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Digitalization of Farming and Sustainable Agricultural Development: Evidence from Vegetable Growing Sector

Andriy Popovych
Berdyansk college of TSATA, Department of Management and Economics, Shidnyi ave., 71108, Berdyansk, Ukraine.
Author email: apopovych@kse.org.ua

Abstract

Digitization is one of the most recent processes of transformation of world agriculture by overcoming existing environmental, economic and social problems and can be called the "third green revolution", since digital farming technologies allow to analyze and process large amounts of information, control and reduce production risks, meet the information needs of a wide range of stakeholders, from the state to the end consumer, as well as to ensure overall security. To answer the question of link between digitalization of the agricultural sector and sustainable development the article analyzes the potential of ICT technologies in agriculture, studies models of digital farming, considers the prospects for using digital economy tools in solving the problems of sustainable development of the agricultural sector. In particular, the article examines the advantages of ICT in terms of the rationality and sustainability of agriculture, provides an overview of the main technologies of intelligent farming in interaction with the infrastructure of the agricultural market. It also analyzes potential shortcomings, identifies barriers that impede the timely and large-scale implementation of information technologies in agricultural enterprises, limit the availability of the “digital revolution” in agriculture for small farmers and women, especially in developing countries. A practical analysis of this problem consists in conducting an economic and statistical analysis of the use of modern high-precision agricultural technologies in the vegetable growing industry. As a result of an econometric assessment of the data of small and medium-sized agricultural enterprises, the main factors of the existing development trends are identified and the main problems of sustainable development of sub-sectors are highlighted. The final model presupposes the development of an integrated approach to organizing sustainable development aimed at preserving natural landscapes, as well as improving scientific methods for environmental monitoring of agricultural lands and other areas that have not been effectively used.

Key words

agriculture, digitalization, ICT, sustainable development

1. INTRODUCTION

The digital economy is the future stage in the development of the global economic system due to the transformation of all spheres of human activity under the influence of information and telecommunication technologies. The spread of the Internet and other innovative technologies indicates the impossibility of ignoring their impact on the global economy in general and on its individual industries such as agriculture in particular.

Over the past decade, the priorities of the agricultural sector towards increasing its efficiency have changed to those based on up to date innovative solutions. Information and communication (ICT) technologies, which are usually understood as automation, informatization, digitalization, are being actively implemented today in all sectors of the economy, including agroindustry [1]. The purpose of introducing ICT in the agricultural sector is to increase the productivity of agricultural and processing enterprises by improving business processes with the help of innovative services [2].

"Digital agriculture" as it is often called implies the full-scale implementation of the digital economy, which consists of digital production technologies and robotic systems, as well as the commercialization and export of new scientific developments. The digital transformation of agriculture sector makes it possible to provide a technological breakthrough to farming to increase in capital and labor productivity at "digitalized" agricultural enterprises [1].

On the other hand, the modern paradigm of agricultural development presupposes both productive longevity and environmental sustainability with the preservation of habitat and focus on the optimal use of natural resources. It requires the deepening of the integration of ecology, crop production, livestock production and the business [2]. Achieving this level is possible with the gradual development of economic methods that ensure the relationship between natural and anthropogenic ecological systems and aimed at harmonizing the laws of ecology and economics [3].

The experience of the development of the agrarian sector testifies that as a result of the "technological revolution" classical extensive agriculture is being replaced by intensive and scientifically grounded. Information and satellite systems, multi-operational energy-saving agricultural units are widely used, considerable attention is paid to the selection of high-yielding varieties of agricultural crops, the creation of biologically active components for soil enrichment, new environmentally friendly means of combating weeds, pests and quarantine diseases of agricultural plants [4].

