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EVALUATION OF INNOVATION TECHNOLOGIES IN PRECISION AGRICULTURE

AUTOREFERAT

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I. GENERAL CHARACTERISTICS OF THE DISSERTATION

Agriculture is a key factor in the development of each country's national economy. The multifunctionality of the industry can be associated with ensuring the food security of the population, the production of raw materials for industry, providing employment and livelihood for part of society. Agricultural production has a multiplier effect on the development of all industries, regions, ecological and social systems.

From the beginning of civilization until today, the development of agriculture has been determined by many different factors, influences and challenges, but although with some exceptions, the production of food and raw materials has increased in proportion to the growing population and higher consumption. In the coming years and decades, the sustainable development of agriculture and societies, respectively, will depend on established trends in the world population, climate change, migration from rural to urban areas, limited and declining natural resources, scientific discoveries, innovation and new technologies.

In recent decades, there has been a major improvement in agricultural productivity to meet the demand for food for a growing world population. But progress often comes with social and environmental costs, including water scarcity, soil degradation, and ecosystem stress, loss of biodiversity, declining fish and forest resources, and high levels of greenhouse gas emissions. The productive potential of natural resources has been damaged in many places around the world, compromising the future fertility of the planet.

Innovation is beginning to transform every link in the food chain. In developed countries, digital technologies make farm production more efficient and focused. However, population growth still remains a serious challenge, as it will lead to an increase in demand for food. According to an FAO report, the world's population growth of 10 billion by 2050 is expected to boost agricultural demand for meat, fruits and vegetables.

High-resource farming systems that have caused massive deforestation, water scarcity, soil depletion and high levels of greenhouse gas emissions cannot ensure the sustainable development of agricultural production. Innovative systems are needed that protect and improve the natural resource base while increasing productivity. A transformative process is needed towards 'holistic' approaches such as agri-environment, agro-forestry, precision and digital agriculture, which are also based on traditional knowledge. Technological improvements, together with drastic reductions in the use of fossil fuels throughout the economy, would help tackle climate change, which affects all ecosystems and every aspect of human life. Greater international cooperation is needed to prevent emerging cross-border threats to agriculture and the food system such as pests and diseases.

Sustainable development requires agricultural production to be optimized in order to achieve the yields with the lowest possible resource costs. This means summarizing all the knowledge, good practices and experience gained over the years, integrating into production concepts environmental opportunities and constraints, new technologies and anything that could contribute to optimizing the exploitation of resources, production, marketing and consumption of more, better and safer food and raw materials.

Precision agriculture is a new technology-based concept that allows producers to adequately manage arable land depending on spatially and temporally differentiated information. It is an innovative, technology and information-based, intelligent approach to identifying, analyzing and managing variables to obtain cost-effective production with optimal production and conservation of resources. Precision agriculture has great potential in achieving economic and environmental benefits, which are reduced in the use of water, fertilizers, chemicals, labor and equipment. The essence of the approach is to make the right management decisions based on the changing characteristics of the arable land and to maximize yields and minimize costs by applying the right amount of nutrients or preparations.

Precision agriculture differs from traditional agriculture in its level of management. Instead of unified management of entire units (fields, blocks or areas), the approach is customized and refined for small areas in individual fields and plots. Efficiency is improved on the basis of more precise investment (treatments, seeds, fertilizers, etc.) according to the specific needs of crops or animals in the right place, at the right time and in the right amount.

Although each of the existing technologies improves the technical efficiency of production (increases yields per unit area, optimizes the amount of resources used, reduces the need for labor, etc.), their adaptation in practice is not fast enough. In many cases, farmers do not have the opportunity to invest in such technologies, in others the problem is their complexity and the inability of farmers to set up, synchronize and manage them. The economic efficiency that underlies any investment intention is not guaranteed. It is still difficult to define exactly what the marginal benefits and marginal costs of each technology are, because it depends not only on them but also on the specifics of each farm, each field and the variation of individual factors of production.

The purpose of this study is to analyze the technical and economic efficiency of innovative technologies in agriculture, based on which to assess the possibility of their implementation in Bulgaria with sector-specific production and institutional conditions.

Based on the adopted methodology, the subject of the study is to assess the effect of the application of innovative technologies in precision agriculture.

The object of study is the soft fruit sector, analyzed by four farms in the UK and one in Bulgaria.

In the present study, several scenarios have been developed based on applied technologies. The main hypothesis of the study is that the introduction of innovations helps to increase technical and total economic efficiency.

The survey focus on the following stages:

1. Defining and clarifying the essence and content of the concept of "Sustainable Development" and its specifics in agriculture;
2. Synthesis of theoretical framework for innovation, innovation policies and the attitude of farmers to innovation in agricultural production systems;
3. Definition of precision agriculture as an alternative approach to sustainable development in conditions of limited resources and growing demand for food, raw materials and energy;
4. Presentation of modern and most effective technologies in precision agriculture;
5. Adaptation of methodological tools for research, analysis and evaluation of the technical and economic efficiency of innovative technologies for growing soft fruits;
6. Conducting a practical study in the United Kingdom and in Bulgaria in order to collect empirical data on the cultivation of soft fruits using different technologies;
7. Analysis of the efficiency of the technologies under the specific conditions in both countries;
8. Highlight production solutions and institutional optimization for sustainable development of the soft fruits sector in Bulgaria;
9. Conclusions and recommendation.

II. MAIN CONTENTS OF THE DISSERTATION

CHAPTER 1: THEORETICAL BACKGROUND OF SUSTAINABLE DEVELOPMENT AND ITS LINK TO INNOVATION AND TECHNOLOGIES

The first chapter of the study is based on a variety of theoretical sources, and as a result of survey a large number of definitions, the theoretical framework of the study has been adapted. An overview of the evolution in the concepts of innovation is made, the main factors influencing these processes are considered, as well as their peculiarities in agriculture. Different definitions of precision agriculture are presented and the main technologies for growing different crops are observed. Based on the theoretical analysis, a methodological framework of the study was adapted.

I.1. Sustainable agricultural development

Achieving sustainability in the development of agricultural systems and maintaining it in the long term is a complex task due to the delicate links between the economy, ecology and society, which are often in conflict with each other. On the one hand, the harmful effects on the environment must be minimized, which is usually associated with the reduction of artificial fertilization, spraying with chemicals, the use of good agricultural practices, etc. On the other hand, this will have a negative impact on the yields. Globally, the nutrition of the population is a serious problem and if, as a result of reduced food production, it deepens and more and more people remain hungry and dissatisfied, the social condition for sustainable development will not be meet.

The study adopts the framework of agricultural sustainability, covering the following elements:

• Environmental safety: The conservation of resources and the maintenance of environmental safety are the main criteria for the ecological sustainability of agricultural production.

• Economic viability: Maintaining and improving the productivity per unit area or per animal at sustainable levels within the productive capacity of resources is a fundamental for the economic sustainability of production systems.

• Social responsibility: Agricultural activity must ensure the well-being and quality of life of both farming families and society.

The technologies introduced in the last 30 years definitely change the agriculture and make the production process much more innovative and sustainable. Of course, agriculture has undergone a major evolution and many transformations. The process is based on the urge of man to discover new and new solutions to problems, and subsequently to unite in one the pursuit of economic benefit, social welfare and preservation of ecological balance.

I.2. Innovation and innovative technologies

The development of the agricultural sector is highly dependent on the innovation process. Innovation is a prerequisite for increased productivity, competitiveness and plays a key role in creating employment, generating income, reducing poverty and social exclusion. FAO defines agricultural innovation as a process' through which a person or organization introduces the use of new or improved products, processes or forms of organization in society or the economy in order to increase efficiency, competitiveness, sustainability, thus helping to achieve food security, economic development and sustainable management of natural resources "(FAO 2015).

I.3. Precision farming

There are a number of definitions of precision farming. Clark (1998) defined it as a management system designed to optimize farm profits and minimize environmental impact by spatially controlling the use of inputs.

According to Robert et al. (1995) precision agriculture (or so-called spatially specific agriculture) is an information and technology-based process management system in agriculture designed to identify, analyze and manage the spatial and temporal variability of fields to optimize the technical and economic efficiency of holding and minimizing the harmful impact on the environment.

