INDUSTRY 4.0 VERSUS AGRICULTURE. DEVELOPMENT PERSPECTIVES OF AGRICULTURE IN THE REPUBLIC OF MOLDOVA BY ASSIMILATING DIGITAL TECHNOLOGIES

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Abstract: *For the Moldovan economy, the agriculture in current conditions is one of the priority sectors that contribute to the strategic development of the country in such areas as improving food security, increasing the number of territories with agricultural specialization in a difficult socio-economic situation and ensuring a high standard of living for the rural population. Digital technologies contribute to the achievement of these objectives by adapting agriculture to external conditions associated with geopolitical and macroeconomic changes. The underlying problems currently facing the agricultural sector are the unfavourable climatic conditions of recent years, lack of labour, caused by mass migration, but also the need for innovation and a reliable scientific approach to improving production in plants and animal husbandry.*

This research aims to study the concept of Industry 4.0 in Agriculture trough the existing national and international experience in digital technologies. The authors analyze the state of the Moldovan agro industrial sector to determine the technical, human and financial potential for implementing digital technologies as solutions for streamlining the management of agricultural enterprises to ensure sustainable development of the national economy. Another

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purpose of the study is to identify promising areas of agricultural development based on digital technologies, and to evaluate the possible effect of their implementation on the production cycle and increasing the quality and competitiveness of domestic farm products.

***Keywords**: Industry 4.0, digital agriculture, informational technologies, digital platforms.*

Introduction

The primary trend in the modern development of the international community has become the implementation and development of information and communication technologies (ICT) in all fields of activity: financial, economic, educational, entertainment, marketing, and other areas.

The term Agriculture 4.0, along with Industry 4.0, is increasingly addressed in the Sustainable Development Strategies and Growth Policies of many countries in the world. Sustainable development in agriculture through digitization involves the development of new management models based on information technologies to ensure increased productivity on farms, soil conservation and biodiversity minimizing the negative impact on the environment, providing a stable level of production and profit.

Agriculture, in the current conditions of socio-economic development of the country, is a priority area to ensure food security and welfare of the population. Moldovan agriculture has a differentiated potential for the growth and regional specialization due to different climatic, socio-economic and technological conditions.

Ecological losses, water scarcity, arable land degradation, growing energy needs, and the emergence of new diseases and pests are putting considerable pressure on the economy, and it is increasingly difficult for farms to carry out profitable activities and meets the needs of the market in agricultural products.

Digital technologies are the future of agriculture, and attempts to ignore them are hampering the development of this sector.

The Internet of Things, robotics, artificial intelligence and large volumes of data are applied by farmers around the world and contribute significantly to streamlining agricultural processes.

Technological innovation in the latest research in the field is considered a solution for agro-industrial countries. Agricultural technologies, based on IT products, automation and robotics, widely used will catalyze the increase of productivity and profitability of farming activities. Research in the field considers digital technology - a realistic way to meet current challenges.

The digitalization of agriculture improves working conditions for farmers, reduces the negative impact of agriculture on the environment, but also ensures a much higher profitability of agricultural holdings.

In a short time, digital agriculture will take the place of the traditional one, producers understanding that by investing in technology - they can achieve efficient results, such as saving seedlings fertilizers, herbicides, pesticides and fuels.

This research aims to study the concept of Agriculture 4.0 analyze the state of the agricultural sector in the Republic of Moldova to determine the technical, human and financial potential for implementing digital technologies as solutions for streamlining the management of agricultural enterprises to ensure sustainable development of the national economy.

The paper is also a study of existing national and international experience in the application of digital technologies in the agricultural sector.

The degree of the problem investigation

Digital technologies are a new direction to increase the efficiency of the agro-industrial complex and the sustainable development of the agricultural sector. Contemporary researchers highlight several trends for implementing modern technologies and approaches in agriculture.

Some researchers, Vasiliev A., Briuhanov A.[1], Greve M., Boincean B.[2], Neverova O., Peciura E., examine the development of the agricultural sector by applying green technologies, the creation of processing enterprises on the principles of "green economy". These authors highlight the accessibility of technologies and innovations in agriculture in the context of regional development; also the need for financial and human resources for IT changes, and their efficiency for economic growth.

The complex approach to economic, financial and environmental efficiency is supported by researchers Lebedeva O., Gafiatov I.[3]. The authors are concerned about business results and increased productivity, noting that overloading the soil with bio-additives and fertilizers should not affect the environment and product quality for consumers.

An important issue for digital innovations and technologies is the management efficiency at the regional level. In this order of ideas, we

[1] A., Vasiliev; A., Briuhanov, *Evaluation of the effectiveness of the best available technologies for intensive animal husbandry* // Technologies and technical means of mechanization of crop production and animal husbandry. 2016. No. 86. p. 31-142.

[2] B., Boincean, *Ensuring the sustainable development of the agricultural sector in the Republic of Moldova through ecological modernization*. NooSfera, no 10-11. 2014, pp. 91-103.

[3] O.I., Lebedeva; I.Z., Gafiyatov, *Organization of effective land use in the framework of the "green economy"* // Problems of the modern economy. 2015. No. 1 (53).

mention the research conducted by Gunkova A., Krylatykh E., Tryachtsin M.[4]. Quality management parameters are associated with professional competence and knowledge of product characteristics; the rationality of the introduction of technologies; the assessment of the consequences of changes in the production cycle in terms of impact on labour productivity; the profitability of basic processes and cost reduction.

