An Approach to Estimating the Economic Effect of Using ERS Data to Solve Agricultural Issues

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Abstract. The research objective is to study the possibility and prospects of applying qualimetry techniques to estimate the economic effect of using Earth remote sensing data in agriculture when digitally transforming the sector, considering both quantitative and qualitative efficiency indicators of economic, technical, environmental, and political and social nature and the impact of the environment on them. Based on the systematic analysis of the state and development trends of both the Earth remote sensing technology infrastructure and agriculture itself, a theoretical rationale for applying qualimetry techniques to estimate the economic effect of using these technologies in agriculture with a mathematical description of individual and integral estimates of their efficiency has been formalized. Qualimetry techniques have been compared with the efficiency estimating method based on the system of production functions. The scientific novelty of the study is the development of a scientifically grounded approach based on a formalized mathematical description to choosing a base object for estimating the economic effect of using ERS data in agriculture as part of a promising digital precision farming platform based on Earth remote sensing technologies and obtained, in turn, as a result of mathematical simulation of creating the country's economy digital management platforms.

1. Introduction

Currently, an increasing number of countries give strategic priority of their development to the digitalizing economy to ensure more effective interaction between the state, business, and the population. Based on the positive experience in the digital transformation of countries, this process is becoming more large-scale and dynamic. The digitalizing economy has significantly affected agriculture, turning it into industrial production.

Following the developed countries, some enterprises in our country began to implement individual Earth remote sensing (ERS) and precision farming (PF) technologies based on ERS data. However, the non-integrated, unsystematic nature of such implementations against the background of the traditional conservatism of agriculture often does not lead to the economic benefits expected. Since ICTs are currently becoming one of the leading costly resources along with material, financial, and human ones, there is an urgent issue of estimating its efficiency, including economic one, under the conditions of dynamically changing hardware, software, and information means of ERS technologies.
2. Applying of the qualimetry principles to estimate the economic effect
In 1968, in the USSR, military engineer G.G. Azgaldov introduced a new scientific area – qualimetry investigating the issues of quantitative estimation of product quality [1]. Currently, this area has significantly expanded to the quantitative measurement of the properties and states of various objects in many spheres of human activity, including the economic effect of implementing innovations [2, 3] since estimating the efficiency of complex and multifaceted business innovation implementing processes is impossible without an adequate scientific basis. The coming era of digital economy transformation leading to significant unpredictability of the environment and accordingly, the instability of the modern business development, which, along with the economic effect, is also forced to consider social, environmental, and some other effects arising against the background of the globally digitalizing society and resulting traceability of all processes, makes this issue especially relevant.

Typical qualimetry technique approaches include:
- analysis of both quantitative and qualitative indicators of innovations, their implementation environment, the requirements of all stakeholders,
- factorial analysis of internal and external innovation implementation indicators and the reasons leading to their variability,
- a systematic approach to implementing innovations considering the interests of all stakeholders based on the search for some optimal compromise in meeting their requirements,
- the use of scientifically grounded measures to improve innovation and forecast the stages of their development,
- the use of economic, technical, environmental, and political and social information to estimate the integrated effect of implementing innovations.

Based on the system analysis, to estimate the efficiency of implementing innovative projects, it is first required to find and justify the criteria for such estimation, adequate to the implemented project motivation [4]. E.g., P. Drucker, a management expert, identified the below main conditions and drivers for the emergence of innovations [5]:
1. Unexpected success or failure, unpredictable external impetus.
2. The discrepancy between the actual situation and its simulation.
3. Needs for the production changes.
4. Unexpected, spontaneous structural deviations in some markets or industries.
5. Changes in demographic trends.
6. Changes in consumer sentiments and perceptions.
7. The emergence of new knowledge that can be embodied in innovation.

Currently, in the real sectors of the global economy, the main technological development drivers are digital transformation based on ICTs, the use of new materials in the production, the use of biotechnology, and the success of nanotechnology, electronics, and optics. This is approved by studies of changes in the market value of enterprises when investing in different types of assets. Thus, a dollar invested in digitalization brings a 12-dollar increase in their market value, in contrast to the investment in other tangible assets, leading to a slightly more than a one-dollar increase in their value [6].

