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OPPORTUNITIES FOR APPLYING DIGITAL TECHNOLOGIES IN THE AGRICULTURAL SECTOR

ABSTRACT

Of a Dissertation Work for the Award of "Doctor" Academic and Scientific Degree under a Doctoral Programme "Economics and Management" (Agricultural Economics) "

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SVISHTOV
2023

The dissertation work was discussed and proposed for defence under the provisions of the Law on the Development of Academic Staff in the Republic of Bulgaria by the Department of Agricultural Economics at "Dimitar A. Tsenov" Academy of Economics – Svishtov.

The dissertation consists of 185 pages, including 13 pages of appendices. Structurally, it is composed of an introduction, an exposition in three chapters and a conclusion. 111 literature sources are used, of which 85 are in Bulgarian and 26 are in English. There are 22 figures and 31 tables in support of the exposition.

I. GENERAL CHARACTERISTICS OF THE DISSERTATION

1. Relevance and Significance of Research

In the era of digital transformation, digital technologies are entering every human activity, including the agricultural sector. The ongoing digital revolution is dynamising economic entities that are challenged to implement innovative tools in their businesses.

The relevance of this dissertation arises from the opportunities for the penetration and application of digital technologies in the agricultural sector. In this regard, attention is focused on the presentation of theoretical frameworks and formulations related to the digitalization of agriculture, trends in the practical application of digital technologies and research related to innovation and digitalization in agriculture. Examples from practice based on digital technologies in the agricultural sector are presented, based on which the benefits of their implementation are outlined.

2. Object and Subject of Research

The **object** of research is digital technologies. They are expected to contribute to increasing the efficiency of processes and bring about the creation of new products and services in the economy, respectively in agriculture. From this point of view, the **subject of the study** are the possibilities of applying digital technologies in the agricultural sector.

3. Research thesis

The dissertation defends the thesis that it is necessary to use digital technologies to develop sustainable solutions for current and future challenges, including in the agricultural sector.

4. Objective and Tasks of Dissertation

This paper **aims** to trace and analyse the application of digital technologies in the agricultural sector. This objective is specified in the following research **tasks**:

First, to reveal the nature and distinctive characteristic of digitalization in the economy, respectively in the agricultural sector - a foundation for deriving basic concepts.

Second, to develop the methodological foundations of digital technologies and propose a model for partial approbation in the agricultural sector.

Third, to analyze the state of the art of digital technologies applied in the agricultural sector.

Fourth, to formulate recommendations for the penetration of digital technologies in the agricultural sector.

5. Research Methodology

The research methodology, the analysis and the evaluation of the set scientific tasks are specified and adapted to the specific features in terms of digital technologies. It reflects the author's searches and researches during the development of the dissertation in the study of the problems in the field of digital technologies in the agricultural sector. Among the scientific research methods used are: method of comparative analysis, method of induction and deduction, content analysis, retrospective analysis and others.

For the convincing and proving power of the analysis in the dissertation various methods of illustration are used - schemes, tables, graphs, figures, numerical examples.

The dissertation work is based on an analytical study of Bulgarian and foreign scientific literature and, as a priority, on extensive consultations with scholars and specialists in the field of the agricultural sector in search of evidence for the possibilities of applying digital technologies in the agricultural sector.

6. Research Limiting Conditions

In the dissertation the terms digitalized technologies and digital technologies are used as synonyms.

For the purpose of this thesis, the research period is 2014-2020 mainly for two reasons:

First, it creates conditions for basing the research on up-to-date public data, allowing for author's interpretation;

Secondly, it provides the opportunity to trace the state of digitalisation of the agricultural sector after the measures implemented in the 7-year programming period (2014-2020).

The analysis focuses on exploring the opportunities for the application of digital technologies in the agricultural sector, which are tracked by the Digital Economy and Society Index (DESI), introduced in 2015 to measure the penetration of digital technologies in the economy and society. The constant updating of the index, namely the inclusion, exclusion, aggregation of groups of sub-indicators that form it during the period under review, have made the analysis difficult and limited in terms of comparability of data across years.

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II. BRIEF PRESENTATION OF THE DISSERTATION THESIS EXPOSITION

CHAPTER ONE

THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF DIGITAL TECHNOLOGIES

Chapter One is theoretical and foundational in nature and aims to lay the foundation for the dissertation research. It provides an overview of the possibilities for the entry, respectively application, of digital technologies in the agricultural sector. Theoretical positions and formulations related to the digitalization of agriculture are examined. Basic concepts such as digital technologies in agriculture, digitalization, precision agriculture, etc. are outlined. Trends in the penetration of digital technologies and research related to innovation and digitalisation in agriculture are reflected. In order to systematize the possibilities for the application of digital technologies in farms, a brief overview of practices for their penetration in the agricultural sector is made.

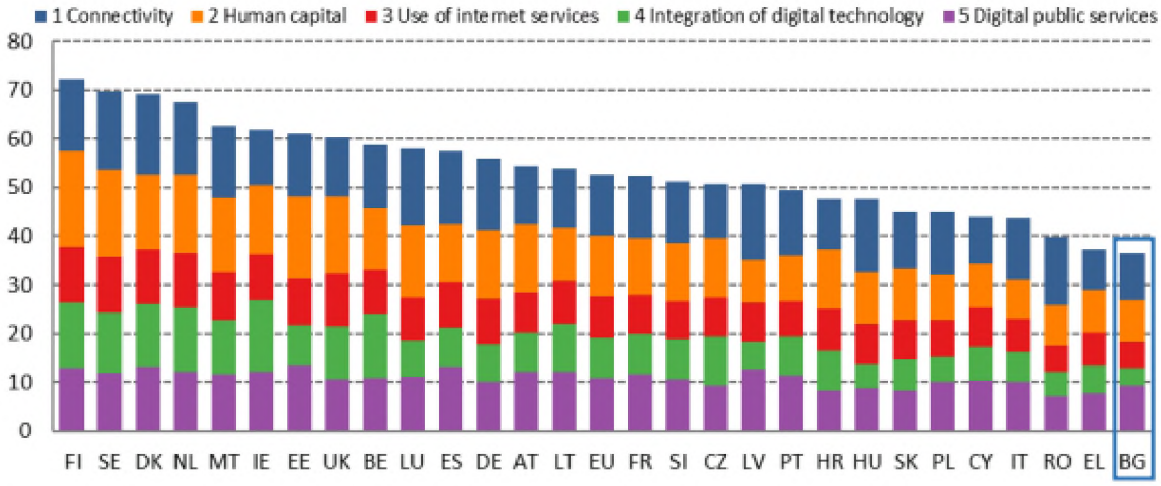
1.1. Digital technologies in the economy - the role of the state

