Digital technologies in agricultural development: the experience of Latin American countries

Diana Pamela Chavarry, Wilmer Paul Chavarry

P. LUMUMBA Peoples’ Friendship University of Russia (RUDN University), Moscow, Russia

Abstract. The article highlights the main problems of agriculture in the Latin American and the Caribbean (LAC) region and considers "smart agriculture" as one of the directions for solving these problems. It is concluded that information technologies in the industry in LAC are most developed in Brazil, Argentina, Colombia, and Uruguay, and much less in Ecuador, Peru, and several other countries. Among the areas of digitalization of the region's agricultural industry, the following were highlighted: specialized software, digital sensors, drones, robots, autonomous vehicles, territory mapping systems, GPS, cloud technologies, the Internet of Things, big data, precision agriculture, and others. The thesis substantiates that, despite the advantages of using digital technologies in the agricultural sector, LAC countries may face some problems in their implementation, including the high costs of digitalization of production processes, the deterioration of the situation of small farmers due to the risk of monopolization of markets by companies owning modern digital technologies, a reduction in the need for labor resources, and, as a consequence, an increase in unemployment. It is emphasized that these, as well as other risks when introducing digital technologies in agriculture, require further understanding and the adoption of effective measures to minimize them.

1 Introduction

Agriculture, which provides the vital food needs of the population, is a strategic sector for the economies of modern countries. However, despite its importance, innovative technologies come to this area late compared to the industrial sector of the economy. This is what happened with digitalization processes, which today affect agriculture less significantly than, for example, the automotive industry, electronics, chemical industry, textile industry, and several other industries. Moreover, in terms of the level of digitalization, countries and regions of the world are developing extremely unevenly. Thus, LAC as a whole lag behind advanced countries in terms of digital technology development, and some LAC countries demonstrate a more significant lag in this matter (for example, Honduras, Venezuela, etc.).

We also note that the overwhelming number of countries on the LAC continent are agricultural, and the share of exports of their agricultural products seriously exceeds the volume of exports of industrial goods. At the same time, unsustainable agricultural...
practices in several LAC countries, as well as a set of problems in the industry, lead to a paradoxical situation in the region: being the largest food exporter, a significant proportion of the population experiences hunger. LAC is currently at its highest level of hunger since 2000, according to the Food and Agriculture Organization of the United Nations (FAO). In the first year of the COVID-19 pandemic alone, from 2019 to 2020, the number of Latin Americans suffering from hunger increased by 30% [1], and 9.7 million people in 13 LAC countries faced acute food insecurity for the first time in recent years [2]. The Pan American Health Organization predicts that hunger will affect 67 million people in the region by 2030 [3].

To solve the food problem in LAC countries, the most important task is a serious transformation of agriculture, allowing for more rational use of land, high crop yields, productivity in livestock farming, as well as the safety of products during storage and transportation. In this regard, the development of advanced technologies, including in the field of digitalization, is of particular interest to the LAC region.

2 Materials and methods

To analyze the processes of digitalization in agriculture in LAC countries, the analytical method, the generalization method, the statistical method, and others were used. An analysis of publications on the topic was carried out, and it was concluded that, despite the relevance of this issue, neither in Russian literature nor in scientific periodicals in a foreign language, the issues of digitalization of agriculture in LAC countries are sufficiently covered.

Among the authors of works in foreign languages, we can highlight the following: Estrela A., Monterio de Ora H.R. [4], Freeman K., Valencia V. [5], etc. There are practically no studies on digital technologies in the agricultural sector of LAC countries in Russia. You can, for example, highlight the work of A.D. Klyukin. and Kivuli D.S. [6], considering trends in the development of digital technologies in agriculture in LAC countries. But such works are rare.

To obtain more reliable research results, the most striking examples of the introduction of digital technologies in agriculture in LAC countries were selected, and the experiences of these countries were analyzed.

In conclusion, using the generalization method, the main conclusions about the work were drawn.