The concept of precision farming was first proposed in 1929 (Oolman, 1995). Theoretically, it is assumed that the advantage of precise practices in agriculture consists in higher average yields, lower costs for input resources, better product quality and less damage to the environment. Roberts, English, and Mahajanashetti (2000) point out that the net economic benefit that a farmer receives from the application of variable rates of fertilization, spraying, etc., is defined by differences in the field. In particular, the differences are in two aspects - the first is the degree of spatial variability of the inherent characteristics within the field, and the second is the variability of yield between zones.

Although there are more complex definitions, precision farming is a way to "apply the right treatment to the right place at the right time" (Gebbers and Adamchuk, 2010). This is a concept of agricultural management based on the observation, measurement and response of variability between crops or in the ways of raising animals. The first definition of precision farming is presented by the USA House of Representatives (1997), which defines PA as "an integrated information- and production-based farming system that is designed to increase long-term benefits depending on the specifics of the site and the whole efficiency of agricultural production, productivity and profitability, while minimizing adverse effects on wildlife and the environment”. Such a definition focuses on "whole-economy" management strategies using information technology, highlighting potential improvements in production and reducing negative environmental impacts.

Precision Agriculture (PA) is a management approach that uses information technology, satellite positioning data (GNSS), remote sensing and proximal data collection. These technologies aim to optimize the return on raw materials, while potentially reducing the impact on the environment. Precision farming is a modern production concept. It is seen as a complex system designed to optimize agricultural production through the use of information on crops, modern technologies and methods. It implies the introduction of a unified approach, including tillage, sowing, application of plant protection and fertilization, harvesting.

The benefits of PA are related to the increased yields and profitability of the farmer’s production. Other benefits come from better working conditions, better animal welfare and environmental protection. In this way, the PA contributes to the establishment of the broader goal of agricultural sustainability. The application of PA is possible through the development of sensory technologies combined with procedures for linking the mapped variables with appropriate agricultural practices such as plowing, sowing, fertilizing, application of herbicides and pesticides, harvesting and animal husbandry. An important role is played by positioning systems, which are the main source of "accuracy" - (GNSS, GPS, GLONAS, GALILEO). PA is most widely used by large farmers, especially in major cereal areas in Europe, the United States and Australia, where the main driver is the business model for maximum profitability. Controlled Traffic Farming (CTF) and Auto-Guiding Systems are the most successful applications used by large grain growers. Variable Rate Application (VRA) methods optimize the use of fertilizers or pesticides depending on the needs of the plants.

In vegetable production, fruit growing and viticulture, the methods of machine monitoring of the production lead to higher quality of the products, which is of key importance for a high market price. In addition, for crop production, irrigation is subject of increased control, as water shortages are becoming more frequent. In this regards, PP technologies that use accurate indicators of water stress are applied to maximize water use efficiency.

Precise livestock farming is based on the automatic monitoring of individual animals used for meat, milk and egg production and for monitoring animal behavior, welfare and productivity, as well as their physical environment.

Precision agriculture will play a key role in the European Union due the growing demand for food, feed and raw materials, while ensuring the sustainable use of natural resources and the environment. Nevertheless, the adoption of PA in Europe faces specific challenges related to the size and diversity of farm structures. The assessment of potential actions to support the adoption of PA by medium and small farmers is identified as an important step in this context. In particular, the new Common agricultural policy provides a key opportunity with a number of tools and measures that can be used by the Member States.

I.4. Methodology for evaluation of innovative technologies in the production of soft fruits

Based on the adopted methodology, **the subject of the study** is to assess the effect of the application of innovative technologies in precision agriculture.

The object of study is the soft fruit sector, analyzed by four farms in the UK and one in Bulgaria.

In the present study, several scenarios have been developed based on the appliedd technologies.

The main hypothesis of the study is that the introduction of innovations helps to increase technical and total economic efficiency.

In order to assess the economic and environmental benefits of the precision technologies used in soft fruit production, it is important to identify relationship between inputs and outputs.

Theoretically, it is assumed that the advantage of precision agricultural practices are associated with higher average yields, lower input costs, better product quality and less damage to the environment.

Based on the adopted methodological approach "Case study", five farms, object of the analysis, were studied. The survey for the assesment of the innovative technologies in precision agriculture is based on own study conducted in the UK and Bulgaria for the period 2016-2019. The analysis related to the effect of different technologies in four farms in the UK and one farm in Bulgaria.

Each of these farms is specialized in the production of soft fruits, and they grow the same variety of blackberries, which allows a comparability of results. In farm "A" - UK, this variety of blackberry is grown in open fields, where the plants are in the soil of raised beds. In Farm B, UK, the areas are covered with standard poly tunnels and the plants are grown in coconut fiber (in pots). At Farm C in the UK, blackberry growing is based on areas covered with advanced tunnels, and the plants are grown in coconut fiber (in pots); tracking trends and a conclusion about the impact of technology. Farm D, UK, uses glass greenhouses in which plants are grown in coconut fiber (in pots). In Bulgaria, a Berach farm is analyzed, which implements two production technologies. Open fields where plants are grown in the soil of raised beds and fields covered whit standard polyethylene tunnels.

Group of indicators is used to assess the impact of innovative technologies in of soft fruits production. The methodological framework correspond to the adopted research approach and the objectives of the dissertation.

First, **the technical efficiency** presented based on the indicator land productivity. The management of production on the basis of many separate parts of the field (herd), with individual (specific) characteristics, implies a more precise definition of the need of each plant (animal), a more efficient response of the operator.

The average yield in each of the surveyed farms is presented as ton / hectare. The collected data are for the period 2014-2018, by the application of method of averages.

Average yield = (Quantity of production (tonnes)) / (Area (hectare)) (1)

Secondly, an analysis of the distribution of labor resources is made and the number of seasonal and full-time workers is monitored for the four years of the study. In this regards, the possibilities of different employment technologies can be assessed and the trends in different production systems can be compared.

Thirdly, the production structure of the farms is presented. The data provide information for the direction of specialization and diversification of production in the soft fruit sector.

Fourth, the total economic efficiency, which is based on the income / costs, is evaluated and observed.

Revenues are formed mainly from the sale of products and are a function of yield and market price. Based on different study it can be concluded that the revues should be higher after the implementation of precision technology based on better yields, better quality and higher sale price.

Revenue = Quantity of products (tonnes) x Market price (EUR) (2)

The estimation and analysis of the revenues is based on the average price in the sector for the analysed period.

The cost analysis is based on survey on their changes in different technological systems. The investment costs, which are an important part of the effect of innovations in the sector, include cost for roofing and their equipment - sensors, software programs and others. The investment costs also include irrigation and roof construction, which vary and their analysis is important for assessing the effectiveness of the applied technology. The amount and distribution of investment costs are the basis for decision-making whether to implement innovations and new technologies in production.

Production costs are another major factor that influences the total economic efficiency. They are divided into groups, which cover labor costs, materials and packaging. Material costs include those for nets, propagating material, machinery and preparations. Labor costs cover not only the costs of full-time and seasonal workers directly involved in production, but also those of specific activities related to the implementation and maintenance of innovation systems. It is important to distinguish the different items in order to trace the severity of the individual costs and their amount in the individual technological systems.

Based on the analysis of revenues and costs, the coefficient of economic efficiency in the different production systems on the farms in Great Britain and in Bulgaria is estimated and compared.

Economic Efficiency = Revenues / (Costs) for different technologies (3)

Gross profit is also used as an additional indicator for analysis and evaluation of the efficiency of the applied technologies.

Gross Profit = Revenue - Costs (4)

This indicator helps to observe the profit of the various systems before transforming it into net.

Profitability analysis based on revenue and costs is a possible option for financial analysis and assessment of the impact of innovative technologies, but due to the fact that farms are located in different countries with different law system, such an option is difficult to apply.

Another important indicator, which helps to assess the impact of various innovations on the production process is product quality.

The main quality indicators in the present analysis are the share of quality products (which are sold on the market fresh) and the share of low-quality products (which are processed or discarded).

Share of quality production = (fresh production (tonnes)) / (total production (tonnes)) (5)

Share of substandard production = (processed or discarded production (tonnes)) / (total output (tonnes)) (6)

<u>CHAPTER 2:</u> ANALYSIS OF TECHNOLOGIES IN THE PRODUCTION OF SOFT FRUITS AND THEIR TECHNICAL AND ECONOMIC EFFICIENCY

II.1. Soft fruits - types, economic importance, technologies

In the group of soft fruits are most common are raspberries, strawberries, blackberries and blueberries. This group also includes cranberry, gooseberry and others. The economic importance of these crops has increased over the last two decades due to their classification as indispensable resources of vitamins and biological antioxidants, which play an important role in human health.