Belokrylova E., Waage M., Sergienko O.[5] reflect regulatory aspects of environmental control and compliance with production standards in their work. In this case, the competitiveness of products and the possibility of exporting to the world market are assessed based on meeting the requirements of international law, introducing environmental management in agricultural and agricultural enterprises.

Researches in this field cover three main areas. The first is the application of new technologies in agriculture in developing countries, as well as territories with a difficult socio-economic situation, but favourable climatic conditions for the production of products from the industries concerned. There are specific business factors, government support and rapid growth rates[6].

Other scientific publications analyze the role of digital technologies in the development of the agro-industrial complex and agriculture in terms of job automation and increase labour productivity, marketing opportunities for production efficiency and optimization of resource potential[7].

The third group of works is related to the identification of the possibilities of using digital technologies according to the level and scale of the business, the types of property, including for small farms, which form the basis of the local agricultural economy of developed and developing countries.

Methods and materials applied

Research materials and methods include the analysis of the existing regulatory framework in the Republic of Moldova in the field of ICT development in the country's economy, compared to the normative

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[4] A.G. Gunkova; Yu.A. Kholopov, *Improving the environmental and economic indicators of the enterprise based on the implementation of the best available technologies* // Bulletin of Volgograd State University. Ser. 3, Economics. Ecology. 2017. No. 9. pp. 23-32.

[5] O.I. Sergienko, *Food security: the transition to technological standardization of environmental impacts based on the use of the best available technologies (BAT)* // Problems of the modern economy. 2011. No. 4 (40). pp. 95-102.

[6] U. Deichmann; A. Goyal, & D. Mishra, *Will Digital Technologies Transform Agriculture in Developing Countries?*, Agricultural Economics, 47(S1), 2016, 21-33.

[7] IDEAGRO (2015), *The Era of Digital Agriculture*. Available at: http://www.ideagro.es/index.php/noticias/89-the-era-of-digital-agriculture.

framework and international best practices for ICT implementation in the agri-food sector and research conducted in this field by domestic and foreign scientists.

Systemic and situational approaches contribute to assessing the dynamics of agricultural sector development as part of the country's economy, following factors that have a situational impact in the current period: trends in developing management and control in the agricultural sector, introducing innovations that positively affect socio-economic indicators. Development and the environment, increasing employment and farm incomes, financing mechanisms and fiscal incentives.

The modelling of socio-economic processes makes it possible to analyze the effects that arise from the rational use of digital technologies: improving the quality of working conditions and the attractiveness of the agricultural industry for investment and innovation while ensuring high quality and competitiveness of domestic products on the international market.

For the evaluation of the human, technical and financial potential of agriculture for the implementation of information technologies, statistical methods of analysis were applied based on data provided by the National Bureau of Statistics of the Republic of Moldova, as well as surveys conducted by authors on farms to determine their readiness for the agriculture digitization.

Results obtained and discussions

The interest in the issues of introduction and evaluation of the efficiency of innovative technologies in agriculture and the agro-industrial complex is associated with the increase of financial and production results, with new opportunities to implement accelerated import substitution models. Traditional and modern technologies ensure high results, contribute to updating reserves to increase production volumes and labour productivity. The introduction of changes in agricultural production and management technologies must be accessible and meet a set of criteria (see Fig. 1).

The technical criterion of accessibility means that the technology complies with the norms and standards of industrial safety for people and the environment, that there are no conflicts with the equipment used in the production process.

Economic feasibility is determined by several significant criteria: reducing costs, increasing profit margins and increasing the profitability of the main production areas.

Environmental accessibility is associated with the possibility of rational ecological management, reducing the concentration of harmful substances in the soil.

The human criterion is the ability of staff to use technology in the production and management process, in the presence of high qualifications, in employee training, continuity of technical education, academia and continuing education. It is also necessary to talk about creating working conditions that meet safety and hygiene standards, making working with the new technology convenient, harmless and economical in terms of working time and productivity.

Traditional agricultural production methods are still relevant today, which allows for a constant increase in results (economic, agricultural machinery, productive plant varieties, efficient fertilizers, rational agro technology techniques). However, the potential of previous achievements has already been exhausted, therefore, in agriculture; the pace of application of digital technologies and innovations is steadily increasing based on approaches to regional and national economic development programs promoted by the relevant international financial institutions (FAO, UNICEF, and UN).

In international practice, the perception of the need for radical modernization of the agri-food sector dates back to the first decade of the 21st century, being determined by the rapid growth of the planet's population and the need to provide vital resources, including land and food.

Given the limited amount of land resources, the problem of food security of the population cannot be solved by the unlimited increase of arable land, but by increasing the efficiency of agricultural production. In the current period of economic development, the possibility of increasing the efficiency of resource use in agriculture is associated, primarily with the need to develop precision agricultural systems and streamline operational management in response to changing natural conditions, the market and other requirements.

The concept of precision agriculture involves the use of ICT as a critical element, which increases the speed of processing large amounts of data and exchanging information.