Our modern times are characterised by an increasing penetration of digital technologies in all activities of society. The efforts of various economic actors in the state, in the public and in the private sector are directed towards an ever wider implementation of digital technologies.

A number of laws and regulations have been adopted at the national level concerning the widespread use of information and communication

technologies, which are in line with the European legal and political framework.

Bulgaria ranks 28th out of the 28 EU Member States in the 2020 Digital Economy and Society Index (DESI) (Figure 1).



Source: European Commission

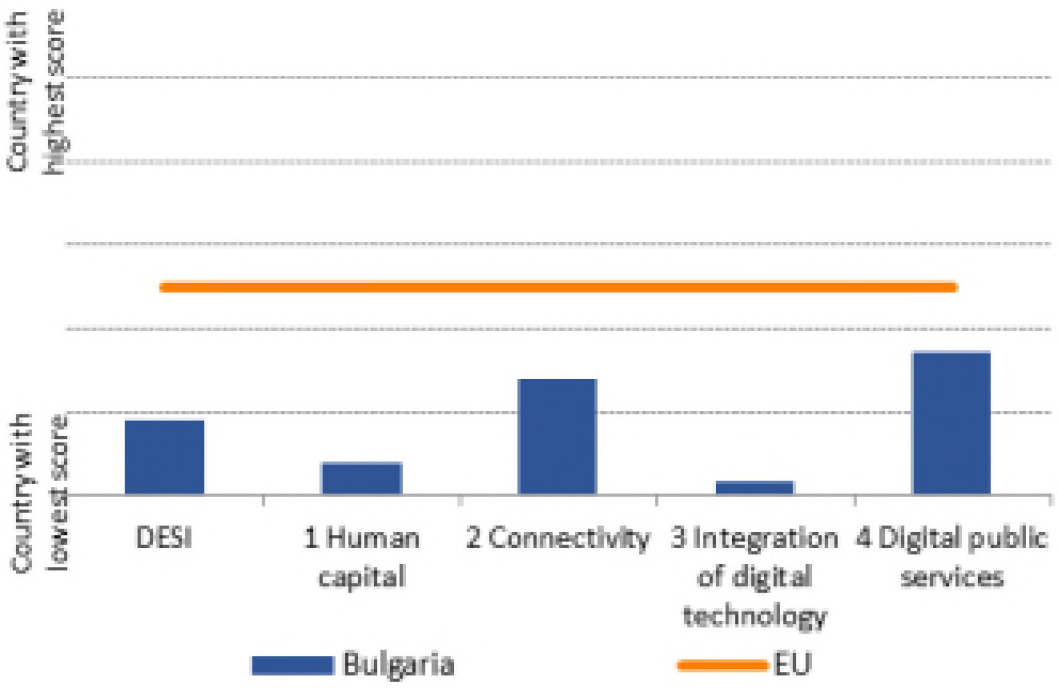
Figure 1. European ranking of Member States to measure the digital penetration index in the economy and society (DESI) for year 2020

By 2022. Bulgaria occupies the 26th (penultimate) place compared to the member states in the European ranking. This is an indication of the uptake of digital technologies, albeit at a slower pace compared to other EU member states.

For the penetration of digital technologies in the economy, the state has a decisive role to play in creating the necessary preconditions for their successful implementation.

According to the results measured by 2023, Bulgaria's lower achievements in the adoption of digital technologies (graphically presented

in Figure 2) are the result of the indicators of *human capital* and *readiness for the implementation of digital technologies* in business.



Source: European Commission

Figure 2. Graphical representation of Bulgaria's achievements on the introduction of the Digital Penetration Index in the economy and society (DESI), 2022

In the strategic document of national importance "Digital Transformation of Bulgaria for the period 2020-2030", adopted by Resolution No. 493 of the Council of Ministers on 21 July 2020, the subsequent steps regarding the development and penetration of digital technologies in public life are outlined.

The foregoing outlines the role of the state in providing the necessary preconditions for the implementation of the penetration of digital technologies in the economy and society (respectively in the agricultural sector), in line with the

objectives set for implementation at European level. The implementation of these measures necessitates the derivation of the theoretical basis for their understanding, characterization, interpretation in the multiplicity of literature sources.

1.2. Theoretical foundations of digital technologies

Digital transformation and its impacts have long been the subject of in-depth research.

"The verb "digitalize" was first used in 1953. Today, "digitization" means the transformation of analogue information in any form (text, photographs, voice, etc.) into digital form using electronic devices (scanners, cameras, etc.) so that information can be processed, stored and transmitted through digital circuits, equipment and networks.

Hence, in modern language the word "digital" is associated with the possibility of representing information by two digits, 0 and 1, to perform basic information activities - collecting, storing, processing and disseminating information using computer systems.

This gives a reason to define digitalization as a process of transforming information into digital format.

On the other hand, digitisation is associated with the integration of digital technologies into everyday life through the digitisation of everything that can be digitised.

In this study, digitalization is considered in this aspect.

For the purposes of this dissertation research we adopt a generalized formulation of digital technologies in the economy (or agricultural sector) - a set of hardware and software tools for creating digital information,

converting different types of information from analog to digital (digitalized) form, processing, storage and distribution of digital information.

