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Digital farmer

DIGITAL TRAINEESHIP IN AGRICULTURE

DIGITAL FARMER HANDBOOK

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PREFACE

Welcome to "Digital traineeship in agriculture" a manual that aims to provide a tool available to all stakeholders for updating skills and creating practical and digital experiences at the same time. A strong impact at European level and a high potential for transferability are expected.

Precision agriculture represents a revolution in the traditional approach to cultivation. In this context, the use of advanced technologies has allowed farmers to refine their practices, optimizing resource efficiency and reducing environmental impact. This form of agriculture relies on the acquisition and analysis of detailed data related to soil, climate, and crops themselves, to make informed real-time decisions.

Technologies applied in agriculture include GPS, advanced sensors and DSS, drones, and agricultural management software. These tools enable farmers to precisely monitor soil and crop conditions, optimizing the distribution of water, fertilizers, and pesticides. Additionally, the use of drones provides a detailed aerial perspective, facilitating the timely detection of issues in crops.

Main contents of the manual:

- Introduction: explains the relationship and importance of agriculture, industry, digitalization, education and training. Technologies, machines, tools, devices, and approaches used in agriculture and with great potential to be used are also summarized in this section.
- Module 1 - ICT Information and Communication Technologies: smartphones based on new sensing technologies, artificial intelligence (AI) algorithms and machine learning (ML) create a new intelligent middle layer between people and systems to solve complex problems efficiently or, even, to address many everyday problems.
- Module 2 - Decision Support Systems: it discusses the applications and utilization of agro-DSSs, through some examples.
- Module 3 – Block Chain Technologies: it explains the Blockchain technology which a new digital technological approach is underpinned by Industry 4.0.
- Module 4 - NIR and Drones: it provides information about Near-infrared (NIR) spectroscopy techniques and drones used in agriculture.
- Module 5 - Farmbot: they become increasingly important within an agricultural strategy, as automation leads to an optimization of processes, thus creating a reduction in costs and a contribution to environmental sustainability
- Module 6 - e-Commerce Software, Marketing and Advertising Platforms: it explains types of advertising and marketing platforms in agriculture and E-Commerce Software in agriculture..
- Module 7 - Digital traineeships methodologies: it represent other work integrated as well as work-applied learning and skill development opportunities that create additional occasions.

- Conclusions as a summary of all sections.

To further enrich your learning experience, the manual contains numerous links and online resources directly integrated into the text. These links provide immediate access to additional information, practical examples, step-by-step guides, and complementary resources. We have carefully selected these online resources to offer you a practical, action-oriented approach, allowing you to explore specific topics in more detail or access practical tools directly linked to the concepts discussed.

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CHAPTER 1

Introduction

CHAPTER 1 Introduction

Authors: Arzum Işıtan, Cem Gök

Organization: Pamukkale University

WHAT WILL WE LEARN IN THIS CHAPTER?

What is the Agriculture 4.0?
What is the smart farming?
What are the general definitions in smart agriculture?
What are the effects of training on agriculture?
How to integrate technology, education, training, and agriculture?
What is the educational needs?

Keywords: Agriculture 4.0; Smart agriculture; Industry 4.0; Education 4.0; Digital transformation

1.1 Glossary and abbreviations

In the following table, some words/abbreviations/definitions useful for understanding the chapter have been reported.

Industry 4.0	The concept that has been spoken since 2011 and in which objects communicate and interact over the internet in order to maximize production, efficiency and competitiveness.
Education 4.0	Education 4.0 is a technique of learning through advanced technology and automation that is connected with Industry 4.0.
Society 5.0	It is a technology that aims to benefit from Industry 4.0 and the internet of things by taking into account the interests of society, and to produce new sustainable solutions for the protection of the environment and nature.
Digital transformation	Digital transformation, in line with the opportunities offered by rapidly developing information and communication technologies and changing social needs; it is a holistic transformation realised in human, business processes, and technology elements.
Virtual Reality (VR)	Virtual reality is the combination of reality and imagination with fictions created using technology. Virtual learning environments allow technology to be incorporated into educational environments and enrich students' learning experiences.
Augmented Reality (AR)	Augmented reality is a live or indirect physical view of the real-world environment and its contents enriched with sound, image, graphics, and GPS data. This concept is briefly the changing and augmentation of reality by the computer

Table 1.1. Glossary and abbreviations

1.2 Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter.

The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives a value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	***Competences and skills***	***Duration time***	***Learning tools***
• Understanding of the core topic related with digital agriculture • Become familiar with existing digital farming tools • Basic knowledge on how to use presented vital techniques and methodologies in practice • Understanding digital platforms and their benefits • Basic knowledge of digital platforms	• Making definitions about digital / smart agriculture • to explain digital tools used in agriculture • Learning the benefits of digital agriculture	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 1.2. Competence map

1.3 Purpose of this handbook

The Covid19 pandemic has shown us that health, nutrition, and education are the most important priority areas in our lives. During this great pandemic, in which many countries of the world were caught off guard, imbalances and differences occurred between countries, between cities within countries, between schools within cities, and even in the education and training of some occupational groups.

It is undeniable that agricultural technologies, the importance of which has always been understood in periods when the world is experiencing critical changes, such as the pandemic period, are directly related to health, nutrition, and education. For some time now, there has been increasing use of digital technologies in the agricultural sector, which transforms the working environment and production systems resulting in more efficient use of resources and obtaining low carbon emissions. Thus, it will be easier to develop more technological and more environmentally friendly agricultural policies.

In order to increase the use of new technologies in agriculture, producers need easy and fast access to information, adaptation to new technologies and gaining new skills and competencies to use novel technologies.

In this instance, the Digital Farmer project aims to develop international multi-stakeholder cooperation between educational institutions, research centres, universities, industrial consultancy firms, and regional promotion companies to improve vocational training in agriculture. The Project partners are:

- Cosvitec Scarl – Italy
- Accion Laboral Plataforma Para La Implantacion De Programas De Inclusion Laboral En Colectivos Desfavorecidos – Spain
- Institouto Proothisis Kai Pistopoiisis Proionton Agrodiatrofis – Greece
- Pamukkale University – Turkey
- Business Inovation Council – Romania
- Agency For Territorial Marketing – Slovenia
- EFCC Estonian Fieldbus Competency Centre OÜ – Estonia

The Digital Farmer project, developed through European partnership to enable and build a large and innovative agro ecosystem, aims at:

1) empowering stakeholders in the agricultural sector through VET;
2) developing open-source training materials and support tools for educators and trainers for distance education in the field of agricultural VET;
3) disseminating good practices and tools available at European level;
4) establishing an international and multi-sectoral network in order to test innovative applications within the framework of Erasmus+ and to carry out digital training that ensures the continuity of vocational-based learning.

Within the scope of the project, it is aimed to develop digital and innovative teaching materials and innovative work-based learning methodologies, awareness-raising platforms, and platforms for the exchange of good practices. The first of these materials is the "*Digital Traineeship in Agriculture*" manual, which is a pathway for VET trainers in agriculture, and also serves as a framework for the implementation of experiences of work-based learning, in a digital format.

Apart from the Introduction and Conclusion sections, this manual consists of 7 main sections:

- Decision Support Systems (DSS)
- ICT Information and Communication Technologies
- NIR and Drones
- Farmbot
- Blockchain Technologies
- e-Commerce Software, Marketing and Advertising Platforms
- Digital traineeships methodologies

At the end of each section, methodologies and techniques are indicated to implement digital traineeships, in accordance with the three targets of this output: trainees; tutor, training organisations, and companies (platforms to be used for online meetings, planning the activities, and the techniques for an efficient communication through a digital instrument). In addition, for the Digital Traineeship to be carried out within the scope of the Digital Farmer project, there are separate forms for each section of this manual for application, measurement-evaluation, and follow-up:

1. Learning Agreement for Digital Traineeship
2. Digital Traineeship
3. Learning Plan
4. Digital Traineeship Quality Program
5. Digital Traineeship Agenda
6. Traineeship quality and assessment surveys
7. Traineeship experience reflection paper
8. Certificate of Attendance

This chapter, "***Introduction***", explains the relationship and importance of agriculture, industry, digitalization, education and training. Technologies, machines, tools, devices, and approaches used in agriculture and with great potential to be used are also summarized in this section.

1.3 Manual structure

In order to achieve this goal, the manual is characterized by an introduction, six teaching modules and a conclusion. Specifically, the chapters, their content and advantages are:

	MODULE	DESCRIPTION	DEVELOPABLE SKILLS and KNOWLEDGE
1	**Introduction**	This section provides basic information about digital farming and its benefits.	• making definitions about digital/ smart agriculture • to explain digital tools used in agriculture • learning the benefits of digital agriculture
2	**ICT Information and Communication Technologies**	Some ICT technologies that can be applied to agriculture are introduced.	• to understand the main ICT technologies used in modern agriculture • learning how Industry 4.0 technologies are being used in agriculture
3	**Decision Support Systems**	This section discusses the applications and utilization of agro-DSSs, through some examples.	• knowledge of the practical application of DSS in agriculture • knowledge about advantages and disadvantages
4	**NIR and Drones**	The chapter provides information about Near-infrared (NIR) spectroscopy techniques and drones used in agriculture.	• to explain the applications of the the image processing to explain the main application areas of drones.
5	**Farmbot**	This section contains detailed information about Farmbot.	• to explain the applications of sensors • to define the unmanned vehicles.
6	**e-Commerce Software, Marketing and Advertising Platforms**	The chapter explains types of advertising and marketing platforms in agriculture and E-Commerce Software in agriculture.	• knowledge of the practical application of marketing and advertising platforms in agriculture • knowledge about advantages and disadvantages of digital/e-commerce platforms • knowledge about trends of marketing and advertising platforms in agriculture • ability to collect, manage, process and use various data

7	**Blockchain Technologies**	This chapter explains the Blockchain technology which a new digital technological approach is underpinned by Industry 4.0.	• knowledge of the practical application of Blockchain technology in agriculture • knowledge about its benefits • blockchain applications
8	**Digital traineeships methodologies**	This chapter represent other work integrated as well as work-applied learning and skill development opportunities that create additional occasions	• gaining a sense of time management
9	**Conclusion**	This section is a summary of all sections.	• explains digital agriculture • define tools used in digital agriculture • list the advantages of digital agriculture.

Table 1.3. Manual structure and Description

1.4 Relationship between agriculture, industry, digitalization, education, and training

With the use of steam turbines in mines, textile workshops, steam trains and ships, the development process called the *1st Industrial Revolution* started, and this changed the history of the whole world. At the beginning of the 20th century, mass production was started with the use of electrical energy (*2nd Industrial Revolution*), and at the end of 20th century, the *3rd Industrial Revolution* took place with the use of digital systems and information technologies in production. Today, we are talking about the *4th Industrial Revolution* (Industry 4.0), which aims to maximize production, efficiency and competitiveness, and where objects communicate and interact over the internet[1].

[1] Berktaş, S., & Oraklibel, R. D. Evolution with Industrial Revolution: Division Of Labour And Alienation, 1(6), 11.

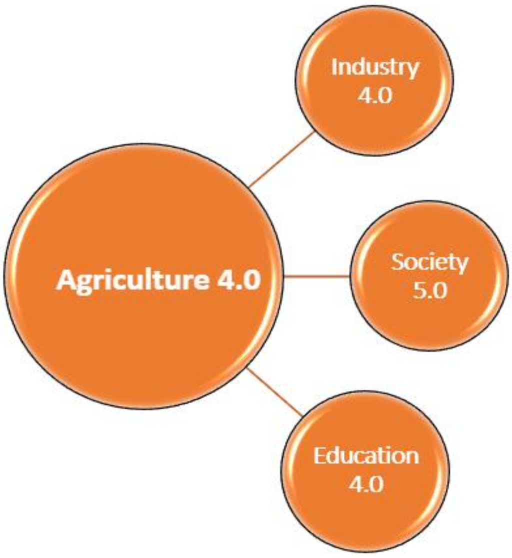

Figure 1.1. Agriculture 4.0 and its relations

Innovations and developments in transportation and production, which started with steam engines, gained momentum in the 20th century. Depending on the increasing needs in parallel with the population increases and industrial development, there has been and continues to be an unpredictable and unavoidable development in all areas of life, from agriculture to the defense industry, from the automotive sector to the aviation field, from diagnosis and treatment methods in health to communication. Technological developments bring about global changes and cause radical changes in many areas. Micro and nanotechnology, 5G internet of things, smart and innovative materials, blockchain technology, advanced and smart manufacturing, artificial intelligence, machine learning, data science and cloud computing, robotics, molecular oncology, cyber security, remote sensing, geographic information systems, sustainable water resources, renewable energy, recycling, vaccine studies, plant genetics, agricultural biotechnology, sustainable agriculture, and digital agriculture are among the main topics of today and the future[1]. For this reason, in addition to traditional education-teaching methods, there is a need for new methods and applications reinforced with information technologies.

Especially in the Covid19 process, internet-based distance education applications, namely education and information technologies, have gained great importance. The "Digital Education Action Plan" prepared by the European Commission reveals how education and training systems can better use innovation and digital technology and support the development of digital competences needed for life and work in an era of rapid digital change[2]. The plan covers basic education, vocational education and training (VET), and higher education. However, progress in the integration of technology into education remains limited. As digital transformation requires agility and adaptability to new conditions and expectations, even the

[1] YÖK (2019). Geleceğin meslekleri çalışmaları. https://www.yok.gov.tr/Documents/Yayinlar/Yayinlarimiz/2019/gelecegin_meslekleri_calismalari.pdf .

[2] European Commission. (2018). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Digital Education Action Plan. Brussels, 17 January, COM (2018) 22 final.

most successful organizations have difficulty in fully completing their transformation. Digital transformation, in line with the opportunities offered by rapidly developing information and communication technologies and changing social needs; it is a holistic transformation realized in human, business processeses, and technology elements[1]. The digital transformation process requires transforming and managing many different elements (people, process, and technology) together, and this is not easy. Technology is changing rapidly, but changing habits is very difficult.

The transition process from the information society to the "super smart society", which includes the philosophy that "technology should be perceived as a help to society rather than a threat to society", is called Society 5.0[2]. The rapid and recognizable digitalization that occurs in daily life offers harmonious, sustainable, facilitating, accessible, comfortable, and safe opportunities in the education and training process. If we take a look at the education and training process; education 1.0 was shaped to meet the needs of the agricultural society, and teaching was carried out by transferring information from teacher to student with the help of concepts and having the student memorizet. The change that started with "teaching of technology" in Education 2.0 turns into "use of technology in education" with Education 3.0, while it turns into "design and innovative use of technology in education" with Education 4.0[5,3].

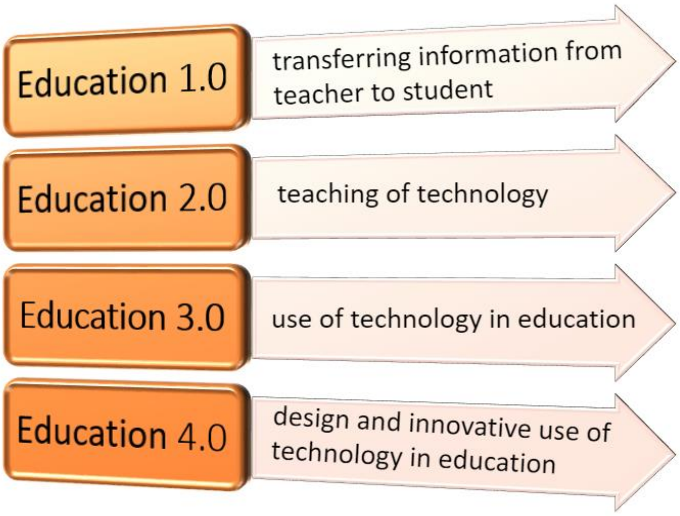

Figure 1.2. The transform of Education

Education 4.0 offers[5,6]:

- *3R* (Recalling-Remembering, Relating-Associating, Refining-Separating), in which a constructivist education approach will be used and which regulates understanding,
- *3I* (Inquiring-Inquiry, Interacting-Interaction, Interpreting-Interpretation) and

[1] https://dijitalakademi.bilgem.tubitak.gov.tr/en/what-is-digital-transformation

[2] Kocaman Karoğlu, A. , Bal, K. & Çimşir, E. (2020). Digital Transformation of Education in Turkey in Society 5.0. Üniversite Araştırmaları Dergisi , 3 (3) , 147-158 . Retrieved from https://dergipark.org.tr/tr/pub/uad/issue/57871/815428

[3] Puncreobutr, V. (2016, Aralık). Education 4.0: New Challenge of Learning. St. Theresa Journal of Humanities and Social Sciences, 9(5), 92-97.

- a three-stage *3P* (Participating-Participating, Processing-Processing, Presenting-Presenting) learning process based on producing results.

