitor the implementation of 4.0 technologies in the production process. The selection process followed the request for proposal criteria and was carried out by a panel of specialists in Brazil.

Projects consisted of at least one producer who must adopt a 4.0 technology in their production process and one or more technology suppliers who will implement the solution. Sector entities, such as cooperatives, associations and universities, could also be present in the working group, to collaborate with the process of implementing and disseminating the solution.

Projects took place in the Brazilian territory, and the adoptions were carried out in 12 states and in large-sized (14%), medium-sized (43%), small-sized (21%) and micro (22%) producers, according to the classification of company size, which takes into account the Gross Operating Revenue (ROB) (BNDES, 2023).

All projects involved adopting at least one 4.0 technology in their production process. The leading technologies chosen by the projects developed were: IOT (21%), Remote Sensing (21%), Artificial Intelligence (21%), Analytics (14 %), Computer Vision (7%), Robotics (7%) and

Geolocation (7%). The projects included crops such as soy, corn, cattle, poultry, sugar cane, apples and coffee (ABDI, 2020).

The steps of the field research carried out are described below:

a) planning: the objective of this phase was to organize the research structure and instruments, align the purpose with those involved and seek to understand the contexts in which the processes were inserted. To gather information, each one of those responsible for the pilot projects was asked to answer a questionary, telling the step-by-step process of adopting 4.0 technologies, considering the experience of the project that was being carried out within the Agro 4.0 Program;

b) analysis: with this step-by-step in hand, interviews were conducted with all of them to clarify doubts and include information. The objective of this stage was to understand the process and results of these activities, as well as the alignment with the research purpose;

c) design: in this stage, the sets of activities carried out by the projects for the adoption of 4.0 technologies were identified. The activities were designed to show the relationship with each other to provide an interpretation of the flow sequence. At this stage, the common points raised between the projects were consolidated and the divergent ones were added to the flow;

d) refinement: after designing the process, and considering the common and divergent actions, a new round of interviews was carried out with those involved for validation and refinement, now focusing on finalizing a flowchart with the ideal model for the adoption of 4.0 technologies.

The software used to assist in elaborating and optimizing the flowchart was Bizagi Modeler, in its free version.

## RESULTS AND DISCUSSION

According to participants' reports, the iterative and incremental research process, based on discussions and optimizations, generated ideas and inputs for improvements in the processes of each responsible person involved in the Program.

The final product expected from the proposed flowchart is a 4.0 technological solution adopted for a productive process in agriculture, whether, for example, to support soil preparation, planting or harvesting or to support the creation and slaughter of animals, to add value, focusing on increasing efficiency and productivity. The primary customer of the technological solution is

DOI: 10.37856/bja.v98i2.4320

the rural producer. However, the customer of this solution's process innovation is the production chain.

To adopt technology in a production process, it is necessary to evaluate its context, considering, for example, motivations, bottlenecks, critical success factors and other instruments that may interfere in this process such as regulations and taxation.

Within the context assessment, the primary bottlenecks identified through the questionnaires and interviews were:

a) lack of infrastructure: the difficulties of cellular network coverage on the properties were highlighted. In most cases, it was possible to provide a connectivity solution (using, for example, radio and satellite), but these comprise new implementation costs. To corroborate this issue, a recent study identified that 70% of the Brazilian territory does not have connectivity (MAPA, 2021);

b) lack of financial resources by the producer: in general, the perception identified was that producers consider implementing these technologies as being high cost and high-risk, which in many cases makes it difficult to carry out the investments on their own. It was pointed out the importance of cost/benefit analyses of adopting solutions and evaluating financing options;

c) difficulty in calculating the return on investment of solutions: as they generally consider the implementation of high-cost and high-risk technologies, it was highlighted the importance of knowing the advantages of gains with technological solutions and how the return on investment can be calculated;