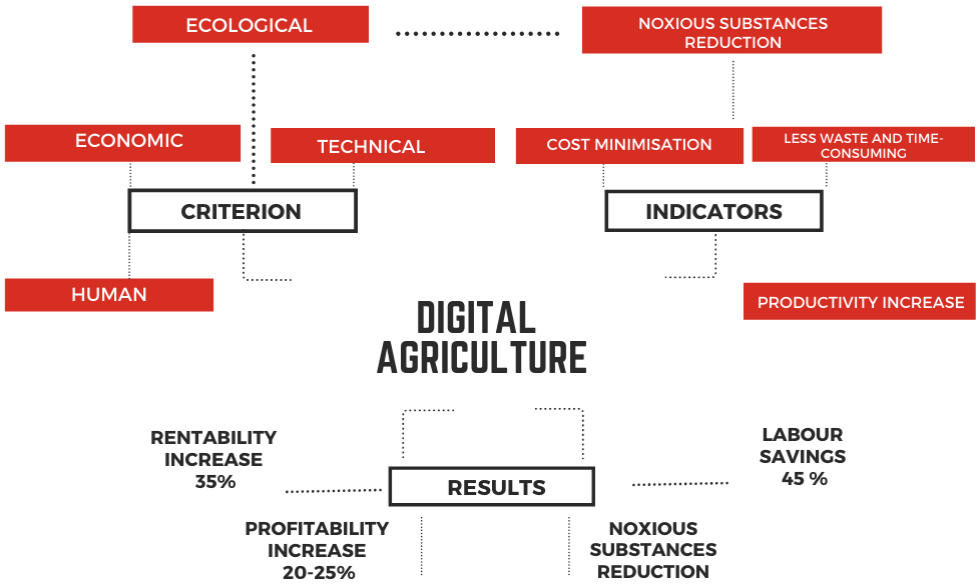

Figure 1. Criteria for access to information technologies in agriculture

Source: developed by the authors

Currently, the world community has already implemented many projects in this area. For example, under the auspices of the UN, the *e-Agriculture Community of Practice* (CAE) was created, which already has over 13,000 members from 170 countries and territories, the latter being representatives of government organizations and departments, specialists in the field of ICT, researchers, farmers, students, politicians, business people, development specialists, and others[8]. Within this community, a digital platform is organized, which allows farmers, farmers, decision-makers and other stakeholders to interact with each other and gain access to information on the sustainable development of agriculture through ICT.

Another example is the online guide, developed by the World Bank, *ICT in Agriculture Sourcebook* designed to disseminate the practices of digitalization of agriculture and the development of agribusiness. This resource is a practical, interactive guide, and contains information on current trends in the event of IT technologies, recommendations on

[8] Information and Communication Technology (ICT) in Agriculture. A Report to the G20 Agricultural Deputies (2017). Food and Agriculture Organization of the United Nations Rome, 2017. – p. 57. Available at: http://www.fao.org/3/a-i7961e.pdf

adopting some measures for the implementation and use of appropriate software products and evaluating their effectiveness[9].

The creation of cloud technologies and digital platforms has played a significant role in the development of ICT, which has made it possible to ensure extended access to databases and decision support programs (DSP), many of which are provided free of charge[10].

Today, in global practice, they have become ubiquitous, being called technological platforms - Technological Platforms (TP). The international community presents the following directions as the central concept of TP:

- Selection of strategic research directions;
- Analysis of the market potential of technologies;
- Consideration of the views of all stakeholders: state, industry, scientific community, regulators, users and consumers;
- Mobilization of public and private sources of financing for development innovative economy and society as a whole.

An example of such projects is the European cloud platform *FOODIE*[11], which not only provides farmers with access to the necessary information, but also searches for and integrates useful data for the agro-industry from various sources (e.g. *The European INSPIRE geoportal*[12]). This portal can be used to access data such as climate, land, ecological, aquatic maps, satellite images of the area, information on real-time weather conditions and climate change forecasts, statistical indicators of agri-food activity, sampling data, data on the biodiversity of territorial agricultural systems and crop productivity, recommended types of fertilizers, including prescribed rules and terms of application.

Other examples of technology platforms aimed at developing and solving problems in the field of biotechnology, agriculture, fisheries and food products refer to the platforms: *"Industrial Biotechnology", "Plants for the Future", "Global Animal Health", "Farm Animal Breeding", "Forestry", "Food for Life", "European Biofuels"*[13].

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[9] Ibidem

[10] WSIS Stocktaking Success Stories, International Telecommunication Union World Summit on the Information Society (WSIS) WSIS Stocktaking Process. Published in Switzerland Geneva, 2018. – 80 p.

[11] T. Řezník; V. Lukas; K. Charvat; S. Horakova, & M. Kepka, *Foodie data models for precision agriculture*. Conference Paper, August 2016. 195 p.

[12] EG / EuroSDR Workshop «Use of INSPIRE Data: Past experiences and scenarios for the future» (2018). INSPIRE Knowledge Base. Available at: https://inspire.ec. europa. eu/events/egeurosdr-workshop-useinspire-data-past-experiences-and-scenarios-future

[13] European Technology Platforms. (2019). Available at: http://www.bio-economy.ru/tekhnologicheskie_platformy/evropeyskie_tp/

National platforms for digital agriculture include "*Agroportal for farmers*" (Georgia), *Agricultural Information Centre* (Moldova)[14], *eRKG application* (Slovenia), *Integrated administration and control systems - IACS* (Hungary, Romania), *Agricultural information system - AIS* (Turkey)[15]. The Russian Federation, Belarus and Kazakhstan have created a common legislative framework and platform for the digitization of agriculture in the Eurasian Community.

The analysis of international practices in this field allows us to conclude that the leading player in the ICT market for agriculture is currently the United States, where the coverage of agricultural production with smart technologies reaches 80%. According to *Research and Markets*[16], the smart farm market in the Americas in 2023 will reach $ 11.93 billion[17]. In Europe, this figure is slightly lower.