Figure 1.3. The offerings of Education 4.0

Some Education 4.0 tools can be listed as follows[5,6]:

- Massive Open Online Courses
- Mobile Learning
- Maker Workshop (Makerspaces)
- 3D Printing (3D Printing)
- Artificial Intelligence
- Robotics
- Simulation

The use of all these practices and approaches in agriculture is inevitable and necessary. In order to increase productivity, use limited resources effectively, and ensure sustainability, individuals and institutions operating in the agricultural sector must keep up with these changes. Agriculture is also affected by digital transformation, and it continues to develop after a long and progressive process from 1.0 to 4.0[1,2]. *Agriculture 1.0* refers to the age of traditional agriculture with low productivity, based on human labor and animal power and using simple tools. Starting from the 19th century and the Industrial Revolution, we are known in the era of *Agriculture 2.0*. The efficiency and productivity of farm works were increased with various agricultural machineries operated by farmers manually and chemicals were used. This had negative consequences such as the destruction of the ecological environment, excessive power consumption, and waste of natural resources. In the 20th century, with the advent and use of computer programs and robotic techniques, *Agriculture 3.0* emerged, which enabled agricultural machinery to perform operations efficiently and intelligently. In this century, with the use of current technologies such as the Internet of Things, Big Data, Artificial Intelligence,

[1] Tekinerdogan, B. (2018). Strategies for technological innovation in Agriculture 4.0. Wageningen University: Wageningen, The Netherlands.
[2] Zhai, Z., Martínez, J. F., Beltran, V., & Martínez, N. L. (2020). Decision support systems for agriculture 4.0: Survey and challenges. *Computers and Electronics in Agriculture*, *170*, 105256.

Cloud Computing, Remote Sensing, the evolution of agriculture has turned into *Agriculture 4.0*.

With the increasing world population and the nutritional needs of this population, the effective and sustainable use of limited resources is gaining great importance. Industry 4.0 and Agriculture 4.0 have also increased our ability to design and develop different machines, tools, software, hardware, and systems that make our lives and production processes easier. With Agriculture 4.0, an unstoppable digitalization in agriculture today, is becoming widespread with the use of up-to-date technologies. The Internet of Things, Big Data, Artificial Intelligence, Cloud Computing, Remote Sensing, Robotics, Gene Editing, Drones, Unmanned Machines, Farmbots, Sensors, 3D Printing, Image Processing, Augmented Reality, Machine Learning, and Blockchain are examples of these technologies[8,1,2,3,4,5,6.]

Farmers may face difficulties in the making right decisions and choices about agricultural management with the huge amount of information (e.g. environmental, crop-related, energy use, and economic data)[8,7]. Because different types of data like location, weather, soil moisture, plant health status, fertilizer use, energy use, wind speed and direction, weeds, etc can be accessed with digital assistants. The data obtained can be used to interpret the past and predict the future, allowing for more timely or accurate decisions[13,8,9,10].

In traditional agriculture, soil fertility analysis is done manually, most of the time irrigation is wasted, and sudden changes in climatic conditions can negatively affect agricultural production and productivity[11]. Such problems can be overcome to a great extent by innovative digital solution techniques. For example, with a digitally supported smart greenhouse application by Yılmaz[12], decreasing costs and rates in greenhouses were determined as follows:

- Labour costs used in production (65%)

[1] Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Research commentary—Digital infrastructures: The missing IS research agenda. *Information systems research*, *21*(4), 748-759.

[2] Alm, E., Colliander, N., Lind, F., Stohne, V., Sundström, O., Wilms, M., & Smits, M. (2016). Digitizing the Netherlands: How the Netherlands can drive and benefit from an accelerated digitized economy in Europe. *Boston Consulting Group*.

[3] Ferrández-Pastor, F. J., García-Chamizo, J. M., Nieto-Hidalgo, M., Mora-Pascual, J., & Mora-Martínez, J. (2016). Developing ubiquitous sensor network platform using internet of things: Application in precision agriculture. *Sensors*, *16*(7), 1141.

[4] Smith, M. J. (2018). Getting value from artificial intelligence in agriculture. *Animal Production Science*, *60*(1), 46-54.

[5] Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS-Wageningen Journal of Life Sciences*, *90*, 100315.

[6] Rose, D. C., Wheeler, R., Winter, M., Lobley, M., & Chivers, C. A. (2021). Agriculture 4.0: Making it work for people, production, and the planet. *Land use policy*, *100*, 104933.

[7] Taechatanasat, P., & Armstrong, L. (2014). Decision support system data for farmer decision making.

[8] Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue, B. (2019). Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural and Environmental Ethics*, *32*(5), 741-768.

[9] Janssen, S. J., Porter, C. H., Moore, A. D., Athanasiadis, I. N., Foster, I., Jones, J. W., & Antle, J. M. (2017). Towards a new generation of agricultural system data, models and knowledge products: Information and communication technology. *Agricultural systems*, *155*, 200-212.

[10] Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. *Agricultural systems*, *153*, 69-80.

[11] Sanghavi, J., Damdoo, R., & Kalyani, K. (2020). Agribot: IoT based Farmbot for Smart Farming. *Helix*, *10*(04), 325-328.

[12] Yılmaz, C. (2017). Seralar İçin Çok Fonksiyonlu Akıllı Kontrol Sistemleri. *Elimko Elektronik İmalat Ve Kontrol Ltd. Şti., Ww. Elimko. Com. Tr, Ankara*.

- Overhead costs (74%)
- Electricity use (20%)
- Fuel consumption (30%)
- Water use (30%)
- Fertiliser use (30%)
- Drug use (35%)
- Labour productivity increased by 15% or more.

As can be understood from these results, digital transformation is very necessary and important in the field of agriculture. It is equally important for farmers and institutions to know, select and use the right digital tools.

1.5 An overview of digital tools and education-training methods used in agriculture

Agriculture 4.0 can also be defined as the integration of automatic equipment and sensors, which include the smart and digital technologies of Industry 4.0, into machinery, devices, systems, and tools used in agricultural production. This digital transformation in agriculture, from production to marketing, enables the creation of new information in the decision-making processes of farmers and agricultural enterprises, increasing their cooperation with various actors in the food value chain, and removing old rigid boundaries in order to improve the profitability and economic, environmental, social sustainability of agriculture[1,2]. The main goal is to produce more, better, and more efficiently with fewer tools. The emergence of agro-ecosystems, with platforms that aggregate data from low-cost sensors and microprocessors or other equipment in the field, which will be detailed in other chapters in this manual, allows the farmers to provide immediate real-time information and make immediate decisions to increase productivity. If we list some systems and applications used in digital agriculture applications today[21,22]:

Use of robots and drones in agriculture: They are used to obtain and display product data, to assist in spraying, irrigation, planting and harvesting operations. With these images processed with different software, it is possible to detect diseases, plant growth and to apply the correct pesticide, fertilizer, irrigation amounts, and procedures.

Internet of Things (IoT): The use of IoT devices in agricultural fields that can send plant-related data remotely allows real-time monitoring of plant conditions and, through statistical models, to predict when irrigation, fertilization or the use of a pesticide is needed.

Blockchain technology: This technology is used to ensure the origin of food and to prevent product quality fraud.

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[1] Sponchioni G., Vezzoni M., Bacchetti A., Pavesi M., Renga F., 2019. The 4.0 revolution in agriculture: a multiperspective definition. XXIV Summer School “Francesco Turco – Industrial Systems Engineering. https://www.summerschool-aidi.it/cms/extra/papers/591.pdf

[2] Pogorelskaia, I., & Várallyai, L. (2020). Agriculture 4.0 and the role of education. *J. Agric. Inform*, *11*, 45-51.

The digital transformation and Agriculture 4.0 described above require advanced digital skills, training, and networking farmers, trainees, institutions, trainers, and advisors. Farmers need to get ready to embrace the upcoming digital change and transformation. However, as it is known, it is very difficult to change habits. In order to break this chain of habits, training should be as flexible and interesting as possible. Developing employee skills is one of the biggest factors that can improve financial and production results, reduce costs, and help businesses maintain a competitive advantage. And digital training can be used for this.

While traditional face-to-face education continues to play an important role in education and training, today, it can be said that self-learning in acquiring digital skills is becoming more important. Digital education offers a flexible working environment and paves the way for self-learning. Approximately 72% of the employees say that they have acquired ICT skills through independent learning in practice according to the latest Eurostat data1.

Gamification, learning clouds, lecture videos, interactive videos, huge open online courses (MOOCs), virtual reality exercises, and interactive problem sets with automatic feedback and classification make self-learning easy. It is believed that MOOCs to be prepared within the scope of the Digital Farmer project will also contribute to providing a kind of modulated approach to lifelong learning and education for trainees and trainers.

1.6 Educational needs in smart agriculture

In 2020, 157 million hectares of land in the EU, 38% of the EU's total land area, were used by 9.1 million agricultural holdings. and used for agricultural production in 2020, which is 38% of the EU's total land area. 71.3 % of farm managers are male and a majority (57.8 %) are 55 years of age or molder. Only about 10.7 % of farm managers are young farmers under the age of 40[2].

Especially, since the 1970s, electronic record-keeping systems and services based on making informed decisions have been offered to producers[3]. It is a fact that the agricultural industry, government agencies and growers have critical needs for skills and innovations in computing and information technology. While lack of training and education is one of the main challenges to smart agriculture adoption, other factors are cost, return on investment and a lack of big data analytics in smart agriculture[24]. So, it is important to actively encourage producers to develop their computer skills and to provide suitable options to develop various computer skills without leaving the farm with distance learning easily accessible via the World Wide Web (www). Today, these options are numerous and easily accessible[4].

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[1] Eurostat Database, 2019. Employed ICT specialists-total, proceedings from Eurostat https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_sks_itspt&lang=en

[2] Eurostat, 2020. Agriculture, forestry and fishery statistics 2020 edition https://ec.europa.eu/eurostat/documents/3217494/12069644/KS-FK-20-001-EN-N.pdf/a7439b01-671b-80ce-85e4-4d803c44340a?t=1608139005821

[3] Kitchen, N. R., Snyder, C. J., Franzen, D. W., & Wiebold, W. J. (2002). Educational needs of precision agriculture. *Precision agriculture*, *3*(4), 341-351.

[4] A. Salam and S. Shah, "Internet of Things in Smart Agriculture: Enabling Technologies," *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, 2019, pp. 692-695, doi: 10.1109/WF-IoT.2019.8767306.

Despite all this progress and facilitation, due to the reasons mentioned below, many producers do not have the necessary infrastructure for many data management and analysis needs to be related to smart agriculture. Although Geographic Information System and other data management systems, smart agricultural machines and unmanned land/air/water machines have become more user-friendly over time, their effectiveness still requires significant training and experience25.

For better education and training in agriculture, it is important to anticipate new skill requirements and tailor courses; accordingly, strengthen the partnership between agricultural education and the agri-food industry, and collect accurate data for in-depth skills assessment[1].

It can be said that one of the biggest challenges in the agricultural sector is the older and less skilled workforce in the sector. Considering the EU economy, the agricultural sector in the EU shows the largest quality mismatch (in 2019 research)[24] . According to field studies, agricultural added value per worker is higher in high-income countries due to reasons such as the adoption of new technologies, the implementation of more efficient practices, and a better educated/trained human resource. The participation of agro-food workers in vocational education and training is still lower than in other sectors[27]. Across Europe, the vocational training received by agricultural workers is less than for workers in any other sector. The proportion of agricultural workers receiving vocational training in Denmark and the Netherlands is 65%, the highest rate in all of Europe.

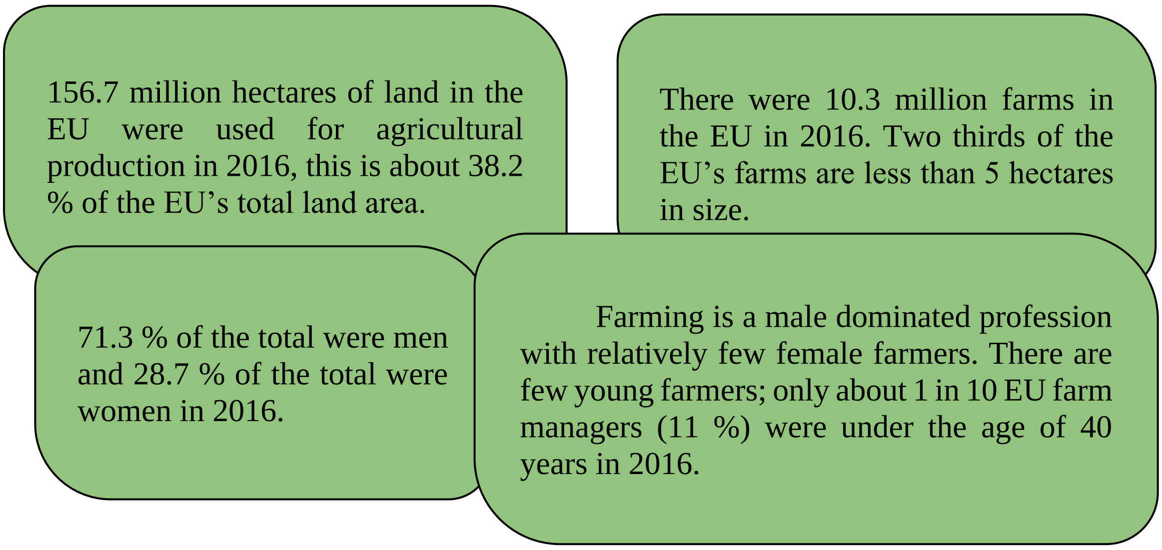

Figure 1.4. The agricultural sector in the EU (Source: Eurostat[24])

When the structural change of EU farms is combined with the priorities brought by the green transformation, sustainable resource management and digital transition, the skills needed,

[1] Masayasu Asai. Skills for the twin green and digital transition in agriculture, 2022. . Farming’s got talent! Vocational education and training for agriculture in transition. https://agriculture.ec.europa.eu/events/farmings-got-talent-vocational-education-and-training-agriculture-transition-2022-11-24_en

such as digital literacy, environmental management, and entrepreneurship, are also changing. To fill these gaps, education systems, training needs, and informal learning opportunities need to be adjusted for barriers assessment[27].

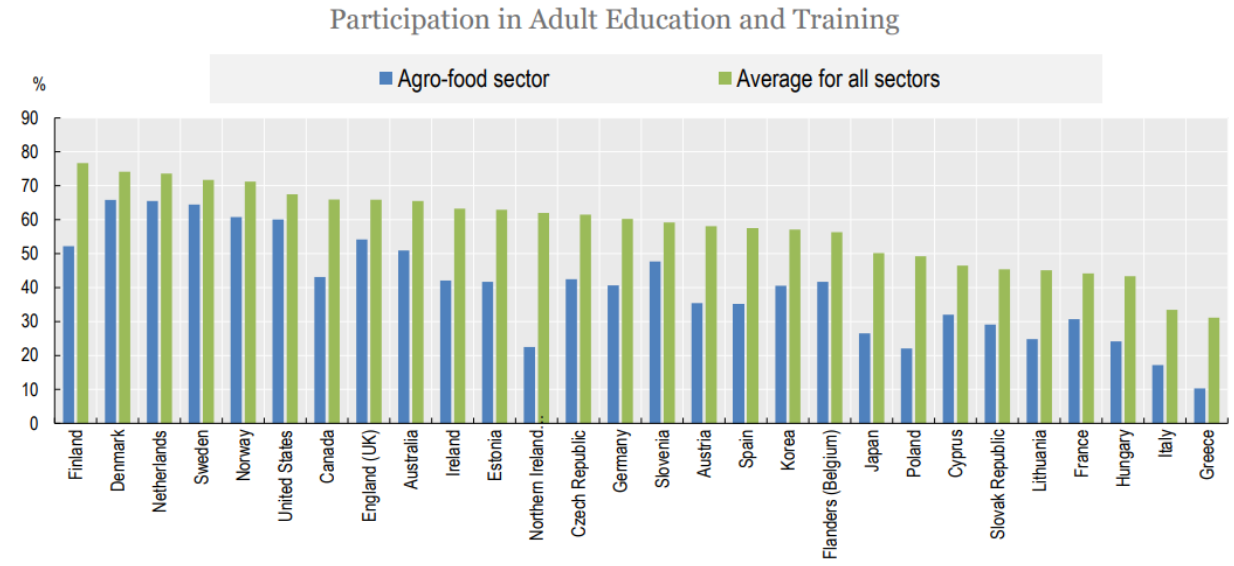

Figure 1.5. Participation of agro-food workers in vocational education and training (Source: The Survey of Adult Skills - PIAAC[1])

Why is the adoption of sustainable and digital farming practices not widespread, despite the proven effectiveness of digital farming systems that help with the economic, environmental, and social sustainability of farming activities?

Training/education, social barriers, land ownership, infrastructure and incompatibility are major barriers to adoption. Digitization in agriculture has the potential to create a digital divide between those who have access to the latest technologies and those who do not2.

