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FARM
Fostering Agriculture
Rural Development
and Land Management

On-line catalogue on existing ICT-DSS tools

"Fostering Agriculture Rural Development and Land Management"

FARM

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Table of Contents

„*In the world of tomorrow, if we want to be the master of our own destiny, confident in our means, value and choices, we must rely on digitally empowered and capable citizens, a digitally skilled workforce and way more digital experts than today. This should be fostered by the development of a high-performing digital education ecosystem, as well as by an effective policy to promote links with and attract talent from all over the globe*“ (2030 Digital Compass, 2021, p.4).

Introduction

Agriculture is a business sector ideal for the application of DSS (Decision Support System) tools because it is based on natural resources, requires the distribution and/or utilization of large quantities of products, goods and services, but also it increasingly demands recording the details of its business operations from the fields to the market. The rapid implementation of technical and technological innovation in agriculture by the agricultural producers relates to a greater and wider quantum of knowledge. The development brings complex problems for which not only knowledge in the agriculture is required, but also from some fields that have been inconsistent until recently, like information - communication technology, environmental protection, food safety etc. These are exactly the areas in which innovations are born on a daily basis. The everyday life imposes the necessity of stakeholders in food production for a continuous acquirement of new knowledge and skills. Almost all agricultural data contain some form of spatial component, and the DSS makes it possible to visualize information that, on the contrary, is difficult to interpret. The value of DSS in agriculture is increasing as advances in technology increase the need and opportunities for the procurement, management and analysis of spatial data on farms and the agricultural value chain. FARM project identified the insufficient linkages between educational institutions, government bodies and stakeholders at the project partner countries where agriculture still stagnates in progress, rate of unemployment increases and driving forces in society disperse inadequately. Farmers keep to traditional methods, while farming and rustication seem unattractive to young people and are not considered a prospective and life mission. Modern approaches in agriculture and number of adequately trained professionals and training programs is insufficient. Innovation and transferability are key strengths of FARM and it addresses deficiency and need for agricultural technology appliance and corresponding training through incorporation of existing and development of new DSS tools to promote digitalization in agriculture.

As a technology, DSS has made great advantages since its initial use in the 1960s by cartographers who wished to apply computer techniques in the making of maps to the present day use of DSS as a diverse set of tools. Today's DSSs has evolved greatly from the innovations created by an initial application of GIS (Geospatial Information System) on which subsequent applications are built. Hence, GIS users, through the formal and informal sharing of their innovations and applications, have been very important in developing the DSS tools available today. Sharing applications and innovations among users remains an important aspect of DSS in the business sector.

The application of DSS in agriculture is multidimensional, example:

- the application of ICT-DSS in integrated land pest management;
- utilization of sugar beet nitrogen by satellite scan and DSS;
- using past experiences to reduce soil sampling errors;
- development of productivity zones through data from the monitoring of multi-year yields;
- weed management at a specific field location: forecasts from hand-drawn maps;
- assess the quality of site-specific fertility management maps;
- gathering more information from the yield database;
- creating maps for soil salinity with the help of DSS;
- application of DSS and mobile technology to determine soil hardness at different depths;
- collocation of multiple self-created data levels.

DSS tools are widely used in the developed countries yet little is known about their appliance at more of the FARM project consortium countries. DSS tools allow for an economically feasible production without compromising farm animals' natural requirement for free movement and space or necessary monitoring of animals' health and welfare which serves in promoting and strengthening agriculture. By adopting good European practices, acquiring and applying professional knowledge, farmers reduce costs, improve and increase production and profits, and consumers get a quality and healthy product. DSS tools provide information with recommendations on how and with which preparations to protect crops from plant diseases and pests. This reduces the use of chemicals for plant protection and nutrition, i.e. protective agents are used only when it is justified and necessary. More and more farmers are using this service, because they have recognized multiple profits - costs have been reduced, yields have increased, and the product is of better quality and more competitive.

Furthermore, spatial DSS are capable to integrate spatially referenced data from different stakeholders aiming at analysing them and contribute to decision-making on sustainable measures for an environmentally sound development. They support communication and collaboration through the provision of digital maps.

The main idea of FARM is to facilitate and reinforce cross-sectorial collaboration in agriculture by providing support to agriculture practitioners to scale-up their activities by integrating innovations for sustainable development of agriculture. The priorities are to foster digitalization in agriculture sector through systematizing and approaching usage of ICT-DSS tools to the target groups; to improve the decision making by emphasizing the vital role of ICTs to empower rural communities, improve rural livelihoods, and build sustainable agriculture and food security. The work on these priorities led to an increase of regional cooperation in agriculture allowing professionals to share best practices, and coordinate regional initiatives. Regional positioning of FARM partner institutions and similarities among them open opportunities for further educative and training activities in digitalization in agriclture. Participants from different FARM countries contributed to define and develop methods and tools that consider various problems in digitalization in agriculture in a view that considers explicitly multiple (national) perspectives. This led to broader knowledge on specific DSS-ICT related issues of the stakeholders, and therefore better grounded, and consensual derived decisions.Those who use this system in agriculture recognize the potential that DSS has for agriculture. However, the people who use DSS for agricultural production are few compared to other business sectors. There is a lack of formal opportunities to share DSS applications and innovations, especially when it is focused on agriculture.

To support and promote the use of DSS in agriculture, our intention was to create an on-line catalogue of the existing DSS tools. Addressing the theme of digitalization in agriculture in one environment as is the consortium of FARM project is a real challenge. The consortium itself consists of five countries that are characterized by a mutual diversity. There differences between partners of the consortium in many aspects, which provides for a major research area. The heterogeneity of consortium partners, among other things, is reflected on the population, the total land, the agricultural arable land, the role of agriculture in the economic structure, the participation of the agricultural population in the total of retail, the agro-ecological conditions for agricultural production, as well as the level of applied digitalization in the country. Those differences were significantly clearer following the desk-research the FARM team made within the IO1 „On the on-line map of European ICT and DSS hotspots“ onto which the IO2 On-line catalogue is based. This correlation between the two FARM Intellectual outputs (IO1 and IO2) provides a basis on which users can exchange views on their applications and innovations in DSS in agriculture. This publication is entitled On-line catalogue on existing ICT DSS tools and will be published and distributed in the FARM project. With it, our intention is to merge these agricultural applications into standard DSS publications in both formal and non-formal agricultural and related education programs. The catalogue includes methodology and literature review, an aspect on the digitalization in agriculture, usage of ICT-DSS tools, an outlook as to what extent are the ICT-DSS tools present at the HEIs curricula, a perspective on the competences, knowledge and skills gained with by ICT-DSS, the benefits of ICT-DSS tools in agriculture, digitalization in agriculture from the socio-economic side, and a selection of the FARM ICT-DSS tools.

Methodology

In defining the methodology of work, it was necessary to consider the following:

1) The objective of the document - the objective of this on-line catalogue is to enable better understanding of DSS-ICT tools in agriculture and to boost to their usage.

2) Purpose of the document - the purpose of this on-line catalogue is to create the base and starting point for the application of DSS-ICT tools in agriculture in the countries of the FARM consoritum.

Heterogenous in the partner countries of the project consortium – the emphasized heterogenous condition leads to differences in many aspects to the relevant research, which primarily refers to the system of statistical records in the country and the availability of other data.

The scope of work planned within the project application - precisely defined scope of work was presented per working days for each partner.

Based on the above, but also other facts, the coordinator of IO2 (Inter-Edu) created a draft work plan and presented it during the on-line meeting in June 2021. The draft plan included specific milestones related to the development of the IO2 and based ypon the on-line survey issued at the beginning of the project, the inter-connection with the IO1 work as well as the joint approach in creating the plan. Within the next three months an analysis on the survey results was made, as well as an analysis on the collected DSS-ICT tools within IO1.The plan was further mutually discussed during the following meetings in September 2021 and October 2021 and the final version accompanied with the Methodology instruction was created and presented during the meeting in November 2021. All the partners of the consortium contributed to the improvement of the concept as well as the content of reporting, and work methodology. On the basis of the initial draft version, the collected suggestions, the outlook on IO1 outcome, and the survey analyses, the final plan for on-line catalogue was created.

The plan stipulates that all members of the consortium take part in the creation of the IO2:

- Inter-Edu as the leading instituion is creating the overall plan and works on the theoretical and some technical part of the IO2;

- UPCT and VMU work on the theoretical part related to the aspects in digitalization in agriculture;
- HSH and UCY work on the technical part of the catalogue.

Respecting the already mentioned heterogeneity within the consortium, it was rational to define more structured forms of topics. The draft document listed topics that should contain individual chapters, and the rest aspects was left to the authors themselves to have it defined. In this way, the situation in which the consortium itself would brought into the trap of creating a strictly unified statements in circumstances different data availability was avoided.

The methodology of work planned a two-phase activity, whereas the first one referred to the following:

a. Zoom team meetings to ensure common understanding of the process;
b. collection of sources and materials for analyses;
c. reviewing of sources and materials;
d. drafting of materials in English and delivering reports to activity coordinator.

The second phase referred to the following;

a. comparative review and compilation of all materials into general one, first draft reading and commenting;
b. selection of relevant DSS-ICT tools for the catalogue;
c. designing and publishing.

The methodology provided according to the plan was complied during the preparation of the the report.

During the creation of the many single samples and the unified catalogue material a large number of technical and scientific articles were consulted as well as documents related to digitalization in agriculture in EU and individual states.

The working language of the on-line catalogue is in English onto which the entire set material is written.

Literature review

Considering the importance of emphasizing the significance of the ICT-DSS and raising the awareness for including them in both formal and informal education and training in the agriculture, this on-line catalogue is further directed towards the following:

- to collect at one place a significant number of ICT-DSS tools;
- to present a clear picture about digitalization in agriculture; and,
- to make it an on-line tool for exchange of good practices in the field of digitalization in agriculture.

In that context, for the preparation of this on-line catalogue, a particular emphasis was put on the available literature in this field, including: scientific and expert papers about ICT-DSS tools digitalization in agriculture in general, as well as studies and key documents and constraints in the agricultural digitalization.

The conditions for agricultural production are rapidly changing due to urbanisation, growing inequities, human migration, globalisation, changing dietary preferences, climate change, environmental degradation, a trend toward biofuels and an increasing population. Farmers need to adapt production and management systems in order to maintain or even enhance the competitiveness of their businesses. Innovations are expressed in structural changes (farm size, cooperation, land ownership, labour/income organisation, equity capital and borrowed capital ratio, infrastructure, market structure) and in farming practices (intensity, productivity and specialisation/diversification of existing systems, new products and technologies, management innovations). Agricultural information, knowledge and the ability to learn are preconditions to handle change successfully. A very good knowledge of innovative technologies and processes is crucial when a farmer plans to:

- increase productivity of traditional production system e.g. by introducing new technology (intensification);
- produce new crops, animals or services (diversification);
- reduce the scope of farm products (specialisation);

- alter the farm's orientation e.g. towards organic farming;
- change the farm's size (e.g. full-time versus part-time farming, family labour versus employees etc.).

Agricultural knowledge and information systems aim to support the knowledge exchange between farmers, technology developers, plant breeders, universities and researchers. Technologies, such as artificial intelligence (AI), robotics, the Internet of Things (IoT), Edge Computing, 5G, blockchain and supercomputing, all have the potential to make agriculture more efficient, sustainable, and competitive. Besides being one of the world leading producers of food, EU agriculture still faces many challenges like: environmental pressurs, climate change and loss of biodiversity. Even more, the use of the digital technologies in the agriculture and rural areas in EU is very low on average. There is a lack of information about the existing technologies, lack of digital skills and lack of research and innovation activities. Therefore, the modernization and digitalization in agriculture is focused towards:

- providing general information on digitalization in agriculture to all the agrcultural stakeholders and decision-makers;
- providing compensatory learning in basic skills which individuals may not have acquired earlier in their initial education or training;
- acquiring, improving or updating knowledge, skills or competences in digitalization in agriculture.