The production of soft fruits in Bulgaria has rich traditions. Strawberries and raspberries are the most common, while blackberries and blueberries have begun to develop more significantly in the last decade. According to the data of the Ministry of Agriculture and Food, Department of Agrostatistics in 2018 strawberries are 726 hectares, of which only 42 hectares are grown in polyethylene tunnels or glass greenhouses. From the group of soft fruits, the raspberries UAA is the largest -2499 hectares. There are no official statistics for blackberries and other crops due to their low relative share. The growing popularity of blackberries and blueberries for fresh consumption is expected to lead to the statistics collection.

The technologies used in the production of soft fruits have undergone significant development in the last few years, which has contributed to increasing yields and product quality. The traditional cultivation of soft fruits outdoors (without cover and protective structure) has gradually been replaced by alternative methods that are much more technically and economically efficient. In Western Europe, America and Australia, these fruits are grown almost entirely in polyethylene tunnels and glass greenhouses using microclimate control technologies. This is based on the use of precision technologies - smart sensors and sensors for controlling humidity, temperature, light, CO_2 and others. In addition, technologies are used for precise irrigation and plant nutrition, for the diagnosis of diseases, for pest control and etc.

The natural and climatic conditions in Bulgaria allow relatively successful cultivation of soft fruits in the country, but also determine the seasonal nature and the higher risk in open areas. In order to make better use of natural resources and the positive effects of the climate, as well as to minimize the risks, greenhouse technologies are being introduced widely in modern farms.

The main advantage and goal of greenhouse production is to supply the market with fresh fruits or vegetables all year. In addition, the technology reduces the dependence of production on soil quality, as in most cases the plants are grown in an artificial environment and fed artificially. The economic advantage of greenhouse production is associated with higher yields per unit area and better quality of the products, which means higher revenues. Another advantage is the continuous production cycle during the year, which eliminates seasonality and ensures a more balanced use of labour resources. Higher yields and increased product quality lead to more efficient use of labor (increase the speed of harvesting). Greenhouse production allows accurate forecast of the expected production, which is a key factor in contracts with large supermarket chains. It is also important for labor planning.

The production of soft fruits in open areas, which is still practiced in Bulgaria, is considered inefficient and almost not applied in Western Europe, America and Australia. Soft fruits are vulnerable to adverse weather conditions such as strong winds, rain, sunshine, frost, hail, etc., which reduces yields and quality, especially for fresh consumption. The requirements of supermarkets in Europe have imposed quality standards that cannot be achieved by growing outdoors. Even one of the conditions of large chains is that the soft fruits are not grown outdoors.

The data in the present study are based on our own survey conducted in the UK and Bulgaria in the period 2016-2019. The subject of the study are four farms in the UK and one farm in Bulgaria. All farms grow the same variety of blackberries, which allows comparison of results.

Farm "A" (open fields) - Great Britain - open fields where the plants are grown in the soil of raised beds;

Farm B (standard tunnels) - Great Britain - the areas are covered with standard tunnels and the plants are grown in coconut fiber (in pots);

Farm C (advanced tunnels) - Great Britain - the areas are covered with advanced tunnels and the plants are grown in coconut fiber (in pots);

Farm D (glass greenhouses) - Great Britain - glass greenhouses in which the plants are grown in coconut fiber (in pots).

Berach Farm - Bulgaria - two breeding systems are used. Open areas where plants are grown in the soil of raised beds and standard polyethylene tunnels.

II.2. Analysis of technologies in the cultivation of blackberries in the UK

The subject of the analysis is the UK-based company. It consists of five separate production bases (farms) in different parts of the country. The current study was conducted in four of them. The company is international and in addition to the UK develops a farming business in Portugal, China and South Africa. In recent years, the main direction in its production structure is the design, development and marketing of polyethylene tunnels, as well as innovations in greenhouse technologies. The farm produces conventional and organic - blackberries, raspberries, strawberries, blueberries and cherries in an area of 200 hectares in the UK. The company's polyethylene tunnels and technologies are sold in 58 countries around the world.

II.3. Analysis of the results of blackberry growing in the UK

II.3.1 Cost analysis

Investment costs

The investment costs in the four studied farms are different depending on the applied technology.

Table 1 shows the investment costs in the four farms in the UK related to the different blackberry growing systems. This includes all costs for the construction of covering structures and the cost of their equipment - sensors, software programs and etc.

In farm "A" the investment costs are the lowest due to the fact that there is no tunnels, no systems for precise control and management. In this farm the main investment costs are for supporting structure and drip irrigation.

In the B and C farms, in addition to the investment for an irrigation system, there are also costs for the implementation of technologies for controlling the microclimate in the tunnels. The main reason for the higher investment costs is the way the plants are grown. In all farms except farm A, the plants are grown in pots with coconut mixtures.

In farm "D" the investment costs are the highest. In this holding the soft fruits are grown most precisely, with control of the microclimate, irrigation, fertilization, and lighting. In addition, diseases and pests are controlled.

Table 1: Investment costs in euro per hectare.

INVESTMENT COSTS				
Elements	***Farm A*** ***Open fields***	***Farm B*** ***Standard poly tunnels***	***Farm C*** ***Advanced poly tunnels***	***Farm D*** ***Glasshouses***
Construction and technology	-	30000	100000	1000000
Supporting structure	20000	20000	30000	50000
Irrigation equipment	3700	6480	6480	7776
Total investment costs	23700	56480	136480	1057776

Source: Own research

Production costs

The results of the study show that production costs are lowest on farm "A" and highest on farm "D". A significant difference is observed in the cost of planting material. There are several reasons in this regards. First, in farm A, the costs of purchasing the plants are divided into two years, because when they are grown in the soil, they are used for at least two years, and in some cases up to 3-4 years. In the other three farms, the plants are used for one year. This is the reason why plants costs are included in production costs and not in investment costs. Secondly, the density of plants per unit area is different. The number of plants per hectare is the same for farms "A" and "B", and for farms "C" and "D" it is higher due to the specifics of the structures that allow more optimal use of the production area (more linear meters and plants per hectare). In farm "D" in the open fields and farm "B" in the standard tunnels we have 3750 m / ha, in the advanced tunnels in farm "C" we have 4250 m / ha, and in "D" in the glasshouses it is 4500 m / ha.

The same trends are observed in the analysis of labor costs. They are lowest in farm A and highest in D. The difference in production per hectare determines the differences in labor costs.

Table 2: Total production costs in euro per hectare.

PRODUCTION COSTS

Elements	Farm A Open fields	Farm B Standard poly tunnels	Farm C Advanced poly tunnels	Farm D Glasshouses
Production costs for materials	20300	41500	47500	139909
Production labor costs	19350	54570	72600	150200
Packaging and distribution costs	12000	38400	54000	84000
Total production costs	51650	134470	174100	374109

Source: Own research

Production costs are based on the kilograms produced per hectare and the average harvesting speed. It shoud be noted that different growing systems have different average picking speeds. Therefore the cost per kilogram is the lowest in farm "D" and the highest in farm "A". The costs shows the effectiveness of the technology in terms of productivity. The total harvesting costs are proportional to the kilograms per hectare.