In the literature, including the Bulgarian scientific literature, a number of formulations of the term digital technology are found, using as a synonym the term digitalized technology.

Based on the interpretation of the diversity of definitions in the field of digital technologies, the following examples of digital technologies can be derived, including in the agricultural sector:

1. Website
2. Online Buying and Selling
3. Smartphones
4. Blockchain Technology
5. Cryptocurrency
6. Artificial Intelligence (AI)
7. Cloud Computing
8. 5G Data
9. Voice Interfaces or Chat-bots
10. Video Streaming
11. eBooks
12. Digital Music
13. Geo-location
14. Blogs
15. Social Media
16. Gadgets
17. 3D Printing
18. Self-Scan Equipment
19. ATM Machines
20. Digital Cameras

21. Cars and Other Vehicles

22. Digital Clocks

23. Robotics

24. Drones and Missiles

25. Banking and Finances.

The said technologies are used in various sectors of the economy and public life. These technologies are constantly evolving and improving. Among the above-mentioned technologies, the most frequently used are the technologies for big data, the Internet of Things, databases, information systems with applications in various fields, digital technologies for production automation and others. Some of these are discussed later in the text.

1.3. Principle models for introducing digital technologies in the agricultural sector

Modern technologies are penetrating into all spheres of the economy, and this trend, although sometimes at different rates, inevitably affects the agricultural sector.

Digital technologies applied in the agricultural sector are seen as a model for improving working conditions, improving productivity and reducing manual labour.

A number of researchers and practitioners are focusing their efforts on creating theoretical and, at a later stage, functional models for the digitalization of agriculture. In this aspect, different sectors and activities for management, production and marketing in agriculture are covered.

The possibilities of applying intelligent, precision or digital solutions for agriculture are being discussed worldwide and the potential areas of

application of techniques such as fuzzy (multivariate) logic, machine learning and evolutionary computation are being explored.

In the search for solutions to overcome the barriers to the implementation of digital technologies in Bulgaria, attention is drawn to foreign experience in the application of digital technologies in the agricultural sector.

Technological means supporting agribusiness are constantly improving. Different technological solutions are appearing on the market, which depend to a large extent on the human factor and on the extent to which agricultural producers are willing to apply digital technologies or precision farming. This problem is topical for Bulgarian agriculture and calls for the study of farmers' readiness to implement innovative digital solutions.

In our country, there are no in-depth analyses of the state and development of digitalization in agriculture and rural areas of Bulgaria, despite their great theoretical and practical importance.

We agree with the widely held opinion that digital technologies will transform the agricultural sector in a global aspect. In this regard, they must be understandable and accessible to farmers as a matter of priority. We also take into account the fact that there are a number of problems to overcome in terms of policies, infrastructure and human resources.

At the national level it is necessary to strengthen the role of the state, respectively the agricultural knowledge and innovation networks (advisory services and national and regional networks in rural areas) supporting the development and use of digital technologies at farm level.

* * *

Digital transformation is "a process characterized by the widespread introduction and combination of digital technologies in all spheres of social and economic life."

Uniting the efforts of researchers and all stakeholders is a prerequisite for strengthening the wider application of digital technologies in the agricultural sector.

CHAPTER TWO
DIGITAL TECHNOLOGIES - A TOOL FOR DIGITAL TRANSFORMATION OF THE AGRICULTURAL SECTOR

Chapter Two of the dissertation sets the conceptual framework for the digital transformation of the economy and the agricultural sector. From this position the role of institutions in this process is systematized. The above is relevant for: studying the documents on digitalization of the economy at the European level; determining the degree of readiness of the state for the introduction of digital technologies in the economy; outlining the prospects for the development of digital support models for decision-making in the economy, in particular in the agricultural sector.

2.1. European policy for the digitalisation of the agricultural sector

Digital technologies have increasingly infiltrated all sectors of the global economy and society, and traditional relationships in the physical world are largely characterized by a digital dimension. The rapid development of innovation in the digital domain creates economic

opportunities for innovation, growth, new jobs and making people's lives easier.

The European Commission is working towards a digital transformation that benefits everyone, as digital solutions:

- open up new opportunities for businesses;
- encourage the development of reliable technologies;
- support the building of an open and democratic society;
- create the conditions for a viable and sustainable economy;
- support the fight against climate change.

At the European level, the priorities in the field of information and communication technologies (ICT) are outlined in the European Union Strategy for smart, sustainable and inclusive growth "Europe 2020" and in particular in:

- A programme in the area of digital technologies in Europe, the so-called Digital Agenda for Europe 2020, adopted in 2010;
- Digital Single Market Strategy, adopted in May 2015.

The importance of digital data also prevails in the implementation of the 2010 Europe 2020 strategy. In this respect, three categories of broadband internet access for all Europeans in terms of download speed are set to be achieved at European level:

- basic - up to 30 megabits per second (Mbps), ranging from 144 Kbps to 30 Mbps and a deadline for implementation by 2013;
- high-speed - above 30 (Mbps), between 30 Mbps and 100 Mbps and a deadline for implementation by 2020; and
- ultra-high speed - over 100 Mbps for at least 50% of Europeans by 2020.

Despite the measures taken under the above priorities, the country's rural areas are lagging significantly behind in terms of superfast broadband

coverage. The Commission's 2025 target of 1 Gbps for all households may therefore not be reached.

However, Member States need to rethink, reinforce and coordinate their national and sectoral policies to guarantee the digital transition and reap its benefits.

We can summarize that technology companies and digital platforms must incorporate ethical standards and a commitment to core social values in all content and communication. It is important that citizens understand the logic behind algorithms and artificial intelligence. Strengthening skills for working in a digital environment requires a systematic, coordinated and common approach at national and European level, as well as cross-sectoral collaboration between different stakeholders. The "new" environment requires a fundamental change in communication, education, regulation and new practices.