Digital agriculture tools have emerged to mitigate the challenges faced by smallholder farmers, including low productivity and income, financial exclusion and climate change. Digital agriculture is also enabling other actors in agricultural value chains, from agribusinesses to cooperatives, to increase efficiencies in the agricultural last mile.

In its Communication on the future of Food and Farming of 29 November 2017, the European Commission underlined that support for knowledge, innovation and technology will be essential for the Common Agricultural Policy (hereinafter CAP) if it is to be ready for the future. Based on that document, the European Commission has drafted regulations to define the future CAP. Within the draft regulations that set out rules on support for the strategic plans to be drawn up by Member States under the 2021-2027 CAP, Article 5 states that the three general objectives "shall be complemented by the cross-cutting objective of modernising the sector by fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas, and encouraging their uptake". Furthermore, among the specific objectives there is the need to "enhance market orientation and increase competitiveness, with greater focus on research, technology and digitisation” [1].

In April 2019 24 EU member states signed the Declaration on "A smart and sustainable digital future for European agriculture and rural areas" which requires actions in three signifcant areas:

- research and innovation covering AI and the socio-economic, agronomic, and environmental aspects of digitising agriculture.
- adoption and deployment,supporting the CAP'S transition towards a result- based policy and to build a strong smart agri-food sector.
- pooling and sharing of agricultural data between farmers and throughout the food chain [2].

According to the Declaration activities are already taken in the fields of research and innovation, innovation infrastructure and pooling and sharing agricultural data.

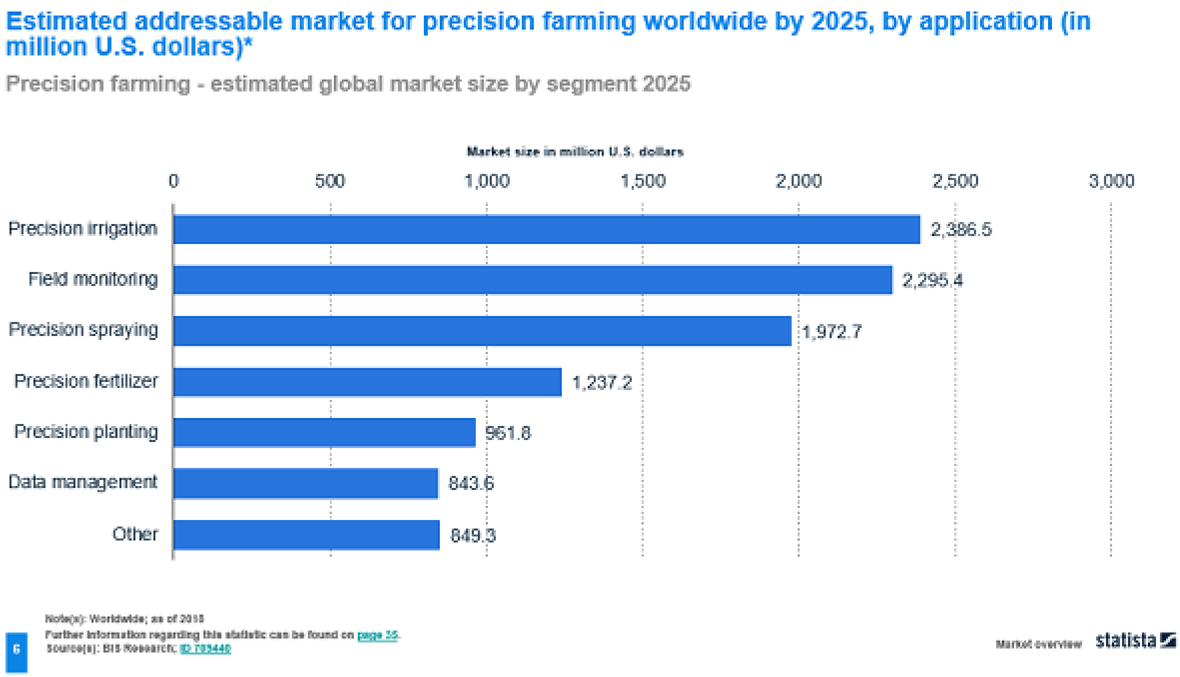

Fig. 1. Estimated addressable market for precision farming by 2025 [3]

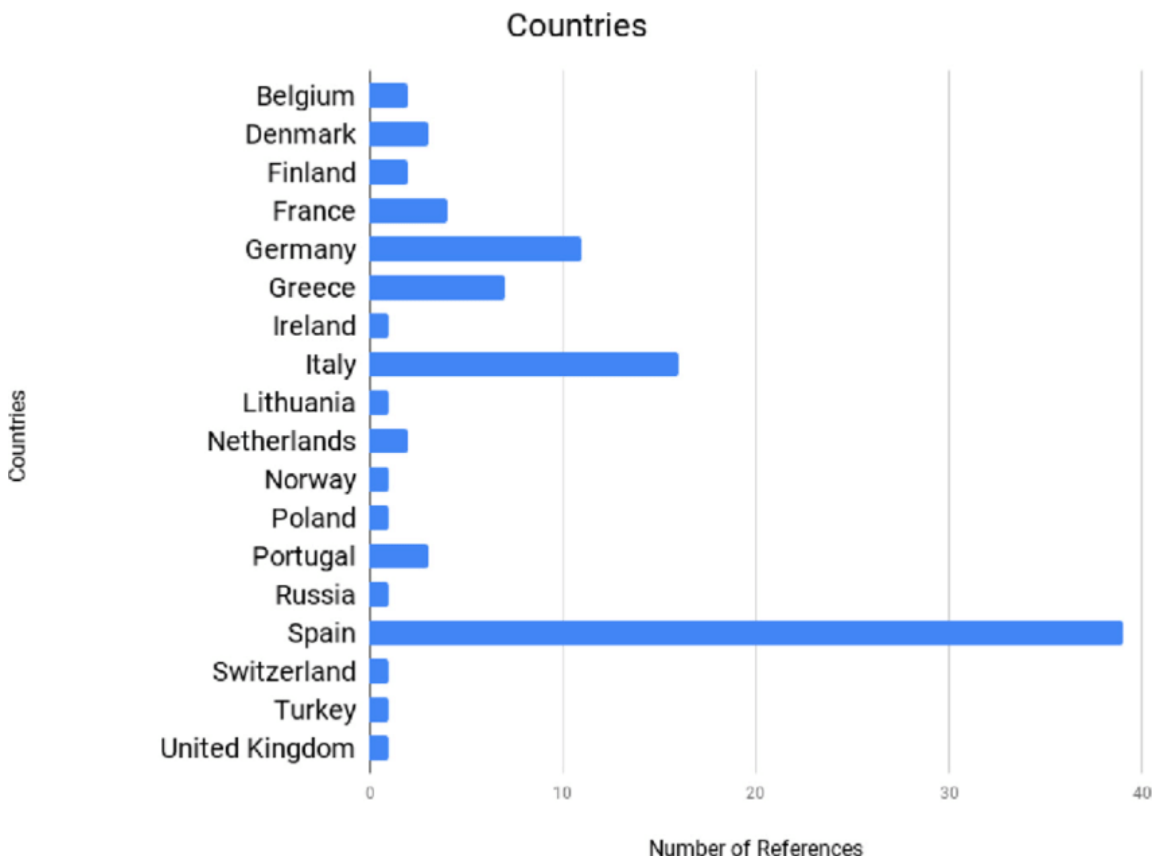

Fig. 2. Big data in smart farming per EU countries [4]

FARM is constituted of four EU countries and one Western Balkan country. To start with the last, the digitalization in agriculture in the Republic of North Macedonia is insignificant. This country's profile is still oriented towards the traditional agricultural production in particularly in the rural areas. The agricultural branch is still unidentified and fragmented and the acceptance of new skills and technologies is taking slow. Particular governmental and non-governmental bodies are taking some initiatives for start-ups in this field, but the outcomes of those activities are still not making visible progress. Cyprus is on the 24th position as per the DESI index 2020 and on the foremost place of all EU countries. The main problems of the Agriculture sector in Cyprus are: over-segmentation of the agricultural land; aging of the farming population, issue of lack of successors from the new generation; low educational level of the farming population; less than ideal soil quality, tough weather/climate conditions like irregular raining seasons, prolonged dry seasons, hailstorms etc; high production costs; problems in terms of trading agricultural goods, caused by the lack of market organization [5]. Lithuania, though an EU state, is also suffering with the full implementation in the agriculture digitalization. The higher educational institutions are making research and pilot projects in the field and the Lithuanian IT companies developed significant amount of innovative public sector solutions [6].

The situation is slightly different in Spain and Germany where the smart farming is already applied as the future of agriculture, with digital technologies enabling efficient and resource-saving farming. In Germany for example, the Federal Ministry of Transport and Digital Infrastructure (BMVI) is leading this process. With the federal funding programme on expanding broadband infrastructure, the BMVI aims to create highly efficient broadband networks in areas that have so far had inadequate coverage. The national government provides substantial funding to implement projects on broadband expansion [7].

In Spain, the important need to have an active role in the digital transformation of the sector to tackle the digital and structural divide, and to counteract the depopulation process in different rural areas to allow the sustainability of the agri-food sector and its subsectors in a very diverse country is already realized. There is a digital boost for the Southern Spain food farming industry which contributed to better cooperation and growing business [8].

The adoption of digital technologies in agriculture differs from country to country, and from region to region. Smallholder farmers have yet to experience the widespread benefits of this digital transformation, and they are lagging behind when it comes to the adoption of digital agriculture solutions and innovations due to lack of trust in the potential of ICTs, limited digital skills, connectivity issues and restricted availability of ICT-based solutions to utilize and scale up. Realizing the full potential of digital agriculture transformation requires identifying, sharing and implementing best practices and proven solutions across countries, involving all actors in participatory processes [9]. Digital technologies can help farmers increase their profitability and reduce their environmental impact, therefore the key question elaborated on the following pages is: what are the implications of the digital transformation for the agricultural sector and how can farmers, the environment and consumers benefit equally from the new opportunities.

Digitalization in agriculture

A digital transformation is in full swing all over the world, particularly in activities related to agriculture and food. Many benefits are expected from digitalization, particularly in terms of improving productivity, working conditions or consumer information, and reducing hunger and poverty in the world, the inclusion of farmers in value chains and the fight against climate change [10]. The FAO estimates that to feed the global population, a 70% increase in agricultural production is needed. Nonetheless, desertification, land grabbing and the relative reduction of farm productivity represent crucial constraints that might limit the possibility of meeting that target. In addition, resource degradation and climate change raise serious concerns about the development paradigm promoted during the post-Green Revolution [11].

Agri-Food 4.0 will emerge in terms of integrating demographic changes, digital technology, climate change, poverty, and unequal distribution of resources in the sector. The high potential of digital applications for agriculture generates enthusiasm about the future of food production. Some view the intelligence offered by digital tools as a way to solve the still pressing food problem. In that context, the development of information and communication technologies (ICT) is changing agri-food systems, both in terms of the production of goods and services and their overall functioning. The arrival of new players (start-ups, platforms, etc.) offering new technological and digital solutions (e.g. sensors, big data, algorithms, block-chain, etc.) modifies traditional structures, diversifies production methods and marketing and calls for major managerial and organizational innovations.

