The relevance of agriculture in Brazilian GDP and new technologies in agriculture

Gabriela de Matos Cézar
Polytechnic and Arts School, Pontifical Catholic University of Goiás

André Luiz Silva Santos
Polytechnic and Arts School, Pontifical Catholic University of Goiás

Marcos Lajovic Carneiro
Polytechnic and Arts School, Pontifical Catholic University of Goiás

Corresponding author
Clóves Gonçalves Rodrigues
Polytechnic and Arts School, Pontifical Catholic University of Goiás
cloves@pucgoias.edu.br

Abstract. The growth of the world population in recent decades has created the need to increase food production, and this growing demand generates the need for greater efficiency and productivity in agriculture. Thus, countries that want to be competitive in the agricultural sector need to introduce technological improvements in order to reduce costs and increase the yield of agricultural activity. In this paper, we highlight the importance of the agricultural sector in Brazil's GDP and present some examples of new technologies, mainly based on semiconductor devices, applied to the agricultural sector.
Keywords: agriculture, livestock, precision agriculture, GDP, new technologies, semiconductors

Introduction

Advances in technology and engineering have brought about significant changes in agriculture. The introduction of new technologies (tools, techniques, software, artificial intelligence, machines, the internet, etc.) has increased the efficiency of the agricultural sector, providing more sustainable and environmentally friendly farming (Ennouri, 2020).

New technologies used in rural areas optimize the use of fertilizers, pesticides, and the amount of water used, in addition to quickly detecting the emergence of pests and diseases, reducing production losses. These new technologies also help determine the correct time for planting and harvesting, optimizing the producer's profits (Yun et al., 2024).

Among these technological innovations we can mention, for example: automation, which includes intelligent irrigation systems responsible for the correct timing and dosage of water used; drones that monitor crops in real time; robotic harvesters and tractors that plant and harvest with precision, minimizing human error and reducing labor; soil sensing using semiconductor devices, etc. (Chen, 2021).

The raising of animals to provide food, wool and other products has also been beneficially impacted by the use of new technologies, such as shorter fattening times for beef cattle (Forbes, 2024).

Precision agriculture, which uses cutting-edge technology for detailed crop management, allows farmers to make decisions based on accurate data. It includes soil analysis and detailed control of

each plant, resulting in more efficient production and reduced environmental impact (Monteiro et al., 2021).

All of the technologies mentioned above have an essential element in common for their functioning: the presence of semiconductor devices.

This paper aims to demonstrate the relevance of the agricultural sector to the Brazilian economy and the importance of new technologies for this sector. The paper is organized as follows: in Section 2, we highlight the importance of the agricultural sector to the Brazilian GDP; in Section 3, we present some examples of new technologies, based on semiconductor devices, that are applied in the agricultural sector. In the last Section, we comment on the need for greater attention to the semiconductor industry, which is strongly connected to the needs of agribusiness.

The relevance of agriculture in brazil's GDP

A country's gross domestic product (GDP) is the sum of all its economic activities, and is usually applied quarterly, half-yearly, and annually (IBGE, 2024). GDP can also be measured separately for states and municipalities. All countries calculate their GDP in their respective currencies. The final goods and services that make up GDP are measured at the price at which they reach the consumer. Thus, they also take into account taxes on the products sold. GDP measures only the final goods and services to avoid double counting. For example, if a country produces $100.00 of wheat, $200.00 of wheat flour, and $300.00 of bread, the GDP will be $300.00, since the values of the flour and wheat are already included in the price of the bread. GDP is not the total wealth existing in a country, GDP is an indicator of the flow of new final goods and services produced during a period: if a country does not produce anything in a year, its annual GDP will be zero.

Based on GDP performance, several analyses can be carried out, such as: a) Determining the temporal evolution of GDP, comparing its growth, stagnation or decrease year after year; b) Making international comparisons on the size of the economies of different countries; c) Programming strategic growth plans for a nation; d) Analyzing GDP per capita (division of GDP by the number of inhabitants in the middle of the year), which measures how much of the GDP each individual in a country would receive if everyone received equal shares.

However, GDP is only a summary of an economy, that is, it is just another economic indicator. GDP helps to understand a country's economy, but it does not express important factors, such as health, education, quality of life, income distribution, etc. One country may have a large GDP and a low standard of living, while another country may have a small GDP and a high standard of living. Table 1 shows the ten largest GDPs in the world (which can be considered as the largest economies in the world) in the year 2023 in absolute and per capita values (Global Finance, 2024). Comparing total GDP with per capita, it can be seen from Table 1 that the only country that remains among the top ten in both indicators is the United States.

