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## Digitization as a tool for revitalizing the livestock industry

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► **Abstract.** Digitalization of the country's economy should currently be considered as an integral prerequisite for its development, the activation of which is necessary at all levels, from the state to the level of an individual citizen. In the agricultural sector, the introduction of digital tools and technologies is necessary in view of their significant potential in the context of increasing the productivity of resources and increasing the level of competitiveness of products, manufacturers, industries, and the state as a whole. The livestock industry in Ukraine is experiencing a severe lack of electronic digital services. The purpose of the article is to justify the importance of using digitization for the innovative development of the livestock industry. The following methods of scientific knowledge were used in the research process: theoretical generalization, analysis and synthesis, data analysis, economic-statistical, graphic, correlation-regression, cartographic and abstract -logical. The main tools of digitization of the process of resource provision of producers of livestock products were summarized. Systematized priority types of information technologies within the framework of digitalization of business processes of producers of livestock products depending on the field of application, the main of which are information systems for determining actual and potential resource needs, selection of potential suppliers and organization of purchase and sale operations (field of resource provision); technologies for monitoring the state of farm animals, optimizing the diet and veterinary measures, forecasting the state of the animal, disease outbreaks, livestock productivity (production); online platforms for selling livestock products, electronic document management services, etc. (sales of products). The directions of using geo-information systems and technologies in order to ensure the development of the animal husbandry industry, which involve taking into account the information needs of potential users (in particular, producers of livestock products, investors and/or creditors, executive authorities, consumers) and providing them with accurate, unbiased, operational data, are substantiated. necessary for making management decisions. Therefore, digitalization should be considered as one of the promising tools for intensifying the development of animal husbandry and increasing the efficiency of production and sale of animal products. The practical value of the work lies in the development of the systematization of priority types of information technologies within the framework of digitalization of business processes for the production of livestock products

► **Keywords:** geoinformation systems; information support; the market; digitization

### ► Introduction

Activation development of agricultural production, in particular industry animal husbandry, depends on modernization in management processes. Insufficient using new ones in modern technologies slows down this process.

Potentially promising for implementation in the process of production and distribution of livestock products are information technologies. As part of the digitization of production processes, it is advisable to use technologies

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for monitoring the state of farm animals, optimizing the diet and veterinary measures, forecasting the state of the animal, disease outbreaks, and livestock productivity. Development and active use of online platforms for the sale of livestock products, electronic document management services, etc., are promising as part of the digitalization of the sale of livestock products. Therefore, digitalization is the basis for making successful management decisions by both managers and investors. Modernization, optimization, and development of the animal husbandry industry based on digitalization of management processes requires a significant amount of time for implementation, which is associated with investment, as well as training of employees in new professional competencies.

Digitization at the level of individual business entities is usually carried out directly on their initiative and financing, however, not only business entities, but also society as a whole benefit. In a broad sense, digitization is the transformation of analogue data into a digital language, which, in turn, can improve business relationships between customers and companies, creating added value for the entire economy and society (Reis *et al.*, 2020). Digitization is an inevitable trend of modern society, which contributes not only to the improvement of the economic efficiency of the functioning and competitiveness of the agricultural sector, but also allows reducing the load on natural resources and the environment as a whole (Burliai *et al.*, 2019).

A number of scientific studies are devoted to the problems of digitalization in the agricultural sector, in particular, in the field of animal husbandry, and the use of modern technologies in ensuring the competitiveness of animal husbandry products. In particular, the process of animal husbandry development to ensure a “green” economy is analysed by J. De Boer & H. Aiking (2019). Attention to the issue of the application of modern technologies in agriculture is considered in the studies of S. Brewster *et al.* (2018). W. Ma *et al.* (2018) focused on the problem of using modern technologies in the context of increasing the productivity of agricultural animals using the example of dairy farms in New Zealand. The study of the development of the livestock industry in the context of changes in supply chains in the EU was carried out by A. Deppermann *et al.* (2018). In the area of changes in agrarian policy, changes in approaches to the use of agricultural land in the EU were highlighted by J.O. Karlsson & E. Rööös (2019).

The relevance of digitalization of the livestock industry and its practical significance determined the conduct of this scientific study and influenced its purpose, which is to justify the importance of using digital technologies to activate the effective development of the livestock industry. The research problem of digitalization of agricultural enterprises was reflected in the scientific work of Yu.O. Voloshchuk (2019), who noted that digitalization can help increase the level of competitiveness of all sectors of the economy and develop innovative entrepreneurship. As noted by K. Stoyanov *et al.* (2021), digitalization is already largely seen as a key competitive advantage for all businesses, regardless of their economic sector or industry. Traditional types of economic activity, such as farming and animal husbandry, were not left out of these innovative approaches. In particular, S. Neethirajan (2023) believes that “the advent of precision and digital animal

husbandry opens up the opportunity for sustainable animal husbandry practices that improve animal welfare and health”. The livelihood of the livestock industry is also directly related to solving environmental problems, as it creates an opportunity to control the state of feed production, disposal, and processing of waste, feeding animals and their health, which is directly related to human health and the state of the environment. Thus, in Germany and France, up to 35% of milking equipment are robots, in Denmark – more than 50%, in the Netherlands – 60% (Petrenko, 2018).

Ensuring the maximum level of efficiency from the introduction of digital tools requires their use at all stages of the economic activity of livestock producers. In addition, it is important to single out tools that will ensure the receipt of positive environmental and social effects and, accordingly, the development of socially and environmentally responsible business at the community, regional and state levels. This approach will ensure the systematicity of the formed recommendations in the context of digitalization of business processes of manufacturers of livestock products.

### ► Materials and Methods

The methodological basis is a systematic approach to the study of economic processes and phenomena, which made it possible to identify the main tools of digitization of the process of resource provision of animal husbandry production and to single out separate areas of information provision and decision-making in the field of animal husbandry, in particular, and producers of animal husbandry products, based on geographic information systems (GIS). An important basis of the study was informational statistical indicators of Ukraine regarding the display of the dynamics of production of livestock products by various farms of all categories (Verner, 2022). Using the method of analysis and synthesis, it was determined that digitalization is relevant within the scope of production work related to monitoring, forecasting the state of farm animals, livestock productivity, optimizing the diet, etc., as well as the active use of online platforms for the sale of livestock products, ensuring constant collection, analysing information for compliance safe measures.

With the help of methods of theoretical generalization, analysis and synthesis, the approaches of scientists to the problem of agricultural production in the conditions of digitalization, in particular in the field of animal husbandry, were investigated; the logical method was used throughout the study. The data analysis was used to generalize domestic and foreign experience in determining the essential characteristics of the key concepts of digitization. The economic-statistical method was used to process statistical data, in particular the dynamics of production of livestock products and the number of agricultural animals and poultry, which made it possible to make forecasts. The graphic method was intended for a visual representation of the system of indicators of the production of products in the field of animal husbandry and livestock of agricultural animals and poultry. When applying the correlation-regression method in the process of developing the methodology, indicators of the development of the livestock industry and building models were predicted. The cartographic method was used to display and monitor milk production and consumption per person

and cow population, as well as to analyse the level of food security in general and separately by economic, ecological and social components. Conclusions and proposals were formulated using the abstract-logical method.

### ► Results

The level of providing the population with food is considered as the most important factor and determining criterion of the level of social life of any country, the viability of its economic structure and state system. In solving this

problem, a special role is played by animal husbandry, which is traditionally an important and integral component of agriculture and determines the socio-economic condition of all categories of farms in Ukraine. In the period 2000-2021, the industry is in a crisis situation and has undergone the most destructive changes. The analysis of the level and dynamics of the production of the main types of livestock products, which provide the processing industry with raw materials, and the retail market with food products for the population, should be considered in Table 1.