Every day in the world we generate a colossal amount of data in different sectors. Agriculture 4.0 is the evolution of precision agriculture and refers to the set of actions that are implemented in agriculture through precise and timely analysis of data and information collected and transmitted by advanced technologies that allow the automatic collection, integration, and analysis of data from fields, sensors, or other third-party sources. The objective of these technologies is to offer as much a precise support as possible to the farmer in the decision-making process concerning his own activity and the relationship with other actors in the supply chain, as well as to increase the profitability and economic, environmental, and social sustainability of agricultural processes.

In practice, farmers can rely on: state-of-the-art weather information; surveys assessing the state of the soil; analyses of the state of health of the plantation. In other cases, big data can lead to solidarity interactions and cooperation between farmers, on a local, national, or even international scale, due to the sharing of information and data collected.

Digital artifacts can ameliorate the farm management process by offering farmers and farm advisors quick-witted intelligence, therefore adding farm efficiency [12]. Indeed, big data and artificial intelligence applications enhance farmers' decision-making capacity through predictive models that five critical information [13,14], helping them to pinpoint problems, identify cause-effect connections, and making better planning decisions [15]. Moreover, the use of digital tools allows farmers to save time [16] and spend less effort on the various farm management tasks [17], improving their working condition [18].

Adopting 4.0 solutions in agriculture also means:

- Avoid waste by calculating the exact water needs of the crop or by detecting in advance the appearance of certain plant diseases or the presence of pests.
- Better control production costs and ability to plan with great precision all the phases of cultivation, sowing and harvesting, which saves time and money.
- Improve the traceability of the supply chain, keeping the entire production process under control, leading to a short chain which, with a low margin of error, allows the production of the highest quality food and sustainability.

At top of it, the farmer can, for example, have access to meteorological data; collaborative mapping of the progress of certain insects; to sensors that will allow him to know the composition of his soil and the water needs of his crops. The data collected gives the farmer a possibility of better managing the care he must give to his crops, thus tending towards a precise plot by plot agriculture. The result can be seen in terms of added value for consumers with increased product quality, for example, more natural products, better organoleptic qualities by optimizing the time of harvest. Precision agriculture also makes it possible to take into consideration the fact that the soil is not only a support for production but is a habitat. Digitization thus offers the possibility of moving towards conservation agriculture via a set of cultivation techniques intended to maintain and improve the agronomic potential of the soil, while maintaining regular and efficient production from a technical and economic point of view.

In addition, the existence of such data gives rise to a surge of start-up creations specializing in digital technology that focuses on agricultural uses of big data. Thanks to control, management and decision support tools, digitalization allows both precision and conservation agriculture, while reducing the difficulty of certain tasks.

The top benefits for farmers include:

1. Improved management and decision-making processes.
2. Improved efficiency through more target applications.
3. An increase in productivity and profit.
4. Improved marketing.

5. Real-time information.
6. Advancements in record keeping.
7. Management of risks and uncertainties.
8. A reduction in regulatory burdens.

For example, digital farming improves productivity and information by eliminating paper forms and paper data collection. It is replaced with mobile forms and a database that stores the farm information. Data collected in the field can instantly be sent to a central office or customers, improving communication accuracy.

The adoption of digital farming eliminates risks and uncertainties by giving farmers access to big data and algorithms to manage their crops. The farmer may also have access to advanced methods to troubleshoot crop and livestock management up to date, so they are not alone in making decisions.

There is an improvement in the flow of processes at the industry level due to better efficiency, optimization of the supply chain, and better industry decision-making. Digital farming also offers a way to improve quality control and assurance, and it flows into the entire rural community.

The effects only grow from there as farmers achieve improved environmental outcomes. There is an impact at the international level with enhanced collaboration and learning. Stakeholders note the impact on agriculture worldwide.

Finally, the digitalization of agriculture contributes to reduce the difficulty and time of certain tasks. Examples include the use of connected robots, tractors, or sensors that allow remote control to avoid travel on large farms. The benefit of digitization in terms of physical hardship also reflects a strong evolution of the farming profession through the necessary acquisition of new technical skills and data analysis.

From a commercial point of view, this also promotes information on the prices of raw materials sold, but also on the yields of crops or livestock. The challenge, however, lies in sorting out the relevant and crucial information for improving processes, but also the energy savings that can result, especially in water.

However, digitalization has not only brought added value to agriculture, but has also created many new challenges, including changes in user competence. The added value, which is recognized through faster and more convenient communication with each other, has actually created redundant information, which on one hand allows the farmer to compare products, markets, prices and opinions, while on the other hand encourages the farmer to fulfill the needs based on others, usually sellers, choice. One of the features of digitization is that while some are developing optimization algorithms, others are trying to push their goods, opinions, and services through search engines. All this is not only making value for the farmers, but at the same time increases the tension for them, who find it difficult to choose the most appropriate searched thing. Thus, in addition to the indisputable added value, digitization also creates an unnecessary amounts of information junk at the same making data mining a second profession for the farmer. The truth is that data mining takes the farmers an enormous amount of their time because of need to navigate in useless information to find what they need.

Despite the above mentioned, and considering it from the management perspective, digital tools are already step ahead comparing to traditional ways of farming, but at the same time they imply new knowledge, skills and competencies that farmers don't have. Uses of these technologies leads to acquiring new skills which are needed for successful operation of different tools for their programming and exploitation. Today, farmers can rest in the tractor cultivating the field, yet they first need to learn how to use the digital technologies which will be used in operation, digital monitoring, command execution and overall performance control. Besides, the farmers will have to program the device and to develop optimal algorithm by activating it. All this has to be done using digital tools and specific knowledge and thinking.

Lots of programmers and software designers work making digital technologies more sophisticated and preprogram as much as possible routine operations in order to help farmers be simple users instead of pushing them to learn fundamentals of digitalization which inevitably led to the digital thinking. Dealing with the digitalization challenges some of the farmers started to look for more advanced and educated workers while others start to learn new techniques of operation and farming by themselves. The most successful ones have mastered the most advanced digitization technologies and thus unrecognizably improved traditional farming. Others are still cautious about technologies and attribute them to mass production unacceptable to the size of their farm due to the challenges it dictates and not only to grow more but also to process and sell, which is seen by them as creating additional challenges that are currently insurmountable.

However, even in such situations, evolution and digitalization are increasingly penetrating farms, offering increasingly compact, cheaper and more manageable digital tools that make it easier for the farmers to understand digital technologies. They are designed to replicate technologies already used by the farmers such as web-based applications, operational keypads replicating TV remote control, joystick, or simulating basic connectors by hiding digital solutions and their algorithms in the embedded computers already preprogrammed by the production team. The preprogrammed experience is based on monitoring of the practices of thousands of farmers and comparing them, with the goal to find the optimal solution that will lead the farmer to success.

Eventually, another benefit of digitalization worth mentioning is the elimination of distances between the city and the villages and the attraction of the urban workforce that was lost historically because of emigration. That is creating unique opportunities for the citizens to engage in farming by developing robots and digital technologies which can be developed and programmed by a specialist living in the city. This scenario is certainly difficult to imagine in the conditions of traditional farming. So today, after losing a farm worker, a farmer substitutes the worker from the city by introducing more advanced digitalized technologies on the farm. In addition, in this way it expands his horizon of socialization by involving the citizen living not only in a nearby city, but also in another state or continent, which allows to take over not only production-technological, but also cultural traditions and practices, which is an opportunity for the farmer to bring globalization into his farm thanks to digitalization.

In addition, digitalization in agriculture today has the potential to generate more value related to the increase of performance and efficiency. In the past, the farmers sought efficiency by carefully memorizing positive and negative experiences and sharing them from generation to generation. Today, with the help of sensors built into the equipment, a database of equipment use is compiled, which allows to identify the experience of farmers using the technology in the world, compare it and discover the most optimal algorithms for operation, efficiency and economy.

It is on this basis that digitalization has made an unprecedented breakthrough looking from an economic and technological perspective. This led to the development of smaller and more operational tools which are more compact. At the same time, they were more precise and better fitted the farmers' needs. Moreover, these tools integrate algorithms which nearly almost completely compensate lack of farmers' knowledge and experience which means that farmers could start their own farming without spending time to learn from the past generations. It means that with digital technologies the global learning become possible and the global practices come closer to the farms and farmers. So, it is possible to say that the digitalization opened window to the global experience and lead the global farming to the faster evolution based on data share.

Due to digitalization family-based knowledge farms become global knowledge-based farms which provides a more effective control climate change, disasters and allow to extrapolate experiences of one region to another. Thus, if a farmer has experienced a drought in the past, he has had to go to the southern regions to learn how to farm in arid regions. Today it is enough to buy digital technologies and devices which will increase efficiency of farming during difficult periods and will ease adaptation to climate change.

Digitalization in agriculture from the socio-economic side

Agriculture is constantly confronted with the opportunities and risks of technological advancement, which requires a study of their environmental impact. An important element of the greening of agricultural production is the introduction of digitization. In theory and economic policy, it is regarded as an integral part of the fourth industrial revolution and is closely intertwined with material and biological technologies. Businesses are much more likely to use innovative information technology solutions that have a positive impact on productivity and streamline production than ever before. Therefore, an important task of modern economic science is to study the risks of digitization in the field of environmental protection. In this sense, Various aspects of economic digitization have been the subject of research by many scholars. Among them, there are some important researches made by Negroponte [19], Brennen and Kreiss [20], Cieniawska and Rühle [21], Petrenko [22], Yudina [23].

In general, in terms of digitization, all countries in the world are divided into four groups, characterized by different stages of development. The main groups are the countries with the highest level of digitization includes naturally developed countries of the world with a high level of GDP per capita and human development index, which is the result of science-intensive and innovative economy. According to the World Bank, in 2018, Norway ranked third in the country's GDP per capita ($ 81.8), the US seventh ($ 62.6), Australia eighth ($ 57.3) (World Bank, 2018). This group includes almost all European Union countries, Japan, Hong Kong and others. And the countries with the lowest level of digitization (0-30%) include the vast majority of countries in Africa, India, Afghanistan, Uzbekistan, Vietnam and others. These countries are ranked last in the country's GDP per capita and human development index. Digital agriculture means the creation, development and application of innovative methods for the use of information and communication technologies in the agricultural sector of the economy. It is defined by the terms "precision farming", "smart farming" and "agriculture 4.0", which mean the development of sustainable agriculture based on digitized production processes. Different levels of digitization can be identified in agriculture (Figure 3).

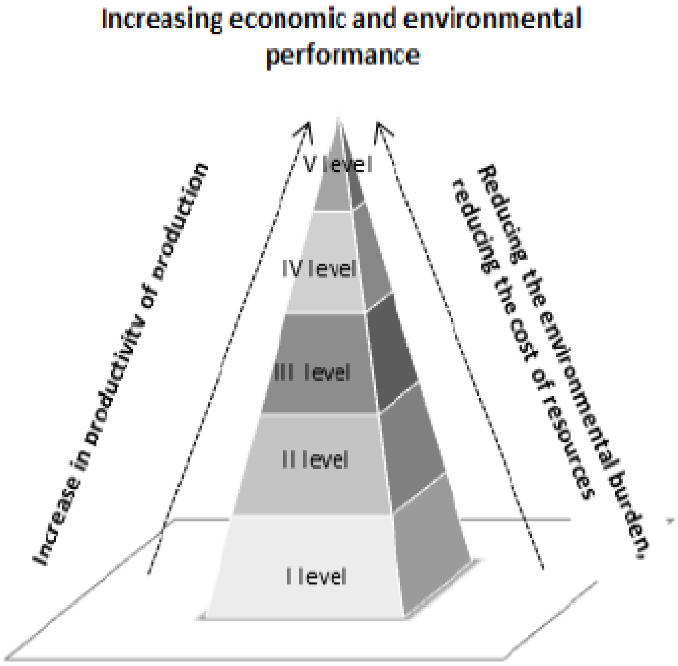

Fig. 3. Levels of agricultural digitization [24, 25].