3. Results and discussion.

3.1. Key problems in agriculture in LAC countries

Agriculture in the LAC region is a leading sector of the national economies of almost all countries. The industry has the largest share of the country’s GDP in Haiti (20.28%) and the smallest in Puerto Rico (0.66%). A significant share of agriculture in the country’s GDP is also observed in Nicaragua (16.78%), Honduras (12.57%), and Bolivia (12.47%). [7]. The total area of agricultural land in LAC accounts for 16% of the world’s total. The region also contains more than 30% of the world’s freshwater reserves [8]. LAC countries are the largest exporters of agricultural goods to the world market. According to some estimates, these goods account for more than 25% of global exports of agricultural raw materials and food [9]. More than 13% of all products produced in the region are exported [10]. Most fruits and vegetables, coffee, sugar, corn, soybeans, meat, and fish are supplied to the world market [11]. The largest importers of LAC agricultural products are the USA, EU countries, China, and Russia.

However, LAC agriculture faces a number of serious problems. The main ones include a low level of modernization of production in the vast majority of countries in the region, etc.
an insufficient level of technology for growing crops, a high share of manual labor, problems of crop loss due to natural disasters, irrational organization of transportation and sales, degradation of agricultural land, insufficient investment in the industry, and others.

Thus, a particular problem is the use of outdated technologies that pollute the environment and agricultural products themselves. Excessive use of pesticides and herbicides, as well as chemical fertilizers, causes harm and poses health risks to consumers.

The main task of LAC countries today is to achieve sustainable development of the industry, in which it could provide food for a growing population while reducing harm to the environment. In this regard, one of the directions for solving this problem is the use of digital technologies in agriculture.

3.2. Digital agriculture is a key trend in the agricultural industry.

Digital agriculture ("smart agriculture", "agriculture 4.0", "e-agriculture") is one of the fastest-growing areas of the agricultural industry in both developed and developing countries. This direction focuses on the use of advanced technologies to improve the production process of agricultural products. Today, the term "smart agriculture" is more common. In general, "smart agriculture" involves organizing it in such a way as to use the minimum necessary number of resources in the process of growing crops or livestock while preserving the environment. Several authors call the introduction of this format of farming a revolution in the traditional approach to organizing the agricultural industry [12].

The implementation of this approach becomes possible using digital technologies, including specialized software, digital sensors, drones, robots, autonomous vehicles, territory mapping systems, GPS, cloud technologies, yield assessment technologies, variable standardization technologies, remote earth sensing [4], the internet of things (IoT), and big data. First of all, new technologies are aimed at transforming the industry into so-called precision farming (or coordinate farming). The basis of such a high-tech system is the understanding of heterogeneity within one field and the importance of assessing these heterogeneities to subsequently take them into account in calculating crop volumes, fertilizer application rates, and the use of plant protection products, as well as more accurate yield forecasting.

It is obvious that traditional methods of farming today are not effective, and there is an urgent need to switch to innovative methods. Integrating digital technologies into the agricultural process provides an opportunity to support productive agricultural activities, meet global demand for food products, and adequately respond to changing factors of the external and internal environment [13]. Factors that contribute to a more accelerated transition to the integration of digital technologies in agriculture mainly include climate change, natural disasters (droughts, floods, and hurricanes), decreased yields due to deterioration in soil fertility due to desertification, and excessive chemical fertilizer. Since negative factors have been increasing in recent years, the need for digital processes in agriculture will only increase. Thus, FAO predicts that the global digital agriculture market will grow by about 11.3% annually until 2027 [1]. According to the consulting company Exactitude Consultancy, by 2029, the volume of the smart agriculture market will be $21.12 billion [14] (in 2022, it was recorded at $19.31 billion). In this regard, we can expect that the pace of implementation of such technologies will increase in certain regions of the world, including LAC as a key agricultural region.

3.3. Using digital technologies in agriculture in LAC countries.
Even though digital processes in LAC are not proceeding at such a rapid pace as in developed countries, nevertheless, digitalization has in one way or another affected many sectors of the national economies of the countries in the region, including agriculture. These processes are especially active today in Brazil and Argentina. Here, areas such as precision agriculture and robotization are considered higher priorities. Uruguay and Colombia are also in the active process of digitalizing agriculture, and Ecuador and Peru are much less so.