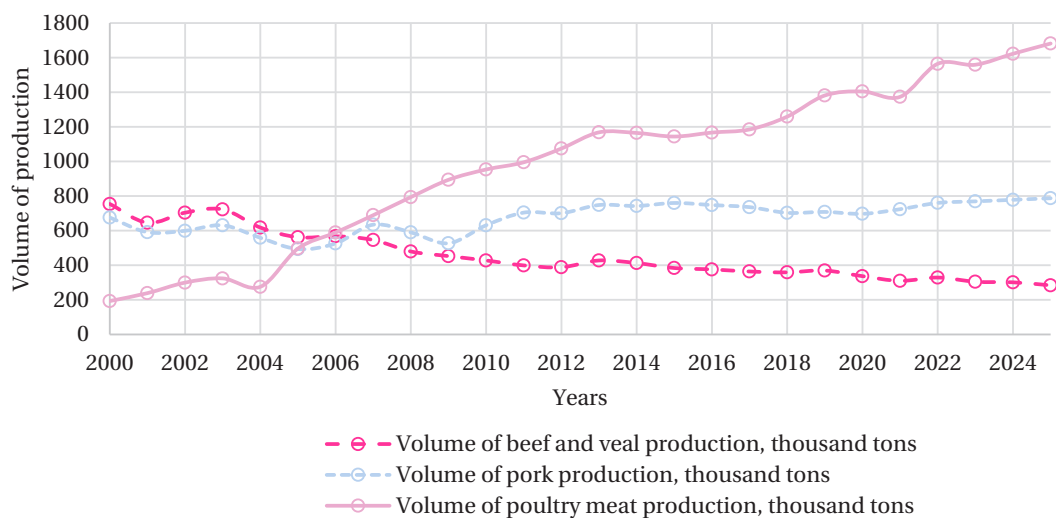
**Table 1.** Dynamics of production of the main types of livestock products by farms of all categories

Types of products	Years						Ratio in% to thousand tons	
	2000	2017	2018	2019	2020	2021	2000	2020
Milk and milk products (in terms of milk)	12 657.9	10 280.5	10 064.0	9 663.2	9 263.6	8 713.9	68.8	94.1
Meat (in slaughter weight)	1 662.8	2 318.2	2 354.9	2 492.4	2 477.5	2 438.3	146.6	98.4
in particular beef and veal	754.3	363.5	358.9	369.5	345.4	310.5	41.2	89.9
pork	675.9	735.9	702.6	708.3	697.2	724.0	107.1	103.8
poultry meat	35.8	1 014.1	1 084.6	1 209.7	1 232.2	1 208.5	>33 times	98.1
other types of meat	196.8	204.7	208.8	204.9	202.7	195.3	99.2	96.4
Eggs, million pcs.	8 808.6	15 505.8	16 132.0	16 677.5	16 167.2	14 071.3	159.7	87.0

**Source:** calculated according to the data of the State Statistics Service of Ukraine (Verner, 2022)

For the period from 2000 to 2021, the dynamics of the production of the main types of livestock products shows an increase in the volume of meat production from 1 662.8 thousand tons to 2 438.3 thousand tons, or by 46.6%, and eggs by 59.7% over the corresponding period. The increase in meat production was due to the increase in pork production by 7% and poultry meat, which increased 33 times during the studied period, while the production of beef and veal decreased by 58.8% or 443.8 thousand tons. Milk production in 2021 decreased compared to 2000 by 31.2% or by 3944 thousand tons. Compared to 2020, the volume of livestock production decreased from 1.6% (meat) to 13% (egg production).

According to the received forecasts, a further decrease in the production of beef and veal is expected (by 26.04 thousand in 2025 compared to 2021 or by 8.4%) (Fig. 1). On the other hand, the volume of production of pork and poultry meat will increase. The poultry meat production industry will develop more rapidly (growth by 5.37% annually, in particular due to the increase in livestock). In 2025, the volume of poultry meat produced will be about 1 681.66 thousand tons, which is 308.16 thousand tons (or 22.44%) more than in 2021. As for the volume of pork production, in 2025, if existing trends and dependence are preserved, it may increase by 63.29 thousand tons or by 8.74% to 787.29 thousand tons.



**Figure 1.** Projected values of meat production volumes until 2025

**Note:** 2022 is estimated data

**Source:** created by the authors

In 2025, the volume of milk production may decrease by 1 164 compared to 2 021.53 thousand tons (or by 12.57%), which in the annual equivalent will amount to

3.3% (Fig. 2). The largest projected increase in production is expected for eggs, which in 2025 could potentially reach 17.348 million eggs, which is 23.29% more than in 2021.

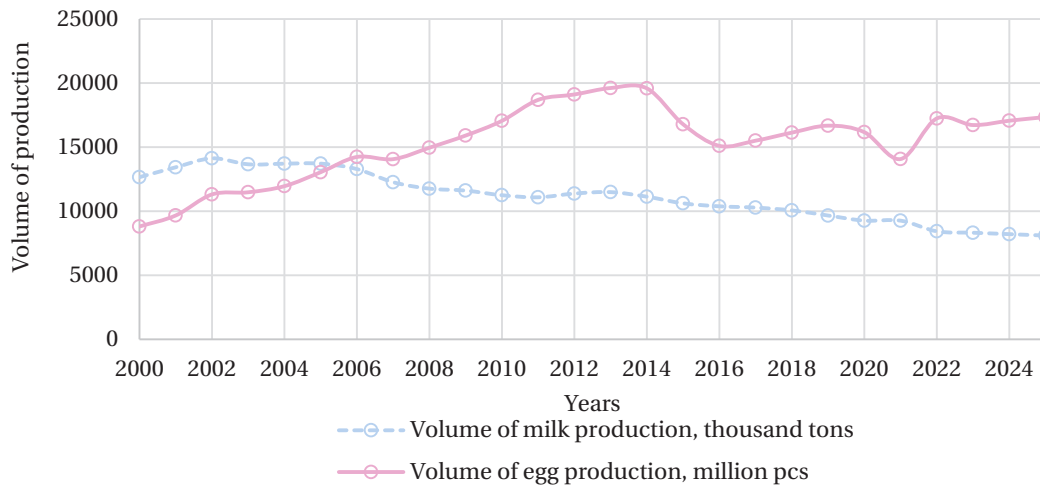


Figure 2. Projected values of milk and egg production volumes until 2025

Note: 2022 is estimated data

Source: created by the authors

Negative factors connected over time with changes in property relations and the implementation of other market transformations led to a catastrophic decrease in the number of cattle, cows, pigs, and poultry. And these are the means of production that are irreplaceable and only in their presence is it possible to produce milk and beef, pork, poultry, and eggs. That is, the number of agricultural animals and poultry and their productivity belong to the factors that decisively affect the volume of

livestock production, the level of development of the dairy and meat industry, and providing the population with the most valuable food products in sufficient quantities. The dynamics of the livestock of agricultural animals and poultry for 2000-2021 and estimated values for 2022 made it possible to forecast these indicators for the short term. Actual data on cattle population (hereinafter – cattle) for 2000-2021, estimated values for 2022 and projected levels for 2023-2025 are shown in Figure 3.