That is, there is a need for environmental management, which can develop on the basis of environmental entrepreneurship, one of the effective development directions of which can be the organization of environmental production of domestic high-quality products that solve food security problems. The main task of green management should be the creation of a management system that, on the one hand, reduces the impact of production technologies on the environment, and on the other, increases production efficiency [5]. The development of rural areas without the effective use of information capital is impossible as it contains valuable data relating to all areas of the economic entity and areas related to the sale, exchange, production of goods and services [4].

According to the generally accepted strategy, sustainable agriculture and the organization of agricultural landscapes should include regional specialization of agriculture, including the integrated use of land, the combined use of irrigated and non-irrigated lands, the development of land reclamation through the creation of various forms of plants, measures for the protection of biological diversity, and others [5]. Thus, the above theoretical substantiation of the greening process allows us to identify the factors that determine the technological and socio-economic basis of the organization of ecological agricultural production, ensuring its sustainable and effective development. It allows to solve the problems of increasing the environmental and economic efficiency of production by restoring, preserving and stimulating the natural cycle of substances destroyed by the processes of intensification of production, as well as maintaining the diminishing potential soil fertility and expanding reproduction due to the rational organization of agricultural land, the use of adaptive farming systems and improving the quality of products and increasing its competitiveness.

Ensuring the sustainability and manageability of agricultural land use is currently impossible to achieve without the use of the latest technologies and, first of all, digital. The most important direction of increasing the competitiveness and sustainable development of regional agri-food systems in the context of scientific and technological progress, the introduction of innovations is the widespread use of biological factors of economic growth: the achievements of genetics, breeding and seed production, new varieties and hybrids of plants that differ from their predecessors in higher indicators of potential yield, content in grain production of valuable nutrients, responsive to fertilizers, irrigation, drought resistance, immunity to diseases and pests. Digitization of agriculture is a prerequisite for achieving the effectiveness of the above-mentioned innovations [6].

2. OVERVIEW OF DIGITAL TECHNOLOGIES USED IN AGRICULTURE

"Digital economy" of the agricultural sector is a fully digitalized and automated production that is controlled by intelligent systems in real time, without human intervention, going beyond the boundaries of one enterprise, with the prospect of uniting into a global industrial network of things and services [7]. The information aspect in the activities of an agricultural enterprise becomes an integral part of any business process, an indispensable condition for the operation of modern technology, a prerequisite for the successful organization of the production process itself and means of improving the quality of the workforce.

The list of the digital methods and techniques used in agriculture today includes but not limited to precision farming, smart farms, smart greenhouses, monitoring the use of agricultural machinery using satellite navigation systems (for example, GPS) and sensors, smart storage for vegetables and fruits, irrigation automation, electronic trading platforms for farmers, technical devices such as drones, which include both ground-based drones and unmanned aerial vehicles and copters, as well as winged drones, etc. The other technical devices of information technologies in agriculture are weather stations, soil moisture sensors and other special applications used to collect data from the environment and soil and transfer them to the cloud system at a given time interval.

The main function they perform include monitoring the state of agricultural crops, calculating index indicators of plant mass, estimating the future harvest, detecting disease-causing manifestations, weed plants, insect pests [7]. The software allows you to register and notify farmers via SMS messages about the spread of diseases and pests in certain areas, store historical data on key soil and crop parameters for each season, as well as general information about diseases, pests and plants. As a result of the use of such technologies by farms, operating costs are optimized and yields increase by an average of 15-20% due to a reduction in the volume of seeds, agrochemicals, fertilizers and water used, which are used strictly "on demand"[8] .

Digitization in agriculture also provides an opportunity to create complex automated production and supply chains, covering retail chains, wholesale trading companies, logistics, agricultural producers and their suppliers in a single process with adaptive management [9]. The digital transformation scenario assumes a systemic, accelerated digitalization of agricultural production and integration with the areas of digital economy programs which dictates the need for the inclusive use of logistics cargo transportation, stimulating domestic consumption, developing product exports and building platforms that provide end-to-end digital solutions to create added value and ensure the competitiveness of agrarian business. In turn, the digitalization of commodity flows and production makes it possible to systematically accumulate trade lots for the export of agricultural products. This creates conditions for attracting private financing for the platforms and applications of agricultural producers, the active involvement of agricultural consulting services [8].