To estimate the efficiency of the innovative development of the real economy sector of Russia, it is important to predict the scenario the country will choose. And there are only three most likely variants given in the probability descending order:
- inertial development focused on the import of new technologies,
- catch-up development based on imported technological innovations with separate centers for the development of Russian innovations,
- stimulating fundamental research and promising R&Ds to achieve leading positions in the field of high-tech products corresponding to the goals of the Strategy for the Innovative Development of the Russian Federation for the period up to 2020.

According to the foregoing, qualimetry is based on three main approaches:
- considering efficiency as a complex manifestation of the efficiencies of individual properties having an interrelated effect in combination with other properties on the entire structure of its hierarchy,
- scientific and practical justification of the possibility of using quantitative scales to measure the manifestation of both individual properties and their combinations throughout the efficiency estimation hierarchy,
- the need to develop practical techniques for quantifying the efficiency of innovations to plan their implementation and subsequent control over this process at all stages.

Various techniques are used to determine the values of indicators being quantitative characteristics of the innovation efficiency properties.

Depending on the way of obtaining information, the techniques are classified into:
- instrumental, when technical measuring instruments are used to gather data,
- calculated, when data is the result of mathematical calculations of various complexity, up to artificial intelligence.

Depending on the information source, the techniques are classified into:
- registration based on technical, statistical, and accounting operations,
- expert, when gathering data is based on a survey of experts,
- sociological, when gathering data is based on consumer surveys.

Estimating the innovation efficiency based on the qualimetry principles is performed in several stages:
1. determining the main innovation efficiency properties and indicators required to obtain the final result,
2. developing a technique for measuring the innovation efficiency indicator values,
3. choosing the basic innovation efficiency indicators,
4. determining the performance indicator values for the investigated object introducing innovation, with the calculation of individual innovation efficiency estimates,
5. calculating the integral innovation efficiency estimation indicator.

Let us give a formalized description of individual and integral innovation efficiency estimates. It is believed that an individual estimate determines a single innovation efficiency property and is defined as the ratio of the efficiency indicator value for the investigated object introducing the innovation to the parameter value for the base object that has already introduced the innovation: $q_{ij} = p_{ij} / p_{ib}$, where $q_{ij}$ is the individual innovation efficiency estimate, $p_{ij}$ is the $i$-th innovation efficiency indicator of the $j$-th object introducing the innovation, $p_{ib}$ is the $i$-th innovation efficiency indicator of the base object.

In qualimetry, like in the theory of management, the concepts of ‘measurement’ and ‘estimation’ are distinguished. Thus, when measuring some properties, the $p_{ij}$ value of its $i$-th indicator is determined with some accuracy in the predetermined units of measure, while the chosen property estimate is determined by comparison of the indicator $p_{ij}$ studied with a similar reference $p_{ib}$ indicator, which itself is a difficult choice problem, to the solution of which many studies is devoted. Thus, the estimate determines the relative value of the indicator chosen to reference one. In the general case, however, $q_{ij}$ is some function of $p_{ij}$ and $p_{ib}$. If an individual estimate takes values more than 1, then this indicates the superiority of the object evaluated over the base one.

The integral estimate characterizes the totality of the innovation efficiency properties and is defined as the weighted mean value of individual estimates:

$$W_j = \frac{1}{\sum_{i=1}^{I} \alpha_i} \sum_{i=1}^{I} \alpha_i q_{ij}, \text{ where } \sum_{i=1}^{I} \alpha_i = 1, \ 0 \leq \alpha_i, \ i \in I, \ j \in J.$$

$\alpha_i$ is the $i$-th estimate weight coefficient.
The higher the integral estimate, the higher the overall level of the \(j\)-th object innovation efficiency.

Thus, the qualimetric approach feature is the use of exclusively relative indicators that allow solving the problem of joint using dissimilar indicators.

Despite the relative simplicity of the general qualimetric estimation structure, its practical implementation is associated with many difficulties. These difficulties primarily concern the first three stages, each of which assumes a multivariate implementation.

At the first stage, the necessary and sufficient number of the estimated innovation efficiency properties should be chosen. On the one hand, these properties should fully characterize innovation. On the other hand, they should have measurable indicators.