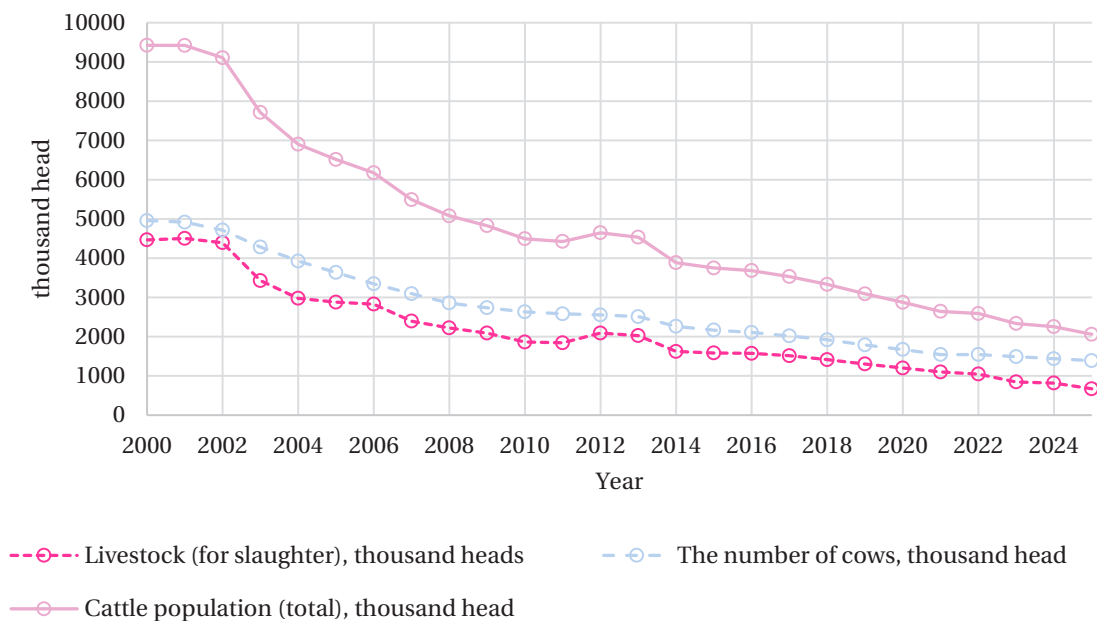


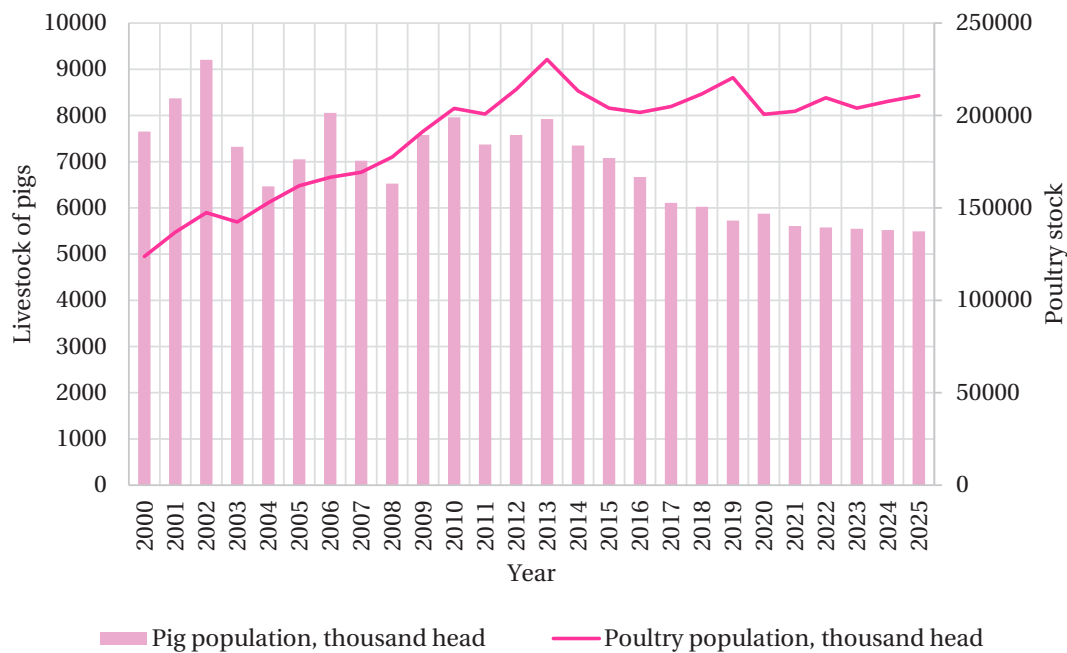
Figure 3. Trends in cattle population changes until 2025

Note: 2022 is estimated data

Source: created by the authors

Based on the forecasting results, it was established that the dynamics of the cattle population (both dairy herd and animals for slaughter) is characterized by a steady downward trend. At the same time, in the next 5 years, the rate of reduction in the number of cows is expected to decrease, while the number of cattle for slaughter will decrease somewhat more rapidly. In particular, in 2025, compared to 2021, a total decrease of 583.59 thousand of cattle (up to 2 060.42 thousand people) or by 22.07% is predicted. Annually, with an unchanged trend, the population will decrease by an average of 6.04%, which is a serious challenge to the country's food security. As mentioned above, firstly, such changes will be caused by the negative

downward trend of the number of cattle for slaughter, according to which it is expected to decrease by 428.25 thousand cattle in 2025 (up to 671.76 thousand people) or by 38.93%. On average, the annual decrease in the number of cattle for slaughter will be about 11.6%, which is an extremely negative trend. On the other hand, the number of cows, according to the constructed forecasts for 2025, will decrease by 284.34 thousand cattle or by 17% in 2025 compared to 2021 and will amount to 1 388.66 thousand cows. The annual decrease will be 3.67%. According to the results of forecasting the pig population, it was established that this indicator will remain relatively stable in the following years (Fig. 4).



**Figure 4.** Trends in pig and poultry population changes until 2025, thousand goals

**Note:** 2022 is estimated data

**Source:** created by the authors

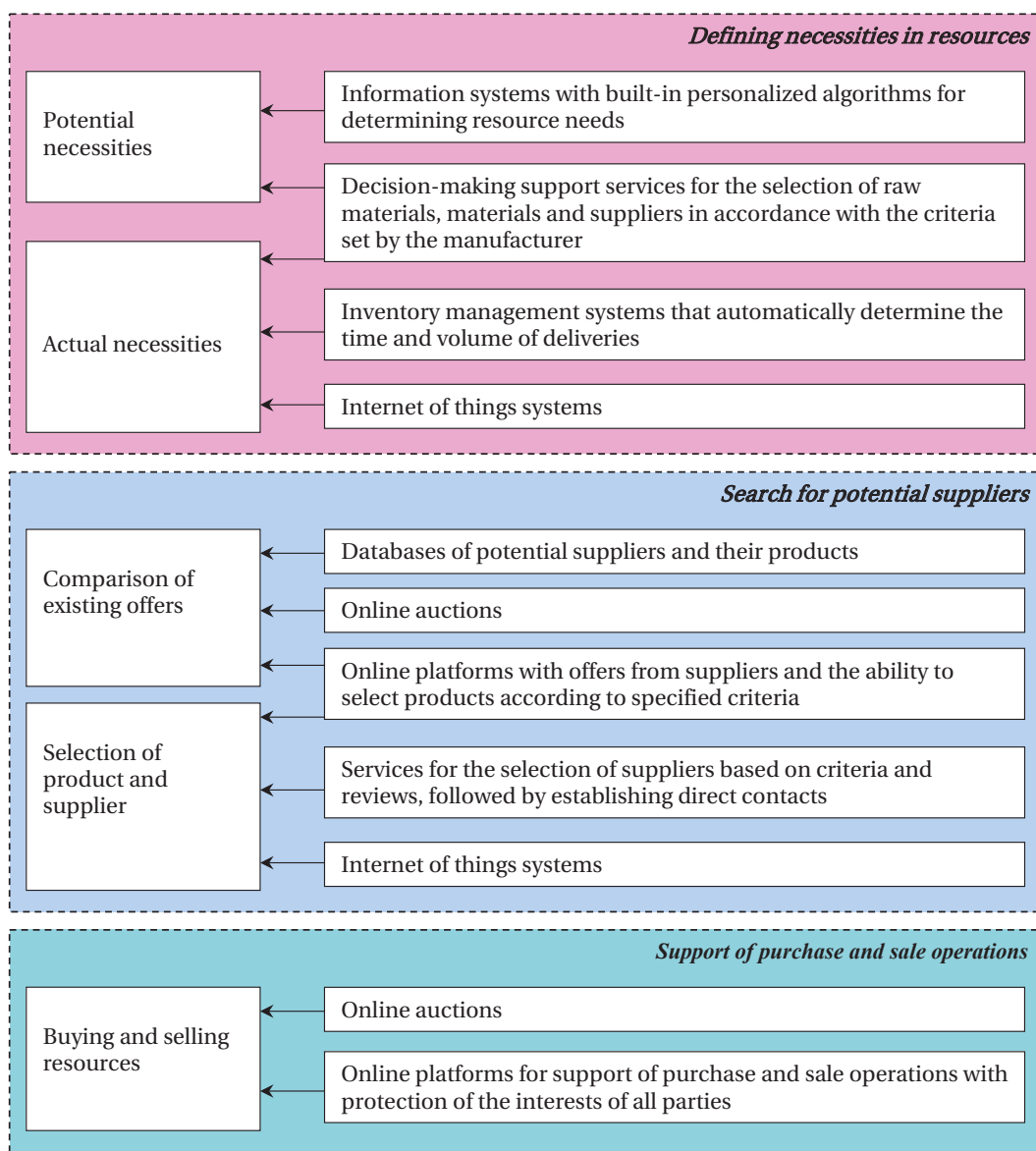
As for the poultry population, it will gradually grow, in particular thanks to the possibility of expanding the export potential of domestic producers. The annual reduction in the number of pigs in 2021-2025 will be approximately 0.52%. In particular, during this period, a decrease in the number of pigs by 116.600 heads is expected (or by 2.08%) to 5 492.2 thousand pigs. As for the poultry population, it will maintain the upward trend (annually by 1.03%) and in 2025 it will grow to 210 718.2 thousand heads or on 8 475.13 thousand heads (4.19%) compared to 2021. In the process of forecasting the population of agricultural animals, it was established that the main influencing factor is the time factor, which is a form of manifestation of scientific and technical progress (hereinafter – STP). Solving the problem of providing the population with food products of animal origin, guaranteed supply of raw materials to processing enterprises, and meeting the country's export needs necessitates the development of tools for revitalizing the development of the livestock sector, one of which is the use of digital technologies.