The creation of information and consulting services in helps rural producers to make better decisions for the development of production taking into account external factors. Advance information on the occurrence of adverse factors (weather conditions, the spread of pests and disease outbreaks, changes in the market situation) and possible risks must be carried out through developed information and communication technologies and automated information systems. Supporting business projects by assessing the effectiveness of new digital technologies, making recommendations for improving production, introducing innovative technologies and disseminating information about new developments allows farmers to keep abreast of modern advances and spend money not on traditional technologies, but to implement an innovative structure in the economy [10].

The movement towards the development of precision farming is the initial stage in the global reform of agricultural technologies. The introduction of satellite navigation in agriculture contributes to an effective assessment of the reliability of equipment, to collecting data on its condition, location and problems that may arise in the course of work. The satellite technologies is a large-scale production and resource-saving complex that provides for full control of transport facilities, fuel reserves and the adaptation of the system to a specific enterprise [11].

The implementation of digitalization contributes to the development of a new agricultural technology policy and growth in related industries: information and communication technologies, production of innovative agricultural equipment, as well as equipment for precision farming, biological products (plant protection products, stimulants and fertilizers), optimization of the use of mineral fertilizers and chemical plant protection products, reducing the impact on the environment, developing breeding and seed-growing centers, introducing new educational standards in training programs in agricultural universities and colleges, as well as in advanced training courses, professional service of agricultural consultants, optimizing the life cycle processes of the agricultural industry due to digitalization of processes [11]. For sustainable development of agriculture, concepts of organizational and economic potential and the global introduction of informatization, accumulating information resources and knowledge for effective economic management, are constantly being developed making it possible to implement economic regulations for operating in specific conditions and to establish the processes of expanded reproduction of goods in all sectors of agriculture [12].

Furthermore, unified electronic systems are being formed that allow for full monitoring and analysis of the efficiency of agriculture in the country. This information system combines the subsystems used in the registration of farmers-producers of agricultural products, identification of land allotted for agricultural work, registration and identification of animals, their health and productivity. It also includes managing the application for financing for agricultural projects, the farmer lending system, as well as leasing operations and the registration of agricultural machinery. All these data will be sent online to a single processing center, which allows you to quickly identify problem areas in the agricultural sector and promptly make optimal decisions to improve the efficiency of the country's agriculture [13].

Distributed information processing technologies and cloud storage technologies also have high potential and obvious advantage in agriculture because of the ability to combine computing power to solve the most complex problems and implement modern highly efficient information systems, depending on current needs. The efficiency of collection, storage and processing of empirical data significantly increases when conducting research and analyzing the effectiveness of the use of certain agricultural technologies [14].

Agriculture is characterized to a greater extent by the automation of routine work, rather than the strengthening of the intellectual capabilities of managers. The most well-known technologies are implemented in the framework of applied computer programs to optimize the placement of crops in zonal systems of crop rotation and animal feeding rations, for calculating the doses of fertilizers, for carrying out a complex of land surveying and land management, for maintenance of the state cadaster of the history of fields and the development of technological maps for the cultivation of agricultural crops, for regulation of plant nutrition and microclimate in greenhouses, for control over the storage process of fruits and vegetables, the quality of cultivated products, soil pollution, for assessment of the economic efficiency of production, for management of technological processes in facilities of production and storage of raw products and foods and much more [13].

The use of geographic information systems (GIS) in crop production makes it possible to obtain more accurate data on the soil, on the peculiarities of sowing certain seeds or on the required amount of fertilizers, which makes it possible to increase the yield. For example, in the process of growing some crops, it is extremely important to observe a certain amount of seeds that must be planted on the site. This process can be monitored using special equipment that has information about the yield levels in different parts of the field over the past years. At the end of the harvest period, the device records the performance of each area. This data is then automatically sent to the geographic information system for further analysis and planning of the next sowing work. GIS allows you to regulate almost any calculations in crop production: they update and build maps of land, control the movement of agricultural machinery, process data and calculate technological operations [15].