Summarizing the international experience in the use of ICT in agriculture, we highlighted the main directions of their application:

1. In **interacting with the authorities**, digital platforms facilitate the interaction between farmers and the governmental authorities by simplifying the procedures for obtaining the necessary information, grants, and documents (e.g. the European REFIT platform[18] and the E-Government Centre in the Republic of Moldova[19]).

2. **Agricultural consultancy services** include assistance for marketing activity, accounting, implementation of ICT in production, legal aid of online farm producers (an example is the European technology platform FOODIE[20]).

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[14] Agricultural Information Center. Available at: https://date.gov.md/ckan/organization/2129-centrul-informational-agricol

[15] Status of Implementation of E-agriculture in Central and Eastern Europe and Central Asia (2018). FAO. Available at: http://www.fao.org/e-agriculture/news/status-e-agriculture-implementationcentraleastern-europe-and-central-asia

[16] Smart Agriculture Market by Agriculture Type (Precision Farming, Livestock, Aquaculture, Greenhouse), Hardware (GPS, Drones, Sensors, RFID, LED Grow Lights), Software, Services, Application, Farm Size, and Geography - Global Forecast to 2025. Available at: https://www.researchandmarkets.com/reports/5023854/smart-agriculture-market-by-agriculture-type

[17] Americas Smart Farming Market: Focus on Solutions (Hardware Systems, Software, Services) and Applications (Precision Crop Farming, Livestock Monitoring and Management, Indoor Farming and Aquaculture) (2018). Analysis & Forecast 2018-2023. – 195 p. Available at: https://www.marketresearch.com/BIS-Research-v4011/Americas-Smart-Farming-Focus-Solutions11833135/

[18] European Commission Platform. Available at: https://ec.europa.eu/info/content/refit-platform_en

[19] E-Government Agency. Available at: http://www.egov.md/en

[20] Farm Oriented Open Data in Europe. Available at: http://www.foodie-project.eu/

3. Agricultural management currently covers several key areas that focus on remote control of the production process and technical means, precision agriculture, remote sensing of agricultural land, control of the location and condition of animals on the farm. Remote control of the production process is achieved using software products that ensure uninterrupted data exchange; for example, *The Pivot Mapper Program*[21] allows the management of remote land irrigation. For the implementation of management processes, signal transmission-reception systems (*GPS navigation systems, GNSS*) are developed.

As part of the agricultural management and demand strategy, large-scale robotization of production processes (agro-robots) takes place, which helps to solve the problems of insufficient staff in agriculture, automation of routine activities, performing heavy work or high-precision operations. (e.g. *Mobile Agricultural Robot Swarms* (Germany)[22] - mobile agricultural robots controlled by special applications by a single operator).

To control "smart technology", new types of systems are being developed. That ensures the precise movement of hardware that allows automatic control of the flow of agricultural machinery on previously created routes along rows of planted plants, complex field contours, with precision high and in adverse visibility conditions (e.g. *CLAAS CAM PILOT* (Germany), *Raven Cruizer* produced by Raven Industries (USA), *CenterLine 220*, developed by TeeJet Technologies (USA), *Leica mojoMINI* from Leica Geosystems (Switzerland), *TRACK-Leader* from Muller-Elektronik (Germany)). Besides, the "smart technology" is equipped with crop mapping systems and soil moisture sensors.

4. Information management and knowledge exchange. For agricultural innovation systems, an example of the implementation of this direction can be interactive education services and qualification courses, international trade of real experience in the industrial application of ICT through regional networks (e.g. *ESCORENA* and *AGROWEB* - European Union) and global platforms, as well as on platforms designed to host agricultural food start-ups, for example, *The FoodBytes platform! Rabobank* (Chicago, USA), which allows the evaluation of the best start-ups (selected by a group of experts) of representatives from various countries in the field of agriculture and finding potential investors for their implementation.

[21] The Pivot Mapper Program. Available at: https://www.pivotmapper.com/

[22] The European Coordination Hub for Open Robotics Development. Mobile Agricultural Robot Swarms (MARS). Final Report. Available at: http://echord.eu/public/wp-content/uploads/2018/01/Final-Report-MARS.pdf

5. Expert systems or decision support systems in agriculture. In the design and construction phase, several software products that allow the creation of projects of recovery systems, hydraulic structures, as well as buildings and structures involved in agricultural production in the GIS coordinate system (e.g. *IRRICAD* - an integrated software package specially designed for the design of the irrigation or pressurized water supply system[23]). At the stage of planning and organizing the production process in agriculture - support systems verify the correctness of farmers' decisions: from choosing crops from different areas of the land to using various technologies for their cultivation or forecasting the consequences of applied agro technical measures, potential yield.

ICTs are widely used in the word for agriculture radical modernization.

In response to the changing agro-commercial environment, ICTs are focused on increasing the accuracy, volume and speed of data transmission and processing, remote monitoring and information system assistance, decision making, which allowed the implementation of precision cultivation processes, automation and robotization of production.

The cloud and platform technologies innovation has made it possible to provide and expand access to databases and decision support programs to an unlimited number of stakeholders.

The primary condition for ensuring their use is the provision of access points to Internet resources in rural areas, which is currently an objective of the Digitization Strategy of the Republic of Moldova[i].