It is advisable to group the mechanisms and tools of digitization of the activities of producers of livestock products according to their areas of application, the basic of which are resource provision, production, and sales. The process of resource provision covers such sub-processes as determining the need for resources, searching for potential counterparties based on the price-quality ratio criterion, and, directly, buying and selling goods. Resource needs can be conditionally divided into potential needs, which are determined on the basis of planned indicators of production of livestock products and livestock of agricultural animals and poultry, as well as actual needs in accordance with the available current stocks of resources, the speed of their use and the needs of livestock at the current moment. The main digitization tools that provide information support for the mentioned sub-processes include, firstly, inventory management systems and modules built into Internet of Things (IoT) systems that monitor the level of resource use.

Information systems focused on calculating potential resource needs are based on algorithms for determining the planned volume of production of each individual type of livestock production. To create such systems, it is necessary to develop and implement a universal (for small manufacturers) or specific (for medium and large manufacturers) methodology for determining planned production volumes, based on which the needs for each individual type of resource will be determined. To simplify the calculation procedure, it is considered appropriate to develop modules that will automatically calculate the enterprise's needs for resources based on an algorithm and mathematical models that will take into account the specifics of the economic activity of a specific manufacturer. Another type of information technology that can be used to determine the needs of producers of livestock products are special personalized services (including mobile applications)

designed to select optimal resources (in particular, feed, veterinary services, technical equipment, etc.) taking into account the key factors for the producer criteria (for example, available livestock, animal breeds, locations, etc.) (The competitive advantage..., 2018).

The search for necessary resources and suppliers, taking into account their prices, available volumes and quality characteristics of the supplier, can be carried out on the basis of special mobile applications, platforms, online marketplaces and services. Such platforms are able to select counterparties according to the specified criteria, perform a comparative analysis of various products and sellers, support online purchase and sale operations, serve as a basis for forming established relationships with the supplier, etc. In general, the main tools of digitization of the process of resource provision of producers of livestock products are shown in (Fig. 5).



**Figure 5.** The main tools of digitization of the process of resource provision of producers of animal husbandry products

Source: author's development

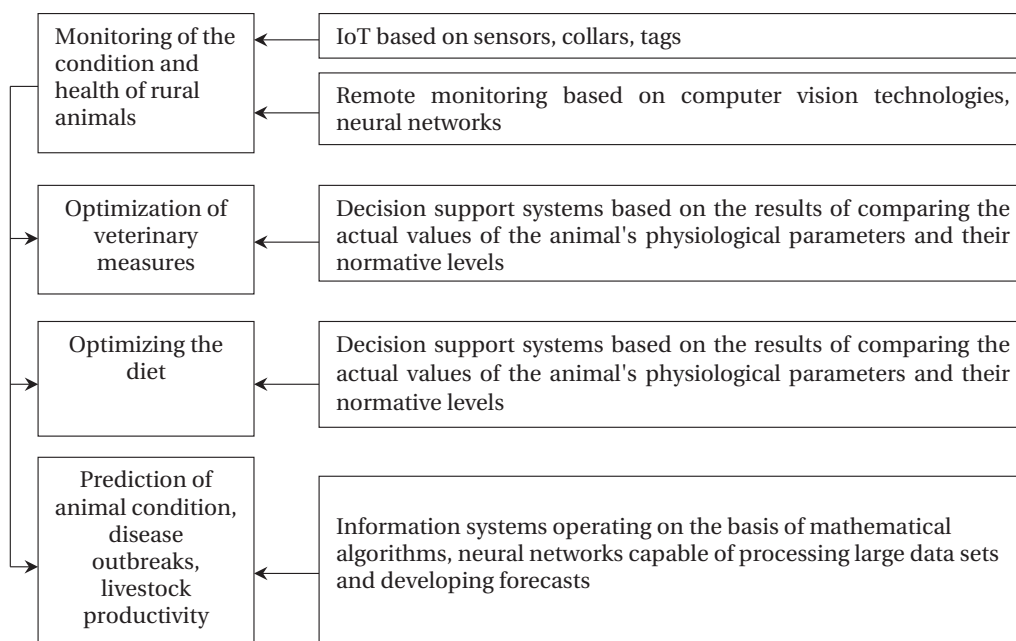
As for the direct production of livestock products, there are currently a significant number of information systems and technologies that aim to collect, process, store, transfer data and automate a number of production functions and processes (Moroz, 2020). The main business processes that can be optimized with the help of information systems and technologies include, firstly, the monitoring of the state of health of animals and poultry, the planning of veterinary measures, and the determination of the optimal diet.

The use of hardware and software complexes based on IoT involves the installation of sensors, the use of special devices such as collars, tags for each individual farm animal, with the aim of further monitoring its health in real time and transferring relevant indicators and indicators to the user on a mobile application and/or an online platform. In the future, the obtained results will be used to determine the optimal ration (including for an individual animal if necessary), list of necessary veterinary services, control of the epidemiological situation, etc. The basis of the operation of such systems are algorithms for comparing the actual values of indicators of temperature, humidity, activity level, etc., which are continuously collected and stored in the database, with normative levels.

Remote monitoring with the help of such tools as cameras, unmanned aerial vehicles (UAVs) is proposed as another way of monitoring the health of farm animals. Such monitoring is based on computer vision technologies and specially developed and trained neural networks. The main advantages of using appropriate information systems are, firstly, the release of jobs related to animal monitoring, secondly, the observation of all livestock at the same time and, thirdly, the possibility of detecting atypical animal behaviour in real time and the formation of timely measures to find the cause and

eliminate the problem. In addition to direct monitoring of the state of farm animals, these systems are focused on data collection. In the process of processing large arrays of data, methods and technologies of artificial intelligence are involved, the purpose of which is to develop forecasts of physiological parameters of animals, their state of health and disease outbreaks. In addition, it is advisable to implement information systems into the economic process of producers of livestock products, which, based on the processing of collected data, determine the optimal ration for each individual farm animal or group of animals, taking into account their current condition, the level of provision of proteins, fats, carbohydrates, trace elements, etc.