Thus, the use of modern information and communication technologies is one of the main conditions for the effective development of agriculture. It is necessary to introduce and develop "e-agriculture", to train highly qualified IT specialists in the field of agriculture, to improve the knowledge and skills of small and medium-sized agricultural producers. In other words, information and telecommunication technologies should provide automated data exchange at the federal, district, regional and district levels [3]. At the same time, in many countries, primarily developing countries, agriculture lags far behind in the use of digital technologies in comparison with other sectors of the economy. If we compare the share of information and communication services in GDP, at present in the United States the indicator is 25%, in the EU countries - 15%, in developing countries - no more than 5% [16].

The progress of the process is slowed down by the existing problems of the countries based on social, economic, psychological and other prerequisites. The introduction of large-scale machine production faced a number of contradictions caused by the need to use a colossal amount of information and the impossibility of processing it using traditional technologies. The low threshold for informatization of society is explained by the psychological unpreparedness of the population for informatization, a low level of computer literacy, conservatism of the population and a lack of desire to accept innovations.

The slow introduction of ICT in agriculture of developing countries is due to the presence of such constraining factors as problems with the Internet (especially in remote regions), which makes it difficult to use software online, lack of financial resources for the implementation of information and communication technologies in most agricultural producers, lack of digital literacy and digital skills among agricultural producers, low level of infrastructure provision for the implementation of digital technologies and platform solutions. Therefore, the main reasons for the lag in the development of digital agriculture are, firstly, the low share of coverage of the territory of the regions with the Internet and communications, secondly, the lack of funding, thirdly, there are problems in the legal framework: the lack of the necessary legal mechanisms to regulate the use of digital technologies and, finally, the lack of the necessary specialists.

The problem of insufficient development of agriculture can be solved by attracting investments, targeted state support and large-scale informatization of industries [17]. Increasing the economic efficiency of the agricultural sector to the level of competitiveness in the world market is impossible without improving all areas of the economy, as well as introducing innovative technologies and production automation into its structures. Nevertheless, it is possible for agriculture to receive targeted expansion and development, subject to the creation of new links of the digital economy, with an increase in the productivity of agricultural enterprises to provide food to residents in the required amount, which will lead to the stability of the country's food security and an inevitable recovery of the economy as a whole.

At the same time, each country has its own digital agriculture system that meets the needs of that country and acts in the interests of national policies. As practice shows, the effectiveness of any national digital agriculture system is determined by the presence of a modern infrastructure that ensures information security, cybersecurity and personal data protection, electronic platforms for the provision of electronic services, digitized information under the jurisdiction of government bodies, full coverage of the territory with 4G and 5G broadband communications, information platforms, on the basis of which the interaction of services with persons employed in the agricultural sector is ensured, informational and financial support for people employed in agriculture.

3. THE STATE OF AFFAIRS AND DIGITALIZATION TRENDS IN FARMING

Stability of production is an indispensable requirement for the effective development of any branch of the national economy, but this factor is especially important in agriculture. The existing instability of agricultural production is manifested, first of all, in the annual fluctuations in the volume of crop production. Moreover, an increase in production does not necessarily lead to a decrease in the level of its variability. This is a consequence of the fact that the main focus is on increasing production volumes, and the task of increasing its sustainability remains unresolved. Therefore, it is necessary to develop such a structure for the use of agricultural land, which would optimally combine both an increase in production volumes and an increase in its sustainability in each agricultural enterprise.