Figure 1 shows the annual evolution of Brazil's GDP in trillions of US dollars from 2000 to 2023, and Figure 2 shows the corresponding annual percentage growth rate.

The values in Figures 1 and 2 were collected from the World Bank national accounts data and OECD National Accounts data files (WB, 2024) and are available in Table 1. Consistent growth can be seen over the last 24 years, except for two moments:in 2009, due to the global financial crisis of 2008, and in 2015-2016 due to the political-economic crisis established in Brazil.

Table 1. The highest absolute and per capita GDP in the world in 2023.

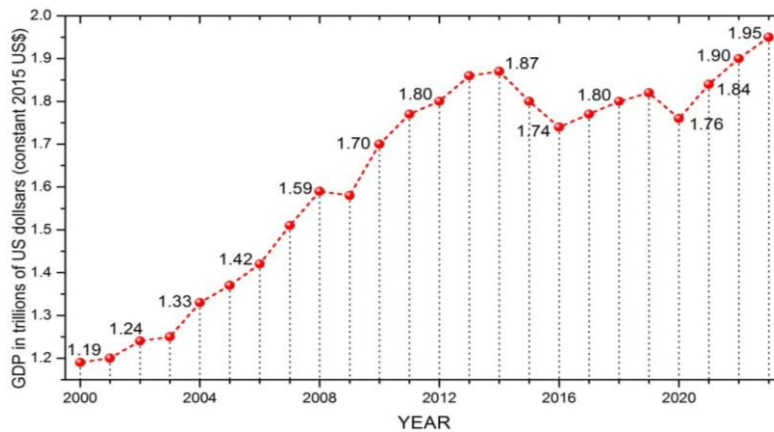| Country	Total GDP (trillions US$)	Country	Per capita GDP (US$)
1º USA	18.6	1º Luxembourg	143,743
2º China	11.2	2º Macao	134,141
3º Japan	4.9	3º Ireland	133,895
4º Germany	3.4	4º Singapore	133,737
5º UK	2.6	5º Qatar	112,283
6º France	2.5	6º United Arab Emirates	96,846
7º India	2.2	7º Switzerland	91,932
8º Italy	1.8	8º San Marino	86,989
9º Brazil	1.8	9º USA	85,373
10º Canada	1.5	10º Norway	82,832

Figure 1. Annual evolution of Brazil's GDP in trillions of US dollars from 2000 to 2023.
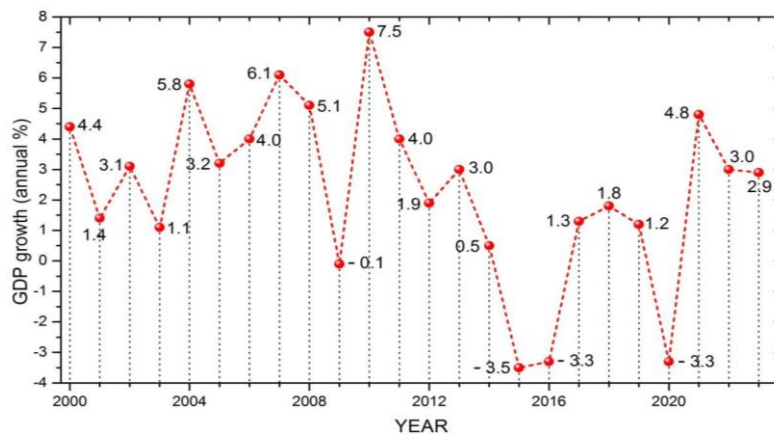

Figure 2. Annual evolution of the annual growth rate of Brazil's GDP from 2000 to 2023.

Table 2. Brazil's annual GDP in trillions of US dollars (constant 2015 US$) and percentage GDP growth.