It is important to support farmers with training, resources, and incentives to adopt new technologies. Thus, it can be said that the EU agriculture sector can both address urgent problems such as food security and climate change and make the most of the digital age by increasing the sustainability and profitability of agricultural production. There are some barriers to agricultural learning, also[27,29]:

- Cost
- Lack of time to complete/deliver staff training
- Geographic accessibility
- Gender inequality
- Poor rural infrastructure
- Fragmented learning infrastructure
- Inclusion of seasonal workers

[1] The Survey of Adult Skills (PIAAC). https://www.oecd-ilibrary.org/education/skills-matter_1f029d8f-en

[2] https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture

•Reluctance to share knowledge

To overcome these barriers:

- Special attention needs to be paid to the introduction and application of digital technologies to small and family farmers.
- The farmer should be at the centre of the strategy and should not be "forgotten".
- Collaboration should be encouraged, and knowledge shared through online communities of practice[1].

The "EIP-AGRI Seminar: New skills for digital farming" report[2] highlights some of the barriers and the requirements to overcome them: addressing barriers to participation in agricultural education and VET, ensuring that agricultural education and VET are aligned with industry needs, digital integrating tools and practices into agricultural education and VET, and addressing the skill gap that may lead some farmers to fall behind. Here, the development of technical farming skills as well as cognitive and "soft" skills come to the fore[3].

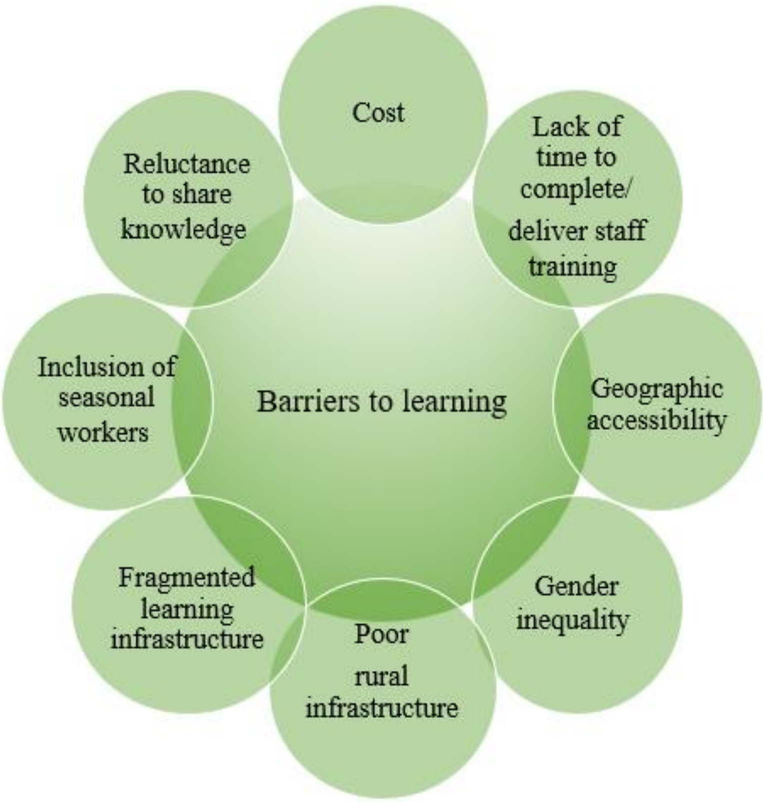

Figure 1.6. Some barriers to agricultural learning (Source: 27)

[1]https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2020/Series%20of%20Webinars/20-00244_Status_digital_Agriculture-revFAOV4.0-MASTER-FILE-20-JUNE_REVIEW-FAO_PL_print%20(002).pdf
[2]https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_seminar_new_skills_for_digital_farming_final_report_en_2020.pdf
[3]https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_seminar_new_skills_for_digital_farming_final_report_en_2020.pdf

There are basically three approaches to education (traditional, experiential, and performance-based). *Critical Thinking, Problem Solving Approach, and Problem-Based Learning* are more preferred so that the training can highlight the real or simulated situations in which trainees will eventually operate, making the training more engaging and lasting. Problem-based teaching has been an important teaching strategy in agricultural education from the very beginning, and this method helps learners apply what they have learned in their daily work[1].

In particular, the tools used for distance learning have recently made education more effective, sustainable, and accessible by eliminating the concept of time and place. Massive Open Online Courses (MOOCs), game-based learning tools, Virtual (VR) and Augmented Reality (AR) applications are increasingly used in vocational education and training. Virtualised practical training is a new methodology for training[2], also.

Virtual Reality (VR) is the combination of reality and imagination with fictions created using technology. Virtual learning environments allow technology to be incorporated into educational environments and enrich students' learning experiences[3]. Augmented reality (AR) is a live or indirect physical view of the real-world environment and its contents enriched with sound, image, graphics, and GPS data. This concept is briefly the changing and augmentation of reality by the computer[4].

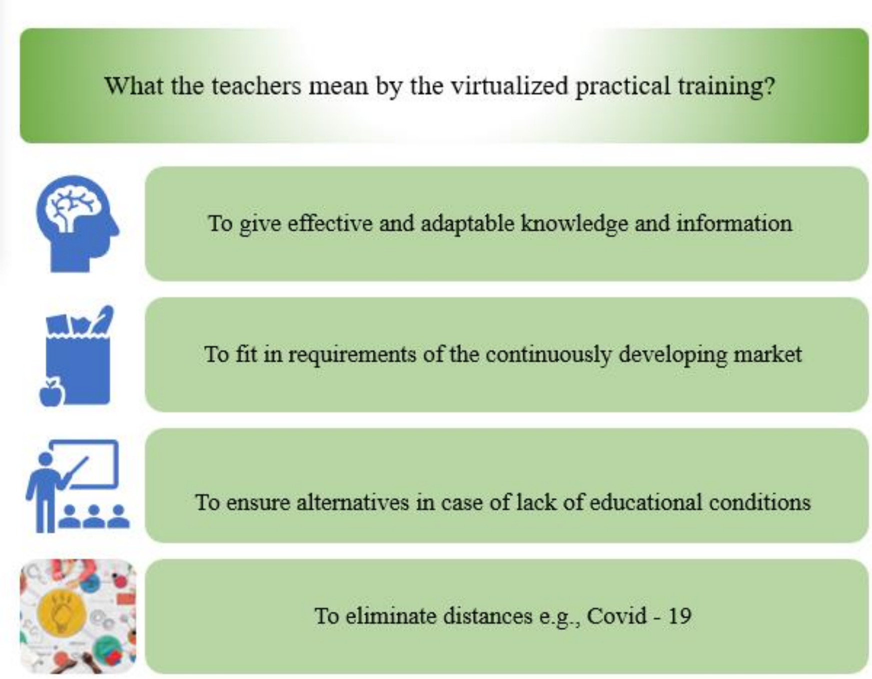

Figure 1.7. Virtualised practical training (Source: Innovation in agricultural education[30])

[1] Saleh, J. M. Systematic Review: Training Needs of Agriculture Extension Workers.

[2] Éva Sári, Innovation in agricultural education, 2022. Farming's got talent! Vocational education and training for agriculture in transition. https://agriculture.ec.europa.eu/events/farmings-got-talent-vocational-education-and-training-agriculture-transition-2022-11-24_en

[3] https://tr.wikipedia.org/wiki/Sanal_ger%C3%A7eklik

[4] https://tr.wikipedia.org/wiki/Art%C4%B1r%C4%B1lm%C4%B1%C5%9F_ger%C3%A7eklik

It is important to use new education and training approaches and technological elements in agricultural education as well. It is clear that accessible and sustainable education solutions will play an important role in promoting, disseminating and increasing the use of digital agriculture.

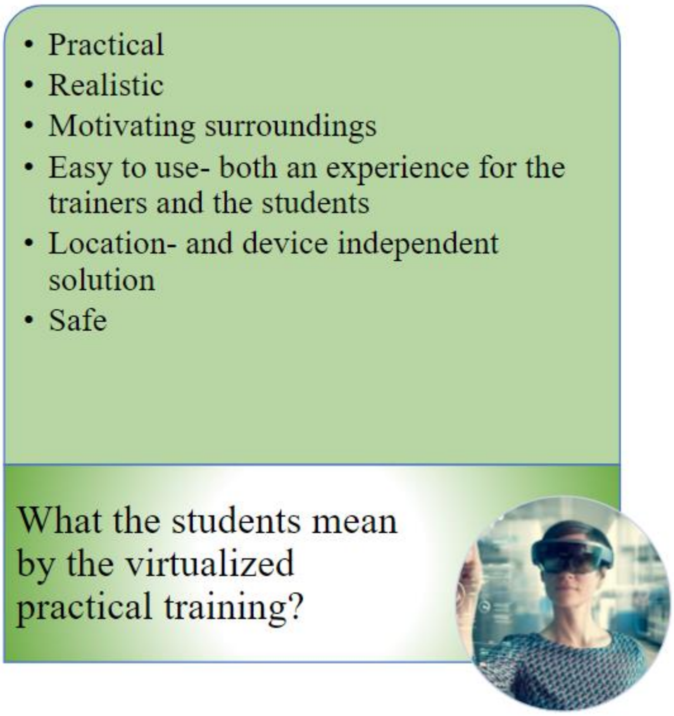

Figure 1.8. Practical training (Source: Innovation in agricultural education[30])

As one of the outputs of this project, MOOCs are used by millions of people around the world to learn for a variety of reasons, including career advancement, career switching, complementary learning, lifelong learning, corporate e-learning, and training, and more.

1.7 How to use

This section focuses on digitalization in agriculture, digital tools, Industry 4.0, Agriculture 4.0, and digital agriculture education and includes links to digitalization in agriculture. Dedicated to farmers and field workers who want to learn and learn more about the subject for their farm or business. This chapter provides a brief overview of the concepts of digitalization in agriculture used globally. The importance of digitalization in agriculture, its advantages, opportunities, and the obstacles in front of it are briefly explained, and it is aimed to create awareness and foreknowledge.

HINTS FOR EDUCATOR

Some of the other resources that can be accessed to gain in-depth knowledge on the subject a listed below:

Industry 4.0 in Agriculture: Focus on IoT aspects:
https://ati.ec.europa.eu/sites/default/files/2020-07/Industry%204.0%20in%20Agriculture%20-%20Focus%20on%20IoT%20aspects%20%28v1%29.pdf
FARMING 4.0: THE FUTURE OF AGRICULTURE? https://euagenda.eu/upload/publications/untitled-62960-ea.pdf
Other sources of information and use:
https://ec.europa.eu/eip/agriculture/en/digitising-agriculture/learning-and-using-digital-technologies-0.html

https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-digital-strategy-agriculture.html

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European Commission. (2018). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Digital Education Action Plan. Brussels, 17 January, COM (2018) 22 final.

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Smith, M. J. (2018). Getting value from artificial intelligence in agriculture. Animal Production Science, 60(1), 46-54.

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Rose, D. C., Wheeler, R., Winter, M., Lobley, M., & Chivers, C. A. (2021). Agriculture 4.0: Making it work for people, production, and the planet. Land use policy, 100, 104933.

Taechatanasat, P., & Armstrong, L. (2014). Decision support system data for farmer decision making.

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Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. Agricultural systems, 153, 69-80.

Sanghavi, J., Damdoo, R., & Kalyani, K. (2020). Agribot: IoT based Farmbot for Smart Farming. Helix, 10(04), 325-328.

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The Survey of Adult Skills (PIAAC). https://www.oecd-ilibrary.org/education/skills-matter_1f029d8f-en

https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture

https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2020/Series%20of%20Webinars/20-00244_Status_digital_Agriculture-revFAOV4.0-MASTER-FILE-20-JUNE_REVIEW-FAO_PL_print%20(002).pdf

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_seminar_new_skills_for_digital_farming_final_report_en_2020.pdf

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_seminar_new_skills_for_digital_farming_final_report_en_2020.pdf

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CHAPTER 2

Information and Communication Technologies

CHAPTER 2 Information and Communication Technologies

Author: *Valerio Alessandroni*
Organization: *EFCC Estonian Fieldbus Competency Centre Oy*

WHAT WILL WE LEARN IN THIS CHAPTER?

What is smart farming?
Why ICT in agriculture 4.0?
What are Cloud-, Edge- and Fog Computing?
What are Fieldbus technologies?

Keywords: Agriculture 4.0; Precision Agriculture; Smart Agriculture; Cloud computing; Edge computing; Fog computing; Internet of Things; IoT; Fieldbus technologies; Wireless communication; ISO/OSI model; Artificial Intelligence; Virtual Reality; Augmented Reality; Big Data; Sensors; Mechatronics; Robots; Agribots; 5G

2.1. Glossary and abbreviations

In the following table, some words/abbreviations/definitions useful for understanding the chapter have been reported.

Android	Linux-based operating system designed primarily for touchscreen mobile devices such as smartphones and tablet computers.
API	Application Programming Interface.
App	Abbreviation for application, usually refers to a software for a specific device or purpose.
Application	A computer software designed to help you perform a specific task.
Assessment	In education, there is a wide variety of methods or tools that educators use to evaluate, measure the progress, skill acquisition, or needs of students.
Browser	A software program which provides access to web pages, e.g., Microsoft Edge, Mozilla Firefox, Google Chrome, etc.
Cascading Style Sheets (CSS)	A feature of HTML that enables a range of styles for headers, body text, bullet points, links etc.
CD-ROM	Compact Disc Read-Only Memory. A computer with a CD-ROM drive is needed to read this kind of disc.
CMS	Content Management System. A software package that makes it possible for non-technical users to publish content (text, images, etc) on a website.
DSS	Decision Support System.
Distance Learning (DL)	A method thanks to which lectures are broadcast or conducted by correspondence, without the student needing to attend a school or college physically but with the help of digital tools.
Digital Competence Framework for Educators (DigCompEdu)	A scientific framework that describes how to be digitally competent to educators, providing general reference frames in order to support the development of educator's digital competences in Europe.
Digital Competence Assessment (DCA)	Assesses users' skills against competence areas such as content creation or safety.
eLearning	eLearning encompasses all forms of technology enabled learning (TEL) whether that happens on campus or at a distance. Learning & teaching is mediated through ICT services and hardware. This will include computers, tablets, mobile devices and handheld devices. It also includes services such as Moodle and Google Apps.
HTML	HyperText Markup Language. The main language for displaying web pages and other information in a web browser.
ICT	Information and Communications Technology.
iOS	Apple's mobile operating system.
iPad	Tablet computer designed and developed by Apple. It is particularly marketed as a platform for audio and visual media.

Modular Object-Oriented Dynamic Learning Environment (MOODLE)	A digital space for learning and consulting materials for studying.
Network	A collection of computers and other hardware interconnected by communication channels that allow sharing of resources and information.
Podcast	Pre-recorded audio or video files delivered onto the internet, and which can be played back through a computer or digital players such as iPods, MP3s, etc.
Proxy Server	An online tool (also known as a gateway) which is applied to a private network to re-direct its own users to selected websites.
QR Code	Quick Response Code. A two-dimensional bar code which can be read quickly by a cell phone or tablet device with a camera and QR reader application. Used to encode small amounts of information such as a website URL, GPS location, product information, etc.
Software	A generic term describing all kinds of computer programs, applications and operating systems.
VPN	Virtual Private Network. A remote access technology that allows you to connect to a network using any internet connection.
Wifi	A way of transmitting information without cables that is reasonably fast.
WYSIWYG	What You See Is What You Get, refers to what you see on the screen.

Table 2.1. Glossary and abbreviations

2.2. Competence Map

Learning outcomes	*Competences and skills*	*Duration time*	*Learning tools*
• To understand Agriculture 4.0 and ICT in agriculture • To understand the applications and the utilization of ICT and automation systems	• To learn the practical application of ICT in agriculture • To learn the advantages and disadvantages of automation in agriculture • To learn the collection, management and use of data for Agriculture 4.0 applications	Per MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 2.2. Competence map

2.3. How to use the Chapter

Below is a list of links and tutorials on how to use different ICT and automation systems in agriculture. It is dedicated to farmers and field workers who want to learn and learn more about the subject so that they can choose the best ICT or automation system for their farm or business.