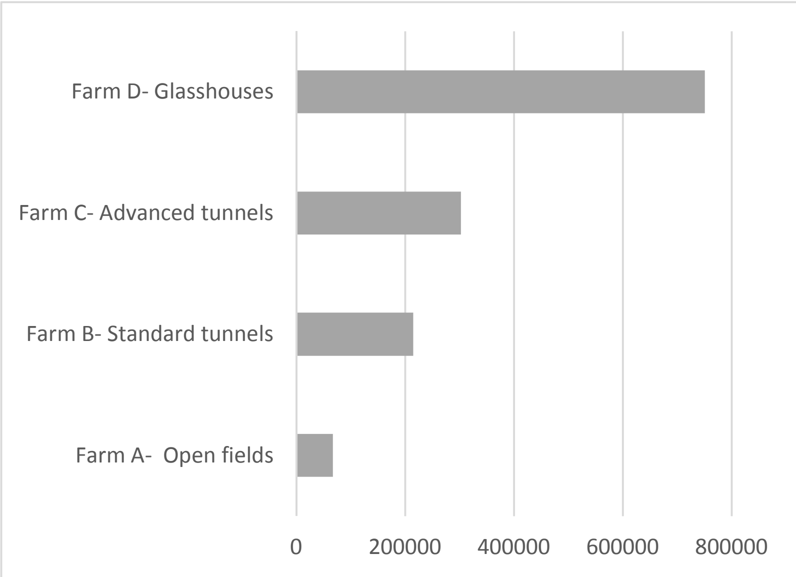
Another major element of production costs is packaging and distribution costs. They include the total costs for the purchase of the necessary packaging materials (panettes, labels, etc.), the transport costs, as well as the labor cost. There is a proportional relationship between the amount of production per unit area and the cost of labor and materials. Labor costs depend on the speed of packaging, which is directly based on the quality of production.

II.3.2 Revenue analysis

In order to calculate the revenues of all four farms, object to the analysis, the average prices of the production and the produced quantities are used.

At the three farms (A, B, C) the price of the production is 6.72 euros per kilogram. All three farms deliver their products to the market at the same time of year. The revenues of the four farms are presented in Figure 1.

Figure 1: Average income per hectare from the four farms in the UK.



Source: Own research

The average price of products from farm "D" is 10.72 euros per kilogram, which is 36% higher than the average in other farms. The main reason is associated with the applied technologies in this production system, which allow to produce in early spring (mid-March) and late autumn (mid-September to mid-December), when market prices are much higher.

The results indicate that the income per hectare of farm "D" is the highest, while the open field of farm A have the lowest income per hectare. The trend can be explained with the higher price of farm "D", on the one hand, and on the other, with the higher average yields.

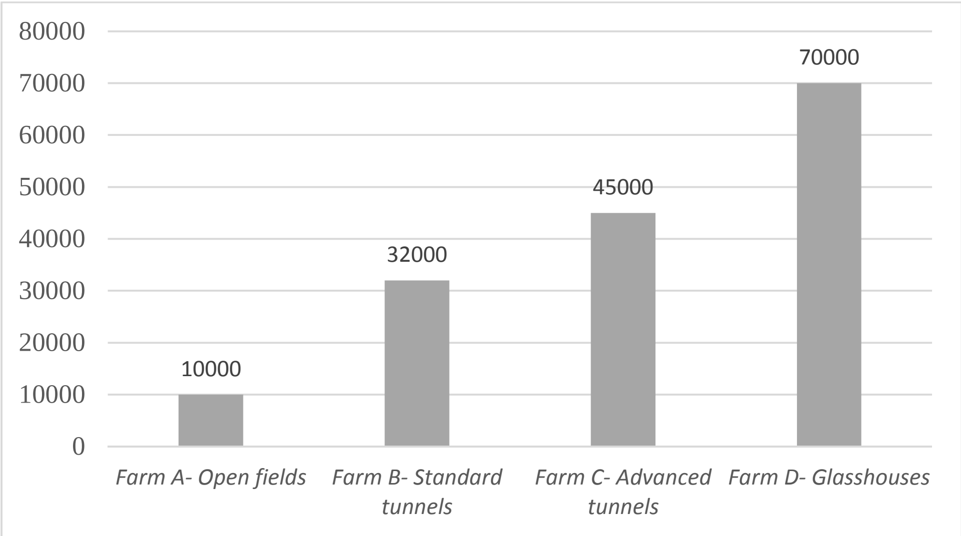
II.3.3 Analysis of technical and economic efficiency

The average yields as a result of the economic activity of the four farms in the United Kingdom are indicators of technical efficiency (Figure 2). The technical efficiency is represented by the yields in kilograms - class 1 production per hectare.

It is observed a significant difference in technical efficiency on the four farms in Great Britain. It is the lowest in open fields (farm 'A') and the highest in glasshouses (farm 'D'), which is an expected result.

Glasshouses provide an opportunity for implementation of the most modern technologies of precision agriculture. These technologies guarantee the crops optimal conditions for growth, which allow maximizing yields: irrigation, lighting, temperature, humidity, control of diseases and pests, nutrients and carbon dioxide. Also, the impact of the environment is largely eliminated.

Figure 2: Technical efficiency, kilograms of production per hectare.

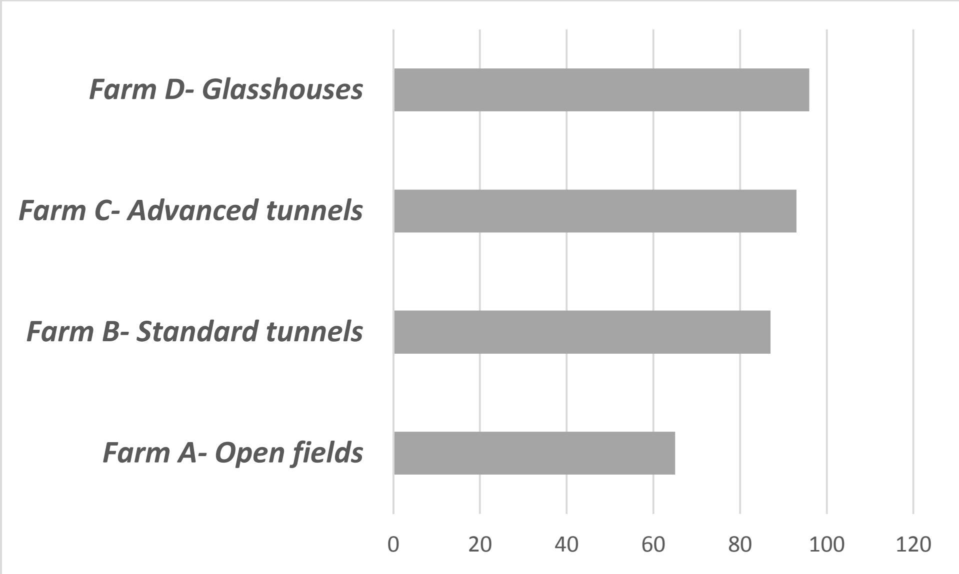


Source: Own research

In open fields, the plants are exposed to natural conditions, the actions against diseases and pests is difficult. Despite a good drip irrigation and fertilization system, the sun, rain and wind can destroy the production. It should be emphasized that for the purpose of the analysis the optimal possible yields are applied. In years of bad weather conditions, technical efficiency can be much lower. The comparison between the technical efficiency of farm "B", with standard tunnels, and farm "C", with advanced tunnels, is interesting. Farmers that are unfamiliar with precision technology, could conceive that these are just tunnels. However, the advantages of advanced tunnels to ensure better growing conditions show a big difference in technical efficiency. In advanced tunnels, there is an increase of 13 tons in yields per hectare.

The second aspect of technical efficiency analysis is the production quality. The products must meet certain requirements in order to be sold in supermarkets. Fruits are divided into Class 1 and Class 2. Class 1 are fruits that meet quality standards, and Class 2 fruits are used for processing or discarded. Figure 3 shows the technical efficiency, presented as a percentage of production class 1.

Figure 3: Technical efficiency according to the quality of the products, percentage of class 1



Source: Own research

The analysis of the technical efficiency, based on the quality of the products, shows that blackberries that are cultivated outdoors registered the lowest results. Outdoor fruits are exposed to the natural conditions. Soft fruits are damaged by the effects of wind, sun, rain. Under optimal conditions, the results show that 65% of the production is class 1. Under unfavourable conditions, this percentage can be much lower. This can lead to large losses for farmers. In the other three technologies, are observed much better results in the evaluation and analysis of the production quality. In standard tunnels, the class 1 output is 87%, which shows the advantages of these technologies. The risk for farmers is significantly reduced, which ensures security if all other plant growing conditions are met.

In the advanced tunnels we have 93% production class 1, and in the glasshouses - 96%. The results are very high, which is clearly presents the advantages of implementation of precision technologies.