Fluctuations in the production of agricultural products in the developing countries are often caused by a significant deterioration in the quality characteristics of agricultural land and land degradation. The main reasons for the decrease and annual variation in harvest volumes are associated with the lack of substantiated scientific and methodological approaches for the reorganization of agricultural enterprises, strategies for land use, the formation of a land use system, reliable, high-quality information on soil, geobotanical, hydrological, geological, soil-erosion and other types of survey, assessing the ecological state of lands, applying the landscape-ecological approach in solving issues of land use, organizing land tenure, land use, state financing of programs and measures for land restoration, increasing their productivity, lack of proper control over the state and use of land by agricultural producers.

An increase in the intensity of the degradation processes of the land and property complex, which has a negative impact on the development of harvest growing, is also associated with a sharp deterioration in the financial and economic situation of agricultural producers, with a decrease in the general level of farming culture and a violation of the requirements of the farming system, with the use of depleting types of land use and technologies.

International agreements and support from the Food and Agriculture Organization of the United Nations play a significant role in the development of national digital agriculture systems of developing nations which have significant agricultural sectors constituting important part of domestic economy. It supports the implementation of a unified statistical data system on agricultural production, which is of strategic importance for agricultural policy planning. An integrated web system TRIACS is supported in the developing countries, which includes modules for administration and control over payments of subsidies to farmers. Farmers are supported in the development of digital technologies in agricultural and horticultural crops. The US Agency for International Development has developed software that allows the small-scale farmers to keep records of plants and send SMS alerts in case of plant diseases.

The Ukrainian Horticultural Business Development Project (UHBDP), sponsored by the Canadian Government through MEDA, provides tangible assistance to farmers. The program operates in the Nikolaev, Kherson, Zaporizhya and Odesa regions. The uniqueness of the program lies in the fact that it is a non-profit project of one or several companies, and it is aimed at a wide range of people working with the land. Assistance was also provided in the introduction of innovative technologies, in terms of digitalization, the creation of a database and a map of farms. This assistance is personal and is aimed at small farmers and land users, they are the focus of the project.

Within the framework of the program, continuous and local soil monitoring of agricultural lands using GIS technologies was deployed, information databases on soil fertility were formed, ecological frameworks were developed taking into account the relief conditions, genetic characteristics of the soil and its agricultural use, providing a deficit-free level of energy balance of the agricultural landscape. In addition, an landscape structuring of agricultural lands was carried out and the most effective measures to maintain and reproduce soil fertility were determined, taking into account its state in each agricultural landscape, recommendations were developed for the effective use of agricultural lands, the prevention and elimination of the consequences of negative processes (de-humification, erosion , over-consolidation, desertification, etc.), work has been launched on chemical reclamation and phytomelioration of acidic and saline soils, restoration of the fertility of degraded and low-value lands.

The creation of a system of information support for decision-making processes based on GIS technologies made it possible to increase the overall efficiency of agricultural production by presenting relevant analytical information on the entire range of necessary parameters for making optimal and timely management decisions. GIS technologies are especially important in the management of agricultural production in regions with risky farming. These territories require constant monitoring of the conditions for the development of crops and the conduct of agrotechnical and agrochemical measures. Surveillance can be carried out both in individual fields and within a district, region, or over a wider area [18].

In the process of introducing and using GIS technologies in crop production, the project at least partly connected number of agricultural units to satellite navigation systems, which allow, using a GPS receiver and special software, to obtain the exact coordinates of the contours of the fields. An important element of the process of collecting, analyzing and processing the necessary data for the subsequent adoption of informed management decisions and their expert support is software and hardware (dispensers, measuring sensors) and their relationship [19].

4. EMPIRICAL ANALYSIS OF ICT USAGE IN SMALL FARM VEGETABLE GROWING

For the purpose of this research the vegetable farming in the East and South Europe is chosen where over the past 35 years, the amplitude of fluctuations in vegetable production reached 242% of the average annual harvest for this period. The volumes of other agricultural products harvesting also experienced significant fluctuations, which negatively affected the efficiency of the related processing industries.