d) lack of technical training of the farm/agribusiness operation workforce: identified the need to update operators and other farm/agribusiness employees on the opportunities that technology brings and how to operate them;

e) lack of management culture in the farm/agroindustry: although many producers are already aware of the need for improvements in farm/agroindustry management, there are still cultural aspects that may need to be developed;

f) significant changes in the production process and risks of change: in many cases, some changes in the production, commercial or administrative processes of a farm/agribusiness precede the implementation of technology. This change often helps with performance and making more significant gains from the technology. However, this brings some concerns to the producer/agribusiness, including uncertainties in the use of new techniques and changes in teams, which generally work for years within the same format;

g) difficulty in accessing good, simple and affordable solutions: especially when it comes to small and medium-sized properties, the perception identified was that there is a large offer of technologies and solutions, but that they are often complex, difficult to customize, integrate, use and have high costs, which hinders adoption.

Still within the context assessment, the critical success factors for the adoption of 4.0 technologies in agribusiness were also identified:

a) people: the entire process of adopting 4.0 technologies involves people who are essential for the enterprise success. It is important to carry out awareness-raising, training and acculturation actions for employees;

b) processes: the productive and administrative processes must be clear and well structured. In many cases, the adoption of 4.0 technologies implies reviewing and optimizing these processes;

c) strategy: the definition of strategic guidelines for the adoption of technologies must give clear direction to the objectives, goals and results to be achieved in the short, medium and long term;

d) culture (innovation and digital): this is a set of beliefs, values and norms of the organization that must be disseminated among its employees. It includes, for example, encouraging participation in events and fairs to learn about technology application cases and their benefits, encouraging the emergence of ideas for solutions, based on the problems faced by each of the employees, assessing/considering tolerance for risks inherent to innovation, among others;

e) resources/infrastructure: consider the infrastructure and investments required to adopt 4.0 technologies, seeking more viable alternatives.

Based on the process of consolidating the experiences of the pilot projects of the Agro 4.0 Program, according to the steps defined in the previous chapter, it was possible to present a proposal for a flowchart for adopting Technologies 4.0 (figure 2).

The diagnosis stage aims to apply data analysis methods to identify and prioritize the bottlenecks in the productive processes and the results of the farm/agribusiness. These could be waste, low productivity, unskilled or uncommitted labor, problems related to climate, irrigation, diseases, pests, other environmental factors, and difficulties with demand/supply forecasts, among others, to better understand which improvements 4.0 technologies can help with.

DOI: 10.37856/bja.v98i2.4320

The optimization stage aims to identify alternatives, and implement and evaluate improvements in production processes that are necessary before adopting the technology. In many cases, the support of specialists who can collaborate in this step is required.

In the prospecting stage, the proposal is to evaluate the alternatives for solving the problems and needs of the farm/agroindustry, considering the different technologies, available suppliers and mechanisms for raising funds, if necessary.