The second stage is one of the most difficult: a general technique should be determined and a procedure for obtaining the innovation efficiency indicator values developed considering the technique relevancy, accuracy, and reliability, as well as its implementation costs.

The third stage is choosing a base indicator. This stage also allows for a multivariate solution: as such an indicator, the value specified in the regulatory documents or that related to the competitive or the best model, etc., may be chosen.

The subsequent stages associated with the calculation of individual and integral estimates are purely technical ones and do not cause any particular difficulties.

Finding the \(i\)-th estimate weight coefficients is the most difficult problem, and partly for this reason, the efficiency estimating techniques are often classified just based on those for calculating the weight coefficients of particular individual estimates.

3. An approach to estimating the economic effect of applying ERS data in agriculture based on qualimetry techniques

In this section, we consider the possibility of and conditions required for applying qualimetry techniques to estimate the economic effect of using ERS data. In terms of the production process, agriculture looks and is usually described as a system of constituent interrelated elements in the form of resources used in production. To manufacture certain products with qualitative and quantitative characteristics specified, strict proportions between the system elements (resources) should be observed, which are determined by the general and specific requirements of the planned goods production technologies. Deviations from process requirements for the quality and quantity of any resource entail certain changes in the structure of using other resources, which will ultimately lead to a change in the quantitative and qualitative parameters of the product. When realizing the significance of digitalizing economy as one of the resources that most affect the economy, along with material, human, and financial ones, under the conditions of their finiteness, the issue of their rational use is becoming apparent. Therefore, depending on the resource base, the state of agricultural machinery, and the staff qualification, each country determines its approach to the digitalization of the sector, choosing individual digital technologies. Thus, in the USA, about 40-50 % of farms use PF technologies. By this indicator, the USA occupies a significant share of the world market, i.e. about 40 %. Herewith, the most demanded PF technologies are the following: 90 % of farms use soil express analysis; 80 % of farms use the GPS navigation of agricultural machinery in the fields with the yield monitoring and mapping; 60 % of farms apply fertilizers in dosages according to the strategic process maps of fields; 30 % of farms use vegetative indices and ERS data based on satellite images. In the EU, almost all countries start using some PF technologies, while Germany is the leader in their implementation [7, 8].

As can be seen, even in the USA, which is the leader in all the industrial innovations, not all ERS technologies are used. Although theoretically, based on current ERS data, many different plant growing problems can be solved that require gathering and storing a lot of additional data, both obtained over a long time interval and real-time ones, with their necessary integration with readings of sensors, devices, and other mechanisms located on agricultural machinery [9, 10, 11]. These ERS technologies include the following.

Equipment, including actuators and sensors for PFs:
- parallel driving technologies,
- soil sampling and analysis devices,
- precision fertilization,
- the yield determining and forecasting sensors.

Monitoring on agricultural fields:
- controlling the boundaries of used and unused land plots,
- monitoring of the agrochemical state of lands,
- monitoring of yield distribution by field maps,
- analysis of the relief of fields and surrounding areas.

Agricultural machinery monitoring:
- primary gathering data on vehicle motions in an automated mode using GPS navigation systems,
- visualizing the agricultural machinery motion in the fields,
- primary real-time accounting of the work performed.

Means for processing data transmitted by various sources in enterprise departments:
- accounting the products manufactured,
- analyzing financial indicators,
- real-time control,
- re-planning work [12, 13, 14].

In Russian precision farming, certain digital technologies have also begun to be applied using ERS data [12, 15]. As an example, the below companies can be indicated.

The use of the DatumGroup GIS system helps the employees of the Rostov Department of the Ministry of Agriculture to monitor the state of crops online, calculate the NDVI index, and forecast their yield.

Sovzond using the Geoanalitika.Agro GIS system supplies ERS data from the Landsat 8, Sentinel-1, and Sentinel-2 satellites, and the RapidEye service, and agrometeorology data for real-time analysis.

The marketed KosmosAgro GIS system provides a cloud technology for analyzing satellite ERS data to use several vegetation indices and monitor the state of lands with forecasting yield and the dynamics of work in the fields. If required, mapping fields, early diagnosing plant diseases, and detecting pests are possible.