Comprehensive monitoring of all operational processes in livestock complexes is carried out on the basis of specialized information systems and software and hardware complexes, which integrate the above-mentioned technologies. Such systems and technologies are implemented in the form of online platforms, web services, mobile applications, etc. Their main purpose is continuous monitoring by management personnel of business processes related to the analysis of animal health, feeding, veterinary care, etc. The final product of such systems is recommendations for optimizing individual operational processes based on the processing of economic process monitoring data. In general, the implementation of digital tools and technologies in the production process will enable a significant increase in the productivity of farm animals, including due to a personalized approach, round-the-clock monitoring, the use of precise mathematical algorithms and the processing of large arrays of objective information. A summary of digital tools designed to increase the efficiency of production processes in animal husbandry is shown in (Fig. 6).



**Figure 6.** The main tools of digitization of the livestock production process

**Source:** author's development

Digitization of the process of sale of livestock products is primarily related to the digitization of data on the flow of finished products with the indication of the levels of its quality characteristics, the available volume, if necessary, photos and/or videos. With the help of online platforms, auctions, marketplaces, manufacturers will have access to the maximum number of potential buyers who are able to automate and secure purchase and sale operations. Electronic document management services are in growing demand (Electronic document management..., 2019), which make it possible to significantly save time and labour resources when working with documentation, ensure reliable storage of documents and significantly simplify the procedures for buying and selling goods.

One of the key needs of the livestock industry, without the satisfaction of which its further development is impossible, is the attraction of sufficient investment capital, which will ensure not only the expanded reproduction of the industry, but also its intensification due to the introduction of the latest technologies at all stages of the creation of the product chain, from resource provision to the realization of the finished product. Making investment decisions should be based on the analysis of the potential development efficiency of the investment object (Zakhodym, 2023). At the same time, it is necessary to take into account not only the efficiency of the direct economic entity or their aggregate at the community, regional or state level, but also the peculiarities and potential of the environment within which they function. Firstly, this concerns the availability of infrastructure facilities that are important for ensuring the business processes of producers of livestock products. Important is not only the existence of such objects, but also the possibility of forming and deepening interaction between them and producers.

Given the above, an integral element of the process of attracting investment resources is providing potential investors with the most accurate, complete information necessary for making an investment decision, in the most convenient format. One of the methods of visualization of relevant data is their presentation with reference to the coordinate system on the map. For this, geo-information systems and technologies are used, which make it possible to collect, record, process (including using modelling methods), transfer geospatial data, as well as support management decision-making. Currently, geo-information portals are being actively created at all levels of administration (primarily at the community and regional levels), which, although they perform different functions, have a common goal – ensuring the development of the respective territories.

The creation of geo-informational portals aimed at providing information for the development of the livestock sector has a number of significant advantages, namely: free, round-the-clock access to data. The main costs are the costs of creating a portal (one-time costs), its refinement and improvement (if necessary), administration (monthly expenses for the salary of a specialist), payment for virtual hosting services (monthly) and domain name (annually), solving non-trivial tasks within making management decisions (if necessary). In the case of using all the capabilities of geographic information

systems (GIS), the actual socio-economic benefits from the geoinformation portal may significantly exceed the listed and other types of costs; easy-to-understand format. In particular, data about objects (animal farms, complexes, pastures, processing enterprises, distribution networks, etc.) are displayed on the map with reference to their location. This makes it possible to significantly simplify the perception of data in various formats, to identify stable relationships between them, and to significantly improve the results of information analysis. Based on the analysis of spatial data, it is possible to form a mechanism for making informed political decisions within the framework of forming and changing the agrarian policy of the country and regions, including with regard to promoting the development of the livestock industry and ensuring the food security of the state; the possibility of spatial analysis, i.e., analysis of geographic data. The most common way of using the corresponding method is to optimize the placement of objects in space based on certain criteria and restrictions.

Geographic information systems are widely used to collect and process data, and are often used to create unique maps based on user requests. Agricultural universities and scientific institutions occupy a significant place among the key players in the development of these systems. This is due to the fact that researchers who use geographic information systems and technologies usually specialize in certain branches of agriculture. Moreover, they are often part of an extensive informal network of scientists in a university, region, or state specializing in issues related to the production, distribution, and consumption of livestock products.

In the context of decision-making in the field of providing the population with livestock products, spatial analysis can be used, firstly, to determine the locations of livestock farms, complexes, processing facilities, construction of infrastructure facilities; use for the management of natural resources involved in the production of livestock products. Based on official data, as well as processed data of satellite images, which are applied to the map, it is possible to organize continuous monitoring of water and land resources, in particular, to assess their availability, current state, and dynamics. An important stage of such an analysis is the assessment of the suitability of the land for animal husbandry and the determination of areas that are suitable for grazing (for example, according to the criteria of the presence and steepness of slopes, the suitability of vegetation cover, etc.). In addition, based on the results of geospatial data processing, it is possible to establish in which territories the grazing of agricultural animals is ecologically destructive. In such cases, a decision is made to temporarily refuse the use of the corresponding areas in animal husbandry until their restoration; decision-making support in the grazing planning process. In particular, such decisions can be based on the results of modelling the carrying capacity of pastures (Meehan *et al.*, 2018), take into account such factors as rotational grazing, periods of rest on pastures, distribution within the existing landscape, etc.; the possibility of monitoring the state and development of vegetation within pastures. Provision of continuous monitoring with automatic upload of new satellite images will make it possible to timely detect

degraded areas, which, among other things, arise due to excessive grazing.

On the basis of obtaining relevant operational data, decisions will be made regarding the provision of optimal grazing of animals not only by the criterion of economic efficiency and provision of the physiological needs of livestock, but also by the ecological criterion; infrastructure planning that will ensure business processes of production and distribution of livestock products. The corresponding function is implemented by planning and reconstruction/construction of infrastructure facilities taking into account the actual location of livestock farms and complexes, the concentration of consumers of livestock products; identification and continuous monitoring of regions with potentially increased demand for livestock products, in order to plan the infrastructure of sales markets; assessment of the potential eco-destructive effects of animal husbandry on the surrounding ecosystems. In particular, retrospective, current and potential assessments of the levels of water pollution, soil erosion, emissions of harmful substances (including carbon monoxide), etc. are determined. As part of the task of such an assessment, maps are created on which the state and dynamics of the relevant quantitative indicators are visualized. Such maps

can be used in the process of ensuring sustainable ecologically oriented development of animal husbandry.

The basic function of GIS in the process of development of the livestock industry and the markets of the corresponding products is the provision of information to all interested parties. Firstly, the following groups of users should be included in the circle of stakeholders: producers of animal husbandry products; potential and existing investors and/or creditors; decision-making subjects in the context of regulation of the livestock industry (at local, regional, state levels); consumers of livestock products; organizations and institutions for monitoring the ecological state of territories. The structure of the input data that will be loaded into the GIS should be determined taking into account the information needs of potential users, which, in turn, are determined by the types of decisions they make. This approach will ensure the systematicity of the data collection process (which can later be automated) and maximize the effectiveness of GIS implementation within the livestock sector. Therefore, special attention should be paid to the possibilities of implementation of geoinformation systems and technologies in the process of making management decisions. Table 2 details the types of livestock producer decisions that can be supported by GIS.

**Table 2.** Areas of information support and decision-making support for producers of livestock products based on GIS

Type of management decision	Required data	The technology of using GIS
Determination of the location of livestock farms/complexes	- pastures; - water bodies; - producers of crop production for fodder (location and capacity)	Data visualization on the map
	Land carrying capacity	- visualization of pastures (based on official data or satellite data with subsequent classification of surface types); - determination of the amount of photosynthetically active biomass within pastures (vegetation index); - calculation of throughput based on the standard of consumption of pasture grass; - optimization of the location of the farm/complex, taking into account the priority of factors (forage base, water bodies)
Determination of the location of processing facilities	Existing animal farms/complexes	- creation of shapes with data on the production capacity of producers of livestock products, roads (in particular, their classification by type); - optimization of the location of processing facilities
Determination of areas suitable for grazing	- territories of existing/potential pastures; - landscape of pastures; - water objects	- visualization of data on the map and superimposition of layers; - classification of territories according to the level of suitability for grazing, their carrying capacity
Determination of pastures subject to "rest"	Pastures with a low vegetation index, degraded pastures	- data visualization on the map; - classification of pastures according to the level of photosynthetically active biomass

**Source:** author's development

Most of them involve solving optimization problems with various optimality criteria and constraints. The key procedures in most of the presented problems are the classification of objects according to defined criteria, which will result in different display of objects of different groups. For example, in the case of classification of pastures by the level of the vegetation index, they can change

colour on the map from bright saturated green (high level of photosynthetically active biomass) to yellow (critically low level of the vegetation index).