The main goal of this study is a theoretical and methodological substantiation of the need for the introduction and effectiveness of the use of information technologies on the platform of geographic information systems (GIS) in the implementation of agrotechnical measures in vegetable growing. For this analysis, the database of the UHBDP in terms of growing vegetables, collectively referred to as tomatoes, cucumbers and peppers, by small farms in Bulgaria, Romania and Ukraine is used.

Analysis of the time series of vegetable production in the region makes it possible to distinguish three stages in the development of vegetable growing, formed under the influence of general structural changes in the agrarian economy over the past thirty plus years, that is, during the transition of the studied countries from a planned socialist economy to a market economy and the improvement of the latter. In the pre-reform period, vegetable farms for sowing annually bought seeds of the elite and the first reproduction, which ensured a sufficiently high yield and varietal purity. Mineral fertilizers were widely used and the intensive development of technology has also contributed to the annual increase in the yield of vegetables.

The process of reduction of acreage of vegetable crops in the 90s was accompanied by a decrease in yields and gross harvest of vegetables. This situation is associated with the prevailing price disparity in the sub-industry, which led to a shortage of working capital from producers for the purchase of mineral fertilizers, chemical protection products, high-quality seeds, and equipment renewal. The technology of growing vegetables was simplified everywhere, the quality of the product obtained decreased. The fall in effective demand led to a decrease in their production by more than 3 times while sales dropped by almost 40 times. Vegetable lands were often sown with other crops with lower agrotechnical qualities and a high degree of weed infestation. During the period from 1990 to 2001, the technical equipment of vegetable growing has sharply decreased. Depreciation of energy resources, primarily tractors, amounted to 90%, other equipment - 65%, the doses of fertilizers, the volume of capital investments in the reconstruction and construction of reservoirs, pumping stations, rice irrigation systems were reduced significantly, which led to a decrease in productivity, the gross harvest of vegetables in the region decreased annually by an average of 12%.

The alignment of price relations in agriculture and related sub-sectors in the period after 2002, the intensification of the financing of vegetable growing from the state and regional budgets led to the fact that the domestic vegetable market became profitable, and it became profitable for producers to invest in its production. The increase in the doses of mineral fertilizers ensured an increase in the yield of vegetables. Since 2005, the area under vegetables has expanded by an average of 7% per year. However, natural and climatic conditions do not allow excluding the import of vegetables from the balance of products.

In the first post-reform decade, the main factors of fluctuations in the indicator were the economic crisis, the unstable price situation in the rice and adjacent markets and the lack of funds from producers to carry out reproduction processes in the sub-industry, as well as natural and climatic features. The low value of the sustainability of the trend in the area under vegetables in the last decade is a consequence of the reactions of producers to the changing conditions in the markets of agricultural raw materials by shifting the area under crops for more profitable crops like corn and sunflower.

The analysis of the structural variability of the trend was carried out by using the econometric modelling. Its advantage is the use of one general regression equation, rather than several piecewise linear dependencies in the period under consideration.

The linear regression equation with dummy variables is:

$$y = \alpha + \beta\bar{x} + \gamma\bar{d} + \varepsilon \qquad (1)$$

where y is the dependent variable, x is a vector of independent variables, d is a vector of dummy variables (if it corresponds to the truth, it is equal to one, otherwise it is equal to zero), α is a free coefficient, β, γ are estimated regression parameters, ε is the regression error.

The difference in the size of the harvest of the current year to the previous one in absolute terms was chosen as a dependent variable, and the absolute value of the difference in the amount of fertilizers applied to the vegetable crops and dummy with unit value in case of application of GIS technologies as independent variables. Analyzing the relationship between the volatility of vegetable yields in the region and the difference in the doses of fertilization and use of GIS technologies, an empirical linear equation was compiled:

$$YLD_{ij} = \alpha + \beta FRT_{ij} + \gamma GIS_i + \varepsilon \qquad (2)$$

where YLD_i is the difference in yield of a type of vegetables in agricultural organizations of the region, FTL_i is difference in the amount of mineral fertilizers applied per hectare of planting a type of vegetable crops in agricultural organizations of the region during the period under review, c/ha, GIS is a dummy variable, the value of which is equal to one if the farmer used GIS technologies and zero if not, i is individual farm, j is correspondingly means tomatoes, cucumbers and paprika.