Smart Farming:

"Survey for smart farming technologies: Challenges and issues", https://www.sciencedirect.com/science/article/abs/pii/S0045790621001117

Precision Agriculture:

"Precision Agriculture - An International Journal on Advances in Precision Agriculture", https://www.springer.com/journal/11119

"Educational Needs of Precision Agriculture", https://www.ars.usda.gov/ARSUserFiles/50701000/cswq-0196-114689.pdf

Agriculture 4.0:

"Smart Farming - Industry 4.0 in Agriculture", https://www.emnify.com/blog/smart-farming-iot

The Internet of Things (IoT):

"The Interplay between the Internet of Things and agriculture: a bibliometric analysis and research agenda", https://www.sciencedirect.com/science/article/pii/S2542660522000701

Cloud, Edge and Fog Computing:

"Teaching and learning cloud computing", https://pdf.sciencedirectassets.com/

Big Data:

"Big Data Tutorial For Beginners", https://www.youtube.com/watch?v=zez2Tv-bcXY

Artificial intelligence (AI):

"43 Examples of Artificial Intelligence in Education", https://onlinedegrees.sandiego.edu/artificial-intelligence-education/

"Artificial Intelligence for Teaching, Learning and Assessment", https://www.youtube.com/watch?v=shFpPQNNJwA

Communication and Fieldbus technologies:

"Fundamentals of Communication: 8 Basic Concepts and Definitions", https://online.arbor.edu/news/fundamentals-communication-eight-basic-concepts-and-definitions

"Standardisation and efficiency are guaranteed with ISOBUS technology", https://hexagon.com/resources/resource-library/standardisation-efficiency-guaranteed-with-isobus-technology

Communication between sensors and actuators:

"Learning Fieldbus Technology using open and flexible educational equipment", https://www.sciencedirect.com/science/article/pii/S1474667015331608

Remoting the I/Os:
"What is remote I/O?",
https://realpars.com/remote-io/
The 5G technology:
"Everything you need to know about 5G",
https://www.qualcomm.com/5g/what-is-5g

2.4. The European Framework for the Digital Competence of Educators

The European Framework for the Digital Competence of Educators (DigCompEdu) responds to the growing awareness among many European Member States that educators need a set of digital competences specific to their profession in order to be able to seize the potential of digital technologies for enhancing and innovating education.

The DigCompEdu Framework synthesizes national and regional efforts to capture educator-specific digital competences. It aims to provide a general reference frame for developers of digital competence models, i.e. Member States, regional governments, relevant national and regional agencies, educational organisations themselves, and public or private professional training providers.

It is directed towards educators at all levels of education, from early childhood to higher and adult education, including general and vocational training, special needs education, and non-formal learning contexts. It invites and encourages adaptation and modification to the specific context and purpose.

This Chapter explains the main components building up the general Digital Competences of training providers, with special reference to ICT technologies.

2.5. Introduction - Technological revolutions in smart farming

In this Chapter, some of the ICT technologies that can be applied to agriculture are introduced.

At https://ec.europa.eu/eip/agriculture/en/find-connect/online-resources you can find interesting websites, databases and other online resources that give information about innovation in European agriculture and forestry, or that may inspire you to develop your own innovative projects or ideas.

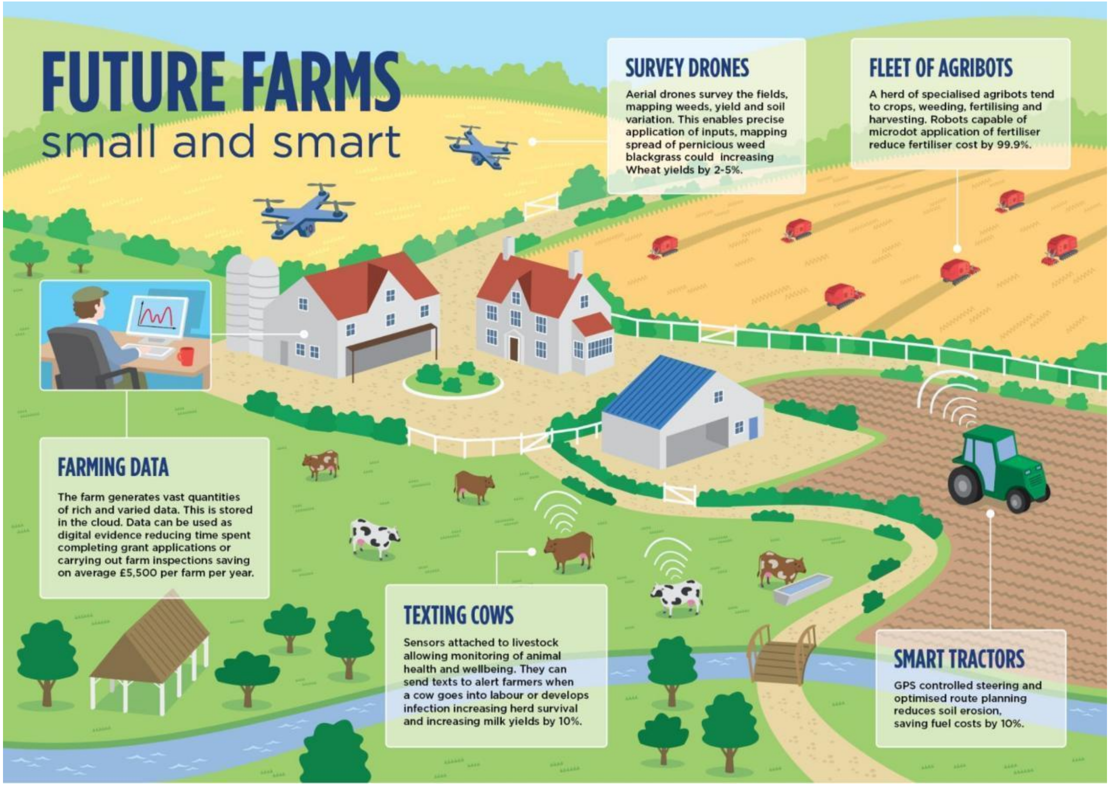

Figure 2.1. How the gig economy can transform farms in the developing world

Source: www.weforum.org/agenda/2018/03/this-is-how-farm-drones-will-transform-the-way-your-food-is-grown/

2.6. Opening

With an increasing population, the demand for agricultural productivity is rising to meet the goal of "Zero Hunger".

The Food and Agricultural Organization of the United Nation (FAO) predicts that the global population will reach 8 billion people by 2025 and 9.6 billion people by 2050 (FAO, 2009). This practically means that an increase of 70% in food production must be achieved by 2050 worldwide. The great increase in global population and the rising demand for high-quality products create the need for the modernization and intensification of agricultural practices. At the same time, the need for high efficiency in the use of water and other resources is also mandatory.

The agricultural sector is penalized by low and severe incomes shortage of qualified workers. Consequently, it will be necessary to devise ways to increase productivity despite limited resources. Fortunately, **technology can help**. Many research shows that agritech has the potential to increase productivity, satisfying food demand and remaining, at the same time, competitive on the market.

2.7. Smart farming

In recent years, concepts such as smart farming, smart agriculture, or precision agriculture have become popular. These concepts are generally regarded as the same, and the terms are often used interchangeably. In general, smart farming uses the new technologies in the agricultural domain to make maximum use of resources and minimize the environmental impact.

Figure 2.2. Smart Farming
Picture by Agriculture Machinery & Materials Company, Pixabay
https://pixabay.com/it/photos/natura-app-rurale-campo-all-aperto-7449065/

Farming 'smarter' is no longer an 'advanced' tactic for savvy farmers; it's becoming an increasingly necessary way to optimise and preserve human and natural resources.

Farm labour is becoming increasingly scarce due to urban migration and ageing populations.

Intensifying climate change is altering growing conditions in less predictable ways.

Earth's resources and biodiversity are diminishing. Smart farming tools can help reduce these impacts, minimize environmental constraints and reduce production costs in farming activities.

Smart farming tools introduce a new level of technology into agriculture, including mapping, robotics, geomatics, automation, decision making and statistical processes.

Farmers can optimize the agricultural activities in a sustainable way with modern technologies. This integration has boosted the agriculture production due to high potentiality in assisting the farmers.

The impulse towards technological advancement has revived the traditional agriculture methods and resulted in eco-friendly, sustainable, and efficient farming. This has revolutionized the era of smart farming which primarily aligns with modern technologies.

In fact, **the key to smart agriculture** is in utilizing **information and communication technologies** to make agricultural cultivation and production automatic and intelligent.

Specifically, **wireless communications** play an active role in the development of agriculture, and every generation of wireless communication technology drives agriculture to a more intelligent stage. Moreover, it is of importance to exploit the **up-to-date communication technologies** to further promote agricultural development.

Smart farming incorporates **information and communication technologies** into machinery, equipment and sensors used in agricultural production systems. Technologies such as the IoT and **cloud computing** are advancing this development even further by introducing more robots and artificial intelligence into farming.

For example, farmers can use smartphones and tablets to access real-time data about the condition of almost anything involved in their day-to-day operations.

The use of smart farming tools is possible due to the use of **sensors** connected to a **network**.

A sensor is a device that:

- Measures physical quantities from the environment
- Converts these measurements into a signal

The signal is read and interpreted by an instrument.

The measurements read by include (but are not limited to):

- Temperature
- Humidity
- Light
- Pressure
- Noise
- Speed
- Direction
- Size & weight

Hint for educators: The Smart Farming 4.0 training system from Lucas Nuelle focuses on the Internet of Things (IoT), sensors and actuators, geo-positioning systems, Big Data, UAVs, drones, robotics, etc.

Through numerous measuring points and fault simulations, learners experience Smart Farming in a compact and easy-to-use training system. Combined with a comprehensive e-learning course, you'll teach using realistic animations and videos

Learn how you can simulate "Precision Farming" by bringing tractor and seed drill virtually into the classroom.

2.8. Precision Agriculture

One of the most promising concepts, which is expected to contribute a lot to the required increase of food production in a sustainable way, is precision agriculture (PA).

PA deals with the use of **digital solutions for specific interventions**, which take particular account of needs of the soil and plants. The target of these interventions is to improve as much as possible the production yield of plantations and contain costs and environmental impact.

Examples are the interventions to make irrigation more efficient without wasting resources, planting technologies adapted to biochemical and physical characteristics of the soil, the use of pesticides with reference to the specific needs of each single area and plant, or the use of fertilizers only in the necessary quantity.

Precision agriculture aims to **optimize and improve agricultural processes** to ensure maximum productivity and requires fast, reliable, distributed measurements in order to give growers a more detailed overview of the ongoing situation in their cultivation area, and/or coordinate the automated machinery in such way that optimizes energy consumption, water use and the use of chemicals for pest control and plant growth.

Currently, sensors can offer highly accurate measurements of crop status. Based on those values, actuators can manage agricultural processes related to animals, crops, greenhouses, irrigation, soil, and weather. This can result in improvements to harvest forecasting, weather prediction, increased production, water conservation, real-time data collection, and production, lowered operation costs, equipment monitoring, remote monitoring, and accurate farm and field evaluation.

Figure 2.3. Precision Agriculture Series: AgriTech and the Data Challenges of 2021
by Jodi Lifschitz, Dataloop AI Blog
https://dataloop.ai/blog/precision-agriculture-challenges/

At a higher level, having gathered information from many heterogeneous systems, well evaluated scientific knowledge can be organised in the form of smart algorithms to provide a better insight into the ongoing processes, do the reasoning of the current situation and make predictions based on heterogeneous inputs, produce early warnings about potential dangers that threaten the cultivars, and improved automated control signals, based on plant responses.

The algorithms required to handle the distributed data in real time are far too complicated to run locally on a low-power Wireless Sensor Network (WSN) node.

However, in the context of **Internet of Things (IoT)**, all the objects will be interconnected, and therefore the computational overhead can be easily shifted to the cloud or be distributed among more than one interconnected device.

Hint for educators: "Increasing Food Production with Precision Agriculture"
This hands-on lesson teaches students how precision agriculture uses geographic information systems (GIS) to help farmers and manufacturers make smart, efficient, and responsible decisions about how and when they plant, grow, irrigate, harvest, and transport crops.
https://agclassroom.org/matrix/lesson/513/

2.9. Agriculture 4.0

As the concept of digital transformation is gaining momentum in all areas of life daily, revolutionizing the way we produce and interact, the applications of digital tend to "specialize" in the individual sectors of application.

And one of those who have more to gain from this innovation process is undoubtedly agriculture, which often comes considered with a "traditionalist" environment and little inclined to change, but which instead in recent years is experimenting with evident and easily measurable results the potential of digitization.

So if - when we turn specifically to manufacturing - the term to indicate digital transformation in production environments is "**industry 4.0**", the entry of technologies of fourth industrial revolution in agrifood is "**agriculture 4.0**".

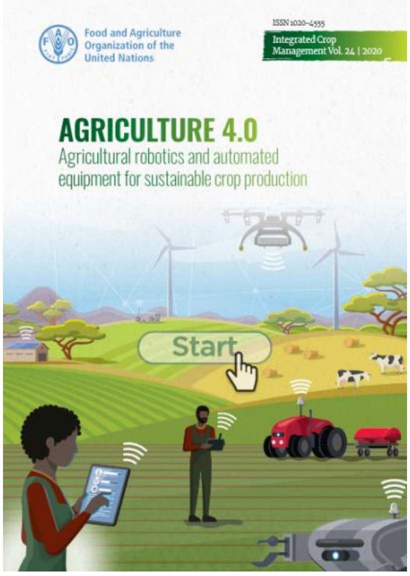

Figure 2.4. "Agriculture 4.0 – Agricultural robotics and automated equipment for sustainable crop production"

FAO http://www.fao.org/3/cb2186en/CB2186EN.pdf

Agriculture 4.0 is the result of the application of a series of **innovative technologies** in the field of agrifood, and can be considered as an "upgrade" of precision agriculture. This thanks to the automation of the collection, integration and analysis of data that comes directly from the fields through sensors and other sources.

Digital 4.0 technologies in this context are useful to support - thanks to data analysis - the farmer in his daily activity and in the planning of strategies for his business, including relationships with all the rings of the chain, generating a virtuous circle capable of creating value for the individual company and a cascade for its partners.

Thanks to these new solutions and to the application of digital technologies, from the **IoT** to Artificial **Intelligence**, from the analysis of large amounts of data to self-driving tractors and the use of drones, farms can increase the economic, environmental and social sustainability and profitability of its business.

Hint for educators: "Connecting VET teachers to Agriculture 4.0", https://www.agriteach.hu/sites/default/files/events/upload-field/agriteach_textbook_en.pdf

2.10. The Internet of Things (IoT)

The increasing demand for food, both in terms of quantity and quality, has raised the need for intensification and industrialization of the agricultural sector. The **"Internet of Things" (IoT)** is a highly promising family of technologies which is capable of offering many solutions towards the modernization of agriculture.

Scientific groups and research institutions, as well as the industry, are in a race trying to deliver more and more IoT products to the agricultural business stakeholders, and, eventually, lay the foundations to have a clear role when IoT becomes a mainstream technology.

The term "Internet of Things" (IoT) was first coined by a British visionary, Kevin Ashton, back in 1999. As the phrase "Internet of Things" reveals, the IoT paradigm will provide a technological universe, in which many physical objects or "things", such as sensors, everyday tools and equipment enhanced by computing power and networking capabilities will be able to play a role, either as single units or as a distributed collaborating swarm of heterogeneous devices.

Agriculture is one of the sectors that is expected to be highly influenced by the advances in the domain of IoT. Scientific groups and research institutions, as well as the industry, are in a race trying to deliver more and more IoT products to the agricultural business stakeholders, and, eventually, lay the foundations to have a clear role when IoT becomes a mainstream technology.

The **structure of IoT** is based on three layers; namely, the perception layer (sensing), the network layer (data transfer), and the application layer (data storage and manipulation).

Despite great improvements, IoT is still evolving, trying to obtain its final shape As the term "Internet" implies, networking capability is one of the core features of the IoT devices.

The internet as we know it today is mostly an internet of human end-users, while the IoT will be an internet of non-human entities, therefore a lot of machine-to-machine (M2M) communication will take place.

At the same time **Cloud Computing**, which is already very popular, and **Fog Computing** provide sufficient resources and solutions to sustain, store and analyze the huge amounts of data generated by IoT devices.

The management and analysis of IoT data ("**Big Data**") can be used to automate processes, predict situations and improve many activities, even in real-time.

Moreover, the concept of interoperability among heterogeneous devices inspired the creation of the appropriate tools, with which new applications and services can be created and give an added value to the data flows produced at the edge of the network. The agricultural sector was highly affected by **Wireless Sensor Network** (WSN) technologies and is expected to be equally benefited by the IoT.

Realistic IoT/WSN deployments in the agricultural sector are quite demanding and remain a challenging task. Sensor modules need to be accurate enough, with the appropriate measuring range for the situation at hand, and shielded against environmental factors which can either create false readings or even destroy the sensor permanently.

Due to the distributed nature of IoT, in cases of battery-operated nodes, placed in open fields or other agricultural facilities, replacing the power source can be a very difficult task, if not impossible. Therefore, very strict power constraints affect the selection of hardware and the lowpower features of the selected peripheral devices are always considered when designing a new system. Software-wise the components which are to be integrated in order to implement the functionality of an end-device have to be carefully inspected.

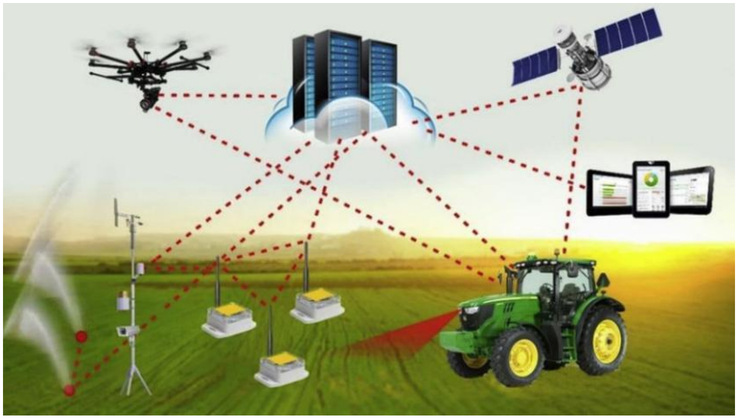

Figure 2.5. "IoT in agriculture"

Source: "Internet of Things in agriculture, recent advances and future challenges", Antonis Tzounis , Nikolaos Katsoulas , Thomas Bartzanas , Constantinos Kittas, Biosystems Engineering

2.10.1 Cloud, Edge and Fog Computing

Cloud Computing is a well-established paradigm for building service-centric systems.