When planning the livestock of agricultural animals on free grazing, it is considered extremely important to take into account the available fodder base from the point of view of potential green mass. M. Meehan *et al.* (2018)

suggest using GIS to determine the number of individual species of farm animals that graze on pasture during a specific period. The key condition for effective production of products within the framework of the relevant task should be that the number of animals does not exceed the carrying capacity of the available pastures. The latter is determined by the amount of green mass that can be obtained on a specific plot/pasture. At the same time, the condition should be

imposed that the optimal number of animals is such that it will ensure simple/extended reproduction of pastures in the form of preservation or improvement of the fodder base and other vegetation. As for other users of information about the state and dynamics of the development of both the livestock industry and the market for corresponding products and market infrastructure, the possibilities of using GIS to satisfy their own information requests are shown in Table 3.

**Table 3.** Areas of information support and decision-making support in the field of animal husbandry based on GIS (except for product manufacturers)

Type of management decision	Subject of decision-making	Required data	The technology of using GIS
Justification of the priority objects of stimulating the development of animal husbandry, areas of ensuring food security	Executive bodies	- indicators of the livestock sector; - consumption of livestock products; - the population of rural areas animals; - food safety	Visualization of data on the map with a mandatory emphasis on territories with an insufficient level of consumption of livestock products
Determination of the location of sales networks	Subjects are involved in the process of selling products	Location of producers and their capacity, processing facilities, roads	- creation of shapes with data on production, processing facilities, roads (including their classification by types); - optimization of the distribution network location
Justification of measures to preserve natural resources and ecosystems	Environmental institutions, organizations Executive bodies	- localization of natural resources and biological ecosystems; - location of farms/ complexes; - livestock density; - emissions of CO <sub>2</sub> , CO	- data visualization on the map; - automation of data update based on updated satellite images; - determination of the amount of photosynthetically active biomass within pastures; - layering with stock density and CO <sub>2</sub> emissions localization of biological ecosystems and biomass index

**Source:** author's development

Firstly, the category of stakeholders in the context of information provision should include executive authorities at all levels of management, who need the most accurate, unbiased and operational information about the current levels and dynamics of indicators in terms of the following groups of factors:

1) the structure of the livestock of agricultural animals – for monitoring the specialization of regions. For visualization, it is advisable to use pie charts;

2) stocking density per unit of the corresponding area. In particular, the specified information is useful for environmental monitoring in the context of emissions of environmentally hazardous substances, in particular, carbon dioxide. It is advisable to display the data in the form of charts, taking into account the time factor. In addition, such maps should display the main indicators of the ecological state, in particular, the amount of carbon dioxide emissions;

3) volume of production of the main types of animal husbandry products. For visualization, it is recommended to use choropleth maps, on which areas/regions will have different colours depending on the production volumes of each individual type of livestock production. Darker colours will represent areas with higher indicator levels;

4) available pasture areas by region for monitoring their dynamics;

5) level of livestock morbidity for monitoring the epidemiological status of livestock;

6) volumes of production and consumption of the main livestock products per capita, the level of satisfaction of physiological needs in the main types of livestock products. It is advisable to visualize in the form of choropleth maps, with the simultaneous display of diagrams of the dynamics of indicators.

Regarding the display of data as part of the analysis of the state and trends in the development of livestock product markets, the key indicators that should be displayed on cartographic images are the locations of existing sales markets (in particular, wholesale) (Brewster *et al.*, 2018). It also includes retail sales points, trading points, animal slaughter points, etc.), the number and concentration of the population, the capacity, and location of producers of livestock products. Examples of maps that can be used to monitor milk production and consumption per person and cow herd (Fig. 7) were given, as well as an analysis of the level of food security in general and separately by economic, ecological and social components (Fig. 8).

In general, the generalized concept of implementation of geo-information systems and technologies into the system of institutional support for the development of the livestock industry and markets for the corresponding products is presented in Figure 9.

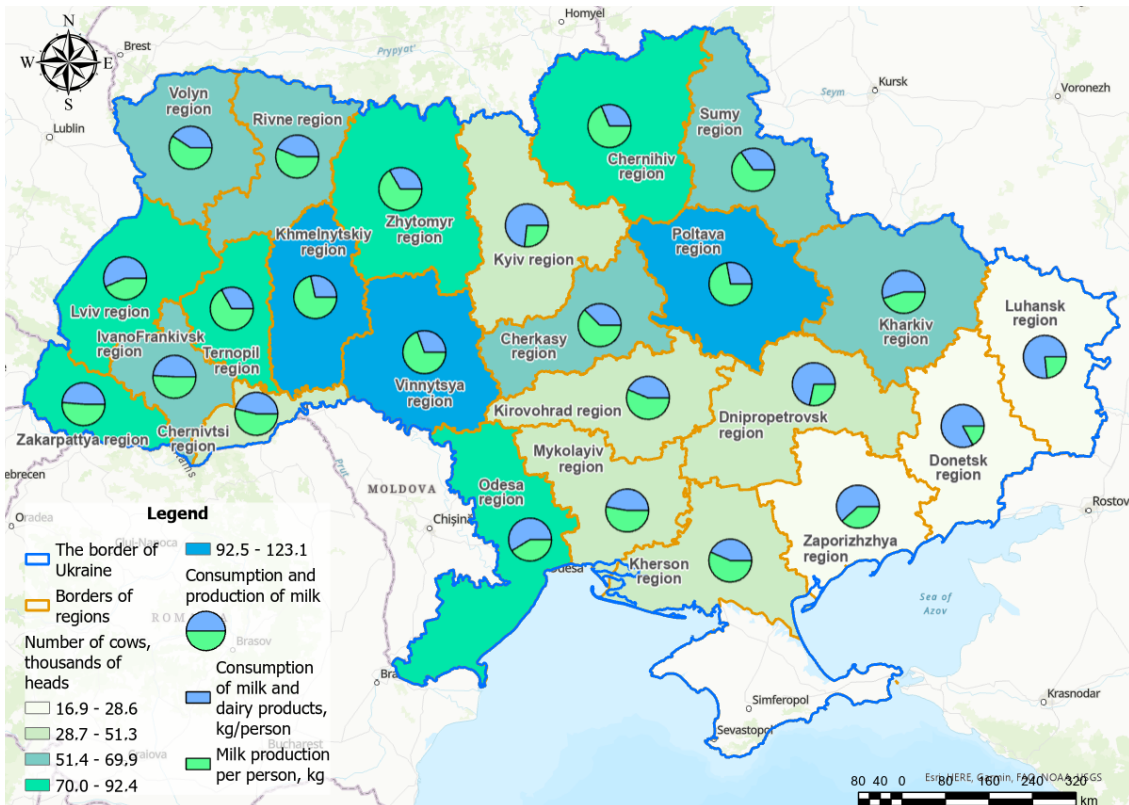


Figure 7. Map of the distribution of regions of Ukraine according to the number of cows, volumes of milk production and consumption