2.2. National policy for digital transformation of the agricultural sector

Nationally, the documents related to the introduction of digital technologies in the economy and in particular in the agricultural sector, without claiming to be exhaustive, are:

- National Broadband Development Strategy 2012-2020 - the document is aimed at ensuring fast and ultra-fast internet access for all European citizens;

- e-Government Development Strategy in the Republic of Bulgaria 2014-2020, in fulfillment of the mandatory requirement for the implementation of the e-government policy, defined by standards, interoperability and security of networks and information;

- Updated strategy for the development of e-government in the Republic of Bulgaria 2019-2025 - setting the overall strategic framework at central and local level for achieving digital transformation of the administration and public institutions;

- Updated e-Communications Policy of the Republic of Bulgaria 2015-2018 - prioritizing measures to improve the current regulatory framework and stimulate investment;

- Innovation Strategy for Intelligent Specialisation 2014-2020 - it points out that Bulgaria has the capacity to digitally transform enterprises through Industry 4.0 technologies.;

- Concept for digital transformation of Bulgarian industry (Industry 4.0), which should become the basis for the development of Strategy 4.0.

- National programme "Digital Bulgaria 2025" - providing state support for the creation of digital innovation hubs to be partly financed under the Digital Europe programme. The programme provides opportunities for businesses to access technological expertise and experimental facilities to support the digital transformation of industry and government;

- National Plan for Recovery and Sustainability in the Republic of Bulgaria - it is particularly important for small and medium-sized enterprises, start-ups and public organizations that wish to develop and implement innovations to have easier access to the technologies and research infrastructure of academic institutions;

- National Strategy for Small and Medium Enterprises (SMEs) in Bulgaria for the period 2021-2027 - provides objectives and measures to support industry and SMEs to implement Industry 4.0 products,

technologies, business models and processes. One of its 6 priority areas is "Digitalisation and skills".

- Strategy for digitalization of agriculture and rural areas in the Republic of Bulgaria focusing on: building and developing appropriate digital infrastructure for communication and connectivity; innovation for modernization and technology for precision agriculture; developing digital networks and using software applications in business management and decision making; awareness, training and advisory services for developing digital skills and qualifications, research and innovation, partnership for exchange and transfer of innovations, developing infrastructure for expertise and access to it;

- National Programme "Bulgaria 2030" - it is planned to create a fund for the development of Industry 4.0, as well as to finance project proposals of enterprises that have won the "Seal of Excellence" under Horizon 2020 and Horizon Europe programmes.

Among the presented documents, the most focused on the agricultural sector is the Strategy for Digitalization of Agriculture and Rural Areas in the Republic of Bulgaria. Another important document with concrete relevance is the strategy for digital transformation of the economy.

The main directions for reaching the European average level of penetration of digital technologies in the Bulgarian economy and society, set out in the draft Strategy for Digital Transformation of the Economy, are:

- Improving collaboration between ICT business, industry, science and government;

- Technological renewal of Bulgarian industry;

- building human, scientific, organizational and institutional capacity for the development of Industry 4.0 in Bulgaria;

- promoting the use of artificial intelligence technologies in Bulgarian industry.

Digital technologies must ensure accessibility for all economic actors, including farmers. The national policy is aimed at inclusion and support through training, provision of resources and incentives to bring new solutions to the agricultural sector.

2.3. A model to support the introduction of digital technologies on farms

Digital infrastructure is a foundation and a prerequisite for the digital transformation. It includes communication networks as well as devices, facilities, systems, protocols, data, storage and other means that enable connectivity, information exchange, data sharing, service delivery, application use, process management, etc.

The key common **models** for the realization of the so-called Fourth Industrial Revolution are: "Internet of Things (IoT), simulations, augmented/virtual reality (VR/AR), autonomous robots, cloud computing, 3D printing, horizontal and vertical system integration, Big Data, artificial intelligence (AI) and cognitive systems, machine self-learning, intelligent mobile applications, blockchain technologies, digital platforms, etc. Some of these are characterised by significant transformative potential, and namely:

Internet of Things (IoT) includes all sensors that can collect information in real time and send it for further processing and analysis.

These sensors can monitor, for example, inventory, wear of certain parts, user behaviour and in general anything that can be quantitatively or qualitatively measured.

In the agricultural sector, and more specifically in crop production, the use of IoT devices, machines and systems is being observed. The devices work on different principles and provide information on basic indicators such as moisture, soil composition, climatic conditions, plant health, etc.

Artificial Intelligence and Machine Self-Learning. These are systems that show intelligent behaviour by analysing their environment and taking action to achieve specific goals with a certain degree of autonomy.

AI-based systems can be entirely software-based - operating in the virtual world (e.g. voice assistants, image analysis software, search engines, voice and face recognition systems), or they can be implemented in hardware devices (e.g. advanced robots, autonomous cars, drones or IoT devices). When the accumulated information is very large and at the same time the analysis times are very short, pre-described patterns are used, which the system searches for in the data and automatically takes certain actions if they are found.

In the agricultural sector, for example in viticulture, innovative solutions based on artificial intelligence have been successfully introduced, allowing growers to monitor soil moisture and assess fruit quality and vine development. The innovations are expected to increase productivity and profit while reducing costs.