Argentina became one of the first countries to, since the 1970s, begin to develop direct seeding (no-till) technologies, which today are characteristic of “smart agriculture.” The development of the technology was carried out by the National Institute of Agricultural Technologies of Argentina (INTA) and the Argentine Association of Direct Sowing Producers. The country is now a leader in this technology, which has allowed it to restore the potential of arable land and lead to more intensive growth in the agricultural industry (over the past 20 years, harvest in Argentina has tripled, from 40 million tons to 125 million tons). Note that 93% of the cultivated areas of this country are today subject to direct sowing technology [15].

Uruguay can be cited as an example of the introduction of digital technologies in the agricultural sector in the LAC region. Several years ago, digital tracking systems were introduced here, which significantly improved the performance indicators of industry enterprises. More active use was made of technology, such as digital sensors that collect the necessary information during the production cycle. Today, in Uruguay, digital tracking systems for livestock, crop rotation in fields, the use of chemical fertilizers, etc. are widely used [5].

There is also a pilot project being implemented in Uruguay to develop blockchain technology. This technology allows you to solve several problems, including tracking the conditions of storage and transportation of products produced by agricultural enterprises, improving supply chains by reducing logistics costs, reducing the cost of products on the market by reducing the number of intermediaries, and improving product quality by tracking agricultural experience in other regions, etc. The blockchain system is more actively used in Uruguay by dairy product producers, who receive organizational and technical support from the National Milk Institute (INALE) and the Center for Innovation and Entrepreneurship at the University of Uruguay [1].

The example of Colombia is also indicative, where digital technologies in agriculture are also actively developing. Moreover, support for the implementation of such technologies is provided by the state and is largely aimed at small businesses and private farmers. According to a report by the Inter-American Development Bank, Colombia can now be called the center of agri-tech innovation for small farmers in the LAC region. It is in this country that you can find the most informational tools that are used in the agro-industrial complex [10]. To implement such innovations in Colombia, a favorable regulatory environment was created, government support for start-ups was expanded, and an investment culture was created. Moreover, it was Colombia that became the first country in LAC to use e-commerce to promote the products of small farmers to buyers without the participation of retail chains and a chain of intermediaries.

Other countries where there is also a trend towards more active digitalization of the agricultural industry today are Peru and Ecuador. Thus, there has been an increase in the volume of government support in Peru, mainly within the framework of projects such as Innóvate Perú and StartUp Perú [10]. In Ecuador, interest in the digitalization of agriculture is growing since the country has a fairly extensive structure of the agro-industrial complex and, to a greater extent than many other LAC countries, exports agricultural raw materials and food to the world market.
Thus, it is worth noting the Smart Agro 4.0 system, aimed at active digitalization processes in the countries of the region and within the framework of which small enterprises are also supported. The program has already made it possible to improve the yields of crops grown by LAC farmers, increase labor productivity, reduce costs, and promote more active promotion of products to the market (Table 1).

**Table 1.** Results of using Smart Agro 4.0 technology in LAC.

<table>
<thead>
<tr>
<th>Country</th>
<th>Culture</th>
<th>Local organizations</th>
<th>Participation of family cooperatives</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>Potato</td>
<td>Association of Manufacturers; Development Agency “Rural”</td>
<td>38</td>
<td>Increased production by 50%; cost reduction by 22%; improving the quality and increasing the yield of products</td>
</tr>
<tr>
<td>Colombia</td>
<td>Coffee</td>
<td>Association of Organic Coffee Producers (ASOPROCAFE)</td>
<td>72</td>
<td>Increased yield; increasing water use efficiency through better irrigation management</td>
</tr>
<tr>
<td>Peru</td>
<td>Cotton</td>
<td>Ministry of Agriculture and Irrigation of Peru</td>
<td>3</td>
<td>Increased production by 77%</td>
</tr>
<tr>
<td>El Salvador</td>
<td>Fruits and vegetables</td>
<td>Cooperative Canton of San Bartolo de Guatajiagua</td>
<td>12</td>
<td>Increased field productivity by 80% due to the use of new irrigation systems</td>
</tr>
</tbody>
</table>

Source: [10]

GSMA AgriTech, a company introducing digital technologies into the agribusiness sector, has identified 131 digital tools that are used in agriculture in the LAC region. Among them, several digital applications are somehow related to the agricultural industry. Thus, one of the more common is Agri VAS, which provides information on weather forecasts, market prices for agricultural products, and best practices in farming both within the countries of the LAC region and around the world. This project was implemented jointly with the US Agricultural Foreign Service. Booster Agro is also a large application, with 100 thousand users. This application is distributed mainly in Argentina and Brazil. In Ecuador, a similar application is Agromóvil, where users can follow news on agriculture as well as the export and import of agricultural products. Colombia has developed the Kanpo application, which reflects the dynamics of prices for agricultural products and also highlights best practices in the industry [10].