Modern computing paradigms such as Cloud, Fog, and Edge play a vital role in agriculture. The number of agricultural domain applications that use the combination of Cloud, Fog, and Edge is increasing in the last few decades.

The main applications of **Cloud, Fog and Edge Computing** in agriculture are crop farming, livestock, and greenhouses, which are grouped into different application domains. Some of these applications are implemented with the help of IoT-based sensors and devices by using wireless sensor networks, and some other applications are developed with combinations of new computing. For instance, Cloud and Fog, Cloud and Edge, Fog and Edge, or Cloud–Fog–Edge and IoT.

The term "**Cloud Computing**" was first used by Google and Amazon in 2006. More recently, Cloud has been defined as a computing paradigm for providing anything as a service such that the services are virtualized, pooled, shared, and can be provisioned and released rapidly with minimal management effort.

Fog Computing is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing data centers, typically, but not exclusively located at the edge of the network. Thus, the user's computation demand is served at their proximity rather than performing it in the distance Cloud. Moreover, Fog Computing is primarily introduced for applications that need realtime processing with low latency.

Edge Computing is an emerging area where data processing occurs near proximity to mobile devices or sensors. It has been proposed to improve the performance and overcome problems of Cloud by providing data processing and storage ability at the end devices locally. Edge Computing refers to the enabling technologies allowing computation to be performed at the Edge of the network, on downstream data on behalf of Cloud services and upstream data on behalf of IoT services. Edge computing is achieving considerable importance with new use cases, especially after the introduction of 5G.

Until recently, Cloud computing was considered the traditional approach to meeting the requirements of the Internet of Things. Cloud computing allows access to a shared set of IT resources (such as networks, servers, storage media, applications and services) with minimal interaction between the management center and the service provider. However, the use of cloud computing as a centralized server, which is generally geographically distant, increases the frequency of communications between the peripheral devices used by users (tablets, computers, bracelets or smartphones) becoming a limitation for applications that require a response in real time.

The so-called 'Edge computing', which has become very popular with the advent of Industry 4.0, is a concept of distributed computing that brings computing itself and data storage closer to where they are needed. This minimizes the need for long-distance communications between client and server, improving latency (hence network performance) and saving bandwidth.

In particular, by processing data closer to the source and reducing the physical distance it has to travel, Edge computing (or processing at the edge) optimizes Internet (IoT) devices and web applications. In essence, Edge computing is a 'network of micro data centers that process or store critical data locally in a very limited area'.

The distinguishing characteristics of Edge Computing from Cloud are dense geographical distribution, mobility support, location awareness, proximity, low latency, context-awareness, and heterogeneity.

2.10.2 - Edge computing and IoT

For IoT devices, the 'network edge' is the point where the device, or the local network that contains the device, communicates with the Internet. The limit is a bit blurry: for example, a user's computer or the processor inside an IoT camera can be considered the edge of the network, but the user's router, ISP or local edge server can also represent the limit. The important thing is that the edge of the network is geographically close to the device, unlike traditional servers, which can be very far from the devices they communicate with.

Let's consider a building protected by high definition IoT cameras. These are usually 'stupid' cameras that continuously transmit an unprocessed video signal to a cloud server. On the cloud server, the video signal from all cameras is filtered by a motion detection application to ensure that only the parts containing activity are saved in the server database.

This means that there is constant and significant activity on the building's Internet infrastructure, because the high volume of video footage transferred consumes significant bandwidth. In addition, there is a very heavy load on the server which has to process video footage from all cameras at the same time.

Now imagine that the calculations performed by the motion sensors are moved to the edge of the network. If each camera used its own internal processor to run the motion detection application and send clips to the server as needed, bandwidth usage would be significantly reduced, as much of the footage would no longer be broadcast. Also, the server should only store important clips, so it could communicate with a larger number of cameras without overloading.

Based on the observations gained, a Cloud–Fog–Edge Computing model has been proposed for smart farming and is illustrated below. The Cloud layer is mainly for ample scale data storage and data analytics. This layer is also responsible for loading algorithms and data analytical tools to Fog nodes. This can also be used to store backup data for future analysis. The Fog layer will be installed in local farms. Fog layers will be responsible for real-time data analytics such as predicting pests and diseases, yield prediction, weather prediction, and agricultural monitoring automation. Moreover, this will make decisions on real-time data and do reasoning analysis as well.

Finally, the processed and analysed data can be uploaded to the Cloud layer for backuppurposes or further analysis. The third layer is the Edge, consisting of end devices, tractors, sensors, and actuators. The main goal of this layer is the collection of data and its transfer to the Fog layer.

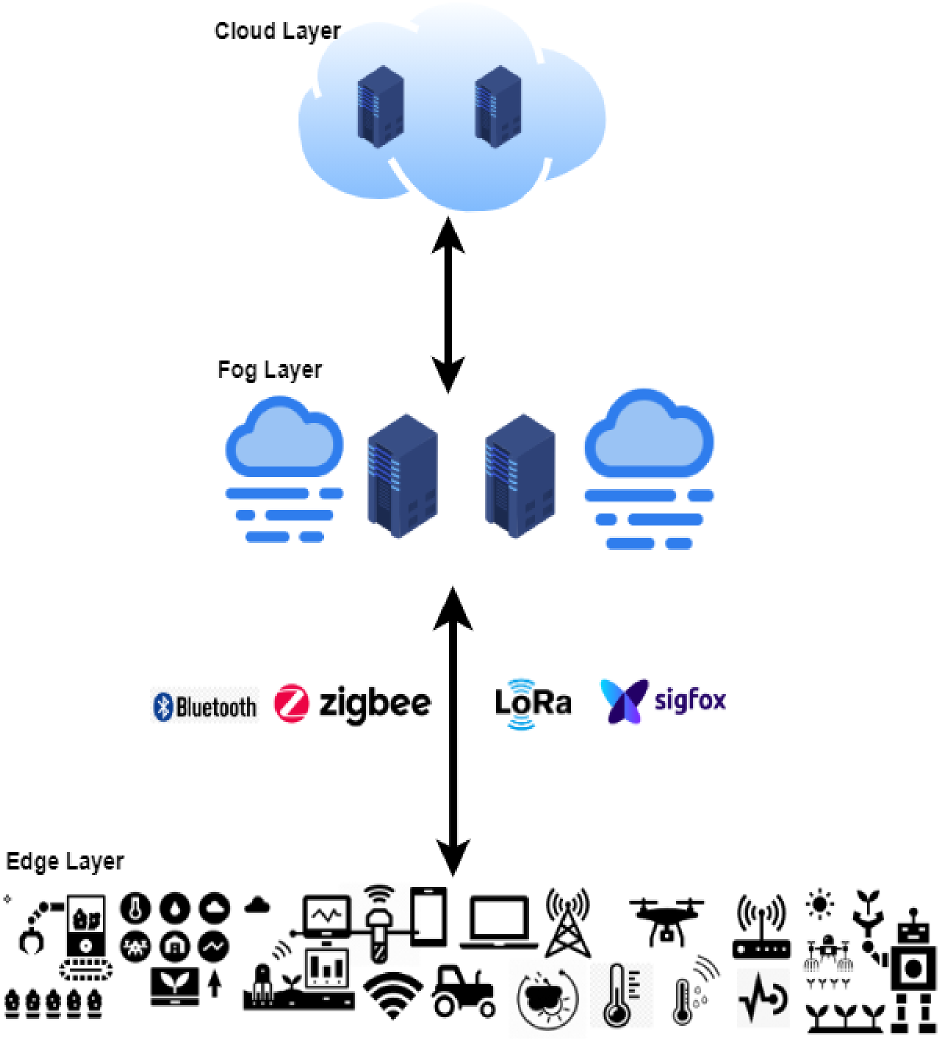

Figure 2.6. An architecture based on Edge, Fog and Cloud Computing.

Source: "A Systematic Survey on the Role of Cloud, Fog, and Edge Computing Combination in Smart Agriculture" by Yogeswaranathan Kalyani and Rem Collier, School of Computer Science, University College Dublin, Belfield, Dublin, Ireland.

Hint for educators:

"What is the Internet of Things (IoT)?", https://www.thinkuknow.co.uk/parents/articles/what-is-the-internet-of-things-iot/

"Implementation Guide - Cloud Computing", https://www.ptech.org/open-p-tech/teacher-toolkit/cloud-computing-3/

2.11. Big Data

Big Data are high-volume, high-speed and / or high-variety information resources (hence the three 'Hs' with which they are often identified) that require convenient and innovative forms of information processing that allow for better understanding. situation, more efficient decision making and intelligent process automation.

From an IT perspective, the term Big Data refers to a data set that is too large or too complex to be processed by normal computing devices. As such, it relates to the computing power available on the market. If you look at the recent history of data, in 1999 we had a total of 1.5 exabytes of data in the world and 1 gigabyte was already considered 'Big Data'.

According to another definition, Big Data is data that exceeds the processing capacity of conventional database systems. The data is too large, moving too fast, or does not fit into the structures of the database architectures. To get value from this data, it is therefore necessary to find an alternative way to process it.

Large volumes of structured, semi-structured and unstructured data, acquired from a variety of heterogeneous sources, fall into the category of Big Data. This data is typically assumed to contain valuable hidden information, requiring substantial effort and resources to uncover it.

Figure 2.7. Big Data
Source: Pixabay

Why is Big Data analytics so important? Because it helps businesses leverage their data and use it to identify new opportunities. This, in turn, leads to smarter business decisions, more efficient operations, higher profits, and happier customers. Today, therefore, Big Data is the frontier of a company's ability to store, process and access all the data it needs.

Big data analytics is currently used for many applications, including product lifecycle management, process redesign, supply chain management, and manufacturing systems data analysis. Of these, manufacturing systems analysis has already received considerable attention, because manufacturing systems are large sources of raw data that are often difficult to model manually.

Numerous applications have therefore emerged to investigate process data for process monitoring, anomaly detection, root cause analysis, and knowledge extraction.

Digital production control systems have been a source of Big Data since the late 1980s when they started capturing data and historicizing it. Initially, the processing was selective and only the most important process measurements were acquired, such as temperatures, flows and pressures.

As memory capacities increased, storage systems and computer networks expanded, thousands of process information began to be stored rapidly, at ever higher sampling rates. Today, it is common to collect tens of thousands of measurements, positions, and control system states, at sampling rates of once per second. It is also possible to store all that data without loss of information in data compression.

Hint for educators: “Data Science for Children: 10 Tips”, https://www.create-learn.us/blog/data-science-for-children/

2.12. Artificial intelligence (AI)

What is Artificial Intelligence? According to John McCarthy, the father of artificial intelligence, AI can be described as 'the science and engineering of manufacturing intelligent machines and programs'. So, it is a way to make a computer, a robot or a software decide as a human being would. For this purpose it is necessary to study the way in which the human brain thinks and the way in which humans learn, decide and work while trying to solve a problem, thus using the results of this study as a basis for software and systems development. intelligent.

The impact and application of artificial intelligence have been prominent and evident in the agriculture sector. The world population is increasing which will require more food and agricultural products.

AI can help us to produce the additional requirement of agricultural products. Agriculture faces many challenges like crop disease, lack of irrigation, water management, the effect on the environment, low output, and improper soil treatment. It can be solved by the applications of AI.

The use of AI in soil management, weeding, crop monitoring and disease management can solve the problems of farmers. The application of AI in agriculture is producing more with less manpower, land, and time. AI in agriculture can foster smart farming practices to limit the loss of farmers and give them high returns.

Figure 4.8. AI in Agriculture
Neuromation
https://medium.com/neuromation-blog/ai-in-agriculture-49c0ea0e2b48

In agriculture, the goal of artificial intelligence is to allow machines to perform complex operations, which normally require the intelligence of human beings to be completed. In this way, machines can take the place of us in solving complex tasks: not only in the execution of repetitive mechanical activities, but also in activities that require human experience or ability.

The artificial intelligence demonstrated by machines is however different from human intelligence and its implementation opens a world of new opportunities for programmers, who can create applications in very different domains: from industrial production, to cybersecurity, to energy management. and so on.

Therefore, before learning the basics of artificial intelligence, it is essential to understand that it is above all a combination of reasoning, planning and problem-solving skills. Languages like Python, R, Lisp, Java, and Prolog are just some of the many languages that can be used for AI programming and creating innovative projects.

Artificial intelligence is a data-centric, compute-challenging technology – a perfect applicant for edge computing. In fact, Edge Computing benefits AI by overcoming the technological challenges related to AI-supported application use cases.

2.12.1 Augmented reality and Virtual reality

Virtual reality and augmented reality are used in many applications in the agritech sector. For example, they can be used to examine the soil and establish the most suitable crops, or to decide which nutrients need to be supplemented for existing crops to give a more abundant harvest.

As an example, the ***farmAR app*** is a cloud-based platform that collects satellite information on land. Artificial intelligence and deep learning make it possible to process the data in order to alert the user in case of any problems such as dry areas, the need to integrate certain nutrients or the onset of a disease. The farmer can then move around the field following the AR directions and reach the area that requires attention.

AR can also be used for the training of workers, helping them to become familiar with machinery before operating them. This avoids costs related to the use of the machines, reduces wear and tear and minimizes the risk of accidents.

Figure 2.9. Augmented Reality In Agriculture

Hridja, Queppelin

https://www.queppelin.com/augmented-reality-in-agriculture/

Hint for educators: "Learn about Artificial Intelligence (AI)", https://code.org/ai

2.13. Communication

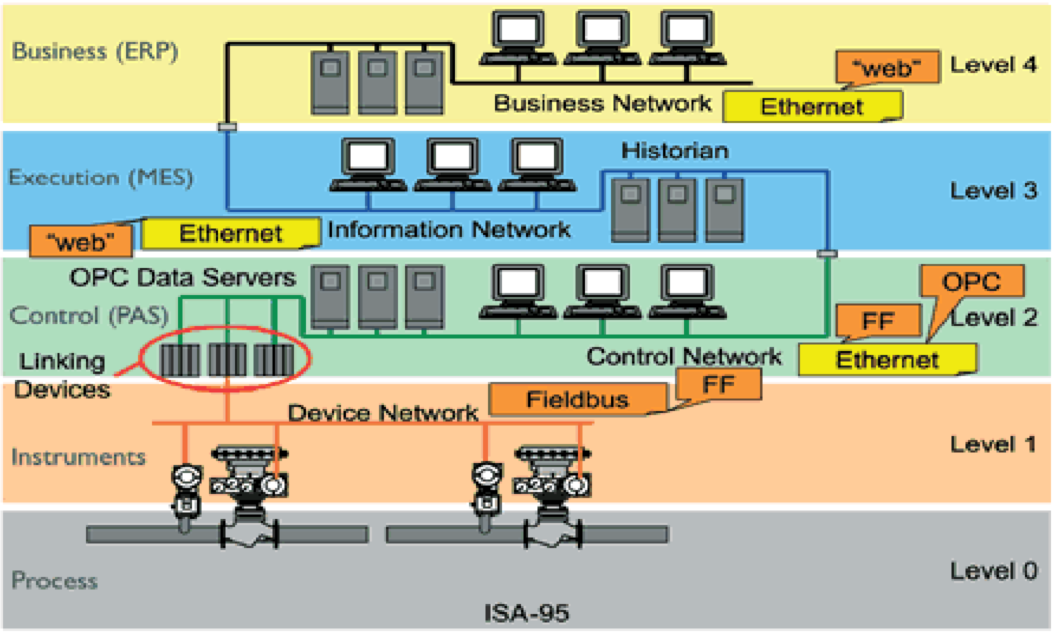

Figure 2.10. Different levels of communication

Source: "Industrial automation - Vol. I", Valerio Alessandroni, G.I.S.I.

In the upper level of the computer-based control architecture, LANs (Local Area Networks) are similar to the local networks used in offices: in most cases, Ethernet. The reference model is the so-called **ISO/OSI Model**.