Along with solving the issues of the aforementioned companies, the Research Institute Centerprogramsystem integrates ERS and ground-based source data of farms to solve accounting problems in not only agronomy but also transport, mechanization, planning, and accounting areas based on GeoServer and 1C: Enterprise 8 systems.

GIS PanoramaAgro offers comprehensive automation of the crop farming control system based on the GPS/GLONASS navigation service, processed multispectral images with the calculation of vegetation indices by fields, monitoring the state of agricultural machinery, and its motion.

There are companies, e.g., GIS for Agriculture, GradoService, GIS Polis-5, IAS GEO-Agro, etc., offering software packages for GIS-based creating databases of individual field indicators such as chemical and physical parameters, yield values, fertilizer input/output balance, accounting operations performed based on the PF technologies, motions of all equipment, including vehicles, soil sampling results, weather data, etc. Ontological database models, as a rule, are heterogeneous and incomplete subsets of some theoretical conceptual information scheme for crop production, which will further significantly complicate integrating agricultural information resources into a country’s common digital ERS and PF platform.

Currently, there are various ERS data sources, i.e. space satellites, UAV, ground data analysis and storage stations, all kinds of sensors built into the agricultural machinery equipment, soil and mast fixed sensors, databases of information systems of farms, and physical media of control departments of organizations. Information items of all these sources are distinguished by their cost and informative characteristics before and after the data preprocessing. Herewith, the ERS technologies depend on various equipment, transport and mechanized means.
All these ERS technology elements have some common features duplicating one another while creating new qualities supplementing the data of contiguous ones with the information required. Herewith, all ERS technologies are continuously improving, sometimes confusing consumers. The sustainable combination of these basic technologies in agro-business will be determined in the nearest future as a result of the competition between their efficiencies since for agricultural enterprises when introducing modern innovations, the issue of their cost is critical.

E.g., the whole world is currently keeping watch over the trends to use sensors and navigation equipment in driving air, ground, and water vehicles. One of them reflects the situation when all the vehicle devices, transmitting and receiving equipment, and accordingly, the control system is installed on it. This version of an unmanned vehicle is still being actively tested in various countries. The second trend is installing GPS sensors on all vehicles with the bridging to the terrain coordinates. They are controlled by spacecraft. The third trend is installing sensors on fixed objects along transport routes and directly on the vehicles and in the roadbed. In this case, the vehicle is controlled by digital cops and vehicle control devices.

As can be seen, the ERS technologies are globally introduced by trial and error; various both technical and software ERS means are continuously improving. In this regard, the current period is sometimes called ‘experimental’ with a forecast of rapid smart agriculture development in the coming years. There are no established trends. Such a rapid change in ERS technologies and their application techniques and means conflicts with the conservatism of production processes in many industries. E.g., in agriculture, only a single cycle of some crop rotations takes over 10 years. Accordingly, at a rapid change in ERS technologies, the efficiency of their application cannot be estimated.

Based on the systematic analysis of the state and development trends of both the ERS technology infrastructure and agriculture itself, we formalize a theoretical rationale for applying qualimetry techniques to estimate the economic effect of using ERS data in agriculture.

Since in the world and particularly in the country, at this ERS application stage, only individual technologies are being introduced, then in this case, it is easier to formally define an individual efficiency indicator, which depends significantly on the ERS data sources, various equipment, transport and mechanized means, soil and climatic conditions, farming systems, staff qualifications, socio-economic conditions, etc.

Then, the efficiency indicator \( p_{ij} \) of the \( i \)-th ERS technology of the \( j \)-th farm implementing the innovation can be represented in generalized form as \( p_{ij} = F_{ij}(ID,OB,M,PK,S,L,SE,KU) \), where \( ID \) is the ERS data source, \( OB \) is the ERS equipment, \( M \) is the transport and mechanized means, \( PK \) is the soil and climatic conditions, \( S \) is the farming system, \( L \) is the staff qualifications, \( SE \) is the socio-economic conditions, and \( KU \) is the types of crops.