Analysing the good practices for implementing smart technologies in agricultural business development, we concluded that the Republic of Moldova has sufficient technological capacity to launch a project to create digital platforms such as virtual incubators to incubate innovative ideas and technologies in agriculture.

At present, in the field of agriculture, the Moldova 2020 Digital Strategy envisages only the development of the following projects: Information system for real-time data transmission through web solutions and mobile telephony with components: *PACT* (*Early Warning and Communication Platform*) and *SIMA* (*Information System of Agricultural Marketing*).

The development of digital agriculture could catalyse a radical transformation of all industries, because digital agriculture will not only change the way farmers work, but will fundamentally transform every link in the value chain in the economy.

[23] IRRICAD Standalone (2019). Available at: https://www.irricad.com/irricad-standalone/

Digital agriculture will affect farmers' behaviour and will affect suppliers, processing companies, distribution and retail of agricultural products to consumers. Digital technologies can be applied at all levels and industries and reflect a radical shift in resource management towards optimized quality, individualized, intelligent and anticipatory, real-time, hyper-connected and data-driven governance.

Each of the technologies considered can bring tangible productions and socio-economic effects both in the presence of adequate equipment manufactured in the Republic of Moldova and abroad, as well as in the presence of the operational capabilities of agricultural enterprises.

The use of digital technologies in the agricultural sector of the Republic of Moldova requires a detailed examination.

In 2018, the Republic of Moldova ranked 139th in the world in terms of GDP (constant USD 2011 international), 124th in total exports, 121st in total imports and 77th for economic complexity according to the Economic Complexity Index (ECI)[24]. With a negative trade balance,

According to the statistical data, in 2018, Moldova exported goods and services worth $ 3.4 billion and imported $ 5.99 billion. In the top of exports were insulated wire ($ 581 million), a product of Automotive industry, and sunflower seeds ($ 201 million), wine ($ 135 million), other categories of agricultural products were shipped in non-essential quantities (wheat, sugar beet), others did not cover domestic consumption needs and were imported (meat, milk). At present, the problem of accelerated import substitution cannot be solved without the introduction of innovative technologies in the country's agro-industrial complex.

The development of agriculture in the Republic of Moldova will determine the establishment of the necessary level of food security both for rural regions and for the country in general. The agro-industrial complex of the Republic of Moldova has about 3 thousand enterprises with various forms of ownership, of which over 500 companies are large and medium.

The most popular agricultural areas in the country are based on the production of:

1) cereals;
2) industrial crops;
3) grapes;
4) sugar;
5) dairy products.

[24] Economic Complexity Index. Available at: https://oec.world/en/profile/country/mda

Climatic conditions and unique chernozem soils have a beneficial effect on the diversity of agricultural sectors and create favourable conditions for the cultivation of plant varieties and animal husbandry.

The main conditions for ensuring the efficient functioning of the agricultural sector:

1) progressive use of fertile lands;
2) the development of animal and crop breeding;
3) modernization and improvement of the processing industry.

Currently, the agriculture of the Republic of Moldova is characterized by a predominance of the cereal and industrial crops industry compared to the livestock industry - 71.32%, respectively 26.9%. The main specialization of crop production is the cultivation of cereals and fodder crops (silage, corn, green fodder), then there are technical species (sugar beet and sunflower).

In the livestock sector, predominate:

1) cattle breeding;
2) raising pigs;
3) sheep breeding;
4) poultry farming.

The rest of the industries (fish farming, horse breeding, beekeeping, rabbit breeding) have a small share in total production.

The development of the agro-industrial complex also occurs with the restoration of industries horticulture, viticulture and vegetable growing, with an increase in the cultivation area of traditional crops of the climatic zone.

The development program of the agricultural sector, at present, must be focus on solving the following problems:

1) modernizing the quality management of agricultural and food products;
2) human resources development;
3) reconstruction of abandoned lands, their reorganization;
4) increasing soil fertility;
5) restoration and continuous development of irrigation areas;
6) raising the level of technical and technological endowment of the agricultural sector,
7) implementation of modern varieties, resistant to drought;
8) compliance with crop rotation and other basic technological requirements;
9) looking for new sources of financing and investments.

According to the National Bureau of Statistics, global agricultural production on branches of agriculture, in 2019 increased by 27% compared to 2015, of which the creation of vegetable origin by 35.5%, and the production of animal origin by only 7.7% (see figure 2).

The agricultural production volume on the territory of the Republic of Moldova has an increasing trend every year (the exception is 2012, characterized by a deep drought that caused the decrease of the average harvest in the main crops). The last ten years have been characterized by an increase of this indicator from MDL 19,873 million to MDL 34,363 million. The rise of the volume of agricultural production indicates a stable growth dynamics and potential. Animal production has also experienced an increasing trend, but with different dynamics and lower rates.

Currently, there is a definite trend towards expanding the volume of the agricultural output by increasing the number of farm holdings and sales revenues from production activities in the period 2015-2018 (see Figures 3, 4). That is due to the transformation of price policy and credit mechanisms, increasing budget allocations for the development of the agricultural sector.