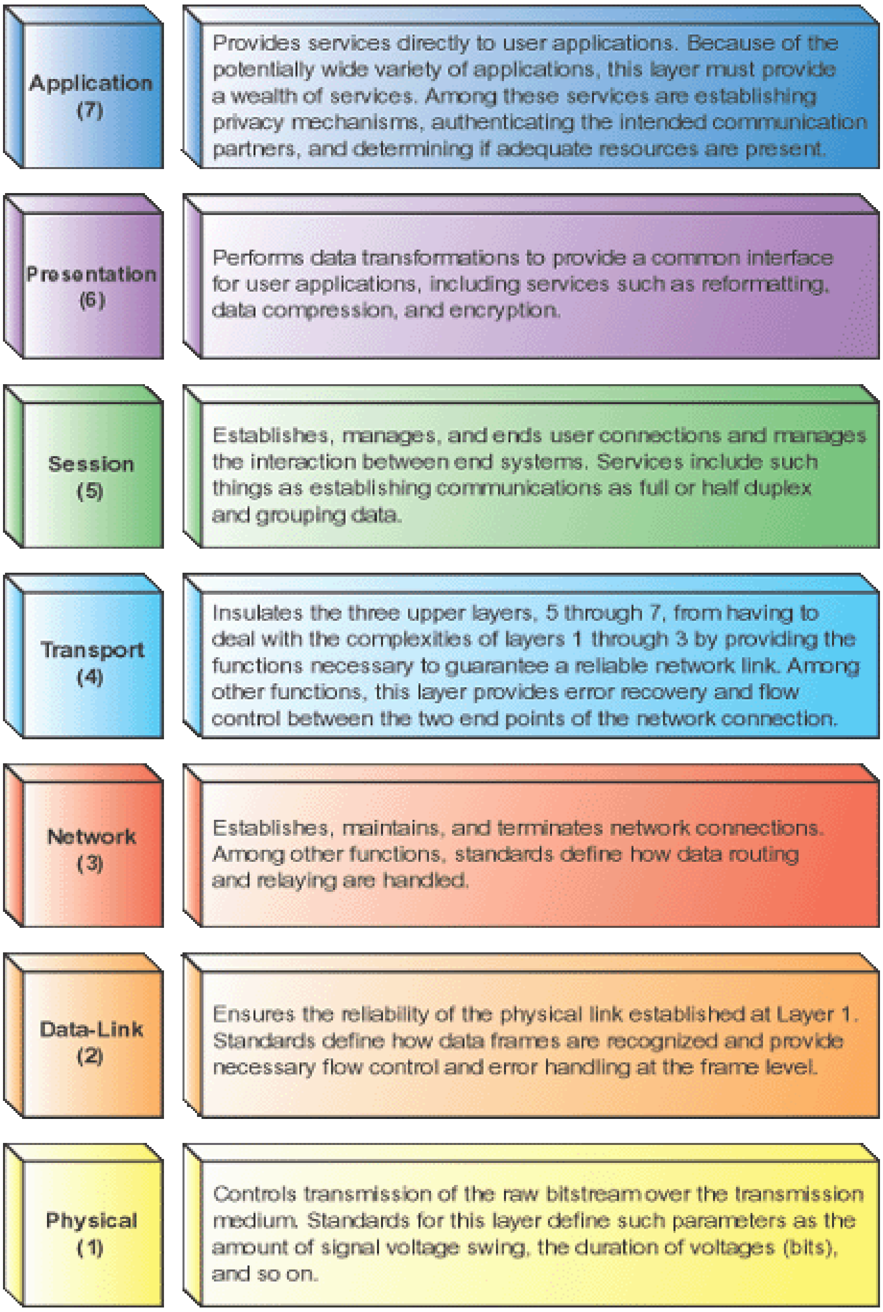

Figure 2.11. The ISO/OSI Model

Source: "Industrial automation - Vol. I", Valerio Alessandroni, G.I.S.I.

2.13.1 Fieldbus technologies

The connection at field level is a different world. Often, simple 'point to point' connections are still used, constituting a major problem in terms of installation and maintenance. The tendency now is to use a connection system common to all the devices composing the automation system which can be accessed by all of them for data communication: the so-called fieldbus.

The **fieldbus** is a special network (bus) that can be used in an industrial environment (field) to interconnect sensors, drives, controllers and other devices equipped with a special interface within a plant or a machine. Other fieldbus technologies are specialized for applications in buildings, in trains, in cars, etc. In this way, the connected units can freely exchange information using a simple low cost support (a cable or a wireless link) and a special protocol.

The analogy with office LANs stops here, because the data traffic in the fieldbus has different characteristics: the messages transmitted on the field are generally very simple, very frequent and must reach their destination in a very short and determined time, so that the control systems can give a real-time response to critical events. On the other hand, in an office environment, the determinism and the short response time are not crucial.

Also fieldbus technologies make reference to the **ISO/OSI model**.

In particular, automation requires different communication systems to meet the different needs of transmission at various levels:

- simple but high-frequency information at the low levels;
- complex but less frequent information at the high levels.

Three categories of networks can be usually identified:

- Networks for the transportation of information. They are used for communication between the systems dedicated to the supervision and management of the factory or the company. The transmitted information is complex and composed of many bytes, but the data rates are not high and it is not necessary to ensure the transmission within a critical time frame. Today, Ethernet-based networks are typically used with the TCP/IP protocol.
- Control networks. They enable communication between the cell or area supervision devices or between the supervision devices and the control devices. The transmitted information is not complex, but the transmission rates are high (seconds or hundreds of milliseconds). It is also necessary to ensure the transmission within a critical time frame. High level fieldbus technologies are normally used.
- Networks for the interconnection of field devices. They allow communication between control devices and the sensors/ actuators. The information transmitted can be very simple (often is a single bit), but the data rates are very high (milliseconds). It 'also necessary to ensure the transmission within critical time frames (of the order of milliseconds). Either traditional serial technologies (such as RS 485 and 4-20mA) or fieldbus technologies can be used.

The electric standard to which most of the fieldbuses make reference is **RS485**. It specifies exact values for the electrical characteristics of the system, as the voltage levels used to represent the 0 and 1 levels in the digital transmission of data over the bus.

The fundamental specifications of fieldbuses have been defined in the **IEC 61158 standard**.

The main technical requirements of a fieldbus can be grouped into three areas:

1) Message handling

- Features of the architecture (single master, multi-master, access policy, etc.).
- adequate transmission capacity (number of data per message)
- guarantee of maximum transmission time

2) System safety and security

- protection against the propagation of faults
- protection of information integrity (control and/or correction codes)

3) Technology requirements

- compatibility to other communication systems and/or infrastructures

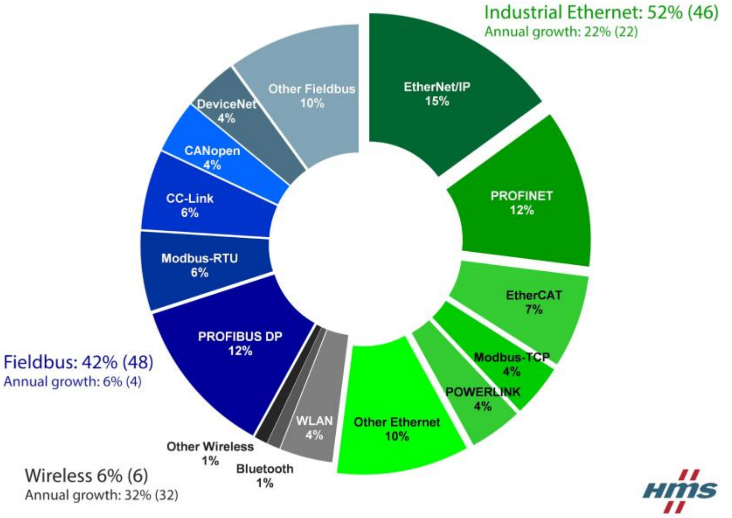

Figure 2.12. Main fieldbus technologies and their diffusion in 2022 (2021)
Source: HMS
https://www.hms-networks.com/news-and-insights/news-from-hms/2022/05/02/industrial-networks-keep-growing-despite-challenging-times

2.13.2 The ISOBUS communication protocol

ISOBUS is an open standard of interconnection of electronic systems developed to meet forestry and agricultural machinery. It allows communication between sensors, actuators and controllers, enabling with this standard the exchange of data between tractors, implements and onboard controllers of different brands.

Standardisation is regulated by ISO 11783, but has been nicknamed “ISOBUS” as a way to compare with "Can Bus", an integrated communication network in which each manufacturer creates its own protocols. The intention of ISOBUS is precisely to go in the opposite direction: to define equal protocols for all manufacturers, allowing communication between equipment of all companies. The international standard has been established and is certified by the Agricultural Industry Electronics Foundation (AEF).

The great benefit that ISOBUS brings is the guarantee of full compatibility between tractors and agricultural or forestry implements, regardless of brands and models.

Before the protocol, each manufacturer used its own language. If, in a single tractor, four solutions from different brands were used, four different adjustments would be necessary, which made the process more complex and expensive, generating a major problem for the sector.

With ISOBUS, there is full compatibility of data transfer between systems and software, which ensures fast and noise-free communication, improving the accuracy of activities and automation of equipment.

When the standard is not used, the machinery needs a cabling structure for each sensor and a screen for each implement. In the case of the same tractor that is used in several stages of an operation, it is common to find cabins full of interfaces, which hinders handling and makes the activities more complex.

The use of ISOBUS, on the other hand, guarantees an organised installation and a much simpler visualisation. The excess of embedded appliances and unnecessary connection cables are eliminated, leaving a single display to connect the tractor and its implements, ensuring the performance of operations with maximum efficiency.

Figure 2.13. ISOBUS protocol implemented in agricultural machinery telematics
Source: Technoton
https://jv-technoton.com/isobus-protocol-is-implemented-in-agricultural-machinery-telematics-by-technoton/

In addition, with an ISOBUS display, it is possible to read much more tractor information than it would normally offer. Data collection, which is available to the operator in real time by means of a single monitor, helps in the use of the full potential of machinery, in making better decisions and in the consequent increase in productivity.

When all agricultural and forestry products use the same language - as proposed by ISOBUS — all implements that are connected to a tractor will be read automatically and their data will be loaded into the same onboard controller.

In an ideal scenario, all products in the world would leave the factory with this standard language. However, as this is not what happens in practice, there are solutions that allow an adaptation, such as HxGN AgrOn ISOBUS Display - a system that enables the implementation of the international protocol through an embedded technology.

The system has two main features. One of them is the Universal Terminal (UT), which allows machines to operate an implement with any terminal and work with different accessories. The other is the Task Controller (TC), which records and provides information on operations and assists in planning. The operator and agricultural or forestry manager may choose to read any data available, according to their situation.

In a hot region, for example, they may want to check the temperature of the cooling system; while, in another location or activity, it may be important to view the hydraulic pressure. This flexibility and diversity of information available is an essential point of ISOBUS.

For more information:

"Fundamentals of Communication: 8 Basic Concepts and Definitions", https://online.arbor.edu/news/fundamentals-communication-eight-basic-concepts-and-definitions

"Standardisation and efficiency are guaranteed with ISOBUS technology", Ronaldo Soares, Hexagon's Agriculture division, https://hexagon.com/resources/resource-library/standardisation-efficiency-guaranteed-with-isobus-technology

Hint for educators: "Driving Digital Transformation in Process Automation", https://www.fieldcommgroup.org

2.14. Communication between sensors and actuators

The fieldbus technology has significant advantages over traditional cabling technologies. A first advantage concerns the hardware and the wiring: the installation is easier, faster and cheaper. Another aspect is the simplification of design and documentation. A further advantage is its flexibility and scalability: it is always possible to add new modules or add new features without modifying the existing wiring.

From a software design point of view, it is important to highlight that a fieldbus architecture allows the easy vertical integration of the system. The devices can be reached via direct communications and high-level software layers can easily interact, even directly, with transducers and actuators.

Also the advantages of a fieldbus-based design are numerous. From the hardware point of view we can derive an extremely simplified structure in which the criteria for sizing and physical subdivisions may be fully released from future logical groupings. The design is simplified as it can proceed in stages: the system modules are independently tested. In the software perspective, the ability to control every local function from any point of the network leads to maximum flexibility in design and to the logical organization of the network.

The advantages of fieldbus technology also extend to the production stage, with a considerable simplification of the number of wirings, the simplicity of the connection of devices to the network and ability to perform functional tests during assembly and installation.

Even the service is greatly simplified since the modular structure, the availability of powerful diagnostic tools (the devices are smart) and the characteristics of the bus communication allow particularly effective and targeted interventions.

In summary, below are some of the main advantages of fieldbus systems compared to traditional technologies:

- reduction of wiring, related costs and installation errors
- use of more and more 'smart' devices, which allow the implementation of a distributed control and introduce new capabilities (advanced diagnostics, self-regulation, self-configuration, etc.)
- system robustness
- easy expansion and modularity
- modular development
- possible implementation of distributed systems
- scalability
- economies in realization
- possibility to more easily replicate the same system
- component standardization
- possibility of multicast communications.

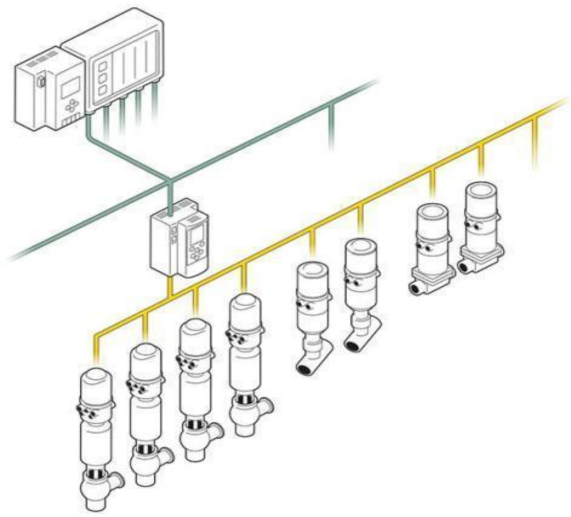

Figure 2.14. The AS-i technology is very popular for connection of sensors and actuators

Source: Interfaccia AS: Lo standard bus di campo, Burkert Italia S.p.A.
https://www.burkert.it/it/Assistenza-tecnica-e-supporto/Supporto/Glossario/Interfaccia-AS-Lo-standard-bus-di-campo

In addition to the advantages offered by the fieldbus in general, a fieldbus on board of the machine can bring additional benefits, although they are less obvious in a first analysis. For example, it allows the manufacture and delivery of machinery by dividing it into modules which are then assembled at the customer.

On the other hand, the main problems of a solution based on fieldbus are the following:

- The same physical medium (bus) is shared by all devices and thus it is necessary to introduce appropriate access mechanisms (this is the responsibility of the fieldbus protocol).
- The digital transmission involves the encoding of information on multiple bits that are serially transmitted: a delay is therefore introduced in the transmission of information as a whole.
- These elements can cause difficulties in compliance with the timing requirements for real-time applications.

A separate consideration is the low level buses, oriented to the interfacing of very simple actuators and sensors, like the AS-interface. These buses are born to replace the wiring at the lower network level, where the traditional fieldbuses tend to be too complex, expensive and slow.

They connect simple binary elements like push buttons, limit switches, proximity switches, photocells, solenoids and relays with control systems at a higher level.

Sensors and actuators are often connected to the network through slave components; the master instead connects the network to its controller or may itself be a slave to a higher level fieldbus.

Hint for educators: "Teaching fieldbus standards to computer engineering students" by T. Ozkul, https://ieeexplore.ieee.org/abstract/document/1393097

2.15. Remoting the I/Os

Over the past 30 years in the field of automation there were two important moments of technological evolution, which introduced permanent changes in the way of conceiving the systems:

- Since the mid-80s, the bus architecture has begun to emerge with success in the installation of machines and systems. The more open systems have evolved to become standard components for automation. After the mid-90s, the openness of the bus systems was extended to the level of control units;
- In the meantime, the open PC-based systems have seen an increasing spread, reaching the popularity of traditional PLCs.

Thanks to the spread of the fieldbus technologies, now even more optimizations are possible in the distributed installation of I/Os or in the rationalization of the control board. All this can be achieved by transferring the peripheral functions directly in the field, to the management of the signals. This process was developed using a large number of I/O components with IP65 protection and is now used to perform the standard functions of automation, removing the control boards. The achievement of this object, however, also involves the optimization of the structure of the control panel and, with it, a rationalization in this area.

The control and supervision based on distributed I/O and intelligence are based on a 'lean control' philosophy, founded on the possibility of using a standard user interface for all control systems, reducing time and costs, achieving a greater flexibility in production, etc.

What is the difference between a distributed I/O system and a fieldbus? It is to be found more in a marketing perspective than in a technological perspective. From the technological point of view, in both cases they are systems used to transmit data, often using a serial line. To make a distinction, however, it is necessary to consider the needs of the user.

Figure 2.15. Control of remote I/O's in agriculture

Source: wtw electronic

https://wtw-electronic.com/commercial-vehicles/?lang=en

The fieldbus is basically an equipotential connection that allows multiple users to connect to a single source. In practice, it is a cable or a twisted pair installed in the plant, which can be connected to various types of devices, theoretically without limits. The user also can normally buy from different vendors the devices that he wants to connect and has extensive guarantees of flexibility and expandability without radically changing the existing wiring.

In contrast, a remote I/O system does not pursue this goal of flexibility and compatibility, but the renunciation of standardization generally leads to an increase in speed or a protocol best suited for the specific application. The distributed I/O is therefore part of a well-defined system, creating an optimal compromise between the openness and the responsiveness to the needs of use.