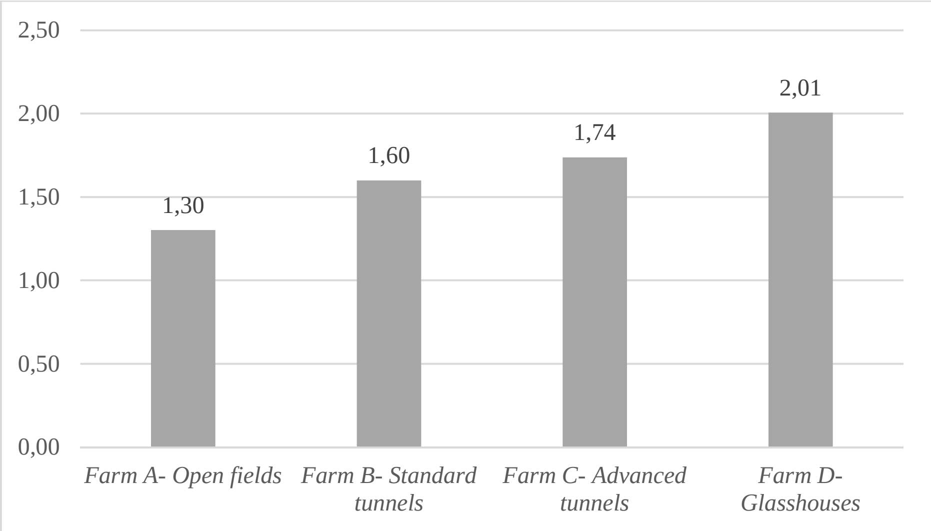
The data show the serious advantages of innovative technologies in precision agriculture and ensure results that are impossible to obtain outdoors.

The assessment of total economic efficiency is presented in Figure 4. It is calculated on the basis of revenues and costs per hectare and is presented in a coefficient.

In the analysis of economic efficiency similar trends are noticed, the lowest efficiency is recorded on farm "A" and the highest on farm "D".

On the other hand, the results show significantly higher efficiency coefficient in the advanced tunnels compared to the standard ones.

Figure 4: Economic efficiency (coefficient)



Source: Own research

The results of economic efficiency coefficient shows the positive effect of the adoption of innovative technologies in agriculture. The analysis of the technical and economic efficiency, combined land productivity, outlined the significant differences in the average yields and revenues. It should also be emphasized that there are serious differences in total costs, especially in the investment costs, which in many cases is the reason for the limited implementation of innovation technologies by farmers.

II.4. Analysis of technologies in growing blackberries in Bulgaria

Berach Farm is located near the town of Strelcha and has 20 hectares of agricultural land. The farm was established in 2013, and the owner's idea is to start growing soft fruits by application of new technologies in the sector.

However, until 2016, all crops are grown in open areas. The results of the first years are insufficient, the yields are low and the quality of the production is poor. The aim of the owner the production to be sold in supermarkets is not realized. The quality does not meet the standards and in unfavourable climatic conditions soft fruits cannot be picked, which does not allow to guarantee quantities for supermarkets every day. Therefore in 2016 the owner invested in standard tunnel structures of the same class as Farm C in the UK.

Blackberries in open areas and standard tunnels are grown in raised beds. Various components are used to enrich the soil. During the construction of the raised beds, 20 liters per linear meter of substrate are added to the soil.

The main component of the substrate is coconut fiber. Coconut fiber is a preferred product in the construction of raised beds by precision farming due to its good drainage qualities. Drip irrigation systems are designed to ensure accurate plant irrigation. Standard tunnels are equipped with sensors to monitor temperature and humidity. A meteorological station has been installed to monitor climate indicators. Shading nets are also built in the tunnels. Shading nets are needed for growing soft fruits in Bulgaria, the reason is the strong solar radiation from mid-June to late August, which damages the fruit.

II.5. Analysis of the results of blackberry growing in Bulgaria

II.5.1. Cost analysis at Berach Farm

Investment costs

Investment costs are lower in the outdoor cultivation system. The costs are related to the support structure and drip irrigation. In the system for growing blackberries in polyethylene tunnels, the main investment costs are for the tunnels structure and technologies for controlling the microclimate. The other costs are the same as in the open space system.

Table 1: Investment costs by items in euro per hectare.

INVESTMENT COSTS		
	Open fields	***Standard tunnels***
Tunnels construction and technologies	-	50000
Supporting structure	6000	6000
Irrigation equipment	6500	6500
Total investment costs	12500	62500

Source: Own research

The tunnels are equipped with sensors for measuring soil moisture, a mini meteorological station for measuring temperature, solar radiation, wind direction and speed, as well as many other important indicators for growing plants.

Production costs

The object of the study are the production costs for labor, materials and the costs for packaging and distribution, presented in Table 4. They compare the systems of growing blackberries in the open and in standard tunnels.

Table 4: Total production costs in euro per hectare

PRODUCTION COSTS		
	Open fields	***Standard tunnels***
Production costs for materials	8450	24830
Production labor costs	28150	88280
Packaging and distribution costs	8450	24830
Total production costs	45050	137940

Source: Own research

Based on the data, it can be concluded that production costs are lower for blackberries grown outdoors compared to the system of growing in standard tunnels. There is no significant difference in the cost of plants. They are divided into two years due to the fact that when grown in the soil, they are used for at least two years, and in some cases - up to 3-4 years. In both systems of growing blackberries in the farm "Berach" the density of plants per unit area is the same - 3750 m / ha. The higher material costs of standard tunnels are assosiated with the compost (coconut fiber) for mixing with the soil in order to ensure a precise environment for irrigation and plant nutrition. The other reason for the higher material costs of standard tunnels can be explained with the biological preparations to control pests and the need to import additional bees (bamboos) to pollinate the plants.

In the analysis of labor costs, the trends are observed - they are higher in standard tunnels. The results can be explained with the production per hectare - 19.1 t / ha in standard tunnels and 6.5 t / ha in open fields with blackberries. The larger production requires higher labour costs not only in the process of cultivation, but also in the process of harvesting. The harvest costs are based on the kilograms produced per hectare and the average harvesting speed. It is important to be pointed out that the different growing systems have different average picking speeds. The higher the production per unit area, the higher is the average harvesting speed. Therefore it can be concluded that the cost per kilogram of picking is lower in standard tunnels, as the picking speed reaches 8 kg / h. In open fields, the cost of picking fruit per kilogram is much higher due to the low picking speed - 4 kg / h, which means low productivity in open fields. The results demonstrate the efficiency of the technologies based on the harvesting productivity. The total harvesting costs are proportional to the kilograms per hectare of production.

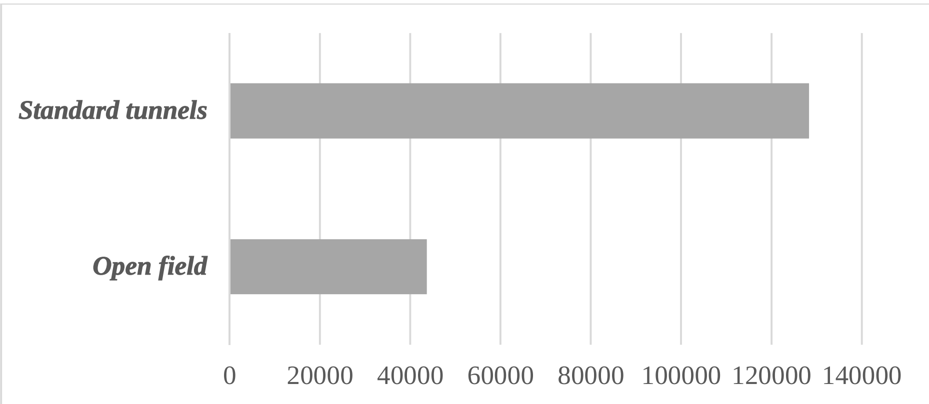
Another main element of production costs, object of the analysis, are the costs of packaging and distribution of the products. The total costs for packaging materials (panels, labels, etc.), the transport cost to the supermarkets, as well as the labor costs are presented. There is a proportional relationship between the amount of production per unit area and the cost of labor and materials. Labor costs depend on the speed of packaging, which is directly based on the production quality.

II.5.2 Revenue analysis at Berach farm

The income analysis of Berach Farm is based on data from own study.

The higher revenues from the implementation of standard tunnels are impressive, which is a result of the higher productivity per hectare.

Figure 5: Average income in euros per hectare for the two systems on the Berach farm.



