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Preliminary communication

METHODOLOGICAL APPROACH FOR RESEARCHING THE OPPORTUNITIES FOR DEVELOPMENT OF DIGITAL AGRICULTURE BASED ON INNOVATIVE BUSINESS MODELS

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ABSTRACT

Digital Farming describes the evolution in agriculture and agricultural engineering from Precision Farming to connected, knowledge-based farm production systems. Digital Farming makes use of Precision Farming technology, yet – in addition – also takes recourse to intelligent networks and data management tools. The aim of Digital Farming is to use all available information and knowledge and thus to enable the automation of sustainable processes in agriculture. The objective of the paper is to present development of theoretical foundations and methodological approach for introducing the digital agriculture. The implementation of the approach will allow to achieve in practice in agriculture and rural areas. I will provide a new framework for analyzing and assessing the impact of introducing the digitization of farms of different types, the different sectors of agriculture and regions of the country. In other side providing new tools to support the design of the farm strategy, organizational modernization and collective action, as well as to improve public policy and forms of public intervention in the agrarian sphere.

Key words: digital agriculture, sustainability, development**.**

INTRODUCTION

Analysis of the current state of research

Precision Farming started when GPS signals were made available to the general public. Precision Farming enables vehicle guidance and site-specific monitoring and control. Combined with telematics and data management, Precision Farming improves the accuracy of operations and allows the managing of in-field (or in-herd) variations. The objective is to give each plant (or animal) exactly what it needs to grow optimally, with the aim to improve the agronomic output while reducing the input (= producing ‘more with less’).

In the early 2010s, Precision Farming was boosted by the advancement of new technologies such as cheap and improved sensors, actuators and micro-processors, high bandwidth cellular communication, cloud based ICT systems and big data analytics. As a result, data is no longer sourced merely from the farm equipment used, but new services are being offered with new algorithms to transform data into actionable intelligence.

The Digital Farming has the parameters in agricultural production processes are somewhat different from industrial processes, as agriculture is heavily determined by natural and biological factors.

The digital single market offers many opportunities for agriculture and food value chains -up to the consumer- to become smarter, more efficient, more circular and more connected. The topic of digital farming is a part of Horizon 2020 Program for investments in farm and food digitization in their broader policy context. This part of the Horizon 2020 is connected with the field of digitizing European industries and building a European data economy. These initiatives bring opportunities for agriculture, food value chains and society at large. Finally, it connected digital policy with the investment opportunities under the Horizon 2020 Work program 2018-2020.

Data is the key ingredient for the European farming sector to become more productive and sustainable and remain competitive in a global environment. Looking at the food production chain as a whole, data is a key tool to demonstrate compliance with legal obligations and risen societal expectations as regards food safety and production methods. With enhanced transparency and traceability, it will be possible to produce more and better food for a growing population while reducing the environmental footprint.

Huge amounts of data are already available. However, going beyond the mere presence and availability of data, Digital Farming means to create considerable added value from such data:

- **Data as a technology enabler:** Digital Farming makes other Precision Farming tools work better. For instance, Variable Rate Technology (VRT) based on soil sampling was initially limited to a handful of soil samples, but was improved with the yield monitoring input. The next step is to improve the variable rate maps with algorithms based on data from multiple fields, and taking into account parameters not directly related to the field itself, like seed characteristics and environmental conditions.
- **Improved production processes:** For the end customer, connected production processes, together with the (partially) automated collection and targeted analysis of data, permits an entirely new level of transparency and evaluation of the current operating situation, providing new opportunities for operational control.
- **Decision support:** For data processing, and in particular data analysis, expert systems are available to the end customer, which would be difficult or impossible for individual farms to attain by in-house data processing. In other words, farmers can now leverage a hitherto unknown level of knowledge from external partners.
- **Data exchange/benchmarking:** Networking with external partners, and in particular the automated integration of information and data, leads to a considerably broader knowledge base and hence to well founded, fast decision-making. Value (algorithms) is created based on data captured in other areas of the production chain.
- **Farm operations, inputs and outputs are optimized:** seeds are optimized for the field and an environmental condition, equipment is optimized for the job. Data is used to enhance the performance of these input products with additional services.