- Level I is the use in the production process of only one computerized object, such as a machine equipped with sensors, which after processing transmits information directly to the operator.
- Level II is the formation of complex objects, for example, tractor units, which are interconnected by an information system with the ability to exchange data to optimize the operating parameters of both tractor and machine.
- Level III is an object connected to a network; an example would be a system consisting of several agricultural machines that are interconnected and operated automatically (self-propelled combine, trailers, transport kit, tractor).
- Level IV is a digital production system that includes not only individual machines and machine units, but also individual links in the technological chain.
- Level V - the highest level of digitization - is a comprehensive mix of systems that are interconnected [24].

It is believed that it is advisable to depict graphically the levels of agricultural digitization in the form of a pyramid, which will show a reduction in the number of individual operations with increasing levels. The above also leads to the conclusion that the increase in the level of digitization of production processes in agriculture directly correlates with the efficiency of production, and inversely proportional to the cost of resources and the load on the environment. For the purpose of greening agriculture, it is advisable to determine the environmental effect of the introduction of digitization of its production processes. Table 1 allows to conclude about the positive impact of the digitization of production processes in agriculture on the greening of the industry.

Table 1. Comparison of economic and environmental effects from the introduction of digital technologies in the agricultural sector * [25]

Tech-nology	Economic Effect	Ecological Effect
Driving in parallel	15% fuel, seed, fertilizer and plant protection cost savings	reducing the load on land resources, improving soil structure and reducing its compaction, reducing the amount of fertilizers and plant protection products
Standards management	resource savings of 10%, increased profits through increased crop yields and animal productivity	automatic application of fertilizers, herbicides, chemicals reduces the negative impact on land and water resources, reduces the level of emissions into the atmosphere
Soil Analysis	reducing production costs, optimizing fertilizer application, increasing yields and increasing efficiency by 10-30%	optimizing fertilizer application, improving soil structure by identifying the need for lime and diagnosing excessive salinity or alkalinity
Drones	fuel saving, minimizing the use of seed, fertilizers and irrigation water, preserving and increasing crops through timely sowing and harvesting, optimizing production costs and improving the quality of production planning for agribusinesses	rational use of land and water resources, optimal application of plant protection products through the use of spot spraying technology in specific areas of the field. Possibility of using bio-organisms
Satellite monitoring	cost savings of fuel, seeds, fertilizers and plant protection products, increase of production efficiency, possibility of land suitability assessment, development of reclamation plan, estimation of potential yield	economical impact on the environment of chemicals through their optimum application according to the mapping of fields and crops
Weather monitoring	increase of efficiency of production operations, increase of yield and its less dependence on climatic conditions, economy of expenses on resources, in improvement of financial results	creation of an archive of data of natural and climatic conditions of the territory

* formed by the authors based on their own research

At the same time the dangers that the digitization of the agricultural sector of the economy entails should not be ignored. Among these, it is important to highlight the following risks:

- Technology reliability and data sovereignty.
- The introduction of digitization requires a continuous increase in the level of education of agricultural producers.
- Innovation and high technology of digitization require highly skilled workers, and some of the low-skilled work will be done automatically.
- Digitization trends in agriculture show high efficiency from its implementation in large companies with large scale production.

In the research of Burliai et al. [25] it was concluded that the digitization is a trend of modern agriculture, the essence of which is to create, develop and apply innovative methods of using information and communication technologies in the agricultural sector of the economy. Some countries like Ukraine have significant digital implementation potential. This is especially true in the agricultural sector, which is responsible for the food security of the population and plays a significant role in the country's economy. The development of digitization in agriculture has a significant economic effect, which is manifested in increasing the efficiency of agricultural production and increasing the competitiveness of the industry. At the same time, it is important to note the positive environmental impact of agricultural industrialization, which contributes to the sustainable development of society.

Precision agriculture is an opportunity for farmers. Broader horizons of precision farming are opened by evolving technology, growing opportunities for information technology and new telecommunications systems. Especially a lot of knowledge and competence is required to apply the concept of Precision farming. Precision farming is an innovative, information-based, production concept for crop production. It relies on a variety of new or evolving technologies (such as the Global Positioning System, sensor technology and geoinformation systems). A specific example of the development of DSS and its consideration by the Lithuanian Agricultural Advisory Service is IKMIS.

Before implementing the concept of precision farming, scientists in cooperation with farmers and students of the Vytautas Magnus University Academy of Agriculture (Lithuania) seek to substantiate the technological processes of precision farming, study their efficiency, reduce the impact on the environment and the cost of agricultural production, and prepare recommendations for precision farming techniques.

IKMIS – an updated decision support system of integrated plant protection information, consulting and training, which consists of 4 electronic services. The decision support system is available (www.ikmis.lt) free of charge to private crop, horticultural and gardening farms, advisors and all agricultural enthusiasts.

The network of meteorological stations of the Advisory Service has modernized, expanded and condensed by integrating the data of the Lithuanian Hydrometeorological Service stations. The farmers are able to see the situation of various agricultural crops by choosing any territory of the country. The data is linked to new disease and pest prediction modules that mathematically calculate the likelihood of disease or pest occurrence. Unmanned aerial vehicles and nitrogen demand measuring devices are used for the accuracy and speed of the information, and catalogues of plant protection products, diseases, pets and weeds are supplemented with high-quality visual materials. This makes easier to identify the disease, the pest and make it easier to select registered plant protection products that eliminate them. IKMIS meet the typical requirements for dataset and transmission (see table 2).

When farmers need advice on the application of integrated pest management, they able to contact crop specialists and district office advisers in an interactive way. In addition, using the IKMIS system farmer able to study remotely according to up to 13 training programs, and with the installed electronic signature they able to sign the issued certificates of qualification and ones for users and distributors of plant protection products. Everything is in one place and without leaving home.

Table 2. Model for the use of station data

No.	Title	Type	Notes
1	Global radiation	Int	[W/m²]
2	Air temperature (20 cm, 2 m height)	Float	[°C]
3	Precipitation	Float	[mm]
4	Wind speed	Float	[m/sec]
5	Wind direction	Int	[deg]
6	Leaf moisture	Int	[min]
7	Relative air humidity	Int	[%]
8	Dew point	Float	[°C]
9	Atmospheric pressure	Int	[mBar]
10	Soil humidity 20 cm	Float	[%]
11	Soil humidity 50 cm	Float	[%]
12	Soil temperature 5 cm	Float	[°C]
13	Soil temperature 20 cm	Float	[°C]
14	Soil temperature 50 cm	Float	[°C]

The developers of the system have also developed a mobile application that is suitable for all smartphone operating systems, so the most necessary IKMIS information can be in farmers „pocket“.

Digital technologies increase the efficiency of agricultural production, complement other factors of production and stimulate innovation, as well as significantly reduce costs. DSS help to overcome information barriers that prevent many small farmers from entering the market, expand knowledge through new service delivery methods and provide new ways to improve supply chain management. In Lithuania and other Eastern European countries, there are few decision support systems, and the main limiting factor is the specifics of agricultural production. The intensity of digital transformations in agriculture, the formation of the digital agrarian sector is highly dependent on the investment climate in the country, increasing investment in industry. Another barrier to the adoption of digital and communication technologies is older farmers, a rapidly aging rural community. In order to attract young people to agriculture and the countryside, it is necessary to take into account their desire to use new technologies, they willingness to develop new types of business in rural areas. It is important to find rational solutions that require investment in innovation, education and training.

For successful implementation of the program of digitalization of agriculture, the state needs to participate in the following areas [26]:

- Development of a methodology for planning, forecasting, monitoring and reporting in the implementation of agricultural development programs;
- Creating a system of educational programs that provide retraining, formation competence frames for digital agriculture;
- Adaptation of legislation to the technological requirements necessary for the intensive introduction of digital agriculture;
- Material incentives for agricultural producers to introduce digital technologies;
- Providing support to telecommunication companies in expanding their telecommunications coverage on agricultural land;
- Maximum implementation of electronic document management, reporting; automation of public services and decision-making systems.

Usage of ICT-DSS tools

For farmers, ICT (Information and Communication Technologies) are part of their daily lives. Indeed, at every moment of the day, they use these technologies, be it in precision farming or the internet, monitoring online markets. In agriculture, we have entered the era of communication between machines and of onboard intelligence. ICT has become a global tool often used by individuals as well organizations, governments, and companies for personal or official agricultural activities. Also, ICT in precision farming and resource conservation practices have a very important role for enhancing crop productivity.

Despite the digital divide that persists between urban and rural areas, agricultural producers are at the forefront of technological advances. Sowing, herd management, tire pressure, RTK GPS auto guidance system on agricultural machinery such as tractors, fertilization, milking parlor, stabling, in each place of an agricultural exploitation we find digital technologies. In the end, agriculture can be considered as one of the most advanced sectors in terms of digital technologies. Furthermore, in the same way as water, seeds and fertilizers, information is a fundamental component in agriculture and ICTs play an important role in facilitating access to information.

Information and Communication Technologies tools incorporate, radio, TV, satellite technology, PCs, satellite innovation, web including email, texting, video conferencing, PDAs and interpersonal interaction sites which have made it feasible for clients across the world to speak with one another to give their clients fast admittance to thoughts and encounters from a wide scope of individuals, networks, and societies. With the progressions in computerized correspondence, the issues of field conclusion and sickness expectation are currently being addressed all the more actually to arrive at greatest farmers.

In the pool of existing DSS ICT tools it's fascinating to focus on their normal angles rather than their particular aspects. In the second part of the catalogue the FARM project selection of the most used DSS ICT tools is presented. The DSS ICT tools for example, can be used to simulate the development of explicit harvests, confirming their varieties under various environmental change situations. Typically, these tools are site-explicit, yet they can be applied at public or potentially provincial level through a connection to a proper Geographic Information System (GIS). There are some instruments accessible, due to the big number of yields and on account of the intricacy of duplicating similar circumstances across various areas. Each tool permits examining various processes of the agricultural activities, from nearby harvest demonstrating under environmental change conditions to the administration of monetary effects on environmental change on the agro-farming sector (soil esteem varieties, request and supply, production, and so forth, etc.).

There are two major ICTs for land management: GIS and Remote Sensing (RS) systems.

GIS systems allow the collection of a lot of information that comes from different sources, in a single spatial representation, which makes it easier to reach a consensus on the planning of the territory. For example, Polish developed Metronamica is ArcGIS based system which is used for assessment of areas to the potential exposure to the UHI (urban heat island) effect. Metronomica integrates scenario analysis, land use modelling in cellular automata, and an indicator-based assessment in a geographic information system [27].

Other example of smart agriculture can be DSS tools formed by integrating the SCS-CN method with GIS software. The goal of the designed solution was to inform farmers about the location of urban hydrological sinks, which gather stormwater in urban watersheds, and the amount of water which could accumulate in each location depending on the defined precipitation and the soil’s moisture conditions. The designed DSS is based on a multicomponent methodology including both atmospheric and soil conditions [27]. It is another example which shows possibilities to link urban areas to the farms and to increase farm productivity based on their connection.