Blockchain is known as a technology that supports cryptocurrencies, but in reality it is much more than that. The essence of blockchain is storing data and transferring it through special clusters. It provides reliability,

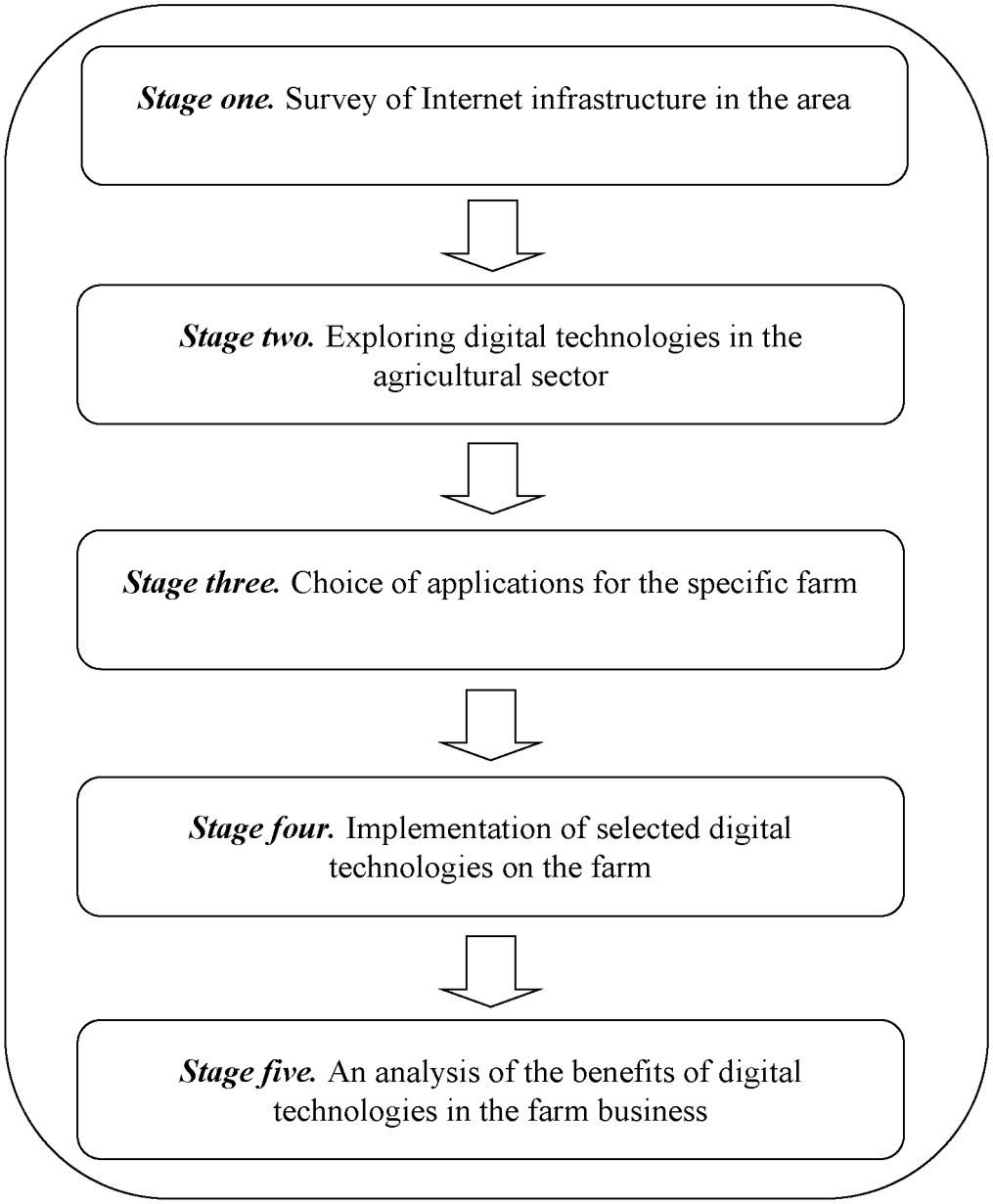
transparency and security in any data exchange - whether it is financial transactions, contractual and legal agreements or changes in ownership.

Blockchain uses a distributed network to keep an immutable record of every exchange, eliminating the need for trusted third-party intermediaries in digital transactions. It could prove to be the foundation of the financial system in the future, enabling much faster transactions.

Blockchain technology is successfully used in product/food supply chains - for example fruit and vegetables. In this way the trust between the participants (producer-buyer/processor-consumer) is increased, including the orientation of groups of consumers willing to pay a higher price with guaranteed origin and quality of the offered food.

To be more convincing on the basis of the researched issues of digital technologies, respectively in the agricultural sector, we would illustrate the model, which is expected to generate economic benefits for farms, graphically through the following stages - Figure 3:

The presented model is of key importance for the study. Its validation is carried out in the subsequent third chapter. For this purpose, as an example of a digital system, successfully applied model in agriculture, is the investigated ONDO Smart Farming system of the Bulgarian precision farming company Ondo Solutions. It manages the irrigation process, climate and other operations on farms. The system has been installed and is successfully working for more than 15 farmers in Bulgaria and North Macedonia.



Source: The figure was developed by the author.

Figure 3. A model to support the adoption of digital technologies on farms

ONDO Smart Farming is composed of compact and flexible hardware, integrated software modules and is extremely user-friendly. It is successfully used to monitor and control plants in all their development phases, at any

time of the day. It not only monitors irrigation and plant nutrition, but also climate - light, humidity, temperature, EC and Ph, CO2, etc.

* * *

The following conclusions can be drawn from the study of digital transformation:

First. In order to deploy the digital transformation at European and national level, a permanent update of the documents on the digitalisation of the economy is necessary.

Second. Coordination of efforts between government institutions at all levels of government, as well as the active involvement of all key stakeholders, including the business community, trade unions, civil society and the technical Internet community in this process, is of crucial importance.

Third. The development of digital support models, decision-making require the acquisition of knowledge, skills and abilities to help create digital operating models applicable in various sectors of the economy, including the agricultural sector. When outlining their perspectives (in terms of their coverage in relation to the different models), we define the available public information as insufficient at the moment to distinguish, prioritize, respectively, the predominance of the expected effects for plant and animal production.

Digital agriculture is the result of the evolution of precision agriculture to connected, knowledge-based agricultural production systems in agriculture. The aim of digital agriculture is to use all available information, knowledge and experience to enable the sustainable management of production processes.