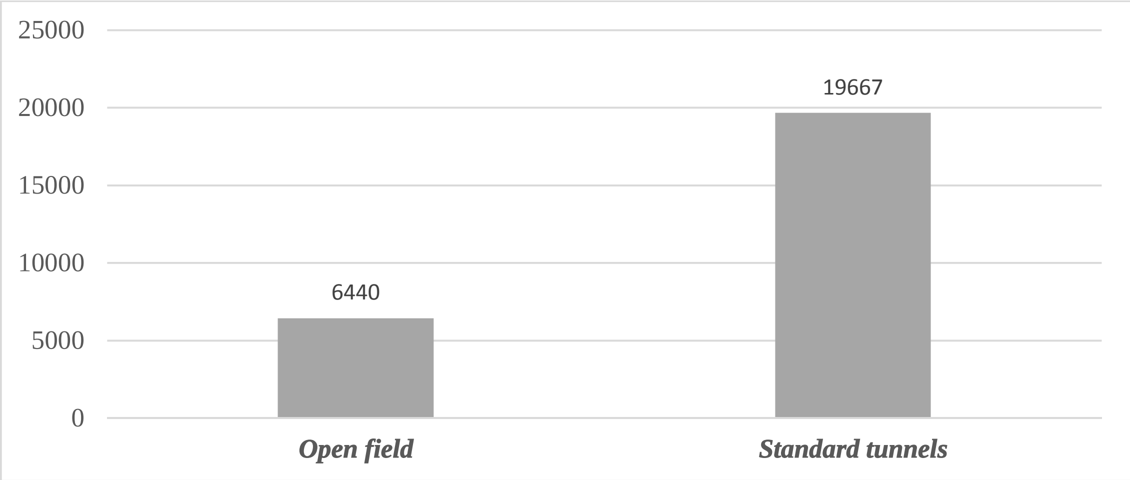
Source: Own research

The prices for the two technologies are similar, but the precision technology lead to the elimination of the seasonality of production and limit the impact of natural and climatic factors.

II.5.3 Analysis of technical and economic efficiency on Berach farm

Technical efficiency is considered in two aspects on the basis of production (yields) and on the basis of product quality.

Figure 6: Technical efficiency, expressed in kilograms of production per hectare.



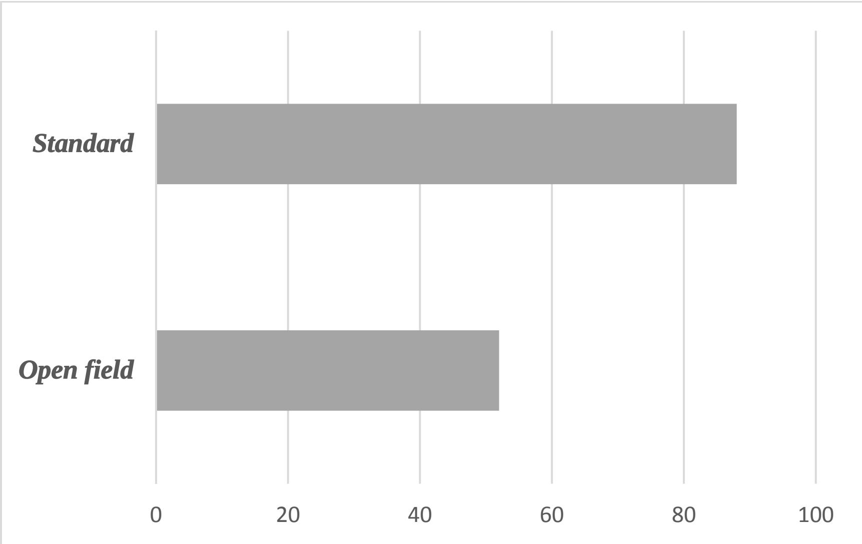
Source: Own research

Based on the average yields in the two systems of blackberry cultivation - outdoors and in standard tunnels, are registered large differences in the results. Standard tunnels have three times higher technical efficiency. Plants grown in standard tunnels have much better growing conditions, which is combined by eliminating the risk of natural and climatic factors. Plant protection through the use of tunnels and precision systems for irrigation, fertilization, disease and pest control leads not only to higher yields, but also to quality optimization and a higher percentage of Class 1 production.

Figure 7 shows the other aspect of technical efficiency, the percentage of class 1 production that meets the quality standards of supermarkets.

The quality of the produced production differs significantly in the two production systems. In the case of blackberries grown outdoors, only 53% of the production meets the quality standards. Due to the rainy summer of 2018, most of the production was lost. The low technical efficiency in terms of quality leads to a financial loss for the Berach farm from the blackberries grown outdoors. The system of cultivation in standard tunnels shows relatively good results in terms of quality - 88% of the produced fruits are class 1 and meet the quality standards applied by supermarkets.

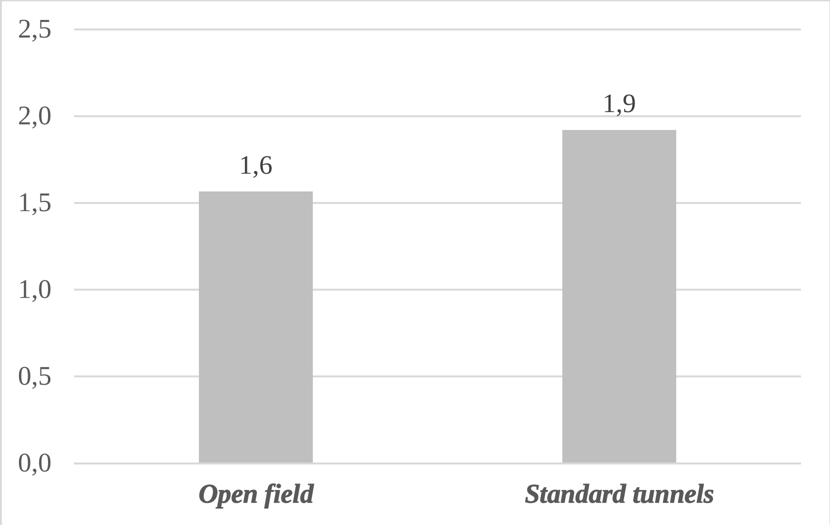
Figure 7: Technical efficiency according to the quality of the produced production, percentages of class 1 production.



Source: Own research

The analysis of the results for the two aspects of technical efficiency - quantity and quality of production outlines the positive effect of implementation of standard tunnels. It is necessary to emphasize that production system in standard tunnels includes all related technologies: meteorological stations, precision irrigation systems, fertilization, air control, sensors, disease and pest control.

Figure 8: Economic efficiency presented as a coefficient



Source: Own research

The assessment of total economic efficiency is presented in Figure 8. It is calculated on the basis of revenue and costs per hectare and is presented as a coefficient.

Coefficients of economic efficiency in the two blackberry production systems on the Berach farm show higher results in the system with standard tunnels. The analysis of technical and economic efficiency highlight that the system with standard tunnels is more cost-effective and more profitable in the long term. The owner plans to buy more tunnels and implement the advanced technology in the future and stop growing blackberries outdoors.

<u>CHAPTER 3</u>: OPPORTUNITIES FOR TECHNOLOGICAL DEVELOPMENT OF BULGARIAN AGRICULTURE ON THE BASIS OF DIGITALIZATION

III.1. A sustainable digital future for European agriculture and rural areas

Digital technologies such as artificial intelligence, robotics, blockchain, high-performance computers, the Internet of Things and 5G have the potential to increase the efficiency and productivity of the agricultural sector, as well as ensure the sustainability of the sector in an economic, social and environmental aspects.

These technologies can optimize results in all sectors of agriculture, to improve decision-making and to reshape the functioning of food markets. In addition, the wider implementation of digital technologies has a positive impact on the quality of life of workers in the sector and the rural population and can attract the interest of the younger generation in agriculture and rural life.

However, the level of digital use in agriculture and rural areas in the EU is low. The lack of information on existing technologies, digital skills and reliable cost-benefit analyzes of the adoption of new technologies are factors that are limiting investment in innovations in the sector.

III.2 Strategies for digital agriculture worldwide

Bulgaria has prepared Strategy for Digitization of Bulgarian Agriculture and Rural Areas, which is in the process of public discussion and will be adopted in short term.