To protect and make safer the food chains GIS-based Environmental Decision Support System (EDSS) have been developed too. The RESTORE EDSS comprises a GIS-embedded modelling tool to assess the transfer of radio caesium via food chains and external radiation exposures to humans based on an understanding of the nature of contamination, geochemical, hydrological, and biological processes, the different pathways for radio caesium, and human behaviour. The EDSS accounts for spatial and temporal variation of these factors and is applicable to a variety of ecosystems. The overall aim of the EDSS is to identify vulnerable areas in terms of enhanced radionuclide transfer into food chains and/or the presence of ‘critical population groups’ that suffer enhanced internal and/or external exposure to radionuclides. Therefore, it provides information to support decisions about where to implement countermeasures and where to restore contaminated land most effectively [28].

The robustness and flexibility of decision-making especially in agriculture can be improved by using effective DSTs, particularly for the farm management. Highly advanced can be the construction and use of decision support systems as combinations of DSTs, such as the commonly used multi-criteria decision analysis (MCDA) methods and an artificial neural network (ANN), integrated with a geographical information system -GIS. The experience of many researchers is that the combination of MCDA techniques based on fuzzy logic, analytical hierarchy process (AHP) and weighted linear combination (WLC), with GIS, and possibly also incorporating ANN, provides decision-makers with a comprehensive tool for efficiently calculating decision support indices (DSIs). Hybrid tools are becoming more popular and relevant among experts due to their multiple functionalities that facilitate decision-making. An integration of DSTs in a DSS and further development of DSIs provides a path for the integration of quantitative and qualitative parameters into the decision-making process, and providing materials to be used in different processes [29].

Therefore, it can be argued that the enrichment and complementarity of conventional farming with ICT DSS tools has not only made farming more efficient and sustainable, but also enabled the integration of smarter resource allocation solutions, led to healthier farming and allowed growing of healthier products. Timely exchange of relevant information led to timely and accurate decisions and moreover all these practices based on networking can be accessed by the farmers all over the world. So, what was known in traditional farming as a farmers' business card and basically was known only to its consumers, today thanks to ICT technologies allows to combine the most advanced farming solutions and help to develop more and more advanced farming technologies and farming practices.

Remote Sensing systems are also very important tools as they ensure the monitoring of terrestrial resources (for example, vegetation, water bodies...), particularly when a single institution oversees supervising a larger territory. Data recovery in the field is an expensive and time-consuming operation. However, GIS and RS systems cannot completely replace local observations, that is, on the ground. Finding a balance between remote and on-site monitoring needs to be found, and it's not easy.

Thus, ICTs can provide solutions to improve the efficiency, productivity, and quality of work of farmers. In addition, they have many uses, especially through drones: data can be collected on the ground thanks to drones specially designed for agriculture. They also allow digital 3D printing of resin or metal parts with complex shapes. 3D is the true revolution in agricultural machinery and will surely be widely used in the future (already now) in precision agriculture.

To speed this process, different modes of communication are being used by extension service, among which recently developed ICT based Internet; websites and on-line communications play an essential role.

In this technological era of smart cities and digitalisation of livelihoods, the primitive method of farming is slowly fading away. With the rise of data-centred and smart farming, people nowadays are more inclined towards using scientific and high-tech procedures for intensive farming. In this race of agricultural evolution, developed countries like Israel, Australia, the United States and most European countries are implementing 'Internet-of-Things (IoT)' in their agri-practices for better and advanced products. In particular, Israel is leading the smart farming industry ingeniously despite the fact that the geography of the country is not naturally conducive to the agriculture, Tel Aviv is a world leader in agricultural research and development [30].

ICT in agriculture is progressively significant, is an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. The challenges facing global agriculture are complex and are becoming difficult to handle properly. Growing global population, changing dietary attributes and varying climate conditions create an alarming condition that has to be tackled efficiently. Global food production and its security for 10 billion people by 2050 is a major target for agriculture sector. Despite of all biotechnological and genetic engineering support, there is a need to get assistance from the big data analysis [31]. To enhance productivity from single acre farmers it is important to apply the more advanced technologies which mostly operate based on big amounts of data collected. To analyse all this data, the big data approaches are necessary. They help not get lost in data diversity and allow farmers to make comprehensive decisions and to solve problems based on accurate facts. DSS in agriculture activities are also utilized as convincing tools to investigate, suggest and propagate innovations/technologies equipped for improving agricultural production, income, and livelihood security of farmers.

In public sectors, it may be good sense to work together with equivalent nations with comparable designs and structures. Artificial Intelligence and Augmented Reality are both supporting Industry 4.0 and smart solutions to the sector. Various European nations include solid clusters inside these fields. Other countries like USA, Japan and Korea have, nonetheless, stronger structures and academic clusters (table 3).

Table 3. Key figures on ICT patents [32]

	Global/EU/DK Patent families 1990-2018	**Global "hotspots"***	**Nationality of Top 10 Global patent holders****	**Nationality of Top 10 European patent holders*****
Artificial Intelligence (AI)	Global: 53.776 EU: 2.438 DK: 38 DK/EU: 1,6%	China (Hong Kong & Taiwan), USA, South Korea, Japan	Japan (6), USA (3), South Korea (1)	DE (3), NL (1), UK (1)
Virtual & Augemented Reality	Global: 36.892 EU: 3.826 DK: 73 DK/EU: 1,9%	USA, Japan, South Korea, Israel, China (Taiwan)	USA (5), Japan (2), South Korea (3)	DE (2), NL (1), UK (1), FR (1), FI (1)
Cyber Security	Global: 83.109 EU: 13.800 DK: 12 DK/EU: 0,009%	USA, Japan, Israel	USA (5), South Korea (1), SE (1), Japan (1)	NL (2), DE (2), FI (1), FI (1), SE (1)
Wireless Communication	Global: 333.334 EU: 32.502 DK: 521 DK/EU: 1,6%	USA, Japan, Israel, UK	Korea (4), USA (2), SE (1), Canada (1)	DE (2), SW (1), NL (1), FR (1), FI (1), UK (1)

* Nationality of the biggest patent holders of the 10.000 most resent patents.
**Top 10 global number of organisations by country (Headquarter) who holds most patents.
***Some non-European companies are registered in Europe, and some with different names. The numbers hence don't add up to 10 cases.

More specifically, it involves the conceptualization, design, development, evaluation and application of innovative ways to use information and communication technologies (ICT) in the rural domain, with a primary focus on agriculture. ICT has the potential to communicate farm information to a large number of farmers simultaneously and quickly.

The data and strategies contain valuable information which can improve the quality of future decision supports [33]. For example, considering historical strategies as a training set, machine learning techniques can be adopted for learning successful experiences from the training set. Although ICT and DSS are only gaining momentum today, they are already blurring the line between large and small farms, as global data collection allows more accurate assessments to be made, and allowed to integrate results and decisions into the tools accessible to smaller farms. That is important to consider and different aspects to evaluate and select any DSS and upcoming challenges, such as accessibility, scalability, interoperability, uncertain and dynamic factors, expert knowledge, prediction and forecast and the analysis on historical information. Already, the technology fits into a farmer’s tablet, computer, or phone application. As a result, the purpose and applicability of ICT and DSS in farming is expanding on a daily basis, and farmers' skills are evolving, finding more areas that can be routinely served by ICT DSS. All this allows the farmers to abandon routine work and focus on creative processes that enable them to find alternative forms of farming, more advanced technological solutions, as well as to implement more innovative experiences that allow more efficient use of limited farm capacity.

Thanks to the evolution of ICT DSS, farm development has become faster and smoother. The concept of farm and farming has changed today. Now it is associated with an educated farmer and high-tech-based farming, which is more and more similar to industrial mass production, which until then was unique in terms of accuracy, efficiency, effectiveness and quality control. The ICT DSS tools make it now possible on farms as well.

To what extent are DSS ICT tools present at the Higher Education curricula?

ICT-DSS are tools to address real problems in future careers (practice oriented and time dimension) but also, they are recognized in higher education for manifold reasons, for instance to conjugate data and intelligence, to pull off the unsurpassed and likely elucidations, and to fine-tune decisions under hesitation [34]. ICT-DSS are tools to address real problems in future careers (practice oriented and time dimension). This also encompasses to adopt a critical point of view (change mental models) and also gaining a broader and integrated perspective. Numerous issues have been pointed out here in decision support and decision support systems, best in class investigate in these fields, moreover their own specific studies in arranging a propelled higher education decision support system.

ICT in higher education has transformed the face of higher education learning and teaching. Increased internet connectivity has led to increased access to higher education learning through massive open online courses (MOOCs), virtual-classrooms, online and open universities. The introduction of ICT brings forth new opportunities for academics in higher education institutions (HEI's) to reconfigure the way they conduct their business of facilitating teaching and learning. A DSS for cutting edge higher education ought to assemble information on each and every educational methodology, offer feedback to their change, and offer decision making sponsorship with high integration and direct association with all the zones of the issue. Propelled training or higher education executives would have tremendously key data and information at their handle, in a clickable structure, for smart examination and access in certain decisional condition. The Higher Education ICT based systems contain general perspectives with the design of fiscal structures, furthermore, have different special highlights concerning [35]:

1. The working and organization of enlightening establishments.
2. Academic self-guideline, even in monetary issues or diverse structures as demonstrated by open and educational commitments.
3. Universities are components that make novel learning/knowledge and hold up the close-by and overall gatherings.
4. Universities have central assignments in education, planning, investigation.

5. International and close-by specific state of affairs.

A best practice example across FARM project partner countries, in the higher education in Germany, an agricultural, geographical and environmental, as well as the computer science departments, carry out projects and educational measures that deal at least in parts with aspects of DSS. With a focus on agriculture, spatial data play an important role and therefore GPS supported mobile systems are often used to capture and visualize agro-data. Such systems can be used on tablets or smartphones and are part of theoretical considerations as well as practical exercises in which students learn how to conceptualize, implement and/or apply data collection systems for environmental, and agricultural purposes. They are also sensitized for the benefits that may occur through usage of such systems for improving the efficiency of agricultural procedures and how the environment can benefit in various respects. Data collected using mobile technologies can be analysed and visualized using GIS which can also integrate remotely sensed data that may come from satellites or drones. In such a way, GPS, GIS, remote sensing and further technologies that interplay with agricultural machinery are prerequisites for precision farming and modern agricultural practice. In precision agriculture, site-specific production processes based on measured data of soil, plant and water supply, are part of the technical foundation of DSS. Sensors and practical robust measurement methods are subject to lectures in order to establish new plant production systems and improve management techniques. This concerns also robotics. At the University of Bonn in Germany, for instance, the work is centered on robotic/computer vision to enable robots and autonomous systems to work in challenging environments, especially agriculture. Important areas of research are agricultural robots and autonomous systems as well as scalable classification and learning approaches. The usage of Neural Networks to classify agricultural data is another example of applying new AI techniques aiming at improving agricultural practices.

All in all, a great variety of DSS are developed or used in different agricultural sectors. Apart from information retrieval systems that are aimed at capturing, manipulating, retrieving and transmitting data to solve professional tasks, knowledge-based systems (aiming at handling and analyzing agricultural data) and expert systems (knowledge-based systems that are used mostly together with a human operator to make decisions in the framework of agricultural tasks, including explanations for users) are system types to be mentioned.

Already in 2009, Kacprzyk et al. classified different types of DSS. They did not specifically focus on agriculture, but all such system categories can play more or less a role within agricultural DSS. They play a role in higher education as well, when the interplay of technology and agricultural tasks and processes is subject to lectures, seminars and exercises, including field trips to test soft- and hardware. The following table gives an overview of DSS types. It was delivered by Kacprzyk et al. [36].