Digital Farming already is a reality in some areas: for instance, GPS guidance systems for controlled traffic farming, site-specific fertilization or plant protection measures as part of a complete production/input cycle using proprietary cloud-based connectivity. This being said, automated data processing and completely integrated, harmonized networks still present a not-so-distant future for agriculture and agricultural machinery. Dedicated efforts by all concerned actors are needed to realize this future vision.

Potential benefits of the use of digital technologies may include improved crop yields and animal performance, optimization of process inputs and labor reduction, all of which increase profitability.

Digitization can also improve working conditions for farmers and reduce the environmental impacts of agriculture. Another gain relates to agricultural data flows. Improving information flows up and downstream in agri-food chains could result in a wide range of benefits for those involved, including farmers and stakeholders in distribution and retail. Also consumers, researchers, government and NGOs see benefits from improvements in transparency.

There are still clear gaps between the applications created by business developers and the real needs of farmers. To develop user-friendly technologies, researchers and business developers should work together and co-create appropriate solutions with farmers, cooperatives, ICT experts etc.

New technologies such as the internet of things (IoT), artificial intelligence, robotics and big data have the potential to lead to unprecedented innovations in agriculture. Also, the appearance and adoption of technologies can boost the creation of new business models based on data produced by different technologies. To ensure that the farming sector can take full advantage of these technologies, it will be crucial to build an innovation ecosystem through which start-ups, entrepreneurs and SMEs can develop technology applications which are adapted to real needs. Balancing all of these groups' different needs may be challenging, but it is necessary for new business models to work.

Digital technologies can support farmers in providing safe, sustainable and quality food. Not only do they help farmers "produce more with less", but they can also contribute to fighting climate change. Existing and new technologies such as the internet of things (IoT), artificial intelligence, robotics and big data can contribute to making processes more efficient and can lead to the creation of new products and services (eip-agri_brochure_digital_ revolution_2017_en_web. pdf).

The European Commission (EC) aims to make the agricultural sector and rural areas in Europe digitised and data-empowered. Under the Digital Single Market strategy, the Communication "Digitising European Industry" sets out its objective to ensure that "any industry in Europe, big or small, wherever situated and in any sector can fully benefit from digital innovations to upgrade its products, improve its processes and adapt its business models to the digital change" (https://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/ ?uri=CELEX:52016DC0180&from=EN). In the Communication "Building a European Data Economy" the EC explores how data can potentially bring many opportunities for European industry, including the agri-food sector (https://eurlex.europa.eu/legalcontent/ EN/TXT/PDF/?uri=CELEX:52017DC0009&qid=1502273159265&from=EN).

The concepts of precision agriculture (PA) and sustainability are the fundamental part of DF. From the first time a global positioning system was used on agricultural equipment the potential for environmental benefits has been discussed. Intuitively, applying fertilizers and pesticides only where and when they are needed, should reduce environmental loading.

According to Hatfield (2000), a farming system is comprised of many elements, but the variations that exist within a field can be summarized in three classes of variation: (1) natural, such as soil and topography; (2) random, such as rainfall; and (3) managed, the fertilizer or seed application. The interaction among these three sources of variation results in offsite impacts.

Kachanoski & Fairchild (1996) illustrated the spatial scaling problem and the value of taking into account the spatial variability of fields. Their results suggested that since the relationships among yield response, soil test, and applied fertilizer are non-linear, a single soil test calibration cannot exist for fields with different spatial variability. Another challenge is to show that PA can have a positive impact on the environment. Unfortunately, only few studies deal with this objective directly, most of them arrive to that conclusion as a by-product of other studies (Hatfield, 2000). Such studies can be categorized as (1) nutrient management, (2) pest management, and (3) soil and water quality.