There are countries that do not have a specific strategy for digital agriculture, but most of the existing digital strategies or e-governments are connected and have some components or specific project in the field of digital agriculture. However, this is a new field and there is a risk that national governments will fail without a specific strategy for digital agriculture. Examples can be given of the OECD countries, which often do not have clear priorities for digital agriculture and face many challenges.

III.3 Strategic documents in the field of information and communication technologies (ICT) in Bulgaria.

- The National Reform Program (NRP);

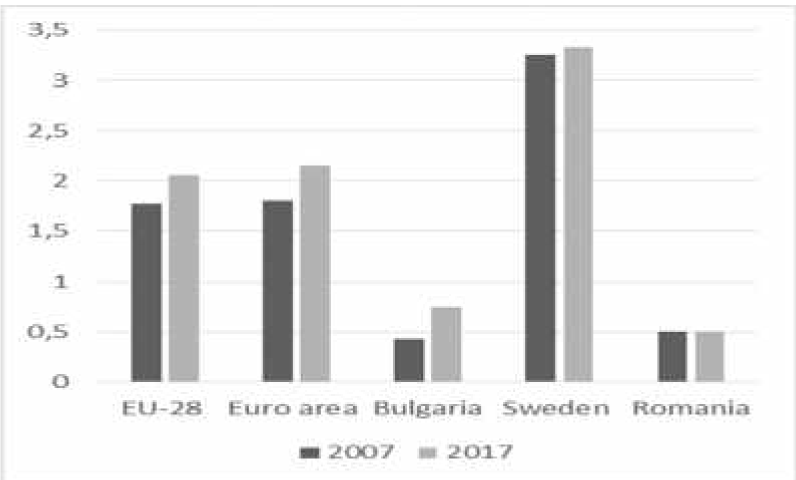
- National broadband strategy 2012 - 2020 and the National Broadband Infrastructure Plan for Next Generation Access (NGA), aimed at providing high-speed and ultra-fast internet to all citizens;
- The updated policy in the field of electronic communications of the Republic of Bulgaria 2015-2018 for the development of the communications sector and for achieving economic growth within the Single Market;
- E-Governance Development Strategy - 2014 – 2020
- The Innovation strategy for smart specialization of the Republic of Bulgaria 2014-2020 (IS3)
- Concept for digital transformation of the Bulgarian industry;
- The National Strategy for Cyber Security "Cyber Sustainable Bulgaria 2020".

III.4 Trends in Bulgarian R&D in agriculture

The EU is stimulating investments in innovation and development, in order to improve productivity and competitiveness in all sectors of the economy. The Europe 2020 strategy adopted in 2010 maintains a long-standing objective, namely, for the EU to devote 3.00 % of gross domestic product (GDP) to R & D activities (EU, 2010).

Figure 9 represent the share of R&D expenditure in GPD in EU-28, Bulgaria and the countries with the highest and lowest level of expenditure.

Fig. 9. Gross domestic expenditure on R&D, 2007 and 2017 (%, relative to GDP)



Source: Eurostat

According to Eurostat in the EU-28 gross domestic expenditure on R&D are EUR 317.1 billion or an average of EUR 620 of R&D expenditure per inhabitant. For the period 2007-2017 the indicator increases by 40%.

Based on the Eurostat data the Member-States can be divided into three group. In the first one, there are the countries with the highest R&D intensities in 2017 - Sweden (3.33%), followed by Austria (3.16 %), Denmark (3.06%), Germany (3.02%), Finland (2.76 %) and Belgium (2.58%).

The other group is formed by countries with close to EU-28 average gross domestic expenditure on R&D. France, The Netherlands, the Czech Republic, Slovenia, The United Kingdom, Portugal, Italy and Hungary are with the R & D intensities in the range of 2,19% to 1,33%.

There are eight Member States with R & D expenditure below 1% of their GDP in 2017. Bulgaria is part of the third group with 0.75%. The lowest R & D intensities is registered in Romania (0.50 %), Latvia (0.51 %) and Malta (0.55 %).

For the period 2007-2017 the majority of the EU Member States registers increase in R&D intensities. There are six exceptions- in Finland is reported the highest decrease 0.59 percent points. By contrast, the biggest growth in R & D intensity is recorded in Austria and Belgium (0.7percent points), followed by Germany (0.57 percent points). In Bulgaria there is an increase by 0.32 percent points. It should be noted that in the country the share of R&D expenditures is really low compare to the EU-28 average. The country is lagging far behind most of the Member-States. The problems during the transition and the slow adaption to the new approaches in the EU led to serious challenges related to the role R&D in Bulgaria.

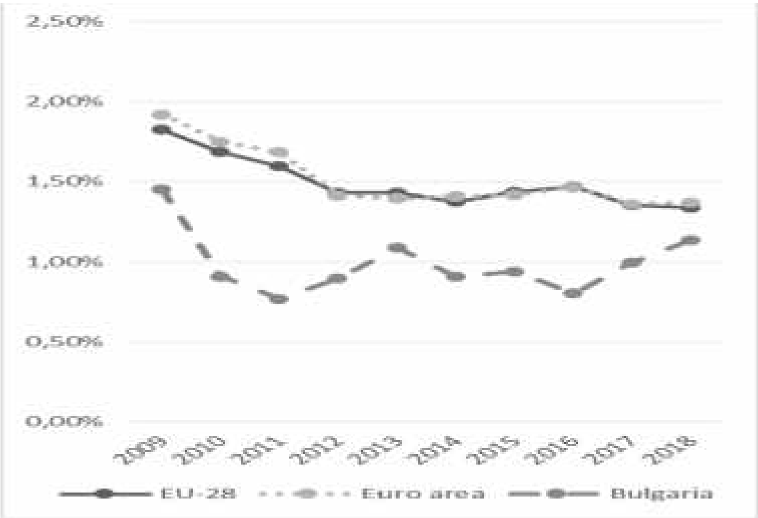
The main concern is how Bulgaria could reach the national target of 1.5 % R&D intensity in 2020. This national target implies a dramatic increase in R&D over the next years, which is hardy possible.

The difference between the research investment in Bulgaria and other transition economies is substantial. Countries like Slovenia, the Czech Republic, Hungary or even Poland recover their research system. Bulgaria is in less favoured position compare to all those countries, with the exception of Romania which had always a much lower research intensity economic structure.

Another important indicator is the share of agricultural R&D in generated gross value added in the sector. The results in Bulgaria are compared to EU-28 and Eurozone. (Figure 10).

The results show that after Bulgaria accession to the EU, the share of R&D expenditures in agricultural GVA is seriously reduced. In 2014, the indicator is 2.3 times lower compere to 2007. In the past few years the share is increasing although it is below 2009 levels. The dynamics can be explained with the global economic and financial crisis, as well as with the challenges in Bulgarian innovation system.

Fig. 10. Share of intramural agricultural R&D expenditure in the Gross Value Added in the sector (%)



Source: Eurostat, NSI

The results indicated that Bulgarian agricultural innovation system is facing major challenges and there are number of steps that should be done in order to overcome the emerging issues.

Horizon 2020 and Common agricultural policy support the R&D and innovation in agriculture. Horizon 2020 provides financial aid in five priority areas for research and innovation and also for clusters under two thematic headings. Measure 16 and LEADER approach under Pillar 2 are encouraging innovation, enhancing social capital and knowledge and information transfer. (Shishkova, 2017). Post 2020 Horizon Europe supports the agricultural innovation system. Bulgaria should improve the administrative capacity and benefit from the EU funds.

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the survey, the following main conclusions can be drawn:

1. On the basis of a literature review, various concepts, definitions and classifications of innovation are highlighted. Nowadays they are defined not only as a technological change, but also as a new marketing method or a new organizational method in business practices in the workplace, organization or external relations.
2. In the agricultural sector, the application of innovation technologies are considered as answer to a number of challenges related to food security, climate change and resource depletion.
3. The development of the agricultural sector is highly dependent on the innovation process. Innovation is a prerequisite for higher productivity, competitiveness and plays a key role in creating employment, generating income, combating poverty and social exclusion.
4. Precision agriculture, on the other hand, is closely linked to innovation in the agricultural sector. It is seen as an environmentally friendly system that optimizes the quality and quantity of the product, while minimizing costs, human intervention and changes caused by natural conditions.
5. Innovation technologies in soft fruit production as a new concept have developed rapidly over the last two decades, helping farmers to achieve optimal growing conditions, improve productivity, competitiveness and sustainability.
6. In order to analyze the potential economic and environmental effects of precision production technologies, traditional concepts in the production economy can be applied, including the optimization of the link between resources - results, profit, efficiency, etc.
7. Based on the methodological framework the method "Case study" is applied. The implementation of different technologies for soft fruits production in five farms was compared: open fields, standard tunnels, advanced tunnels and glasshouses.
8. The production of soft fruits outdoors is considered as inefficient in the UK and other Western European countries. In Bulgaria, this is the main system for growing soft fruits, which is a prerequisite for low yields and poor fruit quality.
9. Based on a comparison of the different soft fruit technologies in the UK, the highest yields are registered in glasshouses, followed by advanced tunnels, standard tunnels and open fields.