Table 4. Overview of DSS types

DATA DRIVEN DSS	*emphasize access to and manipulation of internal company data and sometimes external data, and may be based – from the low to high level – first on simple file systems with query and retrieval tools, then data warehouses, and finally with On-line Analytical Processing (OLAP) or data mining tools.*
COMMUNICATIONS DRIVEN DSS	*use network and communications technologies to facilitate collaboration and communication.*
GROUP GDSS	*are interactive, computer-based systems that facilitate solution of unstructured problems by a set of decision-makers working together as a group.*
DOCUMENT DRIVEN DSS	*integrate a variety of storage and processing technologies for a complete document retrieval and analysis; documents may contain numbers, text, and multimedia.*
MODEL DRIVEN DSS	*emphasize access to and manipulation of a model, e.g., statistical, financial, optimization, and/or simulation; use data and parameters, but are not usually data intensive.*
KNOWLEDGE DRIVEN DSS	*are interactive systems with specialized problem- solving expertise consisting of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems.*
WEB-BASED DSS	*are computerized system that deliver decision support related information and/or tools to a manager/analyst using a "thin-client" Web browser (Explorer); TCP/IP protocol, etc.*

Three specific examples of DSS development and their consideration in higher education in Germany are the following:

1) LandCare DSS

Decision support to develop viable climate change adaptation strategies for agriculture and regional land use management encompasses a wide range of options and issues. Up to now, only a few suitable tools and methods have existed for farmers and regional stakeholders that support the process of decision-making in this field. The interactive model-based spatial information and decision support system LandCaRe DSS attempts to close the existing methodical gap. This system supports interactive spatial scenario simulations, multi-ensemble and multi-model simulations at the regional scale, as well as the complex impact assessment of potential land use adaptation strategies at the local scale. The system is connected to a local geo-database and via the internet to a climate data server. LandCaRe DSS uses a multitude of scale-specific ecological impact models, which are linked in various ways. At the local scale (farm scale), biophysical models are directly coupled with a farm economy calculator. New or alternative simulation models can easily be added, thanks to the innovative architecture and design of the DSS.

Scenario simulations can be conducted with a reasonable amount of effort. The interactive LandCaRe DSS prototype also offers a variety of data analysis and visualisation tools, a help system for users and a farmer information system for climate adaptation in agriculture. This paper presents the theoretical background, the conceptual framework, and the structure and methodology behind LandCaRe DSS.
Scenario studies at the regional and local scale for the two Eastern German regions of Uckermark (dry lowlands, 2600 km2) and Weißeritz (humid mountain area, 400 km2) were conducted in close cooperation with stakeholders to test the functionality of the DSS prototype. The system is gradually being transformed into a web version (http://www.landcare-dss.de) to ensure the broadest possible distribution of LandCaRe DSS to the public. The system will be continuously developed, updated and used in different research projects and as a learning and knowledge-sharing tool for students.

The main objective of LandCaRe DSS is to provide information on the complex long-term impacts of climate change and on potential management options for adaptation by answering "what-if" type questions.

2) WeedAI: Intelligent UAV-Based Weed Monitoring System for Selective and Site-Specific Herbicide Application

The objective of the project is to develop an intelligent real-time monitoring and mapping system for the detection of weed distribution in cereal stands. For this purpose, high-resolution aerial image data is captured at low flight altitude and classified directly on the drone using optimised onboard AI image recognition during the overflight. The innovative procedure enables species-specific recognition at the level of individual plants. In this way, the project makes a significant contribution to reducing the use of pesticides in arable farming and thus promotes sustainable agriculture. The Harz University of Applied Sciences is significantly involved in several project modules and will take on the following tasks in particular: support in the construction of a UAV carrier platform with RGB carrier camera, development of software for flight planning and aerial flights, optimisation of image recognition based on the CNN model, training and testing of the CNN model with the existing image data, integration of image recognition into the UAV system, as well as the final validation of the overall WeedAI system.

The project makes an important contribution to the Federal Government's National Strategy for Artificial Intelligence in the following fields of action: continuous strengthening of AI research as the basis for successful overall development in Germany; rapid transfer of AI research results into application.

3) StaPRaxRegio – Development of highly efficient N-fertilization strategies in agriculture

Within the project StaPraxRegio, highly efficient Nitrogen fertilization strategies are developed under consideration of meteorological and edaphic parameters. Fertilization strategies should be accompanied by technological, decision supporting tools that provide local information and advice to achieve optimal fertilization results while minimizing harmful consequences for water and soils due to the fact that significant amounts of Nitrogen reach the soil and groundwater, but not the crop plant. The local weather conditions, as well as detailed soil information must be provided for such DSS to guarantee that fertilization is not done in a „overall" manner on fields, but takes into account the varying spatial conditions that may occur in specific local regions.

The strategies developed in the project will be provided to farmers, agricultural consultants and other stakeholders. Apart from the aim of more efficient absorption of Nitrogen by the crop plants, the goal of minimizing Nitrogen outwash or emission of Ammoniac to the atmosphere has also feedback concerning climate protection.
The strategies are aimed at being integrated in lectures in agricultural and environmental departments to teach students concerning smart digital technologies that lead to more environmentally friendly practices in rural areas that are dominantly affected by agriculture [36-44].

In another project, of the partner country Lithuania, the study programs in Vytautas Magnus University, Academy of Agriculture, Faculty of Bioeconomy dedicated to agriculture management studies include subjects of information and communication technology. In the study program "Accounting and Finance" current and future farmers learn about:

1. Accounting information technologies
2. Accounting information systems
3. Accounting information technology practice

In the study program “Tourism Industries”:

1. Application of interactive solutions in tourism;

In the study program "Rural Development Administration":

1. Administrative information systems;
2. Public Management Decisions Modelling.

In the study program "Business Logistics":

1. Information technologies in logistics.

In the two subjects of Rural Development Administration study programme teach Agriculture, Rural Development and Land-use Decision Support Systems.

The purpose of the course „Administration information systems” is to provide the newest knowledge based on the concepts and principles of information infrastructure development. The course connects basic functions of information systems of public administration organizations with the main stages of the design and management of administrative information systems, their requirements and the methodology for assessing their effectiveness. It is designed to develop skills to analyze information needs of administration institutions and ways of organizing information provision in real situations. The purpose of the course „Public Management Decisions Modelling” is to provide the newest knowledge based on the theory and methodology of public administration decision modeling. It is grounded by various approaches to public management decision making and decision-making process. In this study subject the ICT DSS also is used as an example of contemporary data management presenting already existing ICT DSS tools that freely available in the market and designed for farmers. In the other partner countries of this project also number of ICT DSS tools is used for learning and teaching. Modern training becomes impossible without the ICT because the student after finishing his studies will enter a market where he or she will either develop or use ICT in his or her activities. This becomes basic driver to choose studies integrating ICT DSS and teaching application and programming of them.

The rapid pace of change in technology innovation and development demands that HEI’s are always in a state of flux [45]. The advent of the Fourth Industrial Revolution (4IR) witnessed the emergence of robot tutors and chatbots, which offers new possibilities for universities to engage with students.

This dynamic transition to an ICT intensive environment creates a world of 'complexity' and poses overwhelming challenges for academics to reconceptualize their teaching [46]. In the context of increasing competition in the market of educational services, there is a need for special measures to promote activities of HEIs. A particular role in the automation of complex learning processes is played by decision support systems, which makes recommendations based on research and analysis of significant aspects of such processes. Research proposed a multi-criteria DSS for evaluating the transfer of knowledge from HEIs to society. In the process, three phases are completed: strategic options development and analysis, measuring institution attractiveness by a categorical-based evaluation technique and formulating recommendations.

In the field of academic or educational planning decision-making comprises far-reaching examination of outsized data volumes started off from manifold systems. Academic or educational workload administration is concerned with distributing teaching resources in order to passably hold up the university's educational agenda or structure (faculties, degrees, courses, admission policies, teaching workload et cetera). In the latest decades, across-the-board researchers' attempts have been made on accepting and formalizing the development of decision making all zones. One of the first portrayals of the structures qualified to support the activity was according to the accompanying [47]:

- Information retrieval systems - are PC based structures/systems that catch, control, recoup and transmit dealt with data vital to settle a specialist task as demonstrated by bare essential trades described by a customer.
- Decision support systems – are learning based (Knowledge-Based) information structures to catch, handle and separate information which impacts or is required to impact decision making performed by people in the degree of a specialist task assigned by a customer.
- Expert systems - are learning based (Knowledge-Based) structures to be utilized as opposed to or together with an individual to settle on decisions in the structure of a specialist undertaking with elucidations for customers.

The ubiquity of technology has also enabled access to education for distance students, socio-economic disadvantaged students and disabled students. Furthermore, ICT offers new ways of delivering a flexible, customized education suitable for differentiated learning environments to anyone, anywhere, and anytime. According to Arnott and Pervan [48] it should be remembered that despite its current problems, DSS has a long history of success in scholarship and practice. Business intelligence and personal decision support systems are now an integral part of most managers' work. The idea that computers can be used to support rather than replace humans is as important today as it was in the 1970s. DSS scholars have contributed significantly to information systems theory in areas such as evolutionary systems development, the incorporation of artificial intelligence into business systems, multi-dimensional data structures, critical success factors, group processes, and managerial information behaviors. Nevertheless, the eight issues identified in this paper should be given careful attention. The key issues are summarized in the following table:

Table 5. Key issues for the DSS discipline

Key issues	Comments
1. Professional relevance	Most DSS research is disconnected from practice. Only Enterprise Reporting & Analysis and Data Warehousing have reasonable relevance scores.
2. Research methods and paradigms	DSS is more dominated by positivism than general information systems. Case study research is underrepresented. A long history of design science research could contribute methodologically to information systems research.
3. Theorethical foundations	Around half of the papers have no explicit foundation in judgement and decision-making. Much DSS research is based on a relatively old theoretical foundation. Enterprise Reporting & Analysis and Data Warehousing research has the poorest theoretical grounding in judgement and decision making.
4. Role of the IT artifact	DSS research had a strong focus on the information technology artifact early in the analysis period, but this focus is declining.
5. Funding	DSS has relatively low competitive grant success and even lower industry support. Industry support is declining. Most research relies on implicit funding through university departments.
6. Inertia and conservatism	The relatively older types of Personal Decision Support System and Group Support Systems still dominate research agendas.
7. Exposure in 'A' journals	DSS needs to increase its presence in information systems 'A' journals other than DSS. DSS researchers are under-represented in European information systems scholarship.
8. Discipline coherence	DSS comprises three relatively isolated subfields.

In the higher education environments, data mining and DSS are well suited technologies to provide decision support by generating and presenting the relevant information and the knowledge towards quality improvement of education processes.

Competences, knowledge and skills gained by ICT-DSS

The use of new technologies has more impact on farms when the interaction between farmers and intermediaries facilitates the exchange of ideas about farming practices that are relevant to farmers. In addition, to be successful they must be easy to maintain and adapt as new information becomes available to keep them relevant [49].

Accordingly, Nitsch [50] remarked that computers can support some of the competences needed for farming, while the coordination ability can be complemented by any ICT system. The use of new technologies as a tool provides a potential means of informing stakeholders on the long-term effects of the management regime that are difficult to derive from experiential learning, i.e., they can illustrate changes in slow-changing, long-lived and low-visibility variables, and highlight the proximity of thresholds beyond which detrimental and potentially irreversible changes can occur within farmers' management of their farms in general [51]. The benefits of precision agriculture are achieved through management changes that increase efficiency and control in the farming system, so farmers need to have the skills to use information and adapt decision making accordingly.

Therefore, an integral step in developing competencies is realizing the benefits of precision farming, the gap between the installation of data collection devices and the actual use of that data to improve management [52].
Agriculture needs a wide range of competences to manage its complexity, including:

1. knowledge about the subject (crop production etc.),
2. skills in formal planning (the ability to keep economic records and make a budget),
3. practical skills (the ability to organize and to get farm tasks and chores done in time).