Source: author's development

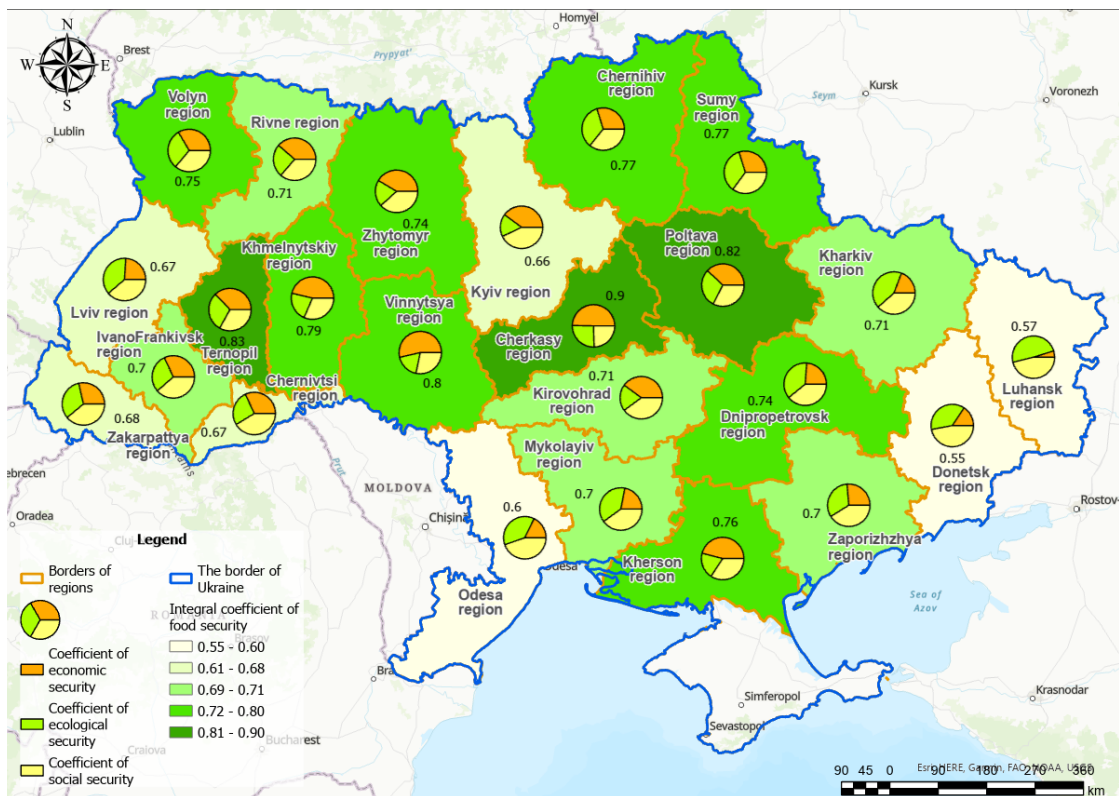
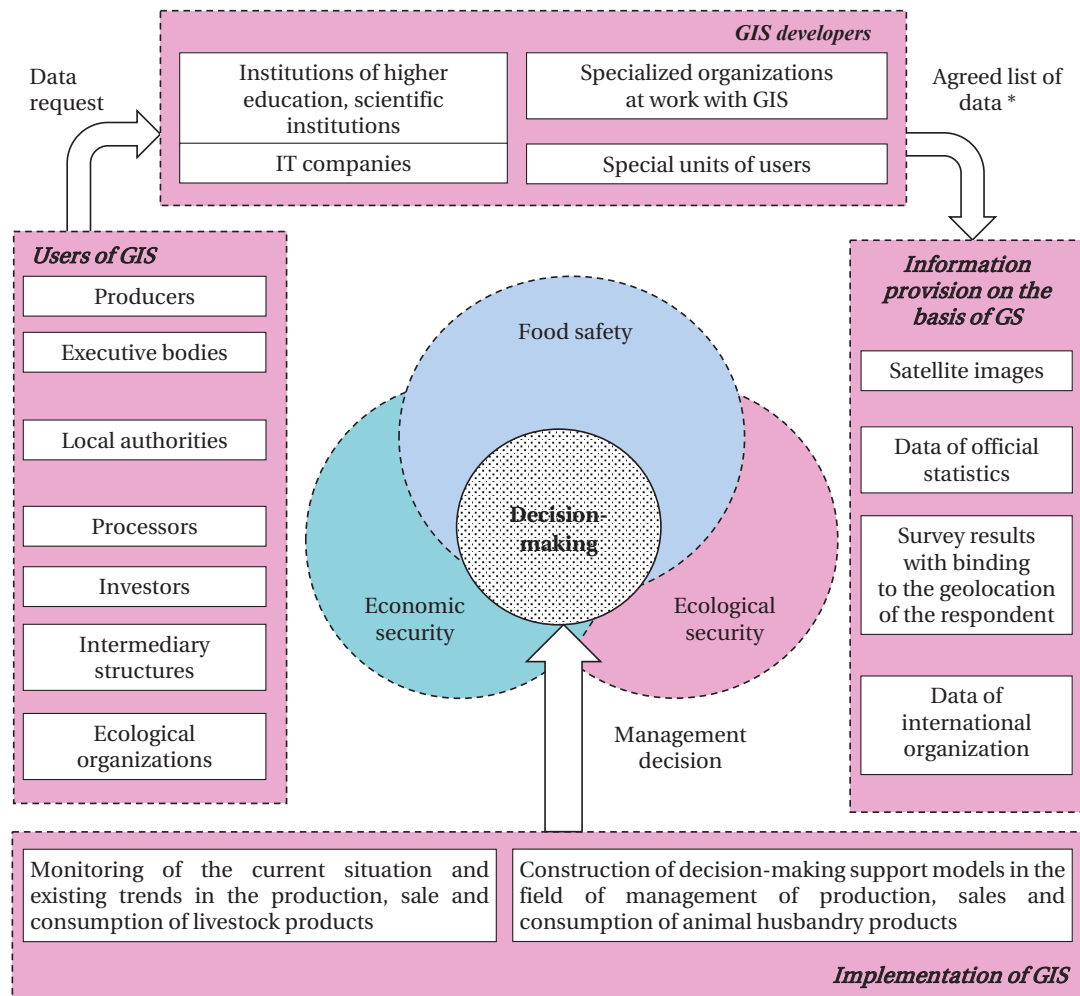


Figure 8. Map of the distribution of regions of Ukraine according to the level of food security

Source: author's development



**Figure 9.** The concept of GIS implementation in the system of institutional support for the development of the livestock industry and the markets of relevant products

**Note:** \* – list of indicators, visualization form, priority sources of information, update period, etc

**Source:** author's development

The application of geoinformation systems and technologies in the system of institutional support for the development of the livestock industry and the markets of relevant products involves the creation of an integrated and effective infrastructure aimed at supporting various aspects of these industries. Thus, such a system can provide more accurate, efficient and sustainable management of these areas, ensuring the growth of product quality, economic stability and sustainability of development.

### ► Discussion

Thus, A.O. Polovynkina & S.O. Solntsev (2020), who noted that digital transformation of business processes of enterprises is a market necessity in the era of the information society, as one of the key trends, focused their attention on researching the problem of digitalization of enterprises in the era of information society and digital economy. Digitalization is also making the livestock sector more attractive to investors. Researchers point out that digital innovation can help increase production efficiency, reduce risk and improve results. Investors, in turn, are more inclined

to invest in an industry that uses advanced technologies that can provide stable and high profits.

T. Lazorenko & I. Sholom (2020) argued: "... all market participants will have to change much faster in terms of digital transformation than is happening today. ... Enterprises that follow the latest trends in the field of digital innovations and are ready to implement them, are able to adapt to more flexible business processes, have a fairly large potential for success". The definition by B.S. Teteriatnyk (2018) is more general and marketing oriented, digitalization is defined as the process of applying information and communication technologies by economic entities to achieve the goal of economic activity, based on the capabilities of the modern IT industry, aimed at changing existing economic relations through their digitization; a set of acts of implementation of digitized objects to achieve the goals of economic activity, considered in their unity and related to the formation of a new form of economic relations – digital. Additional processing and analysis of data collected using sensors and IoT technologies is proving to be very useful. Researchers emphasize that such processing can help in detecting deviations in

the health of animals or even prevent the possibility of diseases. Thus, digital technologies make it possible to carry out individual monitoring and provide timely medical interventions, which affects the general condition of animals and, accordingly, the quality of their products.