To manage the parallel wiring of the signals to and from the machine in modern automatic production lines becomes increasingly complex. To streamline this stage and make it more flexible it is essential to apply the concept of distributed I/O and the market is responding with different solutions. One of the most interesting is undoubtedly the transmission of I/Os via fieldbus, able to manage countless inputs/outputs with communication protocols that ensure speed and security.

Hint for educators: "Teaching fieldbus standards to computer engineering students" by T. Ozkul, https://ieeexplore.ieee.org/abstract/document/1393097

2.16. The 5G technology

Digital transformation is the core of the fourth industrial revolution and 5G network infrastructures quickly become key support assets. Indeed, the manufacturing industry is evolving towards a distributed organization of production characterized by connected goods (products with communication capabilities), low-energy processes, collaborative robots and integrated production and logistics.

In this perspective, the end-to-end communication services provided by the 5G network will be fundamental. Low latency (less than 5ms), reliability and high density (up to 100 devices / m^2) are the most important performance goals that 5G will need to achieve to support all possible applications.

The large number of sensors and objects connected to each other through 5G networks will allow the development of innovative services on collaboration between data.

2.16.1 New levels of performance

5G, a disruptive transformation of the fixed and mobile network, introduces performances 10 times higher than the current ones, representing one of the next architectures for the digitization of the country, the competitiveness of companies and the change in the way we communicate and live for each of us.

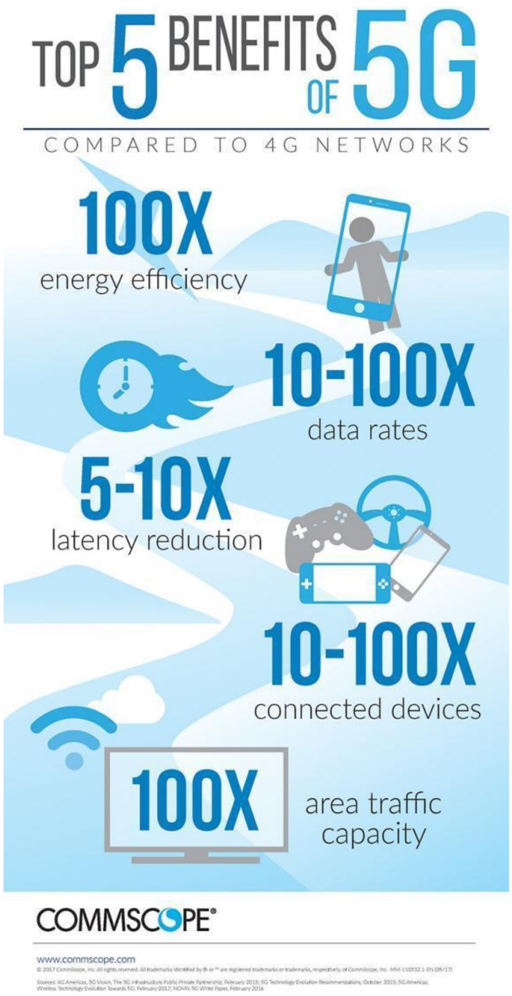

Figure 2.16. Advantages of the 5G technology
Source: CommScope on Visualhunt

In a survey carried out by Gartner in 2018 on a sample of 185 companies, about two-thirds of respondents intend to implement 5G technology by 2020, predicting that 5G networks will be used mainly for Internet of Things (IoT) communications.

One of the main problems facing 5G users is the lack of preparedness of communication service providers (CSPs), because their 5G networks are not yet available or sufficient for the needs of industrial applications. The 'roll out' of commercial services will take time and will be progressive. In the short to medium term, enterprises looking to leverage 5G for applications such as IoT communications, video, control and automation, fixed wireless access, and high-performance edge analytics will therefore not be able to rely on public 5G infrastructure.

From the mobile connection of robots, machines and production lines to the development of new industrial monitoring applications, based on the real-time collection of data from plants, IoT communications remain the most popular application for 5G. The advantages are multiple: an increase in productivity at reduced costs; the ability to more easily reconfigure machines and production lines for greater flexibility; the availability of a flow of data and information that can be analyzed in real time for preventive maintenance.

The expectations for IoT communications seem surprising, as proven and cost-effective alternatives already exist for wireless IoT connectivity, such as Narrowband IoT over 4G and low-power wide-area solutions. However, 5G offers important characteristics, such as the high density of connected endpoints: up to 1 million sensors per square kilometer.

Additionally, 5G potentially fits into IoT categories that require very low latency.

5G holds the possibility to offer great advancements in both individual lives and a variety of industries. Agriculture is no exception, and the areas of autonomous agricultural machinery and data-driven smart agriculture are also expected to evolve significantly through 5G.

There are three major features of 5G that make it different from communications systems of the past.

The first is its ultra-high speed. It is 100 times faster than 4G and is said to let users download a two-hour movie in three seconds.

The second is its ultra-low latency. Users can remotely control a robot in real time without feeling any delay or time lag.

The third is its multiple simultaneous connections. It will allow smartphones, PCs, and all kinds of other devices around us to be connected to the internet.

These features will accelerate the evolution of smart agriculture. The main areas of advancement will be remote monitoring and control of farm machinery, remote sensing, and compatibility with dry-field crops.

An example comes from Japan, where the number of agricultural workers continues to decrease. This has resulted in a shortage of labor on farms. Farmers are giving up their land or outsourcing their operations, leading to consolidation of farms. Proper management of this consolidated land and the increased workload are just some of the issues that have arisen, and there is an urgent need for assistance to the farmers facing these problems.

To address these issues, expectations are rising for smart agriculture, which utilizes ICT and robotics to achieve ultra-labor saving and higher quality in production. Kubota is one of the first agricultural machinery manufacturers in Japan to begin implementation of smart agriculture into society. They have focused our research and development on automated and unmanned agricultural machinery as well as precision agriculture that utilizes data, aiming for a future of smart agriculture that reduces farmers' burden and achieves better productivity.

To realize simultaneous work by multiple agricultural machines in the field under remote monitoring, farmers must be able to monitor a wide area and control the machines dependably. The use of 5G, which enables ultra-low latency communications and multiple simultaneous connections, makes it possible to monitor and control multiple machines and detect people and obstacles in real time.

If the remote monitoring function is improved, one farmer will be able to monitor and control multiple autonomous agricultural machines from home or another location far from the field. This will increase the amount of area a single farmer can cover during limited cropping seasons, enabling support for large-scale farming operations.

5G will also have a tremendous impact on remote sensing, in which agricultural machines and drones assess the condition of fields and crops and utilize the information they collect.

High-resolution image data generally takes up large amounts of capacity, but with 5G, this data can be sent and received at high speeds. The system will collect and analyze field images over a wide range in a short time, quickly assessing the growth of crops and improving fertilizer distribution by focusing on areas with poor growth, among other services.

Furthermore, by quickly collecting large numbers of high-resolution images for AI learning, the system can improve the accuracy and processing speed of AI in a short time. As AI advances, it will be able to suggest the next step required in the field, enabling precision agriculture that is even more data-driven.

Already in 2021, Kubota conducted demonstrations within the local 5G area, including trials for proper operation, remote monitoring, and control of unmanned automated agricultural machinery from a monitoring center located approximately 10 km from the field, along with the transmission, reception, and collection of big data, including growth data acquired from automated agricultural machinery and various sensors placed in the field.

Hint for educators:
https://www.ericsson.com/en/blog/2019/10/explaining-5g-to-kids

2.17. In Estonia the future of agriculture is digital

In Estonia, agriculture has moved forward into an era of digitally enhanced farming, where everything that produces data during the various stages of agricultural production can send that information to be collected, processed and analysed. The use of big data could help farmers step into the future of farming and achieve ambitious targets.

A farm produces many types of data that can be classified into different categories, such as agronomic data, financial data, compliance data, meteorological data, environmental data, machine data, staff data, etc. These sets of data stem from a wide range of more and more powerful and cost-effective sources, such as machinery, drones, GPS, remote sensing, satellites, smartphones, and so on, and are supplemented by service providers, advisory bodies, public administrative authorities, etc.

In addition, other partners in the value chain, such as processors and retailers, are collecting enormous amounts of data about the markets on which farmers sell their products.

The collection and use of data in agriculture is not a new concept; farmers have been doing just that since the beginning of agriculture. What is new however, is the opportunity to develop a data-oriented farming sector thanks to the size and volume of this data, which are growing at an exponential rate.

Another novelty is the quality of real-time information obtained at farm level and the technology used to collect, store, use, manage, share, process and communicate data.

Furthermore, these large and complex series of data demand novel and sophisticated data processing systems. Data needs to be combined to create value, meaning that the better we exchange data, the less disruptive this will be to current business models and organisations. By layering a series of data from a wide range of sources, complex decisions can be made on different levels, such as by the farm, cooperative, input suppliers, public administrative authorities, banks, the scientific community, etc.

The new data-supply chain places informed farmers in a new context and redefines their role in the supply chain, which will enable transformative agricultural business models to develop, leading to cheaper, safer, and better produce. Some experts believe that big data will be the next source of productivity gains and, in combination with other technological developments, could disrupt the agricultural value chain. Big data is being used to improve the functioning of individual farms and the entire value chain by optimising production factors, enhancing transparency throughout the food supply chain, and helping to develop new business opportunities along the entire value chain.

Big data will also make it possible to collect and exchange data at an unprecedented level. In order to tap all of the potential benefits, data are being increasingly shared between farmers, with third parties within the value chain (e.g. input suppliers), and also with those outside of the agri-food chain. Agricultural data are being used for both agricultural and non-agricultural purposes, but the farmer remains at the heart of processing big data, as he/she is responsible for the quality and credibility of data.

The most significant samples of digital agriculture in Estonia are as follows.

Geographical Information Applications

The Estonian public institutions have made serious efforts to develop the GIS systems. Thanks to the X-Road, all the systems are interconnectible and easily combinable via application programming interface (APIs). For example, as the databases of Estonian Land Board, E-Land Register, and Estonian Agricultural Registers and Information Board are interconnected, it is easy to find lots of information about any location in Estonian mainland, such as cadastral register number, intended land use, soil type, protected area restrictions, land owner, land user, etc. Unlike in many other countries, these data are open and accessible to the public, as the trust and security is assured by access with e-ID. Additionally, the GPS technology enables to track the location and movement of tractors and other mobile machinery, so it is possible to gain full information about activities that are allowed and carried out in this location, also the level of productivity, etc.

Many of these data are practically used in operations of web and mobile applications that are developed for farm management, like VitalFields, eAgronom, Terake.eu. Using these apps has saved a substantial amount of time for farmers from paperwork, as filling the fieldbook and compliance reporting for the payment agency are now automated. Currently, developers focus on real-time data transfer from agricultural machinery into accounting without interim reporting. This would enable significant savings from data processing and more operative access to necessary information for farm management.

Open Data, Interoperability, and Standardization are Crucial

A farm produces many types of data from diverse sources and formats. When data is heterogeneous, it is frequently organized in data silos and ends up being separated from other data. Data silos can be created by private companies, public databases, or between states. For small countries like Estonia, avoiding generating data silos at the level of EU Member States is especially important in order to be competitive. Open data, interoperability, and standardization are crucial to avoid data silos. It is also vital to guarantee free access for farmers to public databases. In Estonia, there are well-developed interoperability and interconnectivity between state level Geographic Information systems, but there is still a long way to go to fully open data. Interoperability between private companies mostly does not yet exist. For example, data produced in the tractor's computer is currently not accessible for third parties for using it in different applications as it is protected by the license of the tractor manufacturer. In case of change, the technology provider, it is impossible to transfer the previous data into new technology. Farmers should be granted appropriate and easy access and be able to retrieve their own data further down the line. They also should not be restricted should they wish to use their data in other systems. Access and data portability should be addressed at EU level, as the farmers, who are often SME-s, might easily be run over in the negotiations with big technology companies. Common understanding of data portability at EU level would also encourage independent software development besides of big technology companies, which would be more flexible and better meet farmers' needs.

2.18. The financial benefits of ICT technologies in agriculture

In the last few years, the technology explosion has created an entirely new range of digital farming tools and machines to help farmers make the most out of their land.

You can now test soil for moisture content and nutrients, accurately predict the impact of the weather, select irrigation channels with precision, control greenhouse climates and increase efficiency by making manual tasks automated.

Research undertaken by the ONDO Smart Agriculture Solution company found that digital farming saves up to 85% of water consumption and 50% energy consumption, increases crop yield by 40%, and minimises human error by 60%.

The result is, that much of the farming is done by software behind-the-scenes, with farmers simply responding to what the data tells them.

Compared to traditional farming, farmers no longer make as many decisions as they once did – the data and software make the decisions, the farmers simply carry them out.

Thanks to modern-day technology, some of these actions are already automated, with farmers simply monitoring the technology. So long as nothing goes wrong, farmers need to know less about traditional farming and more about software and computing.

This move away from the traditional farming culture increases profits and protects businesses for a better future. Of course, digital farming is still in the early stages, but we are starting to see signs of how far digital farming can go.

Almost every farm in Estonia has some form of intelligent digital farming technology used on a daily basis.

An increased use of digitalization, remote sensing, and ICT would improve efficiency, quality, and timeliness of controls and audits. Nowadays, many indicators are precisely measurable and procedures can be automatized, so there is no need to maintain the outdated CAP rules and controls just "for any case." The most time and resource consuming rules of the CAP should be found out and simplified via digital technologies. It would significantly reduce red tape and bureaucracy not only for farmers but also for administrators, both national and European, and every saved hour is a victory for our economy.

Digital farming technology is already providing robot harvesting tools to ensure crops can be picked on time. If this trend continues, the need for a manual farming workforce can be drastically reduced.

Even now, drones make it possible for farmers to check vast acres of land without ever setting foot on it.

In the future, it has been predicted that these drones will be able to fly themselves, with the farmer simply receiving a digital report (via email etc) with information on what checks were performed, the result and the action that has already been taken.

The role of the farmer may move from active participant to passive observer (although many consider this to still be a few years away).

2.19. The environmental benefits of ICT in agriculture

Climate change and "green growth" are at the top of the agricultural development agenda. Limited resources, population growth and environmental concerns all challenge agricultural productivity.

Information and communication technologies can improve environmental performance and address climate change across the economy.

Agriculture is often characterized by the overuse of resources, including water, pesticides, and fertilizers. With digitization, several solution providers have developed data-driven decision support systems that optimize the use of these resources, thereby reducing the environmental footprint of agriculture and the overall cost of production. However, the adoption and usage of such solutions amongst smallholder farmers is still restricted. Similarly, traceability solutions have the potential to support consumption decision making. ICT can play a role in encouraging responsible production and consumption, which often leads to a reduction in the environmental and climate footprint of agriculture.

The agriculture sector is at the nexus of climate change, food and nutrition, water and soil, and sustainable livelihoods. Therefore, the sector has a key role in creating more resilient supply chains, restoring soil health, and enabling green-livelihood opportunities at scale. Increasing adoption of Internet of Things enabled devices and rising use-cases of technology such as blockchain within agriculture, have enabled innovative solutions for collaborative action that can incentivize green practices and reduce the overall environmental footprint of the sector, including through regenerative agriculture.

The impact of climate change, only expected to increase and pose greater risks, has been pushing the agriculture sector to a new normal. This change requires the consistent adoption of innovative technologies and practices that offer solutions focused on resilience to climate change. But the mere adoption of climate-resilient technologies will not be enough to address this dynamic environment; there is a need to measure resilience after the implementation of technologies. Global researchers and policy-makers are designing frameworks that can monitor and measure the vulnerability of society and the natural environment to climate change. However, a robust framework or a model for measuring resilience continues to remain a goal. Industry experts, researchers, donors, and government institutions need to come together to discuss existing frameworks, identify best practices and tools, and define important indicators (both quantitative and qualitative) that can result in a robust framework with the potential to become an industry benchmark.

2.20. Conclusions

The use of technology combined with digital transformation can help farmers to achieve targets in increasing effectiveness and productivity, and to respond to dynamic markets. Nevertheless, the main question is, how to implement digital technologies, and use information produced in the farm management in a most efficient way. Paradoxically, while there is more and more data available to farmers, there are fewer and fewer resources (including management and workforce) to process this data, often because of tense economic and market situations. Solutions could be provided by proper guidance and advisory services, but also by using DSS (decision support systems), which would liberate farmers from resource consuming data processing.

It is crucial that farmers and the agricultural sector are fully involved in all the discussions about digitalization, which are currently going on in the EU and in the world. Launching the strategy and developing of the EU common digital market involves many activities and initiatives, which can be useful for the farming sector, like Digital Skills and Jobs Coalition Initiative.

It is very important that the problems and questions mentioned above will be solved while considering the interests of farmers, not only from the point of view of the ICT sector or technology companies.

Digitalization of the farming sector would contribute to its competitiveness, help to raise farmers' income, and attract young people to join the traditional activity, which is vital for the whole society.