Leiva *et al.* (1997) illustrated a methodology to assess the use of precision agriculture (PA) technologies in the framework of sustainable agriculture, in two English farms of 150 and 800 ha. They measured N fertilizer applied and estimated leaching with a simulation model. Energy input, energy ratio, air pollution, nitrate leaching, and soil nitrate concentration were calculated using measurements from the farm and data from the literature. They also calculated farming profitability and they conducted a cost–benefit analysis. They concluded that savings of inputs from VRT, such as fertilizers and pesticides, may help to achieve environmentally benign practices, mainly in terms of decreased risk of air and water pollution and decreased energy use, and thereby sustainability. They state that a full PA system would involve significant extra capital costs but there are opportunities for economies of scale at or beyond 400 ha.

Most pesticides applied in agriculture are for weed control (Hatfield, 2000). The environmental problems facing agriculture from pesticide use have to do mainly with groundwater and surface water quality.

Mortensen (1999) indicated that weeds are spatially variable across fields because of organic matter, soil texture, landscape position, and the interaction of these factors with crop management and crop cultivars. PA provides an enabling set of technologies to help reduce potential environmental problems from pest management. These technologies spatial and temporal field maps of weed distribution, VRT to apply herbicide on areas of weed infestation, and yield maps as a diagnosis tool for weed effects on crop yields.

Insects and diseases can be treated similarly to weeds using the same principles (Hatfield, 2000). Pesticide management models need to balance the private benefits of lower herbicide costs and the social benefits of reduced herbicide usage with the costs of implementing VRT before PA can become part of preferred pest management strategies.

Larson & Pierce (1991) defined soil quality as ‘‘the capacity of a soil to function in a productive and sustained manner, while maintaining or improving the resource base, environment, and plant, animal, and human health.’’ The capability of a soil to function within ecosystem boundaries and interact with the environment, external to that system forms the basis for determining the potential impact of soil management systems on the environment (Larson & Pierce, 1991). PA has a great potential for environmental protection, not only for soil nutrients and pesticides, but also to control soil erosion and soil compaction. Soil compaction and the resulting impeded water drainage appear to be more common than previously thought. The discovery and quantification of these causes of variability suggest many new applications of PA and the need to develop new methods for assessing soil quality, so that remedial actions can be taken in an analytical way (Hatfield, 2000).

If the inevitability of some external farm inputs is acknowledged, PA can help in managing those inputs in an environmentally friendly way. By using site-specific knowledge, PA can target rates of fertilizer, seed and chemicals for soil and other conditions. One example is that spatial management of N can reduce overall N application, and reduce N on sensitive areas, while maintaining profitability. Another example is that spatial management of insecticides and herbicides can reduce overall applications of those chemicals by applying them only where the problem exists. PA can be part of an environmentally benign economically viable system. If the need for external inputs is accepted, information is also needed for proper spatial allocation of the external inputs. Most of the papers reviewed indicate that PA can contribute in many ways to long-term sustainability of production agriculture, confirming the intuitive idea that PA should reduce environmental loading by applying fertilizers and pesticides only where they are needed, when they are needed. PA benefits to the environment come from more targeted use of inputs that reduce losses from excess applications and from reduction of losses due to nutrient imbalances (K deficiency reducing N efficiency, for example), weed escapes, insect damage, etc. Other benefits include a reduction in pesticide resistance development.

Connection with the National and European research

In subsequent years, global agriculture will face a number of serious challenges: rapid growth of world population, climate change, increasing demand for energy, resource shortages, rapid urbanization, population aging in rural areas, competition in world markets lack of access to credit. At the same time, agriculture in Europe, Bulgaria and other countries is at a crossroads.