According to N. Boltyanska *et al.* (2021), digital technologies in animal husbandry make it possible to implement a system of feeding, milking, product quality control, remote control of production processes in real time, as well as to ensure constant collection, analysis, and use of information for compliance with safe measures and careful attitude to the environment. Deserves attention and position I. Lozynska *et al.* (2021), who noted that the widespread adoption of digitalization, with the help of the necessary tools and leverage, will enable decision-making to improve milk quality, herd management, increase cow productivity and production profitability, outlining an overall synergistic effect. Researchers emphasize that such processing can help in detecting deviations in the health of animals or even prevent the possibility of diseases. Thus, digital technologies make it possible to carry out individual monitoring and provide timely medical interventions, which affects the general condition of animals and, accordingly, the quality of their products.

Researchers A. Valiyev *et al.* (2022) systematized and substantiated the factors of the implementation of digitalization to ensure the innovative development of agriculture in Azerbaijan, and based on the survey, the key factors and barriers to the digitalization of agriculture were substantiated, namely: the lack of regulation of legislative processes in this field and the level of cybersecurity and the cost of implementation and use digital technologies. The author also determined the levels of development of digitalization of the country's agricultural sector and substantiated the influence of digitalization factors on the innovative development of agricultural enterprises. As noted by R. Abbasi *et al.* (2022), digital transformation paves the way for the introduction of modern methods of farming and overcoming food security problems.

Scientists J. Kieti *et al.* (2022) defined digital services for agriculture as "a solution that uses digital equipment and devices such as mobile phones, computers, satellites, and sensors to solve problems in agriculture". D. Kos & S. Kloppenburg (2019) argue that digitalization will enable hyper-transparency, changing the roles of stakeholders and expanding the boundaries of global value chains in ways that increase inclusivity for smallholder farmers. Therefore, in order to ensure the systematicity of the digitalization process of the livestock industry, potentially promising types of information technologies for implementation in the production and distribution of livestock products are systematized in terms of the main operational business processes of agricultural producers. In particular, within the framework of resource provision, technologies for determining actual and potential resource needs, selecting potential suppliers, and organizing purchase and sale operations are priorities. Within the scope of production work, it is advisable to use technologies for monitoring the state of farm animals, optimizing the diet and veterinary measures, forecasting the state of the animal, disease outbreaks, and livestock productivity. As for the sale of livestock products, the

development and active use of online platforms for the sale of livestock products, electronic document management services, etc., is promising.

Thus, digitalization should be considered as one of the key tools for revitalizing the development of the livestock industry and increasing the level of efficiency in the production and sale of livestock products. The key issue of ensuring the process of digitalization of business entities is the use of exclusively digital data in business processes. Only under this condition is it possible to implement modern technologies in the economic process of producers of animal husbandry products. In addition, in order to reduce production risks and make adequate management decisions, at all stages of the production process it is important to ensure continuous monitoring of factors affecting the productivity of farm animals and the efficiency of production of livestock products. The solution of part of the management tasks, which lie in the plane of decision-making regarding the optimization of the locations of the capacity of participants in the livestock products market, taking into account the available resources and infrastructure facilities, is solved on the basis of the application of geo-information systems and technologies, which, in addition to attributive data, make it possible to collect, visualize process spatial data.

## ► Conclusions

Therefore, one of the key directions of information provision on the basis of global digitalization is the application of geoinformation systems and technologies in the economic activity of producers of livestock products. In particular, the expediency of creating geo-informational portals with a targeted direction on information provision of the development processes of the animal husbandry industry, which has a number of significant advantages, namely: free 24-hour access to data; easy-to-understand format; possibility of spatial analysis; use for natural resource management; decision-making support in the grazing planning process; the possibility of monitoring the condition and development of vegetation within pastures; infrastructure planning; identification and continuous monitoring of regions with potentially increased demand for livestock products, in order to plan the infrastructure of sales markets; preservation of the environment. The proposed concept of implementation of geoinformation systems and technologies in the process of ensuring the development of the livestock industry and the markets of relevant products takes into account the information needs of all groups of potential users and aims to ensure the food security of the country.

In all the listed tasks, which are solved on the basis of GIS, one of the main stages is the collection of the most reliable and up-to-date data. In view of the above, in many cases the use of official statistics is problematic due to the length of the update, the incompleteness of the data by region, and, in some cases, the inaccuracy of the information. That is why, at the stage of coordination of key parameters of the geoinformation system within the framework of solving a specific problem, it is necessary to establish which data sources are a priority for the user. Currently, a significant part of data for GIS-based information support is accumulated from satellite images, which

are characterized by objectivity and relative promptness of updating. Considering the fact that for both collection and processing of GIS data, unique maps are usually created at the request of the user, one of the main types of developers should be agricultural universities and scientific institutions. This is explained by the fact that scientists who work with GIS and technologies, firstly, are often specialists in a certain field of agricultural science and, secondly, are part of an extensive informal network of researchers of the university/region/state, which, including, specialize in issues of production, distribution, and consumption of livestock products.

Prospects for further research should be a thorough analysis of the economic efficiency of the introduction of digital technologies in the field of animal husbandry,

namely the effectiveness of the use of GIS and their impact on the development process of the animal husbandry industry and the markets of the corresponding products and confirmation of their significance. Of scientific interest for future research is an in-depth study of the issues of digitalization implementation, which regulates the activation of innovative development of the livestock industry, with a similar base of key European countries and partner countries from other regions of the world.

#### ► Acknowledgements

None.

#### ► Conflict of Interest

None.

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## Діджиталізація як інструмент активізації галузі тваринництва

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► **Анотація.** Діджиталізацію економіки країни наразі слід розглядати як невід'ємну передумову її розвитку, активізація якої є необхідною на всіх рівнях від державного до рівня окремої особи-громадянина. В аграрному секторі впровадження діджитал-інструментів і технологій є необхідним з огляду на їх значний потенціал у контексті збільшення продуктивності ресурсів та підвищення рівня конкурентоспроможності продукції, виробників, галузей і держави у цілому. Особливо нестачу електронних цифрових послуг відчуває галузь тваринництва в Україні. Мета статті – обґрунтувати важливість застосування діджиталізації для інноваційного розвитку галузі тваринництва. У процесі дослідження використовувалися такі методи наукового пізнання: теоретичного узагальнення, аналізу та синтезу, аналіз даних, економіко-статистичний, графічний, кореляційно-регресійний, картографічний та абстрактно-логічний. Було узагальнено основні інструменти діджиталізації процесу ресурсного забезпечення виробників продукції тваринництва. Систематизовано пріоритетні типи інформаційних технологій у рамках діджиталізації бізнес-процесів виробників продукції тваринництва залежно від сфери застосування, основними з яких є інформаційні системи визначення фактичних і потенційних потреб у ресурсах, підбору потенційних постачальників та організації операцій купівлі-продажу (сфера ресурсного забезпечення); технології моніторингу стану сільськогосподарських тварин, оптимізації раціону та ветеринарних заходів, прогнозування стану тварини, спалахів хвороб, продуктивності поголів'я (виробництва); онлайн платформи для продажу продукції тваринництва, сервіси електронного документообігу тощо (збут продукції). Обґрунтовано напрями використання геоінформаційних систем і технологій з метою забезпечення розвитку галузі тваринництва, які передбачають урахування інформаційних потреб потенційних користувачів (зокрема, виробників продукції тваринництва, інвесторів та/або кредиторів, органів виконавчої влади, споживачів) та їх забезпечення точними, неупередженими, оперативними даними, необхідними для прийняття управлінських рішень. Тому, діджиталізацію слід розглядати як один із перспективних інструментів активізації розвитку тваринництва та підвищення ефективності виробництва і реалізації тваринницької продукції. Практична цінність роботи полягає у розвитку систематизації пріоритетних типів інформаційних технологій у рамках діджиталізації бізнес-процесів виробництва продукції тваринництва

► **Ключові слова:** геоінформаційні системи; інформаційне забезпечення; ринок; цифровізація