YEAR	GDP	GDP growth
2000	1.19	4.4%
2001	1.20	1.4%
2002	1.24	3.1%
2003	1.25	1.1%
2004	1.33	5.8%
2005	1.37	3.2%
2006	1.42	4.0%
2007	1.51	6.1%
2008	1.59	5.1%
2009	1.58	-0.1%
2010	1.70	7.5%
2011	1.77	4.0%
2012	1.80	1.9%
2013	1.86	3.0%
2014	1.87	0.5%
2015	1.80	-3.5%
2016	1.74	-3.3%
2017	1.77	1.3%
2018	1.80	1.8%
2019	1.82	1.2%
2020	1.76	-3.3%
2021	1.84	4.8%
2022	1.90	3.0%
2023	1.95	2.9%

To calculate GDP, the economy is divided into three sectors: services, industry, and agriculture. Brazil's GDP in 2023 was US$ 1.8 trillion, with the following composition: 67.4% for services, 25.5% for industry, and 7.1% for agriculture. The services sector mainly includes commerce, transportation, communications, and banking, and due to the growth of financial and digital activities, this sector has increased its share in the GDP of practically all countries in the world, including Brazil. Figure 3 illustrates the distribution of Brazilian GDP by sector. The percentage composition of GDP by sector varies from country to country. In the United States of America, for example, the services sector currently contributes 81.1%, the industrial sector 17.9%, and the agricultural sector 1%.

The sector that grew the most in Brazil in 2023 was agriculture, with 15.1% economic expansion in the year, with record soybean and corn harvests. There was also significant growth in the extractive industry, with 8.7%, driven mainly by the increase in iron ore, oil and gas production. This growth in the agricultural and extractive sector (considered the production of raw materials – commodities) caused Brazilian exports to increase by 9.1% in 2023.

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Regarding the domestic market, in 2023 there was a 3.1% increase in Brazilian household consumption, which is consistent with the 2.2% increase in Brazilian per capita income, which reached $9,209.86 (using a quotation of 1 US dollar equivalent to 5.45 Brazilian Real). However, there is a strong income concentration in Brazil, that is, a small part of the population has a very high income, while the majority of the population has a very low income.

As previously seen, agriculture is extremely important in Brazil, accounting for 7.1% of Brazil's GDP in 2023, and was the fastest-growing sector in Brazil in 2023, with 15.1% economic growth. This is largely due to the use of new technologies in agriculture and livestock farming, increasing the efficiency and productivity of this sector. Another relevant factor is that 40% of Brazilian exports of industrialized products belong to the food sector, all of which are derived from agribusiness (Rosário, 2024). The main ones are: sugar, bran and flour for animal nutrition, beef, poultry, cellulose, starches, vegetable oils, animal fats, margarine, processed meats, juices, tobacco products, and others. Thus, Brazil consolidated itself in 2023 as the country that exports the most industrialized foods in the world.

New technologies applied to agriculture

The emergence of new technologies has been a precursor to social and economic development throughout the history of human civilization. Thus, the use and development of advanced and strategic materials represent competitive advantages (CGEE, 2010). In this context, we can highlight the important role of semiconductors.

For example, in the meat production chain, semiconductors play a crucial role in several stages of the process, with the following being highlighted:

1) Automation and Process Control: sensors based on semiconductors are used to monitor variables such as temperature, humidity and pressure in refrigeration chambers, slaughterhouses and transport; microcontrollers, which manage automated systems, such as conveyor belts, packaging machines and tracking systems.

2) Traceability and Identification: radio frequency identification (RFID) is based on semiconductor devices that are used to track products throughout the production chain. This allows for the precise identification of batches, origin and date of production.

3) Quality and Inspection: cameras with CMOS sensors are used to inspect the quality of meat, detecting defects, contamination or anomalies; semiconductor-based computer vision systems help to classify and separate meat based on criteria such as color, texture and size.

4) Logistics and Transportation Monitoring: GPS and wireless communication systems incorporate semiconductors to track the location and condition of transport vehicles; temperature sensors ensure that meat is transported under optimal conditions.

5) Energy Efficiency: Power semiconductor devices are used to optimize energy consumption in refrigeration systems, lighting, and other equipment.

6) Data Processing and Analytics: Server and data center computers use semiconductors to process large volumes of data related to meat production, distribution, and sales. In short, semiconductors contribute to efficiency, safety, and quality throughout the meat production chain.

Thus, we can mention microchips. Microchips are small electrical circuits built on a thin layer of semiconductor material. Microchips have thousands of applications in the most diverse areas of study and knowledge, including the beef industry. In a 2019 study, a group of researchers analyzed the use of subcutaneous microchips to monitor the temperature of cattle raised on pastures (Giro et al., 2019), concluding that despite its limitations, it is a practical method. Monitoring bovine temperature allows for a better quality of life for the animal, having direct impacts on productivity and profitability. There are also relevant veterinary applications for the use of microchips, both in the diagnosis of diseases and in the administration of medications. As described by Doori Oh et al. (2010) microchips could be used to diagnose phagocytophilum, a bacterium transmitted by a parasite called ixodesscapularis, a tick, a disease that commonly affects cattle and can cause fever, weakness, malaise and other symptoms. The use of microchips allows for rapid analysis (approximately 35 seconds), in addition to requiring a small sample for testing.