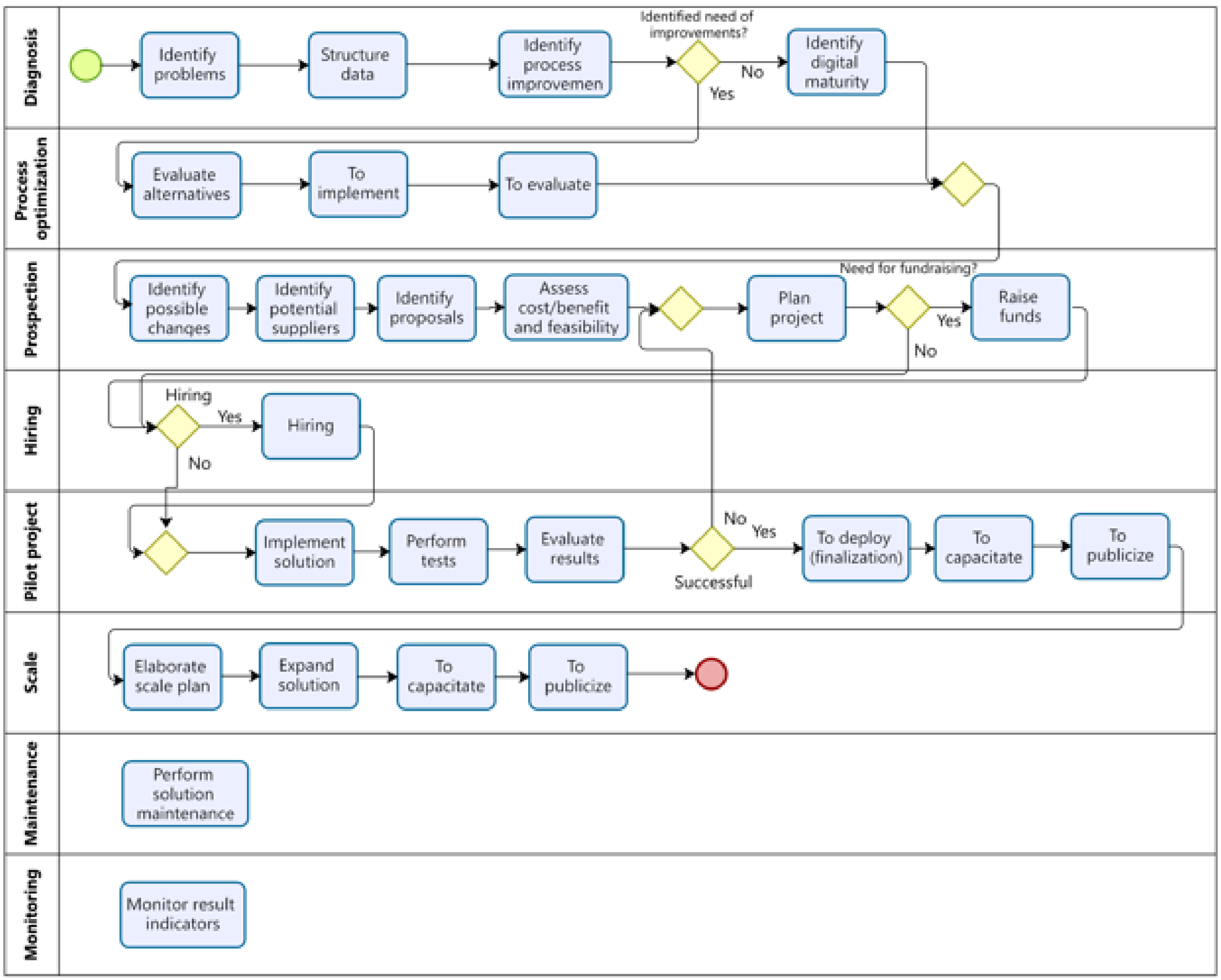


**Figure 2.** Technology 4.0 adoption process flow. Source: author's elaboration.

From then on, in the contracting stage, the supplier that will implement the solution is selected. From this contract, the suggestion is that the technology be implemented in a pilot so that the effects and results are measured on a smaller scale, With satisfactory results, planning and implementation of the solution on a larger scale are suggested, requiring dissemination and training processes for those involved. Like any 4.0 technology solution, performance and results must be monitored throughout its use, and maintenance may be necessary.

It is noteworthy that, throughout the interviews and validation dynamics, it was possible to verify, among the members of the projects, how much the sharing of experiences can generate ideas and speed up the understanding of factors and the prospection of tools and techniques for development and implementation of a technological solution, reinforcing the importance of knowledge management.

As limitations of the research, the number of projects evaluated, 14 in total, selected in the Agro 4.0 Program may be highlighted. As suggestions for future work, it is proposed to expand the study with other projects, including prioritization and more excellent detailing of processes, including a stage of definition and evaluation of performance metrics.