Accelerating the introduction of digitization of agricultural practices, especially amongst medium and small farms, will allow the production of plant and animal products with ever greater efficiency and less environmental impact. Practice shows that the introduction of new technologies will be difficult for small and medium-sized farms wishing to benefit from digitization.

Expensive machines, lack of infrastructure and lack of knowledge are only a small part of the challenges that the agricultural sector should overcome today.

The project is in line with the priorities set out in the National Strategy for the Development of Research by 2020. The Strategy for the Development of Science is developed with the presumption that research, technological development and innovation are driving the knowledge based economy. It is consistent with the goals and measures for its realization, aimed at introducing digitization in farm management, which in turn will affect Bulgarian industry, including agriculture, by strengthening scientific capacity; joint financial instruments in support of science and innovation and building competence centers in areas of priority for the economy. The National Strategy for Research in the Republic of Bulgaria reflects the Government's policy as part of its responsibilities in terms of the country's strategic development. The strategy should support the development of Bulgarian science as a factor in the development of a knowledge based economy and innovation activities. Assisted research is part of the first priority "Raising Income of Bulgarian Citizens, Growth and Modernization of the Bulgarian Economy" by the Government Program for European Development of Bulgaria.

The transfer of knowledge to farmers, the development and implementation of innovative ideas and new management approaches are crucial to increasing the competitiveness and sustainability of businesses, which also provides higher incomes. This is crucial for more resource-efficient and sustainable growth in agricultural production, which would allow for a greater contribution by Bulgaria to achieving the Europe 2020 priority objectives of smart, sustainable and inclusive growth in the agrarian sphere.

The topic of study corresponds with the strategic objective of the Innovation Strategy of Bulgaria - "Increasing the competitiveness of the economy by providing a stimulating environment for innovation and research created by the human resource with more specialized and better knowledge in ubiquitous use of information and communication technologies ". Implementation of excellence and innovation in practice more than ever is a major competitive advantage in the global economic space.

The theme corresponds to the financing of innovative projects "Horizon 2020" - "Food security, sustainable agriculture and forestry, marine and inland research and the bio-economy" since the establishment of competitive farms is a prerequisite for sustainable agriculture and rural development. The majority of farms are run by people who do not have adequate agricultural education and sufficient knowledge in the field of agriculture and agrarian economy and in most need of training, advice and information for sustainable agricultural development in a competitive environment. The opportunities to develop the issues of digitization on agricultural holdings and the models for its application is a timely bridge between fundamental research and farming practice to increase the knowledge and skills of farm managers. They will help managers and owners of farms to make informed and informed decisions in line with national, European and global developments and good practices. This will provide a potential opportunity for continued research beyond the project, including participation in Horizon 2020.

The research theme is fully in line with the objectives of the Common Agricultural Policy of the European Union - to support European farmers in a strong competitive environment around the world, to promote rural development. In line with EU policy objectives, the Rural Development Program (RDP) (2014-2020) has three objectives, with the proposed theme of research being closely related to one of them - "Enhancing Competitiveness and Balanced Development agriculture and forestry economy and manufacturing ". Within this objective, a number of measures are addressed in the RDP, addressing the achievement of one of the priorities:

Improving the viability of farms and the competitiveness of agriculture in all regions; promoting innovative agricultural technologies and sustainable forest management. The interventions aim at increasing the viability and competitiveness of farms through structural adjustment, increasing productivity and efficiency of production to improve economic performance, facilitating the restructuring and modernization of farms, especially with a view to increasing their market share in conditions of increased competition.

The information necessary for scientific evaluation of the project proposal according to the criteria and sub-criteria included in the Form for scientific evaluation of the project proposal (published as part of the Guidelines for Applicants for the competition) should be provided in the sections of the scientific description of the project.

METHODOLOGICAL APPROACH

In connection with the developed guide for attracting key stakeholders at each relevant level of analysis for the purposes of the Theoretical Models for Digital Agriculture (DIAGRO) project, the present study is based on a questionnaire survey among the Municipalities of the Republic of Bulgaria.