Let us simplify this expression. To do this, we expand the aforementioned ERS technology concept, considering the \( i \)-th ERS technology as the previous definition broken down into the ERS data sources, equipment, transport and mechanized means, and crops. We divide Russian farms into \( l \in KPK \) classes based on similar soil and climatic conditions, which have more or less similar socio-economic conditions, farming systems, and the staff qualification, as well as the farms of developed Western countries, adjusted for some factor \( \nu \).

Then, we define the efficiency indicator \( p_{iak}^l \) of the \( i \)-th ERS technology of the \( j \)-th farm for the \( l \)-class soil-climatic zones and the \( k \)-th crop, \( i \in I , j \in J , k \in K , l \in KPK \).

As a basic efficiency indicator, we choose the best one among enterprises in each class of soil and climatic zones \( p_{iak}^l = \max_{j \in J} p_{iak}^l \). Then, an individual efficiency estimate of the \( i \)-th ERS technology of the \( j \)-th farm in the \( l \)-class soil-climatic zones and for the \( k \)-th crop will look as follows: \( q_{iak} = p_{iak}^l / p_{iak}^l \). Now, we can derive a series of integral efficiency estimates.
Integral efficiency estimate of the \(i\)-th farm in the \(l\)-class soil-climatic zones and for the \(k\)-th crop, 
\[ q_{ik} = \sum_{j=1}^{n} \alpha_{i}^{j} q_{ikj} , \text{ where } \sum_{j=1}^{n} \alpha_{i}^{j} = 1, 0 \leq \alpha_{i}^{j}. \]

Integral efficiency estimate of the \(i\)-th technology in the \(l\)-class soil-climatic zones and for the \(k\)-th crop, 
\[ q_{ik} = \sum_{j=1}^{n} \alpha_{i}^{j} q_{ikj} , \text{ where } \sum_{j=1}^{n} \alpha_{i}^{j} = 1, 0 \leq \alpha_{i}^{j}. \]

Integral efficiency estimate of the \(i\)-th ERS technology of the \(j\)-th farm in the \(l\)-class soil-climatic zones, 
\[ q_{ijkl} = \sum_{k=1}^{r} \alpha_{i}^{k} q_{ijklk} , \text{ where } \sum_{k=1}^{r} \alpha_{i}^{k} = 1, 0 \leq \alpha_{i}^{k}. \]

Integral efficiency estimate of the \(j\)-th farm in the \(l\)-class soil-climatic zones, 
\[ q_{jl} = \sum_{i=1}^{m} \alpha_{i}^{j} q_{jl} , \text{ where } \sum_{i=1}^{m} \alpha_{i}^{j} = 1, 0 \leq \alpha_{i}^{j}. \]

Integral efficiency estimate of the \(i\)-th technology in the country, 
\[ q_{i} = \sum_{j=1}^{n} \alpha_{i}^{j} q_{ij} , \text{ where } \sum_{j=1}^{n} \alpha_{i}^{j} = 1, 0 \leq \alpha_{i}^{j}. \]

Integral efficiency estimate of ERS in the \(l\)-class soil-climatic zones, 
\[ q_{l} = \sum_{i=1}^{m} \alpha_{i}^{l} q_{l} , \text{ where } \sum_{i=1}^{m} \alpha_{i}^{l} = 1, 0 \leq \alpha_{i}^{l}. \]

And, finally, an integral efficiency estimate of using ERS technologies in the country, 
\[ q_{s} = \sum_{i=1}^{m} \alpha_{i}^{s} q_{s} , \text{ where } \sum_{i=1}^{m} \alpha_{i}^{s} = 1, 0 \leq \alpha_{i}^{s}. \]

As noted in the first section, determining the weight coefficients of individual estimates is the most difficult task, the procedure of which is significantly affected by the indicator measuring conditions. The use of unreliable data can be exemplified by the results of long-term field experiments on studying the application of various technologies for precision control of nitrogen nutrition of spring wheat based on the so-called proximal method and using UAVs for air sounding of fields [16]. The proximal method was based on the Yara N-sensor [17], and the air sounding of crops was performed using a UAV. The choice has been made in favor of the air sounding technique since a single N-sensor costs EUR 60,000, while several sensors are required, which is very expensive. Actually, in Germany, this sensor costs EUR 25,000. This figure would radically change the conclusions and, accordingly, the weight coefficients.