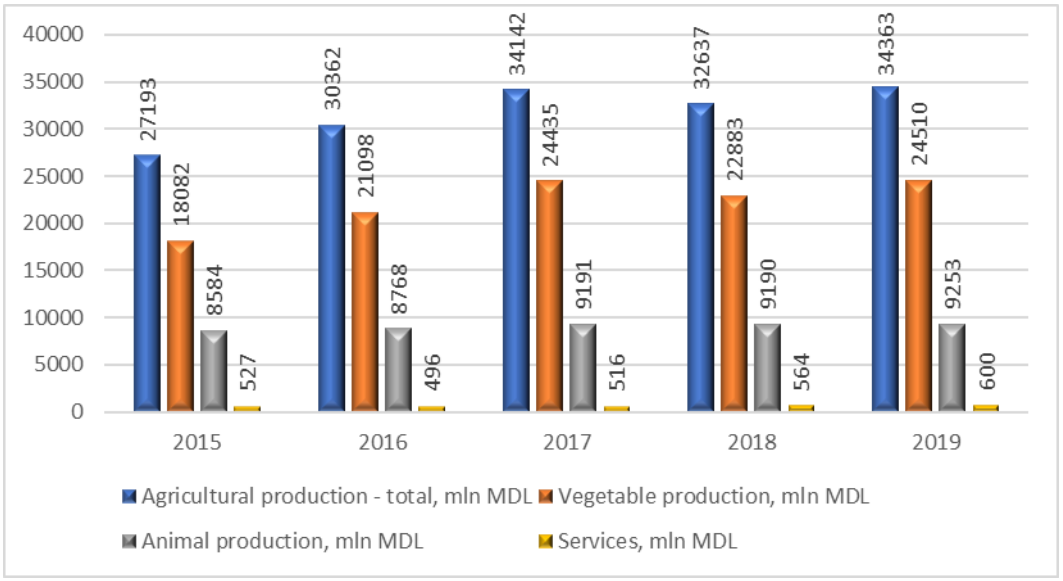

Figure 2. Dynamics of agricultural production by branches of agriculture, million lei, 2010-2019

Source: Prepared by the authors according to NBS data

According to statistical data, the number of agricultural holdings in 2018 increased by 32.89 percentage points from 3168 in 2015 to 4210 in 2018. The largest share of 76.56% of total farm holdings belongs to micro-

enterprises, and 18, respectively, 34% of small enterprises that are the primary beneficiaries and promoters of technological innovations in agriculture.

It is interesting to analyze the dynamics of the average number of staff employed in the agricultural sector in correlation with the dynamics of sales revenues. Thus, in the last 14 years, the number of employees is continuously decreasing, at the same time the increase of sales revenues in this sector denotes the fact of the gradual replacement of the labour with more efficient agricultural equipment and the automation of some production processes.

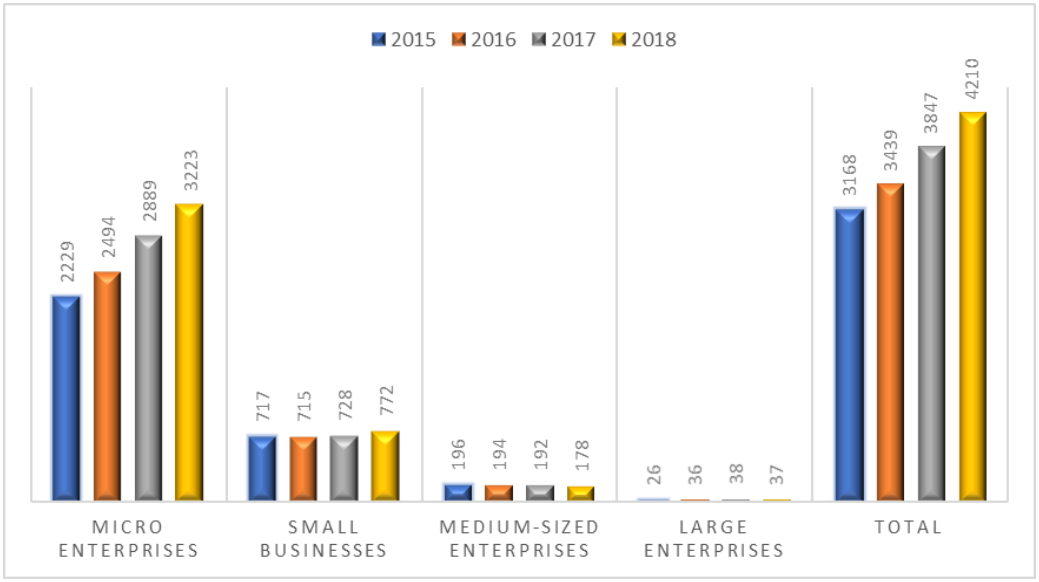

Figure 3. Dynamics of the number of agricultural holdings by categories[25]

Source: developed by the authors based on NBS data

The decrease of the average number of employed persons and the increase of the sales incomes realized by the agricultural exploitations, demonstrate the necessity and accessibility of the farming exploitations for the implementation and capitalization of the information technologies in their activity.

[25] **Note:** For statistical purposes, medium-sized agricultural holdings are enterprises that have up to 249 employees, have an annual turnover of up to 50 million MDL or have total assets of up to 50 million MDL, and are not enterprises micro or small. The small farms have up to 49 employees, have an annual turnover of up to 25 million MDL or have total assets of up to 25 million MDL and are not micro-enterprises.

The agricultural sector in the Republic of Moldova has sufficient development potential in many areas of activity. Innovative agricultural technologies reduce production costs, increase productivity and help improve product quality.