Description and structure of the sample

For the purpose of the study, a team of scientists at the Institute of Agricultural Economics developed a survey in several parts. In the first part of the survey, the questions are focused on the description of the municipality itself (name, number of inhabitants, location), the second part is related to the existence of a strategy for the introduction of digital services and the availability of infrastructure. The third part of the survey contains questions about the financial capacities of municipalities for the introduction and use of digital services, as well as the needs of such services and what they are most used for. After approval of the questionnaire by the team leader, it was sent by official letter to the chairman of the National Association of Municipalities in the Republic of Bulgaria. In July 2019 the National Association of Municipalities of the Republic of Bulgaria publishes the poll in its electronic bulletin.

Overview of municipalities

Municipalities are the main administrative-territorial unit in the modern administrative-territorial division of Bulgaria, in which local self-government is exercised.

Bulgaria is divided into 6 planning regions (NUTS level 2 according to the European classification), 28 administrative districts / regions (NUTS level 3) and 264 municipalities (LAU level 1). Based on the OECD definition of a rural area, there are 20 predominantly rural areas (NUTS 3 level) in Bulgaria, 7 intermediate regions and only one predominantly urban area - the capital Sofia.

In 2012, predominantly rural areas, defined by the European typology of 'urban-rural' at district level (NUTS 3), occupy 54% of the territory of Bulgaria and 37% of the population.

According to the national definition, rural areas are defined at the municipality level (LAU 2) and include the territory of 231 municipalities in which the largest settlement has a population of up to 30,000 people. Rural areas occupy 81% of the territory and 39% of the population of Bulgaria.

In the rural areas of Bulgaria there is a dense network of small towns (1,382) providing basic services to the population, of which 90 are of greater functional importance for organizing the territory as they provide a greater scope of services and / or serve the population of more than one municipality.

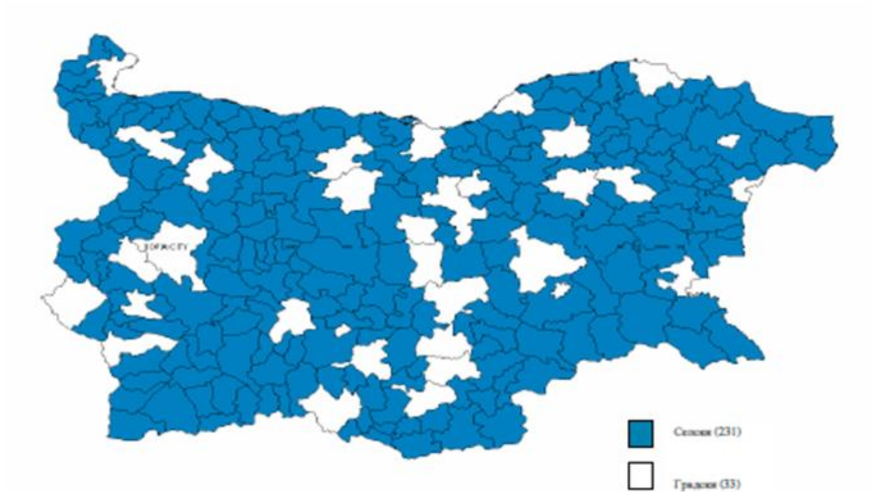

Figure 1. Rural areas at LAU level 1 in Bulgaria according to the national definition
Source: Rural Development Programme 2014-2020

Municipalities with populations below 6,000

The following map shows the municipalities that in 2017 do not meet the first requirement of Art. 8 of the Law on the Administrative-Territorial Organization of the Republic of Bulgaria (ZATURB) for the creation of a new municipality - the presence of a population of more than 6 thousand people.

According to NSI data, between 2000 and 2017, their number has doubled, with one quarter of all municipalities (72 in total) failing to meet this requirement of the law in the last year.