CHAPTER THREE

TESTING THE DIGITALISATION MODEL IN THE AGRICULTURAL SECTOR WITHIN THE PERIOD 2014-2020

Chapter three explores the benefits of the digital technologies implemented and makes recommendations for their application in the agricultural sector. As a member of the European Union, Bulgaria is committed to adhere to the objectives set, including those related to digital technologies. In this sense, the documents produced are in line with the plans set for implementation. For this reason, the research period in this thesis is chosen in two aspects: on the one hand, it corresponds to the seven-year plan, namely the period 2014-2020, and on the other hand, the completion of the period, with a certain conditionality, allows for an analysis based on published official data.

3.1. Study of factors influencing the introduction of digital technologies in the agricultural sector

To study the factors influencing the adoption of digital technologies in the agricultural sector, we stick to the well-established index for the adoption of digital technologies in the economy and society, known as DESI (Digital Economy and Society Index). Developed by the European Commission and officially launched at the Digital4EU Forum in Brussels on 24 February 2015, it is being introduced as a new analytical tool reflecting the current state of each EU Member State and a foundation for the Digital Single Market Strategy. The index is essentially a set of 30 indicators, divided into

five groups: connectivity, human capital, internet usage, digital take-up and digital public services - Table 1.

Table 1. Indicators forming the index of penetration of digital technologies in the economy and society (DESI)

Indicators	Characeristics
1 Connectivity	Fixed broadband connectivity, mobile broadband connectivity and prices
2 Human capital	Using the Internet, basic and specialised digital skills
3 Internat use	Citizens' use of content, messaging and online transactions
4 Digital take-up	Digitalisation of business and e-commerce
5 Digital public services	eGovernment and eHealth

Source: The European Union

Through a weighting system, each Member State is ranked according to its digitalisation achievements. Connectivity and human capital are considered fundamental. These are given 25% of the total score, followed by the uptake of digital technologies at 20% and 15% each for the use of the internet and digital public services. Subsequent selection of sub-contractors has necessitated the reflection of adjustments in the data, manifested in the recalculation for previous periods. The statistical information used is from the "Digital Economy and Society Index (DESI) Report for Bulgaria" - by year, respectively for 2015, 2016, 2017, 2018, 2019, and 2020. When presenting the publicly available data on the index for the penetration of digital technologies in the economy and society - DESI, some differences are found. Official data for 2015 are not available and those for 2016 is in rounded value. In some cases, public information for 2014 is provided. Data for the subgroups forming the Digital Economy and Society Index (DESI) for 2017 have been adjusted to the adjustments that have urgently occurred at the European level.

The permanent updating of the indicator from five groups (listed in Table 15) at its introduction by 2022, respectively by 2023, they are refined and number 4 groups, reduced to:

- Human capital;
- Connectivity;
- Integration of digital services;
- Digital public services.

The aforementioned is in support of the difficulty, which manifests itself in terms of the thoroughness of the analysis and the author's interpretation of relevant, comprehensive, unified information, including for the agrarian sector for the period under consideration.

Bulgaria belongs to the cluster of underperforming countries - Table 2.

Table 2. Information on the Digital Economy and Society Index (DESI) for the period 2015-2020

Indicators	Bulgaria		EU
	ranking	value (%)	value (%)
2020	28	36,4	52,6
2019	28	33,8	49,4
2018	27	33,5	46,5
2017	27	32,4	46,9
2016	27	35,0	49,0

Source: Adapted by the author from Bulgaria's Profile according to the Europe Digital Progress Report (EDPR), 2017, p. 2; Digital Economy and Societal Penetration Index (DESI), Member State Report 2019 Bulgaria, p. 3; and Digital Economy and Societal Penetration Index (DESI), Member State Report 2020 Bulgaria, p. 3.

Note: 2016 figures are rounded.

As of 2022, Bulgaria takes the position and is ranked 26th. In percentage terms, the national figure is 37.7% compared to the European average of 52.3%.

3.2. Partial testing of the model for digitalization of farms

The partial nature of the testing model stems from the fact that it tracks the successful application of a digital ONDO Smart Farming system in agriculture. For this purpose, six farms are studied, one of which shares a foreign implementation experience in the introduction of the digital technology.

The choice of this system is dictated by the fact that Ondo Smart Farming Solutions is a Bulgarian start-up company that offers innovative management solutions by overcoming the problem of insufficient automation of activities in farms. It is the winner in the category "Innovative start-up" in the competition "Innovative enterprise of the year 2020".

In 2021, Ondo is involved in the creation of an education hub to provide farmers with know-how in agronomy, automation and digital crop cultivation.

Ondo's system is working successfully and has been implemented in greenhouses and open agricultural areas in Bulgaria and North Macedonia.

The ONDO case studies, for the purpose of this research, are focused on the application of smart solutions in the agricultural sector. In summary, the particular **results** of their application on specific agricultural farms are:

1. ***"Otbrany" Berry farm (raspberries, strawberries, blueberries, blackberries) – Popovo, Bulgaria.***

- ✓ 30% less water
- ✓ 20% less fertiliser
- ✓ 20%more crop yield
- ✓ 3 times faster response to damage
- ✓ Return on investment: 8 months.

2. *„Roseland“ (roses and vegetables) – village of Konyovo, Nova Zagora, Bulgaria*.

✓ 30% less human resources

✓ 30% less energy

✓ 30% less water

✓ 20% less fertiliser

✓ 20%more crop yield

✓ Return on investment: 10 months

3. Biodynamic farm "Versol" (potatoes, tomatoes, peppers, cabbage, eggplants, cucumbers, spinach, inca berries, alabash and other vegetables and fruits) – village of Lik, Mezdra, Bulgaria.

✓ 30% less losses from human errors

✓ 25% less human resources

✓ 20% less water

✓ 20% less energy

✓ 20% less nutrient

4. ***Greenhouses "Nicole Agro" (tomatoes, lettuce, salad) – Kresna, Blagoevgrad, Bulgaria***.