From the above-considered general dependence of the ERS technology efficiency indicators written in a generalized form as 
\[ p_{n} = F_{n}(ID,OB,M,PK,S,L,SE,KU) , \] it is seen that a foreign analog cannot be chosen as a basic efficiency indicator due to the significant difference in all parameters included in the expression. There is almost the only way, i.e. introducing a correction factor \(v\) for the integral estimate of the ERS technology application efficiency in the country relative to that in developed Western countries, 
\[ q_{s} = \sum_{i=1}^{n} \alpha_{i}^{s} q_{s} , \text{ at } \sum_{i=1}^{n} \alpha_{i}^{s} = 1, 0 \leq \alpha_{i}^{s}, n \in N , \text{ where } n \text{ is the foreign country number.} \]

Note that the system of the Cobb-Douglas production functions has been quite well proven in estimating the efficiency of various resources [18, 19, 20]. This approach has been justified due to the compliance with the rather stringent basic requirements of mathematical statistics: the data analyzed
contain the results of either a one-time observation of the required number of homogeneous objects or the observation of the same object but over significant periods, and the objects observed should be under fairly equal conditions throughout the observation.

Currently, these conditions can hardly be ensured due to the significant dynamics of the entire technological setup of society. Moreover, there are a lot of digital technologies differing in the equipment and software used, staff qualification, etc. In this situation, statistical techniques are usually supplemented or replaced by expert judgment and qualitative analysis. However, these methods can also find a rather narrow application due to too many factors affecting ERS technologies and poor experience in their application.

The practical application of the system of production functions can be exemplified by the information system developed by the Ukrainian NIIEOSKh and the Institute of Cybernetics of the AIC in the 1990s to estimate the efficiency of using six types of resources: $PP = \alpha G^{a_1}Z^{a_2}B^{a_3}T^{a_4}F^{a_5}L^{a_6}$, where $\alpha$ is the model parameters, $i = (1 \ldots 6)$; $G$ is the water resources for irrigation; $Z$ is the land resources; $B$ is the fertilizers; $T$ is the human resources; $F$ is the fixed assets; $L$ is the feed.

For each type of enterprise, depending on the main crop produced (tomatoes, beets, etc.), the model parameters have been calculated based on gathering the required data for 15-20 years of production of crops and their costs at 30 enterprises similar in both size and natural and climatic zone of their location.

4. Scientifically grounded approach to choosing the base object for estimating the economic effect of using ERS data in agriculture

To obtain reliable both quantitative and qualitative ERS technology efficiency indicators based on the qualimetry techniques considered, the Ministry of Agriculture should focus on the integrated testing the most advanced digital technologies, including ERS, at several reference objects - sandboxes at different territorial levels, equipped with modern ICTs, sensors, instruments, process equipment, and a machine and tractor fleet, both compatible with each other and adapted to various digital technologies, covering all possible areas of their global development with the subsequent mass implementation of the most effective of them throughout the country. One of such reference objects could be the Timiryazev Academy with its great scientific potential and experimental resources, including the land ones.

Developed countries began to apply this approach. Thus, in Germany, to search and test the most suitable ERS-based precision farming technologies (PF), the Pregro interdisciplinary project has been launched according to the agreed PF concept, funded by the Ministry of Education and Science. Based on an integrated approach, to implement the project, the agricultural machinery has been equipped with appropriate hardware and software. The project has been conceived to develop precise crop production technologies considering the micro conditions of 20 x 20 m fieldpieces using ERS data. To increase the economic efficiency of new agricultural technologies, several industrial, scientific, and financial institutions have been involved in the project to provide it with the funds and resources required. According to the forecasts, as a result of the experiment, it is expected to increase crop yields up to 30 % and save all resources in the amount of EUR 100-150/ha. Since most farmers in Germany are well equipped with advanced agricultural and computing technique, research and various experiments are intended for the early implementation of proven digital technologies for the differentiated input of chemicals, particularly, fertilizers, considering the characteristics of small crop areas using the entire scope of ERS, PF, GPS, and GIS data. In Germany, most of the farms apply advanced agricultural and computing techniques, which allow accessing the soil map databases, digital data, and ERS images. Germany should not have any problems with the wide distribution of proven technologies since, as already noted, its farms are also well equipped with computers that allow accessing databases of various digital services (soil maps, ERS images, etc.); the informational and consulting service also effectively operates to assist in implementing proven agricultural technologies, sampling and analyzing soil samples, mapping fields, and purchasing the PF equipment required.
China has also begun to perform the first experiments on using the PF technologies near Shanghai. The goal is also to test technologies for balanced nutrition of crops before their commercialization. Up to 11 types of nutrients are involved in experiments on 460 land plots. The first results showed that the yield of watermelons increased within 14 to 27 %, the sugar content of watermelons increased three times, and the rice and wheat yield increased by 9-13 and 18 %, respectively [21].