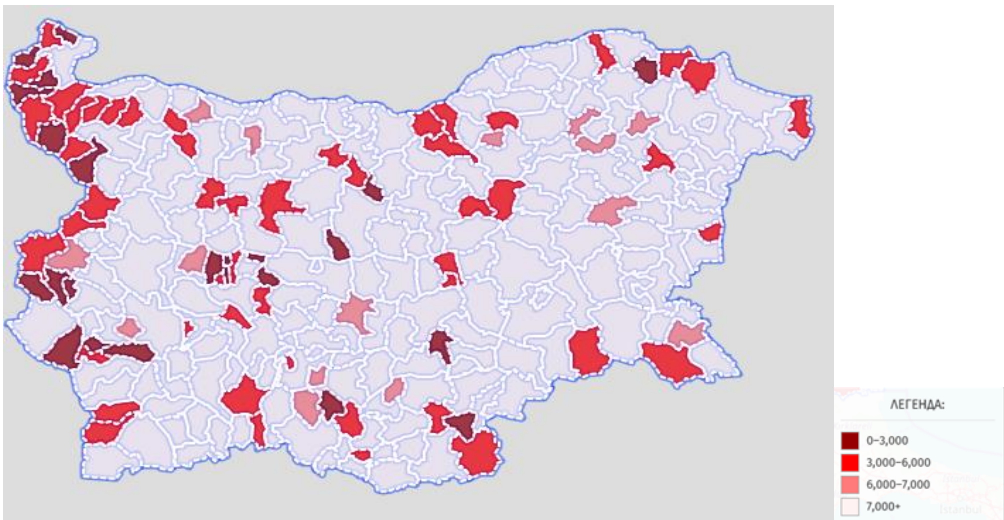

Figure 2. Municipalities with a population of less than 7,000
Source: NSI data 2017, analysis of the Institute of Market Economics

Most of them are located in the border regions, with a particularly clear concentration observed in northwestern Bulgaria. In addition, there are 15 municipalities in which the population is over 6 thousand but less than 7 thousand. The population in most of these municipalities tends to decline, although there are some exceptions such as Gorna Malina.

According to NSI data, the share of rural households with broadband internet access has increased from 30.9% in 2013 to 58% in 2018. It is clear that there has been a big jump in the availability of rural internet supply in recent years (1.88 times). Standard broadband is available to almost all rural households (99%), but in sparsely populated rural areas, only 60% of households have access to a fixed broadband network, compared to 90% on average in the country. Only 10% of rural households have access to next-generation networks. Broadband penetration in rural areas has increased significantly in recent years, but remains low - only 37% of households in predominantly rural areas have an Internet subscription. The use of the Internet and digital services by businesses and households for e-commerce, internet banking, information and training is far from potential.

Analysis of the introduction of digital services in municipalities

Research methodology

The purpose of the study is to analyze, on the basis of analysis, the level of use and implementation of digital services in the municipalities and to evaluate the readiness of the municipal administration to prepare and implement a strategy for the effective use of digital public services. The main methodological approach of the research is the questionnaire method. The results of a sample survey conducted with the assistance of the National Association of Municipalities in Bulgaria were used. The results of a sample survey conducted between July and November 2019 were used. The survey conducted included the municipalities of Belogradchik, Zavet, Koprivshtitsa, Ruzhintsi, Rudozem, Hissarya. The number of inhabitants in the studied municipalities varies from 2046 to 14 337. The municipalities that responded to the survey are a sample of all six planning regions (NUTS level 3). All the municipalities surveyed stated that they did not have a digital introduction strategy, but envisaged that such a strategy should be drawn up within 1 to 3 years (Figure 3).