The people involve develop operating skills to know that action is required, know what to do, and also know how to do it, even if it is clear to them that the actions they perform will not always be optimal [53]. Furthermore, they also need to improve their situated seeing, i.e., cognitive strategy, to accurately use the digital artefacts in the existing practice. It is argued that farmers learn in action through a kind of life-long longitudinal case study set-up, which means that their learning process is more experiential than experimental [54]. Some of the basic management functions [13] that can be considered as operational skills may be the following:

- Sensing and monitoring: measuring the actual performance of automated farm processes using sensing technologies, such as sensors or satellites. In addition, acquiring external data to complement direct observations.
- Analysis and decision making compares the measurements with the standards specifying the desired performance (relative system objectives), identifying deviations, and making decisions to eliminate the detected disturbances.
- Intervention: plans and executes the intervention chosen to correct the performance of the operation's processes.

During this process of knowledge development, a wide range of different individual and social learning situations are of great importance in influencing the farmer. They develop operational skills to know that it is necessary to act, to know what to do and to know how to do it, even if it is clear to them that the actions they take will not always be optimal.

The skills that are developed in agriculture differ among the different types of production, but a common feature is that agricultural production depends on natural conditions, such as climate, weather, and climate change. Agricultural production depends on natural conditions, such as climate (day length and temperature), soil, pests, and diseases that can spread [13].

The technology must fit into farmers' practice and be handled by their experience based, situated knowledge to contribute to increased sustainability in their farming. To increase sustainability in agriculture we need knowledge that is complex, diverse and local [55], access to information to act upon and use for decision-making. The development and use of technology as a social learning tool can facilitate discussions and promote learning among different stakeholders including farmers thus developing a shift from objective-oriented thinking to thinking in terms of learning.

Learning about the use and management of the farm by the farmer in the use of DSS-based innovations, such as that underpinning precision agriculture, involves a learning process mainly of the social type [52]. Also, comparisons with formalized knowledge and results obtained in earlier years and in different places are made either consciously or unconsciously by farmers, in order to form new knowledge and rules of thumb for their work. The experienced farmers could be considered experts on their own farms and are in possession of a considerable amount of so-called intuitive, situated knowledge [56].

It is of great interest to recognize and promote the role of farmers' situated knowledge to develop care in farming practices and thus increase sustainability, good care requires situated knowledge based on attention, responsiveness, and adaptation to constantly changing circumstances, as is the case in farming practice. Toffolini et al. [57] point out that the different circumstances in which knowledge was linked to action within the farmers correspond to the following patterns:

- First pattern: knowledge about a biological object may refer to an action that farmers have already performed and managed, the effect of which is also partly known to the farmer.
- Second pattern: farmers can use fundamental knowledge about biological objects when it allows them to anticipate the effect of a new action they have never performed.
- Third pattern: fundamental knowledge can be used to reinterpret previously observed effects or consequences of an action.
- Fourth pattern: fundamental knowledge can guide action by allowing farmers to identify an indicator to monitor their action.

In summary, the need for earlier knowledge has not disappeared with the development of the ICT-DSS. The knowledge generated so far still remains relevant, and only the way in which the knowledge reaches the farmer changed. Thus, if in the past the effectiveness of a farmer's decisions depended on the amount of knowledge he had accumulated and learned, and on his ability to apply and make decisions based on them, now part of that knowledge lies in the automated equipment capable of performing installed operations on its own. So, a number of processes become irrelevant to the farmer at the level of his knowledge when he works at the field as he tends to rely on knowledge that comes from technology. For this to be possible, the technology developer and digitizer must add that knowledge into the technology in such a way that the farmer would have sufficient knowledge of how to operate the equipment.

Therefore, today, both small and large farmers are similar in that both use the knowledge archives integrated in equipment, but not necessarily have acquired this knowledge themselves through personal experience. In this way, both become users of equipment whose mission is to understand what they want and how to achieve it with the use of the equipment, but not their personal knowledge and human workforce as before.

Also, the source of knowledge is changing. If previously the competence was considered to be the ability to take over the experience of the previous generation, today it is the ability to recognize the required publicly available knowledge and take it from the global or local information sources. So, if the family was formerly the creator of knowledge for the farm, society is becoming today.

This creates a need not only to identify with the family culture and the farming style developed by earlier generations, but also a need and obligation to become part of a global knowledge world, and not because there is need to gain a knowledge but also because the sharing of experience and practice leads to faster and more reliable technology development. Therefore, the success of today's farming depends not only on the ability to farm, but also on the ability to transfer knowledge to a technology developer who creates the technologies of the future for even more efficient farming. This process can be open when the developer allows the farmer to choose whether or not to contribute experience to product future development, and is hidden when information is stored on equipment computers and read during equipment service. Therefore, today, the ability to share knowledge is becoming equally important for knowledge acquisition especially when it is about the ways to get the more advanced tools which integrate ICT-DSS tools in a way which is useful for the farm.

Benefits of ICT-DSS tolls in agriculture

Farmers would benefit from decision support systems in order to support their decisions. DSS are based on web or app, being a software system designed to guide the users on different stages related with decision making, with the purpose to reach a decision [58]. Management required making decisions looking for a long- term sustainability, which make this a challenging.

Agriculture 4.0 is based on the employment of current technologies like Internet of Things, Big Data, Artificial Intelligence, Cloud Computing, Remote Sensing, among others. The implementation of these technologies has shown a significantly improvement in the efficiency of agricultural activities.

There are many benefits of DSS for farmers which can complement previous knowledge, improved direct and external issues impacting a given point. On the order hand, DSS can reduce uncertainty, develop abilities to contrast multiple scenarios with the purpose to utilize large datasets and prove that DSS is a tool to make more accurate decisions.

Decision support system objectives are at optimizing the production efficiency, increasing quality, minimizing environmental impacts, and reducing the use of resources like energy and water. Wolfert et al. conducted a survey on applying Big Data to smart farming. They have pointed out that Big Data is now used to provide farmers with predictive insights in farming operations and real-time operational decisions [13]. Liakos et al. [59] explored the current state of machine learning techniques in agriculture. They have drawn a conclusion that real-time artificial intelligence enables computer programs to generate rich recommendations and insights for supporting farmers to make proper decisions.

The benefits of big data can be viewed in two ways. As an opportunity to select the most optimal solution from all or to categorize into, or distinguish the types of solutions, or to treat it as a factor lacking creativity in making decisions under unknown and never-tried conditions. So big data are good where accuracy is needed in repetitive operations and where the likelihood of errors increases due to the fatigue of the farmer systematically repeating the same operation. In such cases that DSS becomes particularly valuable as a control tool in a known system of factors and signals selecting the most optimal of the known scenarios for the operation.

Meanwhile, no DSS has been developed to change the farmer's creative thinking and to be able not only to recognize a case unknown to it, but also to create a solution that is not programmed in it. This separates human from ICT so far. So although the big data sometimes give the impression that computer technology has moved closer to independent creative thinking, still within the mistake remains a mistake yet it doesn't direct to make a new decision. So far, DSS is still an assistant to the farmer. Farmer manages the farm and DSS makes decisions for the farmer only under clearly defined conditions, thus increasing and optimizing the farmer's activities.

DSS has been used in different agricultural domains like pest management, nutrient management planning, farm economy, livestock, and crop management [60, 61]. As a matter of fact, DSS can make proposals related with the use of a fertilizer, control treatments or the integration of both chemical and non-chemical actions in order to guarantee a crop development and productivity.

The procedure to star using a DSS in agriculture includes the collection of data from the environment where the crop is grown. This data might refer to climatic, crop growth parameters or the presence of pests, flora composition and density. Then, the models in the DSS analyze the data and provided a rank of suitable treatments for each case involved. DSS models can also include rules, guidelines and agenda of management, mathematical equations, and decision aids [62].

In this context, the advantage of DSS is that with the development of ICT, DSS can accommodate large volumes of models that are used not only by a single but by a large number of farms in different parts of the world. This allows to collect a variety of experiences ranging from droughts to rains and frosts that are not typical of some regions under normal conditions but can occur with extreme conditions and climate change. In such critical cases where the farmer lacks personal experience the DSS is able to select a solution based on an accumulated database and offers it when the farmers' knowledge is limited but the solution is already tested in regions where this is common.

The ability of a person to store information within oneself is limited because it is physically impossible to double or triple the volume of the brain. Thus, although it is possible to expand the possibilities of thinking by mastering more effective methods of assimilating knowledge, even in this case the limits of human memory are reached rather quickly, which leads to the formation of conditional specialization and to the retain of only the knowledge that is most needed. But here, too, man has a great advantage. Not only does one's mind store and compare knowledge as DSS does, but he can fill the missing knowledge with the knowledge created in the process of creative thinking. Basically, the farmer still remains more advanced than DSS in that he can make a risky decision in the absence of some data and on the basis of past experience and a similar but not as is needed solution. As a result, DSS fills well-known areas perfectly, and the farmer takes the initiative where DSS is incapable. Such cooperation changes the image of farming and the model of the farmer's activity, but is still more effective than the farmer acting individually.

To summarize, decision support system has been applied to agriculture points, showing significant results that can considerate this technology as a revolution:

- Increased production: real-life experiments with DSS have resulted in an increase in crops yield.

- Data integration: the farmer not only has at his disposal data obtained from his farm, but his database can also draw on public resources (e.g. weather data from AEMET) for more accurate decision making.

- DSS could be used to provide farmers with information about the potential effects of external physiochemical, biological, and management factors.

- Input reduction it is possible to reduce the consumption of different inputs (fertilizers, herbicides, fuels).

- Analyze globally, act locally: Big Data allows you to collect data from your entire farm, analyze it and return the analysis per plot. This allows the farmer to adjust the phytosanitary or fertilizer treatment to a particular area of his farm. With the consequent safeguarding and protection of the environment.

- DSS could inform stakeholders about whether targets for selected soil functions have been reached, and if not, how management could enable them to reach those targets.

- Harvesting at the right time: drones and robots make it possible to analyze in detail and autonomously the state of maturity of the fruit. These data and their analysis are used to determine the optimal harvesting time.

- Protection of the farmer's income: data on agricultural commodity markets can be integrated by analyzing their trends over time (even decades) to advise the farmer when selling his crop in order to obtain a better price.

- Analysis of consumption trends: allows crop sizes, varieties or products to be adjusted according to changing consumer preferences.

- Improved traceability thanks to the fact that the data associated with a product is like the DNA of the supply process.

- DSS to optimize travel paths for minimizing damages to soil sensitive fields from large-scale vehicles. it is essential to consider mechanical impacts of vehicles on the soil structure, especially the risk of soil stresses and compactions [63]. Creating routes that can reduce energy consumptions of vehicles and improve the working efficiency. DSS can proposed shorter path for a heavy vehicle that travels in the field, in order to guarantee the less damage.

- On-board decision-making DSS approach the objective to detect the exact location of diseased crops and then perform corresponding operations like spraying herbicides precisely. As a result, the precise use of herbicides, toxic damages to the fields can be greatly reduced.

- For water resources management an irrigation system should provide farmers with effective decision supports on controlling the amount of water applied to crops and maintaining landscapes [64]. This can ensure wettability of soil fields and basic water needs from crop growths with the minimum water usages.

- The system can optimize the supply chain and it is one of the most effective approaches for avoiding food waste. As a result, the optimized supply chain enables to deliver agricultural products to the nearest destinations within the minimum time [65].