Currently, the digital economy threw down challenges to the Ministry of Agriculture similar to those it faced in the 90s of the last century when the mass implementing PCs began in the country. Establishment of the Institute of Cybernetics of the AIC has allowed choosing the most rational approach – the development of typical, integrated information management systems (IMS) at reference objects with the subsequent replication of the proven tested systems at other enterprises [21]. Thereat, everyone was aware that IMSs will significantly affect both the control systems and the agroindustry enterprise structure. One of these objects was the Kuban multi-unit agricultural complex in the Krasnodar Territory, which included 19 types of agroindustry enterprises. Over a short four-year period, individual software systems tested at reference objects have been transferred for implementation at about a thousand country's enterprises. This technology has allowed tens to hundreds-fold improving the economic efficiency of the development and implementation of information systems. The developed standards for information resources and applications have allowed determining a list of problems, algorithms for their solution, and logical database structures common to all types of AIC enterprises. A creative team of various leading sectoral research institutes and the Institute of Cybernetics of the AIC was formed, which developed integrated information management systems for enterprises, implementing the principles of integrating and typing information systems on a unified methodical basis.

Based on the experience acquired in using the ERS technologies, the Western countries come to the same data and systems integration concept as the Kuban AIC. Thus, J’son & Partners Consulting [22] believes that two digital platforms are being formed in the agricultural economy based on cloud technologies, i.e. economic information aggregators or primary data gathering and accumulation platforms and applied ones. It is believed that only this approach will ensure the greatest efficiency of digitalizing production. Integration should be conducted just based on cloud technologies since in this case, information becomes available for enterprises of different sizes and not only some of the largest ones. In the world, the industrial implementation of this approach is just beginning. Even in the USA, cloud integration technologies were launched only 2-3 years ago.

This concept will affect the relationship between manufacturers and partners in the value-added chain (logistics, wholesale, and retail companies) due to implementing cloud technologies of the direct sale model when the manufacturer ‘sees’ all the chain links up to the end consumer and, accordingly, the time, scope, and nomenclature of demand. Then, based on various mathematical models, particularly, predictive analytics, it plans the production exactly in the volume and within the time required by the consumer, and further using cloud technologies, the products will be delivered in an automatic mode of data exchange between the supply chain partners, minimizing the involvement of intermediaries such as warehouse infrastructure.

The theoretical justification of the conceptual approach to the integration of agricultural data and information systems with information resources and systems of other related industries is a mathematical model of creating digital platforms for managing the country’s economy [23], one of the results of which related to the study subject is a promising digital precision farming (PF) platform based on the ERS technologies.

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5. Conclusions
The progressive integrated implementation of the digital AIC platform with the replication of technologies tested at reference objects is the most effective mechanism for transforming it into a system of scientifically grounded digital infrastructure technologies throughout the AIC. In this case, there will be a significant reduction in both the time and costs for the mass implementing the PF, ERS, and GIS technologies with a significant improving the efficiency of using such advanced innovations. The joint efforts of the scientific community, IT companies, the Ministry of Agriculture, and business will allow obtaining promising digital ERS technologies within a short period, which should become the basic (reference) object for estimating the economic effect of using ERS data in agriculture. In the meantime, only a few farms can take advantage of ERS and other digital technologies.

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