Dozens of companies are introducing digital technologies into the agricultural industry in LAC, including Telefónica and Microsoft. In addition, the most important players in the digital technology market for agriculture are Trimbl Inc., Dir and Co., Topcon, DeLaval Inc., AgEagle Aerial Systems Inc., Afimilk, Raven Industries, Inc., Ag Junction LLC., AGCO Corporation, and GEA Group [14]. Various consulting companies and research groups—Sena, Iica, CGIAR, CATIE, and others—are also involved in the process of introducing such technologies. The well-known Chinese technology corporation Huawei is currently working in several LAC countries to introduce digital technologies (mainly artificial intelligence and cloud technologies) into the agricultural sector in Brazil [15]. In general, we can conclude that this market segment has great potential for its development, as well as many free "niches," which may be of interest to Russian software development companies for “smart agriculture” as well as for the promotion of other technologies.
3.4. Benefits and risks of digital agriculture for LAC countries

Undoubtedly, the introduction of digital technologies in agriculture in LAC allows the countries of the region, many of which are agricultural states, to seriously improve the efficiency of the industry. Benefits include increased productivity in the agricultural production process, more accurate analytical data, a more effective risk management system, reduced waste, improved quality of products, increased yield, reduced harm to the environment, reduced risks from the human factor, and easier manual labor.

Digital technologies for agriculture can dramatically transform existing agricultural management systems, making them more cost-effective, productive, transparent, and flexible, as well as reducing environmental damage. As Yakovlev P. rightly notes, the precision farming system as a tool of “smart agriculture” can lead to a deep modernization of key sectors of the economies of LAC countries, including the agricultural sector [16].

However, such technologies introduce certain risks into the traditional farming process. For a more active pace of implementation of digital technologies in the agricultural industry, certain conditions must be met [6], namely: a sufficient level of development of IT infrastructure in rural regions (mobile communications, Internet access, network coverage); affordable prices for IT services; a sufficient level of education, including digital literacy; state support for both the agricultural and industrial sectors; and the introduction of digital technologies in agriculture.

Several authors have warned that political, social, and cultural challenges may follow when digital technologies are introduced into the agricultural sector [17]. First of all, the question arises about the monopolization of participation in global production networks by companies that own digital technologies. Controlling technologies for the introduction of agriculture by companies, usually represented by TNCs, will contribute to the further promotion of their interests. In this situation, small and medium-sized businesses, which are traditionally actively involved in the agro-industrial complex, may suffer seriously.

In addition, due to the automation of agriculture, the need for labor resources is reduced. For LAC countries, where a significant proportion of the population is employed in agriculture (in total, 125 million people are employed in the industry in the entire region, which corresponds to 16% of the economically active population [18]) and the unemployment rate is quite high, automation and subsequent job cuts can lead to serious consequences.

Serious obstacles to the more active implementation of digital technologies in LAC countries remain limited funding opportunities for small and medium-sized businesses, low levels of computer literacy among the population, the presence of a large informal sector [19], as well as the low level of IT infrastructure in the region. The key problem limiting the more active spread of digital technologies in agriculture in LAC countries is, of course, the high financial costs of introducing such technologies and the lack of large-scale funding from the state.

4 Conclusions

Despite being a leading agricultural region, LAC nevertheless lags seriously behind developed countries in the innovative technologies used in the industry. However, given several problems that have emerged today in the agriculture of the countries in the region, intensifying the pace of innovation, including digital technologies, is becoming an extremely important task.
rural regions, affordable prices for IT services, and government support for the digitalization of the industry), we can state the fact that LAC does not foresee rapid development of these technologies shortly. In our opinion, they will be implemented more dynamically by Argentina and Brazil, which, firstly, are more developed countries in the region, including in terms of the level of digitalization; and, secondly, they are traditionally the largest agricultural countries. Colombia, as well as Peru and Ecuador, have certain prospects.

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