At the same time, we can highlight several needs that farmers are currently facing and some trends in local agriculture IT tools exploring:

1. The need to optimize water consumption and attract water sources funding for the development of optimal irrigation systems and other hydraulic tools. To analyze the condition of the soil and the time of irrigation, farmers need specific tools, such as satellite imagery, field-monitoring drones, and soil sensors. They make it possible to analyze the level of nitrogen and other nutrients in the soil, humidity and other important parameters. According to surveys in recent years, farmers have invested in optimal irrigation systems using mobile devices to monitor and control water flow and water distribution in those parts of the field where it is most needed. However, the number of such farms is minimal, and some farmers are applying these technologies on an experimental basis.

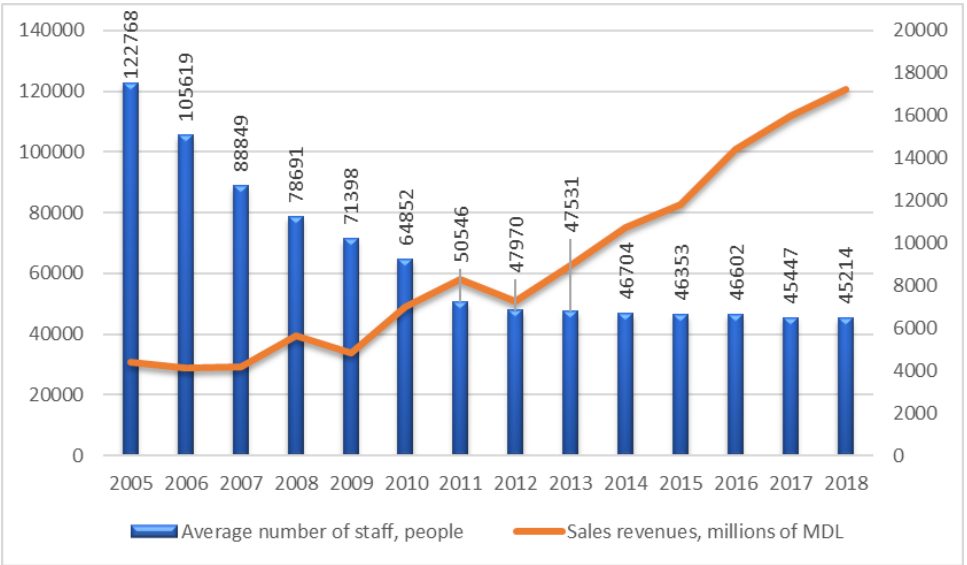

Figure 4. Dynamics of the average number of employees (persons) and sales revenues (millions MDL) in the period 2005-2018

Source: Developed by authors based on NBS data

2. The large gap between technically advanced farmers and continuing farmers to implement traditional methods of tillage and fruit collection. The survey conducted on a sample of 233 agricultural holdings in the Republic of Moldova, for grouping farmers according to the degree of perception of the need to implement IT in their activity allowed us to identify four basic types of farmers:

a. **innovative farmers**, who develop new innovative products to streamline the production process in agriculture, represent 7% of those interviewed;
b. **advanced farmers** in the use of IT products, those who use modern sensors, satellite imagery and other products to increase performance in agriculture - represents -12% of the total;
c. **farmers who are interested** in the implementation of IT in agriculture and experience some products (try to apply some IT products because they understood their usefulness) - 23%;
d. **traditional farmers**, who give up the use of new technologies in agriculture (considers that technologies are expensive and inefficient) - their share is 58% (see Figure 5).

The gap between the four categories of farmers and the large share of traditional farmers (58%) has a negative impact and stagnates the implementation of information technologies in agriculture.

3. Farmers lack of technical skills. This trend complements it the previous

one. Lack of technical knowledge is more characteristic of employees in the agricultural sector than managers. In the survey, we identified that workers do not want to learn and use new technologies and are anxious that the technique will replace their work, and human resources will no longer be needed. Because of this perception, many farmers face resistance to new technologies from employees. At the same time, 72% of the interviewed farmers warned about the lack of workers versed in the use of new technologies, and mentioned the need for investments in training existing employees.

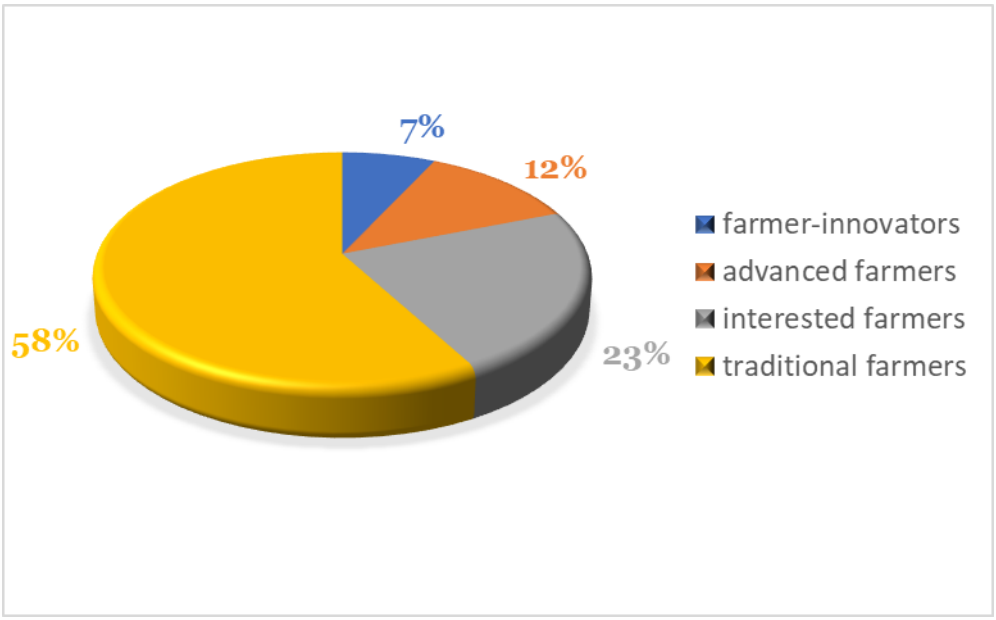

Figure 5. Types of farmers identified by the degree of perception of digital agriculture, in %