In the last case, DSS achieves greater efficiency simply because, unlike a farmer, it can consistently inspect all crops without missing a single one. In the farmers’ case when he has to inspect fields the success of disease recognition success often depends on the extent of the disease or accidental detection. This is because, due to lack of time, the farmer inspects crops and plants at random, in which case the entry of a diseased plant into the random sample is based on probability but not the rule. The probability increases as the spread of the disease reaches greater levels, but it means that farmer will experience grater losses. Therefore, the advantage of DSS is that when it is used, it is likely that cases of the disease will be detected as long as there are few, rather than when the disease is massively spread.

The benefits of using a DSS are that it can improve productivity, improve decision quality and problem solving, as well as facilitate interpersonal communication. It can also improve decision-making skills and increase organizational control [66].

Conclusion

The last decade has seen major improvements, including automated feeding systems, milking robots, manure management, and maximizing production efficiency through instrumentation, animal breeding, genetics, and nutrition. Despite this progress, significant challenges remain. Intensive livestock management is necessary to meet the increasing demand for animal products, therefore, there is a big interest in digitalizing livestock agriculture through precision livestock farming technologies.

The main objective of the project is digitalizing the pig manure production and its physical chemical composition to reduce the environmental effects through the sustainable agronomic valorization of manure as an organic-mineral fertilizer applied in controlled doses on agricultural soils, implementing the carbon footprint and the water footprint and promoting the circular economy.

The following steps can be highlighted as specific objectives of the project:

- DATA Collection:

  Study the production of slurry to be valued through the location of the pig farms, type of farm and volumes produced and determine the availability of useful agricultural area on which the slurry will be applied, indicating its location, type of crops and available hectares, and physical and chemical characterization of the slurry from each farm at origin and in real time.

  Carry out an initial characterization and monitoring of the physical-chemical parameters that define the quality of the soil in the areas with slurry application and establish a target or control area (without the application of slurry).

- Computer design:

  Design a computer model that feeds on “automated” real-time analytics for collective manure management between farmers and ranchers, adapted to vulnerable areas where nitrogen is the limiting factor in organ-mineral fertilization.

- SMART application:

Implement a sustainable agronomic recovery of raw manure by applying it into the soil. To do this, the agricultural area will be studied, and the application dose of slurry will be calculated, limited by its Nitrogen content. A maximum dose of 170 kg N/ha and year will be applied in accordance with RD 261/1996 and the Code of Good Agricultural Practices of the Region of Murcia.

- Calculation of the environmental benefits of the project.

  By evaluating the agricultural performance and quality of the harvest in the areas with the application of slurry and in the control areas and analyzing the minimization of the environmental impact and socioeconomic consequences of agronomic valorization of pig slurry using the SMART application of this by-products as an organic fertilizer.

Regarding the design and development of the database and its analysis system through artificial intelligence, it will be made up of two lines of development:

1. Desktop Software
2. Algorithm with Machine Learning and Artificial Intelligence for the continuous improvement of software and data analysis (Big Data).

The software, connected to the cloud, will act as a planning system for the business resources necessary to carry out the activity.

On the other hand, the machine learning (AI) algorithm will have a basic logic, based on the proximity of the livestock farm to the agricultural plot, availability and analysis of slurry and the needs of the farm based on the previous soil analysis and the type of cultivation to be carried out. In this way, and in the face of a new situation both in the crops and in the nutrient content of the manure, the system will offer an adequate response to these changes.

In the medium term, by incorporating new parameters, which can range from the nutritional basis of the animals to the cleaning method of the buildings, passing through the medication administered, the system could even suggest changes in the working method to the farmers to reduce the composition of undesirable elements in the slurry (heavy metals, etc.).

FARM selection of DSS ICT tools

AeroVision

AeroVision is an independent consultant for the procurement of (geo) information.
Country: Netherlands 🇳🇱
Keywords:

- geo-information 🌍
- supply chain 🔗
- aerial data collection 🗺

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=5

A Field-Scale Decision Support System for Assessment and Management of Soil Functions

The Soil Navigator DSS creates a list of soil mitigation measures that can be applied in the field to achieve the desired soil function performance.
Country: Germany 🇩🇪
Keywords:

- soil 🌱
- soil quality ☆
- case study 📖

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=74

Agrenio

Agrenio is an easy-to-use software solution to support the efficient and rational irrigation and fertilization for the farmers.
Country: Greece 🇬🇷
Keywords:

- irrigation
- fertilization
- arable crops

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=142

Agricam

Agricam offers analysis services and cow care for improved animal husbandry, increased production and reduced antibiotic use, sensors, cow care and VetLink.

Country: Sweden 🇸🇪

Keywords:

- animal health monitoring 👩‍⚕️
- cow care 🐄
- internet of things and data analytics 📈

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=25

Akkerweb: a platform for precision farming data, science, and practice

Akkerweb provides access to external data sources such as weather, parcel boundaries, satellite, and farm management data in commercial Farm Management Information Systems.

Country: Netherlands 🇳🇱

Keywords:

- weather ⛅
- satellite management 🛰
- farm management 🚜

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=32

ASAP - Anomaly hot Spots of Agricultural Production, a new early warning decision support system developed by the Joint Research Centre Germany

ASAP proposes a two-step analysis to provide timely warning of production deficits in water-limited agricultural systems worldwide every month.

Country: Germany 🇩🇪

Keywords:

- irrigation 🚿
- temperature 🌡
- field assessment 🌾

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=133

DSS-IWM: An improved European Decision Support System for Integrated Weed Management

DSS-IWM assists farmers and farm advisors in treating weeds in crops at precisely the right times and the most efficient products in the right amounts.

Country: Germany 🇩🇪

Keywords:

- cost efficiency
- sustainable crop management
- agro-economy

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=91

DSSHerbicide: Weed control in winter wheat with a decision support system in three South Baltic regions – Field experimental results

DSSHerbicide Germany and DSSHerbicide Poland are two DSS developed for weed control in winter wheat in Northern regions of Germany and Poland.

Country: Denmark 🇩🇰

Keywords:

- weed control
- herbicide applications and treatments
- case study

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=163

E-AGRICULTURE: DEVELOPING A DECISION SUPPORT SYSTEM FOR PRECISION FARMING

An effective Decision Support System that gathers weather based and agricultural data, formulates them and displays the most prominent results, prompting the user to take the appropriate action.

Country: Cyprus 🇨🇾

Keywords:

- soil humidity
- precipitation
- temperature

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=53

ecoRobotix

ecoRobotix develops autonomous robots for ecological weeding of row crops, meadows, and intercropping cultures.
Country: Switzerland 🇨🇭
Keywords:

- crop rows 🌾
- weeds 🌿
- autonomous robots 🤖

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=108

Foodie Project - Farm-Oriented Open Data in Europe

The project is dedicated to the use and promotion of open data for agricultural applications and aims at enabling the (re)use of open data in agriculture to create new applications that provide added value to different stakeholders.
Country: Spain 🇪🇸
Keywords:

- crops 🌾
- viticulture 🍇
- data-driven agriculture 📈

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=17

'Fruchtfolge': A crop rotation decision support system for optimizing cropping choices with big data and spatially explicit modeling

The crop rotation DSS provides farmers with economically optimal crop planning and manure application without the need for time-consuming data entry.
Country: Germany 🇩🇪
Keywords:

- temperature 🌡
- moisture 💧
- crop rotation 🌾

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=87

gaiasense Smart Farming System

gaiasense collects data from the field, the satellite, the scientist and the farmer and provides the agricultural advisor with the appropriate tools.
Country: Greece
Keywords:

- fertilization
- irrigation
- pesticides

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=141

HummingBird Technology Limited

The artificial intelligence company provides customers with advanced crop analytics through the use of proprietary machine learning, applying leading algorithms to remote sensing imagery, resulting in higher crop yields.
Country: UK
Keywords:

- crop yield
- sensor imagery
- artificial intelligence

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=63

Improving predictions and management of hydrological extremes

IMPREX provides weather and climate services for the agricultural sector with a focus on drought issues and irrigation.
Country: Netherlands
Keywords:

- drought decision support system
- future climate projections
- data analytics

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=41

irrigNET

The main purpose of the service is to provide information about when and how to irrigate the monitored fields.
Country: Serbia 🇷🇸
Keywords:

- irrigation
- arable crops
- tree crops

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=145

MIYO

MIYO offers a suite of solar-powered sensors and a smartphone application that supplies water to plants on demand.
Country: Austria 🇦🇹
Keywords:

- irrigation
- on-farm sensors
- smart phone application 📱

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=103

Natural Resources Institute Finland (Luke)

Organization that creates a sustainable future and prosperity from renewable natural resources.
Country: Finland 🇫🇮
Keywords:

- sustainable development
- circular bio-economy
- climate smart carbon cycle ⛅

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=29

Next Generation Decision Support Systems for Farmers: Sustainable Agriculture through Sustainable IT

The research paper shows what is needed to make new technologies contribute to resilient farms and farming systems.
Country: Germany
Keywords:

- humidity
- nitrogen efficiency
- mineralisation ability

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=88

OptAGRI

OptAGRI helps agricultural organizations in the collection and storage of data to optimize their logistics processes.
Country: Belgium
Keywords:

- precision agriculture
- machinery
- logistic support

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=82

Polariks

This platform collects data from the greenhouse and enables you to have full control over the growth process. It creates a digital twin based on machine learning and performs predictive maintenance on machinery and robotics.
Country:Netherlands
Keywords:

- viticulture
- crop quality
- climate

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=12

Preciselandbouw

The project will incorporate and further develop precicion agriculture technologies towards smarter applications of remote and nearby sensor data, site-specific data from soils and crops and decision support systems.

Country: Netherlands 🇳🇱

Keywords:

- field plot characteristics 🌾
- weather information ⛅
- precision agriculture 🌾

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=4

Quanturi

Provider of wireless temperature monitoring and data analysis solutions for fermentable materials, systems are specifically designed to monitor hay, compost, grain and many other fermentable materials during storage.

Country: Finland 🇫🇮

Keywords:

- hay 🌾
- temperature 🌡
- production improvement 🗠

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=36

SmartPlant

The “Smart Plant” online platform provides precise and accessible data in real time on risks in appearance of pests and diseases for a specific crop, in a specific location.

Country: Serbia 🇷🇸

Keywords:

- pest and disease control 🧑‍🌾
- arable crops 🌾
- tree crops 🌳

Link:

https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=149

SoilScout

Soil Scout is the most advanced soil monitoring solution for professional agriculture.

Country: Finland

Keywords:

- soil moisture management
- smart farming
- internet of things

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=37

SPON

SPON analyses plants' water requirement, soil water retention, precipitation forecasts.

Country: Slovenia

Keywords:

- irrigation
- fruits
- vegetables
- crops

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=158

Tsenso

Tsenso offers a solution to monitor the temperature of temperature sensitive goods.

Country: Germany

Keywords:

- temperature monitoring
- food storage units
- internet of things

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=96

TARGIS-VRA

TARGIS-VRA can help optimize yield when applying agricultural inputs depending on local soil conditions.
Country: Turkey
Keywords:

- fertilization
- arable crops
- variable rate application

Link:
https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=159

Terrasphere

GEOPOTATO developed by terrasphere sends SMS alerts to potato farmers on when, what and how much to spray against Late blight disease.
Country: Netherlands
Keywords:

- crop quality
- agribusiness intelegence
- satelite-based intellegence

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=6

Yara

Yara offers various solution that help farmers increase yield and reduce emissions based on new ways of collaborating and new technologies.
Country: Norway
Keywords:

- fertilization
- crop nutrition
- precision agriculture

Link: https://www.arcgis.com/apps/dashboards/923e875221154c218a0c9f0e9a5fe22e#id=48

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