Among new technologies applied, the so-called "electronic nose" has been used to determine meat quality. A device known as an electronic nose is a tool capable of detecting odors and flavors, and its operation is based on the human sense of smell. As described by Linda Buck and Richard Axel, humans have a series of receptor cells, each of which is capable of binding to a specific type of odor (Linda et al., 1991). In electronic noses, a series of sensors are capable of detecting the same chemicals perceived as "smell" by humans, and software acts in a similar way to the human brain, combining the individual perception of each sensor (Rezende, 2021). This device is useful in the food industry, and there are several possible applications for this equipment in the industry for the production

and marketing of beef. As examples, the Swedish Meat Research Institute used an electronic nose to determine the degree of spoilage of vacuum-packed beef (Blixt et al., 1999), while Dedy Rahman et al. (2022) conducted a study using the equipment to assess beef quality and predict microbial population.

Along these lines, another technology is the "electronic tongue" (Latha et al., 2012). The electronic tongue is a set of nanosensors developed in the laboratory for liquid analysis, that is, it is a taste sensor for evaluating liquids, which allows the quality of liquids to be checked quickly, accurately, simply and at a low cost, and to attest to the presence of contaminants or foreign substances, pesticides, humic substances and heavy metals. This technology has the potential to be used to attest to the quality of coffee produced in Brazil, being able to monitor the consistency of taste, classify the quality, regions and even producers, and can detect adulterations in the coffee sold.

One area in which the application of new technologies is strongly present is precision agriculture (Zhang et al., 2002). Precision agriculture is a way of managing agribusiness processes that uses modern machinery and technologies that help achieve better productivity. In this sense, the entire production process is considered, from soil analysis, fertilization, planting and harvesting, to the transformation and marketing of products. The great advantage of precision agriculture is that as much data as possible must be collected using modern equipment and effective techniques for better interpretation. This processed and analyzed information then helps in decision-making. One example is the variable rate in agriculture.

Variable rate sensing in precision agriculture aims at the automated application of materials in a given area (Saleem et al., 2023). This process is based on data collected through sensors, maps and GPS, enabling the optimization of agricultural production. These materials include fertilizers, chemicals and seeds, all of which help to improve crop production. There are several forms of technology used in variable rate sensing in precision agriculture, including drones, GPS, satellites, encoders and artificial intelligence (AI). For example, with scientific analysis of pests, it is possible to know which threats are in action at each stage of the crop, and, therefore, apply the correct input in the correct quantity, reducing costs and providing healthier food, exposed to fewer chemical or biological products.

Final Considerations

The current growth of the world population in recent decades has created the need to increase food production, whether of animal or plant origin. This growing demand generates the need for greater efficiency and productivity in agriculture, which, if not met, can lead to a shortage of products and consequently an increase in food prices, opening up possibilities for economic problems and even conflicts between countries. This type of problem must be avoided at all costs, and as seen in this work, Brazil is a country whose GDP depends significantly on the agricultural sector.

Furthermore, the emergence of new technologies in parallel with the growing need for agricultural products has produced a professional and increasingly competitive market. Thus, countries that want to be competitive in the agricultural sector need to introduce technological improvements in order to reduce costs and increase the yield of agricultural activity.

Semiconductors are essential elements for the manufacture of electronic components such as diodes, transistors, cell phones, computers, automated or non-automated machines, vehicles, microprocessors and nanocircuits used in nanotechnology. These devices are essential for precision agriculture and modern technologies that, when applied to the agricultural sector, increase its efficiency, productivity and, consequently, its competitiveness. In short, semiconductors contribute to efficiency, safety and quality throughout the agricultural production chain. Therefore, it would be in the national interest to also invest in the semiconductor sector, which is essential for the production of chips, that is, to invest in a national semiconductor industry that would supply electronic components used in the development of technologies to further boost Brazilian agriculture. This national industry, in addition to reducing the extremely high costs of importing sensors and other semiconductor devices (Rodrigues, 2022), would bring security to the country, since a global shortage of chips (which may be a reality, whether due to conflicts, pandemics, political interests, etc.) would profoundly affect the Brazilian agricultural sector.

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