✓ 35% less human resources

✓ 20% less losses from human errors

✓ 25% less water

✓ 20% less energy

✓ 20% less fertiliser

✓ 100% of the investment is returned

5. ***Greenhouse complex "Angel Metlarov" (peppers, tomatoes, cucumbers, eggplants, strawberries, raspberries) – Svilengrad, Bulgaria.***

✓ 30% less human resources

✓ 30% less water

✓ 20% less fertiliser

✓ 2 times faster response to failures

6. *„MARJAN-MID“ (tomatoes, peppers, aubergines, etc.) – village of Sachevo, Strumcica, North Macedonia*.

✓ 30% less human resources

✓ 5% less energy

✓ 5% less water

✓ 20% less fertiliser

✓ 15%more crop yield

✓ Return on investment: 12 months

A summary of the indicators in terms of the economic benefits of the digital application, adopted as a model for the purposes of this study, is presented in Table 3.

Table 3. Results in management of farm processes and activities after application of web-based technology ONDO Smart Farming Solutions

Farms	Indicators					
	Human resource	Energy	Water	Fertilizers	Crop yields	Return on investmen (months)
	в процент (%)					
„Otbrany“	-	-	30 ↓	20 ↓	20 ↑	8
„Roseland”	30 ↓	30 ↓	30 ↓	20 ↓	20 ↑	10
„Versol“	25 ↓	20 ↓	20 ↓	20↓	-	-
„Nikol Agro“	35 ↓	20 ↓	25 ↓	20 ↓	-	Returned
„Angel Metlarov“	30 ↓	-	30 ↓	-	-	-
„MARJAN-MID“	30↓	5 ↓	5 ↓	20 ↓	15 ↑	12

Source: The table was developed by the author.
Note: "-" Missing information.
„↓“ – decrease.
„↑“ – increse.

From the findings presented, the following benefits of the implemented digital technologies can be derived:

- Saving resources - human, natural, production;
- increase in yield;
- optimization of the technological process.

Thanks to its web-based technology, through ONDO it is possible to exercise control from any device at any time and anywhere when managing processes and activities on farms.

3.3. Recommendations for increasing the benefits of digital technologies in the agricultural sector

Considering that the digital transformation is a process that will continue to transfer digital technologies in all spheres of our life and that it is a starting point in the development of Europe 2030, the following recommendations can be made for the implementation of digital technologies in the Bulgarian economy and in the agricultural sector in particular.

First. The areas in which action is needed by the public administration to introduce digital technologies are: incentives for additional qualification of employees, adaptation of data protection legislation, provision of highly reliable and high-speed networks, etc.

Second. The accumulation of large databases, the processing and analysis of which will enable fast and adequate decision-making in real time, not only in critical situations when malfunctions and problems arise, but also for the strategic planning of processes in agricultural holdings.

Third. Constantly emerging new technologies require rapid action for the adaptation of the workforce, in parallel leading to job cuts. In this context, the effect of competition between human and artificial intelligence should be considered.

Fourth. Ensuring internet access for Bulgarian users should be a major commitment of the government and its main priority in the field of digital technologies, including their application in the agricultural sector.

Fifth. Insufficient high-tech skills of the population are identified as the main, deepening obstacles to the development of the digital economy.

On the basis of the conducted dissertation research the following recommendations for increasing the benefits of digital technologies in the agricultural sector can be highlighted:

Recommendation One. From a ***regulatory*** point of view, the state is the regulator of economic activity. It is obliged to provide conditions for business development. The state creates the normative-legislative bases and frameworks for the introduction and application of digital conditions in the economy, respectively in the agricultural sector, and monitors their compliance. Its role is expressed through the institutions, regulation of markets, resp. the incomes of producers and consumers.

The digitalization of the economy, resp. of the agricultural sector, is only possible with the participation of the state, namely by: building infrastructure for broadband internet access, weather stations, consolidation of data from agricultural holdings, participation of specialists. Actions taken at the state level should allow efforts to be directed towards attracting the interest of more people to the new technologies in order to exploit the potential of the digital economy. The permanent updating of the regulatory and legislative framework is a prerequisite for the modernisation, automation and competitive positioning of the Bulgarian agricultural sector in line with European initiatives.

Recommendation Two. In the ***theoretical*** aspect, it is necessary to provide farmers with an understandable and accessible introduction to the main characteristics of digital technologies, taking into account the specificities of the agricultural sector. If necessary: issuing manuals,

initiating an awareness campaign, conducting training, developing demonstration prototypes, etc. with the participation of stakeholders. The aim is to introduce digital technologies for the agricultural sector that best meet the needs of the farms, taking into account the specificities of the sub-sector and the particular activity. Clarifying the practical relevance (third aspect) requires clarifying the conceptual apparatus.

In terms of economic viability or return on investment, each farm needs an adapted use example, digitisation plan or strategy.

Recommendation Three. In ***practice***, for the successful implementation of digital technologies, it is necessary to unite a variety of registers and data sets (from the Ministry of Agriculture and Food, primarily the Department of Agro-statistics, the State Fund "Agriculture", the National Agricultural Advisory Service, the Bulgarian Agency for Food Safety and others) to achieve a focus on the storage of unified operational information. The introduction of digital technologies in the agricultural sector will complement and build on existing systems. The above is only possible with the involvement of the State.

The use of the data entered in a decentralised way (including by farmers, food processors and traders) will be possible in real time by all users. In this process, the following stages can be conventionally identified:

Stage one. Merging existing data registries.

Stage two. Upgrading of data sets to allow analysis and improvement of forecasting models.

Stage Three. Establishing digital technologies as a method of securely sharing information and highlighting their potential to fully automate data processing.

There is a need for publicly available information that would allow analysing the state of the digitalization of the economy, respectively of the agricultural sector.

Prospective works on the developed issues would be useful for research in this field, provided that sufficient data and realistically established indicators are available.

In conclusion, we believe that digital technologies will enable transparency of production activities and up-to-date information on the state of the agricultural sector.