Figure 3. Share (%) of municipalities with a strategy for using digital services
Source: Questionnaire for the implementation of the Diagro 2019 project

Regarding the existence of infrastructure for the introduction and use of digital services on the territory of the municipality, 80% of the surveyed municipalities indicated that they cannot assess, are not aware and do not know that such infrastructure is in place. They have indicated that they are experiencing difficulties in implementing digital services due to a lack of "human capital" and financial resources. The remaining 20% indicated that there was an infrastructure in place for the introduction of digital services (Figure 4), mainly the so-called. EGovernment and are used for administrative services to the public and business.

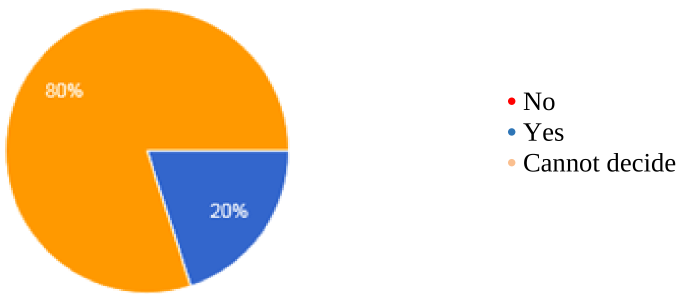

Figure 4. Share (%) of municipalities with infrastructure for digital services deployment
Source: Questionnaire for the implementation of the Diagro 2019 project

Most of the municipalities use digital services for administrative services and only 20% for sales and marketing management (Figure 8). The digital, electronic programs most widely used by the municipal administration are: Cadastral and Administrative Information System (KASIS); Integrated Administration and Control System (IACS); EVENTIS R7 - Business Program and REGIX - Register of Animals and Livestock.

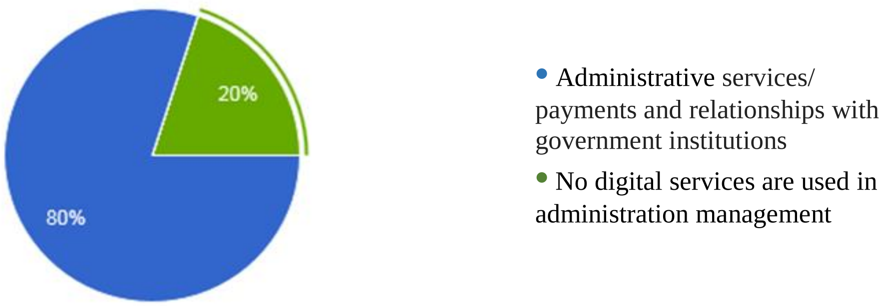

Figure 5. Share (%) of digital services used
Source: Questionnaire for the implementation of the Diagro 2019 project

Reasons for not using digital services in administration are the same share (33.3%) between lack of information about the applicability of digital services, lack of opportunities for implementation and use of these services and lack of knowledge on how to use these services (Figure 6).

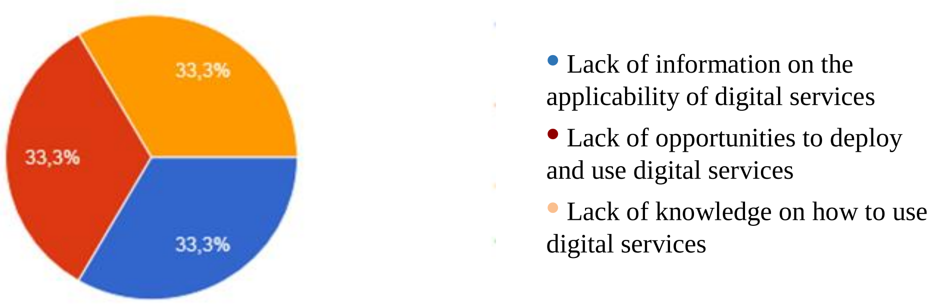

Figure 6. Share (%) of reasons for not using digital services
Source: Questionnaire for the implementation of the Diagro 2019 project

Regarding whether there is a budget planned in advance for the introduction of digital services, all the municipalities surveyed (100%) indicated that there is no such budget. On what budget the municipal endowment would be used to introduce the vast majority of respondents (80%) said that they did not plan to introduce digital services and therefore did not need a separate budget for this. A small number have indicated that they would plan part of their budget for the introduction of digital services, but could not afford the large scale.