10. After the adoption of standard tunnels in Bulgaria, a significant improvement in terms of technical and total economic efficiency has been achieved.

11. The other great advantage after the application of innovations in the studied farm in Bulgaria is a serious improvement of quality, which allows sales of fresh blackberries in supermarkets, an opportunity difficult to achieve before the application of innovative technologies in precision agriculture.

12. Despite the significantly higher investment costs related to the application of precision technologies, farmers should consider their application in order to compete on the Bulgarian and European markets and to meet quality standards.

13. New technologies reduce not only production costs but also the impact on the environment, while on the other hand they can help solve food security problems.

14. There are a number of challenges related to the application, adoption and diffusion of new technologies. The need for skilled labour, investment costs, lack of support and consulting services limit the process in Bulgaria.

15. Bulgaria is one of the first countries in the world to develop digitalization strategy, which has not been adopted at this stage.

16. The most widely applied precision technologies in Bulgaria are GNSS systems, as well as technologies for monitoring yield and spraying.

17. The adoption of these precision technologies is concentrated mainly in large farms in Northern Bulgaria, which specialize in the production of cereals and oilseeds.

18. The majority of the large farms also use soil analysis technology, Geoscan and meteorological stations.

19. Several large fruit and vegetable producers implement precision irrigation systems and precision planting. In contrast, small and very small farms do not adopt PA technologies and their access to new technologies is limited. The livestock sector lags far behind crop production in the implementation of PA.

20. Several companies offer a wide variety of different products - precision farming systems and different software. However, implementation is limited to large farms.

21. The investment in precision agriculture depends on the economic potential of the individual farmer or entrepreneur. Therefore, there is a lack of comprehensive information on investment, the level of digitization and precision farming technologies.

22. In Bulgaria, the benefits of adopting precision technologies are widely discussed in various forums, conferences and seminars. However, there is no official information on their perception by farmers. In this regard, at the end of 2018, a random sample survey of all agricultural producers from the Ministry of Agriculture, Food and Forestry was conducted.

23. Data from a sample of 258 farms show that 49% of respondents are not familiar with new technologies, only 4% of farmers plan to invest, while 38% of farmers do not intend to apply digital technologies.

24. Another possibility for the adoption of innovations and digitalisation of agriculture is related to agricultural hubs. Under Horizon 2020, the SmartAgriHubs project is selected and coordinated by the Wageningen University. The Bulgarian AgroHub.BG is part of the European project SmartAgriHubs.

25. However, the results of the survey show a low share of R&D expenditure in national total budget. Bulgaria is far below the level of 1.5% chosen in the 2020 strategy and needs to review the targets.

26. The share of R&D expenditure in agriculture is declining and Bulgaria is lagging behind the EU-28 average.

27. Despite the high potential of the Bulgarian agricultural innovation system, it is characterized by unclear priorities. There is no good coordination and integration.

28. The digitalization of Bulgarian agriculture and rural areas, including public administration, needs to be a important priority in Bulgaria.

29. The expected benefits of the digitalization of agriculture in Bulgaria are: increased production; better quality; saving of water resources; lower production costs; real-time production information; better animal health; precise assessment of farms; reducing the impact on the environment.

30. Bulgaria ranks 26th among the 28 Member States of the European Union according to the index for the implementation of digital technologies in the economies and society for 2018, which shows the significant challenges that the country is facing.

31. Better coordination between the goverment and the private sector is needed to successfully digitize agriculture.

32. The new programming period 2021-2027 provides opportunities for financial support and Bulgaria needs to improve coordination between ministries, agencies and other actors in the system.

Based on the conclusions made, the following recommendations can be formulated:

- It is necessary to undertake a purposeful state policy in the field of application of innovations and precise technologies in agriculture of Bulgaria. For this purpose, both national and European funding under the CAP and Horizon Europe can be used. This requires clearer coordination between institutions to implement the proposed technological development and digitization measures.

- One of Horizon Europe's priorities is investment in innovation technologies. In order to realize the opportunities, it is necessary to build institutional capacity for implementation of projects under the programs Horizon Europe and RDP 2021-2027.
- In order to apply the innovations in Bulgarian agriculture, it is necessary to stimulate the improvement of the awareness, the educational level and the practical experience of the agricultural producers. A strategy needs to be developed, including not only seminars, but the practical training and the promotion of cooperation and integration between farmers. There is also a need to raise awareness of new technologies and their positive effects and benefits.
- The government should stimulate highly qualified and educated human resources. The Bulgarian scientist should be encouraged to participate in European programs and projects. Young people need to be involved in agricultural science. It is necessary to increase the funds for R&D and to improve the conditions for Bulgarian scientists and specialists. This process will increase the capacity for creation and implementation of innovations.
- Support for public-private cooperation is another step towards improving the national system of innovation in agriculture. Cooperation between universities, research institutes, organizations and enterprises have to be developed in order apply precision technologies. In this regard, national support is needed to increase the investment activity of Bulgarian enterprises. Clear priorities and their implementation for better cooperate between the various units in the process of innovation and diffusion.
- The application of technology and precision agriculture is concentrated mainly in extensive production and large farms. There is necessary to encourage and support their application in high value-added sectors. This will significantly improve their production potential, competitiveness and sustainability.

V: CONTRIBUTIONS TO THE DISSERTATION

Scientific and theoretical contributions:

- Based on a study of various literature sources, a theoritical model for identification of the nature, types and features of innovations in agriculture is presented.
- Based on the analysis and evaluation of different concepts, a definition and main components of precision agriculture are outlined.
- A methodology for research and assesment of the effect of innovation technologies in precision agriculture is selected.

Practical contributions:

- Based on the comparison, the differences in productivity, costs and revenues for different production technologies are highlighted.
- Based on the methodological approach, the effect of innovation technologies in the soft fruit production has been assessed.
- The role of research and development for innovation activity in the agricultural sector is studied.
- The opportunities for institutional support for implementation of innovations and digitalization of rural areas are presented.

VI: PUBLICATIONS RELATED TO THE DISSERTATION

1. Dunchev, D., 2019. **INNOVATION TECHNOLOGIES IN SOFT FRUIT PRODUCTION**- Trakia Journal of Sciences, Vol. 17, Suppl. 1, pp. 215-220, 2019, doi:10.15547/tjs.2019.s.01.036

2. Dunchev,D., Rositsa Beluhova-Uzunova, 2019. **AGRICULTURAL INNOVATION SYSTEM: THE ROLE OF R&D IN BULGARIA,** AGRICULTURAL SCIENCES Volume 11, Issue 26, pp. 59 – 64.

3. Beluhova-Uzunova, R., D. Dunchev, 2019. **PRECISION FARMING – CONCEPTS AND PERSPECTIVES**, Problems of Agricultural Economics / Zagadnienia Ekonomiki Rolnej 2019;360(3):142–155, DOI: https://doi.org/10.30858/zer/112132

4. Dunchev, D., D. Atanasov, **2019**. **IMPACT OF INNOVATIONS ON TECHNICAL EFFICIENCY OF SOFT FRUITS PRODUCTION**, AGRICULTURAL SCIENCES Volume 11, Issue 26, pp. 41 – 45.

5. Стоянов, Г., Д. Дунчев, 2020. **ВЛИЯНИЕ НА ЛИСТНОТО ПОДХРАНВАНЕ ВЪРХУ ПРОДУКТИВНОСТТА НА ДВА СОРТА ОБИКНОВЕНА ПШЕНИЦА**, Научни трудове на АГРАРЕН УНИВЕРСИТЕТ- ПЛОВДИВ, (под печат).