* * *

The process of digitalization is fundamentally changing our lives, including in the agricultural sector.

We believe that the future will require increasingly sophisticated and innovative digital systems of action and operation in the agricultural sector. It is therefore very important to clearly define and articulate the main objectives and sub-objectives of the digitalization process in the agricultural sector.

The country lags far behind other EU Member States in terms of the penetration of digital technologies in the economy and society, permanently occupying the bottom places.

Conclusion

Digital transformation has been frequently discussed in recent years, despite the fact that digital products and services have been developed since the end of the 20th century and the beginning of the 21st century. An

important "conduit" for digital channels to reach customers is advertising campaigns in mass media (radio and TV as a priority).

It is an undeniable fact that the digital economy is evolving very dynamically in a global perspective. It is defined as an important driver of innovation, competitiveness and economic growth. The potential for entrepreneurship at the level of small and medium-sized enterprises, including farms, is significant.

A range of technological solutions and business models are expected to support the development of "qualitatively new forms" of economic activity. Adapting the applied business models to the digital economy will allow organisations to represent the scale of modern technologies.

With regard to the developed issue, the author adheres to the concept of digital technologies. In spite of the difficulties and challenges related to infrastructure and the human factor, they will take their place in the development of the agricultural sector.

Based on the above, we can summarize that the penetration of digital technologies in the agricultural sector and the deployment of their potential depends on the policies of the respective governments, the type of agricultural activity, the willingness of entrepreneurs in the agricultural sector to accept the challenges of the digital society, the size of the farm and its location.

As a result of the research carried out on the topic of the thesis "Opportunities for the application of digital technologies in the agricultural sector" and the in-depth analysis carried out, the following major conclusions can be drawn:

First. In outlining the role of the state in the implementation of digital technologies in the economy, we believe that digital transformation affects all aspects of the economy, society and government. Its success and the full exploitation of the opportunities it offers depend on the existence of a

comprehensive state approach to the design, implementation and monitoring of policy in this area.

Second. In relation to the documents studied for the digitalisation of the economy at European level, the sectoral and horizontal policies affected by the digital transformation and the relevant country policy documents for their implementation should be linked, updated where necessary and closely coordinated in order to guarantee their mutual support and maximum synergy, i.e. the deployment of the digital transformation at European and national level.

Third. The development of models for digital support and decision-making requires the acquisition of knowledge, skills and abilities to help create digital operating models applicable in various sectors of the economy, including agribusiness. In outlining their perspectives, we define the available public information as insufficient at the moment to distinguish, prioritize, respectively override the expected effects for plant and livestock production.

Fourth. Entrepreneurs in the agricultural sector use digital technologies (smartphones, tablets, and in the field - sensors, drones, satellites and others) that help a range of agricultural solutions such as remote measurement of soil conditions, better management of water resources and monitoring of livestock and crops. From the database, they obtain information on the condition of crops or animal health. This allows them to plan their activities more effectively. The potential benefits of using digital technologies are expressed in increasing yields and monitoring animal welfare, optimising inputs and reducing labour operations, optimising technological processes, etc.

The perspectives for digital transformation are outlined, including the acquisition of skills and capabilities that play a key role in the creation of digital operating models applicable in different sectors.

The above supports the author's thesis, namely the necessity of using digital technologies to develop sustainable solutions to current and future challenges, including in the agricultural sector. A transition has been launched to standardise data in terms of the implementation of interoperable models for the purpose of managing the economy.

The overall trend of societal development in all sectors of the economy is towards digital transformation.

The digitalisation of the agricultural sector brings many advantages and a number of actions and tools have already been implemented, but there are still barriers to realising its full potential at global, European and national level. From this point of view, the problems outlined will be a starting point for future developments.

On the basis of the above and the analysis carried out in the dissertation, it can be concluded that its main objective has been fulfilled: to analyse the state and potential of digital technologies through the use of digital governance, which is an integral part of the digital transformation.

IV. CONTRIBUTIONS OF THE DISSERTATION THESIS

The theoretical and practical significance of the present study is expressed in the following main contributions:

Firstly, an analysis of the theoretical positions on the definition of the concept of digital technologies is carried out and an author's interpretation is presented.

Second, a model is developed to support the implementation of digital technologies on farms.

Thirdly, a practical and applied contribution of the research is the study of the benefits of the implementation of digital technologies, allowing to optimize the management of activities on farms.

Fourthly, problems are identified and recommendations are made for the implementation of digital technologies in the economy, respectively in the agricultural sector.

V. IST OF PUBLICATIONS OF THE PH.D. STUDENT ON THE DISSERTATION TOPIC

1. Tashkova, E. (2019). Activities in the region of Blagoevgrad / Regional Directorate of State Fund "Agriculture" - Blagoevgrad. State and problems in the management and development of agriculture.: International Scientific and Practical Conference, Svishtov, 4 October 2019, Tsenov AE, pp. 540-547, ISBN 978-954-23-1762-3.

2. Tashkova, E. (2020). Digital technologies - theoretical formulations and possibilities for application in the agricultural sector. *Annual almanac "Research of PhD students"*. Svishtov: Tsenov AE, No. XIII, Book 16, 2020, pp. 513-522, ISSN 1313-6542.

3. Tashkova, E. (2023). Conceptual framework for digital transformation of the economy. *Annual almanac "Research of PhD students"*. Svishtov: Tsenov AE, No. XIV, Book 17, 2021, pp. 154-179, ISSN 1313-6542.

DECLARATION OF ORIGINALITY

I, the undersigned Elena Dimitrova Tashkova, do hereby declare my authorship of the presented dissertation on "Opportunities for applying digital technologies in the agricultural sector". I guarantee the correctness of the bibliographic citations, which meet the requirements for fair use of foreign scientific works and do not violate the copyright of their authors. The present dissertation has not been discussed in another higher education institution or defended before a scientific jury.

06.07.2023 Ph.D. Student: ……..

Svishtov (Elena Tashkova)