Application of linear regression for the above equation for each type of studied vegetable crops produced the following results:

*Table 1.Results of econometric estimation of the empirical equation for different kinds of vegetables**

Dep. Variable:	TMT		CCB		PPR	
No. Observations:	361		332		192	
R-squared:	0.712		0.656		0.84	
Adj. R-squared:	0.784		0.664		0.929	
F-statistic:	345		205.8		178.7	
Prob (F-statistic):	0		0		0	
Log-Likelihood:	1463.8		953.06		726.31	
vars	FRT	GIS	FRT	GIS	FRT	GIS
coef	2.1486	-10.3178	1.5037	-3.209	2.1889	-7.9265
std err	0.076	1.378	0.035	0.437	0.09	1.434
t	28.234	7.486	42.736	7.35	24.24	5.526
P>|t|	0	0	0	0	0	0
Omnibus:	91.969		45.838		26.359	
Prob(Omnibus):	0		0		0	
Skew:	-0.113		0.03		0.026	
Kurtosis:	1.944		2.066		2.045	
Durbin-Watson:	1.681		1.662		1.701	
Jarque-Bera (JB):	17.547		12.121		7.314	
Prob(JB):	0.000155		0.00233		0.0258	

* - TMT - tomatoes, CCB - cucumbers, PPR - paprika

All coefficients of three equations (2) turned out to be statistically significant at a one-percent level of significance, therefore, a change in the independent factors was accompanied by a change in the resulting amount of dependent variable. Analysis of the set of vegetable yields in the region showed a statistically significant dependence on the parameters of the linear trend in the studied data which are the change in amount of fertilizer used and application of GIS technology. Moreover, all the coefficients have the expected sighs. So, the positive coefficient of a variable standing for difference in mineral fertilizer use negatively affects the stability of the levels of the yields, which characterizes the deviations of the actual levels of the set relative to the previous year, while the negative sign of the coefficient responsible for the application of GIS supports the stability of the trend in the analyzed periods.

Note that the data is best approximated by a linear relationship, which indicates a significant reserve for the improving the stability of the vegetable sub-sector of the agriculture of the region. The coefficient of stability of the yield in this period was 32%, which is 11.5 percentage points higher than the coefficient of the growth trend of harvested areas. Thus, the growth of the gross harvest of vegetables in the region has recently been provided, to a greater extent by the growth of yields, rather than by extensive factors. An increase in the dose of mineral fertilizers per 1 kg of active ingredient per hectare of sowing led to an increase in yield by an average of 2.1 kg for tomatoes, by 1.5 kg for cucumbers and 2.2 kg for paprika. The influence of factors of development and modernization of vegetable growing in the equation identifies the dummy variable. The fact of application of GIS technology by a farmer on average leads to decrease in variability of yields by 10 centners for tomatoes, by

3 centners for cucumbers, by 8 centners for paprika. Thus, it can be concluded that the GIS technology lead to more sustainable development in vegetable growing in small farms.

5. CONCLUSION

Digitalization of agriculture is a developing area aimed at increasing agricultural production through the improvement of information and communication processes. The digital technologies should also provide path to the sustainable development of farming. There are plenty of new tools to by introduced to the agricultural sectors but the degree of implementation of information technologies in agriculture is inextricably linked with the social-economic situation in the country and to expand the scale of informatization, along with economic conditions, political, technical and social conditions are required, especially in the developing countries. However, even small scale application of digital technologies like GIS in particular sub-sector of agriculture can provide necessary proof of positive influence of digitalization on sustainability of agriculture.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest.

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