Source: developed by the authors based on the survey of the sample of 233 farmers

4. Slowing down the introduction of new technologies in agriculture due to the lack of financial assistance and subsidies from the state for the ICT implementation. Among the farmers interviewed, 63% mentioned the lack of financial aid and government subsidies for the application of ICT in agriculture. According to the Analytical Report on the management of financial resources allocated to the National Fund for Agriculture and Rural Development for 2018, prepared by the Agency for Payments and Interventions in Agriculture, the largest share of funding is directed to the purchase of agricultural machinery and equipment - 33.8%, which constitutes MDL 292.4 million of the total allocated financing. The repayment of interest paid by agrarian producers on accessing loans represents 25.5% or MDL 95.9 million, and for the share for stimulating investments in the establishment, modernization and deforestation of multiannual plantations corresponds to 20% or 210.2 million MDL[26]. Analysing the amounts requested by agricultural producers, we can see that in 2018, the most significant requests for subsidies were directed to the development of post-harvest

[26] Analytical report on the management of financial means allocated to the National Fund for the Development of Agriculture and Rural Environment for 2018. Available at: http://madrm.gov.md/sites/default/files/RAPORT%20ANALITIC%202018.pdf

and processing infrastructure. The demands for the implementation of ICT in agriculture were non-essential.

At the same time, 89% of the interviewed farmers mentioned the lack of tax incentive facilities for agricultural holdings that make investments and apply digital technologies in their activity.

5. Slowing down the introduction of new technologies in agriculture

due to lack access to the WI FI network in some localities of the country. There has been a trend for farmers to widely use high-performance sensors, drones and monitoring systems that require Internet access. According to the authors' survey, 18% of farmers surveyed rated the Wi-Fi network as "good quality", 23% called wireless network access "problematic", and 9% of farmers said that the internet is "poor quality". The other respondents rated the quality and speed of the internet as "satisfactory". If certain information is not received in time, and there are connection problems, the value of precision farming is reduced. The survey had as respondents Moldovan farmers who are active users of the 4G network.

6. Increasing the popularity of mobile applications. The interviewed farmers referred to diversify remote management capabilities. In our view, this is an essential step forward the digital agriculture development. Mobile apps have skills for setting and modifying technology parameters. For example, the application can change the settings of an uncrewed tractor or a garden robot without interrupting the work process. Mobile apps for parallel guidance and fertilizer and soil moisture monitoring systems are popular among advanced farmers in the use of ICT.

Therefore, the trend of intensive use of digital products is observed among farmers, creating favourable conditions for the development of intensive agriculture.

Based on the surveys, the main factor, which prevents the introduction of ICT in agricultural activities, is the lack of robotic equipment and software. Many of the Industry 4.0 products offered on the international market either require considerable financial investments or are incompatible with the conditions of activity and require qualified specialists in the field. They create difficulties in using new technologies on farms. At the same time, in the last years, the trends in agriculture, as in other sectors of activity, are the implementation of technical equipment, the use of new projects and innovative technologies that contribute to obtaining guaranteed profits.

Digital technologies in agriculture must be applied based on the strategic approach of the state, the systematic development of innovative

programs for the plant and animal breeding branch of the country's regions. The efficiency of innovations is economically proven, such as production volumes and environmental indicators. However, it is necessary to meet technical, economic, ecological and personnel criteria for the use of Industry 4.0 innovations in agriculture.

Conclusions

The authors of the study described the role of digital technologies and innovations in the development of agriculture, considered the main criteria meant to increase the efficiency of production activity in this branch. The state of agriculture was studied on the example of the Republic of Moldova; the constant growth of the leading agricultural activities was identified, associated with favourable conditions, infrastructure, and state support, introduction of innovations based on obtaining an economic, industrial and environmental effect.

The use of digital technologies in agriculture in the Republic of Moldova will contribute to increasing profits, profitability by reducing and optimizing labour costs and optimal allocation of resources. The results obtained will positively affect the competitiveness of agricultural products; will increase productivity and the rational use of natural resources.

The agro-industrial and agricultural specialization of the economy of the Republic of Moldova requires not only favourable climatic conditions, but also state support for the innovative development of the industry. The positive dynamics of agricultural production volumes is ensured by the use of digital technologies related to a scientific approach to the development of agricultural crop production, precision agriculture and biologically active preparations based on nanoparticles of biogenic metals. It is necessary to develop a regional program to support small and medium-sized enterprises in the field of agricultural production and a preferential tax system of farming holdings that actively introduce digital technologies into their work.

The limits of innovation are related to the physical capacity of arable land, while maintaining the high quality of consumer products. Digital technologies are needed to create favourable working conditions and increase their efficiency, to ensure the demand for engineering and ICT specialists. That, of course, will increase the prestige of work in the agro-industrial sphere and make it possible to solve several social and economic problems.

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