This research is expected to contribute with a first mapping and refinement of a flowchart of the adoption of 4.0 technologies in the field. This flow is intended for rural producers interested in learning about or improving their processes for adopting 4.0 technologies. Still, it can also help suppliers, startups, innovation ecosystem institutions, government and other actors.

## CONCLUSIONS

This article aimed to share the results of the field research carried out to identify the adoption processes of 4.0 technologies by the producers of the Agro 4.0 Program. For its elaboration, questionnaires were used and interviews were conducted with actors from the projects involved. It was possible to understand the elements that characterize the context of 4.0 technology adoption, taking into account factors such as motivations, challenges and critical factors, in addition to identifying processes and sub-processes of this challenge.

DOI: 10.37856/bja.v98i2.4320

## REFERENCES


ASSOCIATION OF BUSINESS PROCESS PROFESSIONALS - ABPMP. 2013. **Guide to Business Process Management (BPM) - standard body of knowledge.** 466p. Available at: <https://www.abpmp-br.org/educacao/bpm-cbok/>. Accessed on: Jan. 20, 2023.

BECKER, T.; BLOCHER, A.; BÜCKER, I.; DREWEL, M.; FAATH, A.; HARLAND, T.; ZELLER, V. 2017. **Industrie 4.0 maturity index: managing the digital transformation of companies.** 1º ed. 64p.

BRAZILIAN AGENCY OF INDUSTRIAL DELEVOPMENT - ABDI. 2020. **Good practice guide for the agro 4.0 program.** 38p. Available at: <https://agro4.0.abdi.com.br>. Accessed on: Oct. 16, 2022.

BRAZILIAN AGRICULTURAL RESEARCH COMPANY - EMBRAPA. 2018. **Trajectory of Brazilian Agriculture.** Available at: <https://www.embrapa.br/en/visao/trajetoria-da-agricultura-brasileira>. Accessed on: Oct. 16, 2022.

CENTER FOR ADVANCED STUDIES IN APPLIED ECONOMICS – CEPEA; CONFEDERATION OF AGRICULTURE AND LIVESTOCK - CNA. 2021. **Agribusiness GDP.** 19p. Available at: <https://www.cepea.esalq.usp.br/upload/kceditor/files/PIB-do-Agronegocio-20set22-2.pdf>. Accessed on: Oct. 15, 2022.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - FAO. 2009. **How to feed the world in 2050**. 35p. Available at: <http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf>. Accessed on: Jul. 13, 2022.

MCKINSEY. 2022. **The mind of the Brazilian farmer in the digital age.** Available at: <https://mente-do-agricultor.mckinsey.com/>. Accessed on: Sep. 10, 2022.

MINISTRY OF AGRICULTURE, LIVESTOCK AND SUPPLY - MAPA. 2021. **Connectivity scenarios and perspectives for agriculture.** 74p. Available at: <https://www.gov.br/agricultura/pt-br/assuntos/inovacao/conectividade-rural/livro>. Accessed on: Sep. 10, 2022.

MIRANDA VIEIRA, S. Information management and process modeling. 2014. **Public Service Magazine,** v. 61, n. 1, p. 97-112.

NATIONAL BANK FOR ECONOMIC AND SOCIAL DEVELOPMENT - BNDES. 2023. **Classification of company size.** Available at: <https://www.bndes.gov.br/wps/portal/site/home/financiamento/guia/porte-de-empresa>. Accessed on: Jan. 21, 2023.

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT - OECD. 1997. **Oslo manual: guidelines for collecting and interpreting data on innovation.** 2º ed. Paris. 166p.

SCHWAB, K. 2017. **The fourth industrial revolution.** 1º ed. Sao Paulo: Edipro. 192p.

VILLELA, C. 2000. **Mapping processes as a tool for restructuring and organizational learning.** UFSC. Florianopolis, SC, Brazil. 182p.


Received in: May, 11, 2023.
Accepted in: Sep, 27, 2023.