Similar is the ratio with regard to the use of specialized software and / or hardware, and if not, is there any need for its introduction. 66.7% of the respondents indicated that they use it for administrative purposes and 33.3% do not use it at all. Of these, with an equal proportion of shares (25%), they indicated the reason for not using such a software product, namely; it is still too early to introduce such a product; lack of financial resources for its implementation; lack of information on access to such a product and plans for its introduction in the near future.

Based on the research and analysis, the following conclusions are summarized:

- Bulgaria ranks 28th out of the 28 Member States in the 2019 European Commission Index on Digital Entry into the Economy and Society (DESI).
- Bulgaria is well below average in implementing digital technologies.
- Lack of interest on the part of municipalities
- Most municipalities do not have the “human capital” to implement digital services.
- There is a lack of knowledge about the opportunities offered by digital services for sustainable rural development.
- Ineffective use of EU funds for the introduction of digital services due to low awareness and lack of administrative capacity in municipalities

EXPECTED RESULTS

The focus of the study in the project and the expected results are the acquisition of new knowledge and skills, the introduction of digitization for the sustainable development of holdings in one important and strategic sector of the Bulgarian economy - agriculture: Digital farming is a modern concept of farm management, using digital techniques to monitor and optimize agricultural production processes. With the introduction of digital technology, the aim is to increase the quantity and quality of agricultural production by using fewer resources (water, energy, fertilizers, pesticides, etc.). The goal is to save costs, reduce the impact on the environment and produce more and better food. The introduction of digital technologies will have a significant impact on improving the competitiveness of farms, to large extent small and medium sized farms.

On the basis of a study and analysis of the existing theoretical provisions, scientific summaries will be made on the nature and content of the "digital farming as a model for the development of agricultural holdings". At this stage in Bulgaria there are no theoretical models for assessing the impact of introducing digital farming on farms, making them specific to the sphere in which the study was conducted and not applicable in a large number of other cases. A novelty in the theory will be the development of methodological tools to assess the impact of introducing digital farming on farms that will enrich the theory. A system of criteria, a proposed system of adequate indicators for its impact, and an integrated indicator - a digitization index that provides for comparisons on the types of farms on a national and international scale as well as on the dynamics will be justified. Appropriate statistical and economic methods will be justified for a more accurate reading of the weight of individual indicators in the final assessment of the impact of introducing digitization in agriculture.

The evocation of the key factors of lasting importance that affect the competitiveness of the agricultural farms in Bulgaria will deepen the theoretical research.

The continuation of the fundamental research is the theoretical development of the following models for introducing innovative solutions to increase the competitiveness of farms is what will enrich the theory. A system of criteria, a proposed system of adequate indicators for its impact, and an integrated indicator - a digitization index that provides for comparisons on the types of farms on a national and international scale as well as on the dynamics - will be justified.

Appropriate statistical and economic methods will be justified for a more accurate reading of the weight of individual indicators in the final assessment of the impact of introducing digitization in agriculture.

The implementation of the results achieved in practice will lead to solving a number of socioeconomic issues and significant economic results in agriculture and rural areas:

- provide a new framework for analyzing and assessing the impact of introducing the digitization of farms of different types, the different sectors of agriculture and regions of the country;
- provide new tools to support the design of the farm strategy, organizational modernization and collective action, as well as to improve public policy and forms of public intervention in the agrarian sphere;
- allow a more realistic forecast of the likely prospects for development of farm structures by types, sectors of agriculture and regions of the country in the specific conditions of EU membership;
- help to build viable and more efficient farms, leading to sustainable rural development and raising farmers' incomes.

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