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CHAPTER 3

Decision Support Systems (DSS)

CHAPTER 3 Decision Support Systems (DSS)

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WHAT WILL WE LEARN IN THIS CHAPTER?

What are DSSs?
What types of DSSs exist?
What are the benefits and barriers?
How can the educational needs of DSS be met?

Keywords: agriculture 4.0; agriculture innovations; decision support systems; innovative technology; digital technology; digitalisation.

3.1 Glossary and abbreviations

PA - Precision agriculture	It is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources.
DSS - Decision support system	It is a computer software application that enhances an organization's capacity for decision-making. Large volumes of data are analyzed, and the best solutions are then presented to an organization. To give users information beyond the typical reports and summaries, decision support systems combine data and knowledge from several fields and sources.
Prescription maps	They allow to carry out variable rate fertilization: this means to optimize the fertilizer dose, associating to each area of the field the most suitable quantity.
IoT - Internet of Things	IoT is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity that enables these devices to connect, collect and exchange data.
Big data	It refers to data sets that are too large or complex to be dealt with by traditional data-processing application software.
AI - Artificial intelligence	It is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals.
Crop scouting	Crop scouting: on-field monitoring of plant diseases and crop damages, carried out by farmers and technicians in order to make decisions based on the data collected.
HI - Harvest index	This is the ratio of grain to total shoot dry matter and is as a measure of reproductive efficiency.
IT - Information technology	It is the use of computers to create, process, store, retrieve and exchange all kinds of data and information. An information technology system (IT system) is generally an information-communications system operated by a limited group of IT users.

Table 3.1. Glossary and abbreviations

3.2. Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter.

The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives a value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	*Competences and skills*	*Duration time*	*Learning tools*
• To be able to learn agriculture 4.0 and IoT in agriculture • To be able to recognize applications and utilization of agro-DSSs	• Knowledge of the practical application of DSS in agriculture • Knowledge about advantages and disadvantages • To be able to use of DSS • Collection, management and the use of data	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 3.2. Competence map

3.3 Decision Support Systems (DSS)

3.3.1. ICT and general overview of the technologies characterising agriculture 4.0

A management strategy known as precision agriculture (or farming) focuses on (near real-time) observation, measurement, and responses to variability in crops, fields, and animals. It can assist lower costs, including labor expenditures, and optimize process inputs while increasing crop yields and animal performance. These all have the potential to improve profitability. By reducing the negative environmental effects of agriculture and farming methods, precision farming can improve workplace safety and support the sustainability of agricultural production[1].

Precision agriculture uses information technology (IT) to ensure that crops and soil receive exactly what they need for optimum health and productivity. This also ensures profitability, sustainability and protection of the environment. It considers aspects such as soil type, terrain, weather, plant growth and yield data when managing crops. The main components of a precision farming system include:

- a prescription map indicating the quantities of product to be distributed according to the position of the machine (also in the same field, there can be different soil types and yields). The map, is created by agronomists, using their experience and data collected from:
  - crop yield during previous harvests;
  - mapping of the physical and chemical characteristics of the soil (using satellite photos or photos taken by multi-spectral cameras using drones);
  - measures obtained by soil sampling activities;
- a GPS ables to provide the position of the agricultural machine in the field;
- the presence of actuators, connected to the mechanical systems, able to distribute the quantity of product in an adjustable way.

Precision agriculture is a systems approach to farming. To be viable, both economic and environmental benefits must be considered, as well as the practical questions of field-level management and the needed alliances to provide the infrastructure for technologies (Glenn

[1] EC, 2019

Davis, William Casady, Ray Massey, 1998). Precision agriculture it's not the only answer and it's not the answer to all the questions, but it is really useful, especially on medium and large-scale fields.

3.3.2. General overview of DSS

A decision support system (DSS) is an information system that supports decision-making activities. DSSs serve the management, operational and planning levels and help to make decisions about issues that may change rapidly and cannot be easily predetermined.

This tool cannot work without a decision maker to whom it can provide guidance on:

- the availability of all the information needed to understand the problem;
- the possibility of exploring the data from different points of view and according to one's needs;
- the possibility of evaluating scenarios resulting from choices.

The purpose of the DSS is not to "impose" a choice, but to provide support to technicians and farmers in analysing the decisions to be made.

Why use these tools in precision agriculture? The advantages are many:

- they support the farmer / technician to control over all the variables necessary to screen decisions;
- they help the farmer or the technician by providing numerical forecasts, even in the very short term;
- they can be managed remotely;
- They keep all the information by creating a historical database.

Specifically, DSSs in agriculture are interactive information systems, consisting of a set of databases, algorithms that simulate the soil-plant-atmosphere system, possible plant and/or soil water status monitoring systems (e.g. wireless sensors) and a user interface. DSSs designed for agriculture, thanks to their sector-specificity, integrate different models oriented to the complex needs of the 4.0 farmer: they are able to collect, organise and process large amounts of data and transfer them to the user in the form of simple and clear information in a summarised graphical interface.

With the emergence of minicomputers, timeshare operating systems, and distributed computing since the 20th century, computerized decision support systems have become widely usable. The introduction of such systems can be traced back to the middle of the 1960s.

Different people perceive the field of Decision Support Systems (DSS) from various vantage points and report different accounts of what happened and what was important (Arnott & Pervan, 2005). As technology evolved new computerized decision support applications were developed and studied. Researchers used multiple frameworks to help build and understand these systems. Today one can organize the history of DSS into the five broad DSS categories explained in Power, including:

- communications-driven: they are used by internal teams to hold meetings or for collaboration between users. The most common technology used to deploy DSS is a web or client server (chats and instant messaging software, online collaboration and net meeting systems);
- data-driven, document driven: they are used by managers and staff. A data-driven DSS is a computer program that makes decisions based on information from internal or external databases. Typically, a data-driven DSS uses data mining techniques to identify trends and patterns that can predict future events. Companies often use these DSSs to make decisions about inventory, sales, and other business processes;
- document-driven: a document-driven DSS is a type of information management system that uses documents to retrieve information. Such DSSs allow users to search web pages/databases, using specific filters.
- knowledge-driven: Knowledge-based DSS include both the organization/company and customers/consumers. It is used to provide management advice or to choose products/services. The data that drives the system is always up-to-date because it provides users with information consistent with business processes;
- model-driven decision support systems: are customized models to analyze different scenarios and meet different needs (e.g., development and planning of corporate budgets).

The history of the numerous technological threads that are coming together to offer managers working alone, in teams, and inside organizational hierarchies integrated support to manage organizations and make more logical judgments is explained here. History is both a guide to future activity in this field and a record of the ideas and actions of those who have helped advance our thinking and practice. Historical facts can be sorted out and better understood, but more information gathering is necessary.

The study of DSSs is an applied discipline that uses knowledge and especially theory from other disciplines. For this reason, many DSS research questions have been examined because they were of concern to people who were building and using specific DSS (Baskerville & Myers, 2002; Keen, 1980).

The next section describes the origins of the field of decision support systems:

- Section 2.3.3 discusses the decision support systems theory development that occurred in the late 1980s and early 1990s,
- Section 2.3.4 discusses important developments to communications-driven, data-driven, document-driven, knowledge-driven and model-driven DSS,
- Section 2.3.5 briefly discusses the main functions of DSSs and how they work and can help farmers.

3.3.3. The development of DSS

A growing area of DSS application, concepts, principles, and techniques is in agricultural production, marketing or new developing technologies.

The first DSS for agriculture cited in the literature is Televis, which was developed by Norway in 1957 for plant protection. Another such system named as Guntz Divoux was developed by France in 1963 and the use of computerized quantitative models to assist in decision-making and planning was started systematically during this period (Holt and Huber, 1969).

For instance, the Decision Support System for Agrotechnology Transfer (DSSAT4) package, which was created with the financial assistance of USAID in the 1980s and 1990s, has enabled quick evaluation of a number of agricultural production systems globally to support decision-making at the farm and policy levels. With precision agriculture, choices are made specifically for selected fields. But there are a lot of obstacles in the way of DSS being successfully implemented in agriculture.

DSS is also prevalent in forest management where the long planning horizon and the spatial dimension of planning problems demand specific requirements. All aspects of forest management, from log transportation, harvest scheduling to sustainability and ecosystem protection have been addressed by modern DSSs. In this context, the consideration of single or multiple management objectives related to the provision of goods and services that are traded or non-traded and often subject to resource constraints and decision problems. DSS is also widely used in the management of forests, where the need for specific needs arises from the lengthy planning horizon and the spatial nature of planning issues. Modern DSSs have tackled many facets of forest management, including log transportation, harvest timing, sustainability, and ecosystem conservation. In this context, taking into account one or more management goals associated to the provision of traded or non-traded goods and services, which are frequently hampered by resource shortages and decision-making issues.

In order to give end users insight into their crucial decision-making process, DSS are tools that are used to gather and analyze data from a range of sources. They are used in crop management in the agricultural sector by assisting the farmer in selecting the best agronomic interventions, such as fertilization, irrigation, and phytosanitary treatments, allowing to achieve the goals of rationalization and optimization of resources and production factors anticipated by precision agriculture. In fact, to achieve high production and maintain, or even improve, the economic balance, modern sustainable agriculture must compromise the use of chemical products (particularly fertilizers and phytosanitary products) and natural resources (such as water, soil, energy, etc.).

DSS may be composed of four main components: database, model base, knowledge base and graphics user interfaces (Mansouri, Gallear, & Askariazad, 2012; Turban et al., 2005). At the end, the number of components is five because it includes users (Marakas, 2003). The functionality of the database is to store, retrieve and organise the raw data that will be used as information to make decisions in the knowledge engine component. The model base consists of the analytical capabilities of qualitative models. The functionality of the knowledge engine is designed to manage the problem-solving process, the problem recognition and the generation of a final solution. The user interface component is designed to facilitate users' interaction with the system. Finally, the user is the one who makes his or her own decision considering the supporting information generated by the DSS.

3.3.4. How DSS are used in agriculture

DSS follow the basic activities of every agricultural expert:

1. crop observation and monitoring;
2. data analysis;
3. decision support on operations to be carried out;
4. correct execution of agronomic interventions.

There are several sources of data for analysis:

- meteorological parameters (rainfall, wind speed and direction, air temperature and humidity and atmospheric pressure) obtained from weather forecasts, weather stations and sensors in field;
- forecast models on phenology, irrigation status and crop-related adversity;
- monitoring of adversities observed in the field and georeferenced using smartphones.

All this data is processed through databases and sophisticated analysis algorithms that allow the transition from raw data to processed data to agronomic advice, enabling the farmer to carry out site-specific interventions. For example, by setting up sensors in different parts of the field, an agronomist / farmer can maintain control over each plot even remotely, via smartphone. In fact, DSS allows alerting systems to be set up that notify when and how it is time to intervene and allow historical data to be stored for complete management.

One of the most representative characteristics of an DSS is that it does not give direct instructions or commands to farmers. Because farmers are in the position of taking the final decisions.

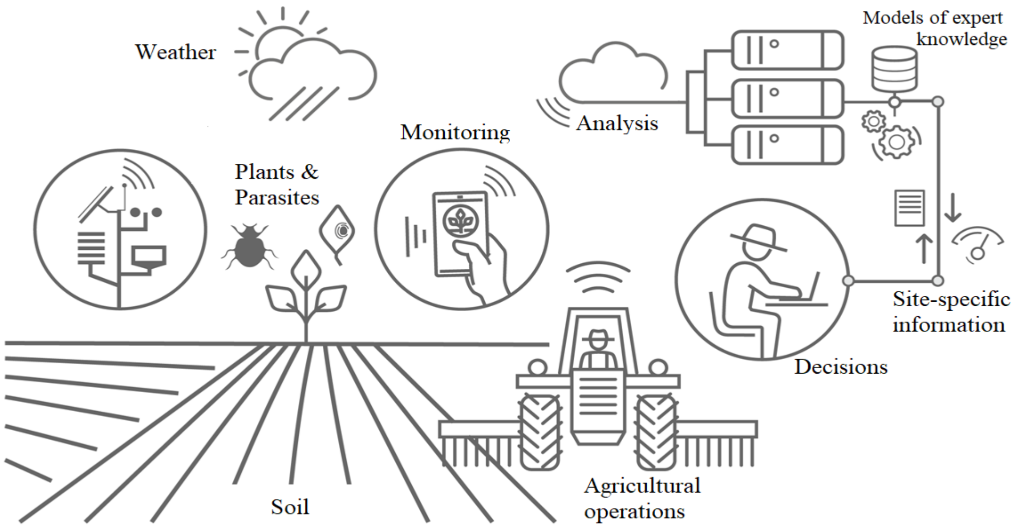

Figure 3.1. Schematic diagram of DSS operation

3.3.5. Common types of DSSs

The usage of DSS in agriculture takes the form of integrated crop management decision support, which covers soil erosion, fertilizer management, weed management, water management, plant protection, and other related topics. With the help of these systems, issues like soil conservation and improvement, local water balance, effective agronomic techniques, canopy management, pest and insect control, lowering pre- and post-harvest losses, forest preservation, combating climate change, etc. are being addressed. The spread of technology transfer in relation to crop management techniques, irrigation planning, fertilizer application, etc. is also greatly aided by web-based DSSs. The most frequent uses are described in more detail below.

Nutrient management. Fertilizers and lime are increasingly expensive but are commonly needed to grow high-yielding and good-quality crops. However, unnecessary use is wasteful, reduces farm profits and increases the risk of diffuse nutrient pollution. For Nutrient management, different DSSs have been designed to recommend site-specific and need-based parameters that result in an optimized fertilizer management strategy.

Insect and Pest Management. Plant protection can be defined as the rational application of agronomic techniques, technologies, and chemicals to enable the highest levels of productivity while respecting farmworkers, the environment, and consumers. Computerized DSSs are not a brand-new idea in pest management. For diseases that need to be regularly controlled or that could spread very quickly, DSS models have been created.

Water resources management. Current researches of ADSSs for water resources management are generally concerning the irrigation systems. An irrigation system should provide farmers with effective decision supports on controlling the amount of water applied to crops and maintaining landscapes (Alarcon et al., 2016). It aims at ensuring wettability of soil fields and basic water needs from crop growths with the minimum water usages (Smart Irrigation Decision Support System, SIDSS).

***Livestock management*.** Farmers are increasingly relying on data and dashboards to make decisions regarding animal and farm management. A key component of an animal health DSS is ‘data warehouse’ which provides the facilities to capture, store and link all relevant information about an animal population of interest. Outputs from such systems can be used to manage and control outbreaks of infectious disease in animals, identify factors associated with the presence of disease, provide an objectively measured point of comparison once control measures have been implemented and provide an additional means to detect emerging disease syndromes. (Nguyen Van Long, Mark Stevenson and Bryan O’Leary, 2011).

3.3.6. Main characteristics of DSS

Defending crops against pathogenic organisms and insects, as well as providing water and nutrition to plants, is an increasingly complex challenge for farmers. The picture is made even more difficult by climate change, the arrival of 'alien' organisms and an increasingly stringent regulatory framework. To the farmer's rescue come tools such as decision support systems (DSS). Systems that can support the operator in defining the best defence or crop nutrition strategies.

The purposes are: to provide decision supports for crop management, from planting to harvesting. DSS normally do not provide solutions, but information; they do not replace the farmer in making decisions, but provide him with additional information on which to base agronomic choices.

Reliability depends on: quality of the input data (use of correctly and periodically calibrated sensors), the quality of the mathematical models that process the input data (most DSS are based on empirical models, sourced from the literature and then implemented in the software without the necessary validations on the territories where the DSS are proposed), the quality of the rules for interpreting the outputs of the models (they must be developed based on expert knowledge and adapted to the various crop situations).

A very important feature is the flexibility to provide information at different levels of detail: from a simple result (reporting on irrigation operations) to an intermediate stage (vapour dynamics and water availability in the soil) to more complex ones (soil-system plant-atmosphere to know the need to supply water for irrigation) (Zhaoyu Zhai, José Fernán Martínez, Victoria Beltran, Néstor Lucas Martínez, 2020).

The application of innovative technologies in agriculture and concepts such as precision agriculture, smart farming, Agriculture 4.0 and sustainable agriculture have led to the development of DSS.

The function of DSS is a topic that is not the easiest to explore, but of extreme importance because of its usefulness and potential. Indeed, one of the key factors for proper farm management is the decisions to be made on a rational basis to respond to any emergencies and/or changes in the crop interventions to be made.

DSS are for the agricultural entrepreneur an instrumental innovative tool in the cultivation and management process in the context of an agriculture increasingly aimed to the well-being of the agro-ecosystem and the business result. Specifically:

- farmers: can optimize yields, quality characteristics and product health, reduce production costs and negative impacts;
- technicians: can provide timely and qualified advice to agricultural producers based on scientific information;
- producers of technical means: they can find in DSS a tool that enhances the value of their products.

In the following sections, there will be:

- study of DSS more specifically through the analysis of some examples (we want to show some examples of DSS applicable on specific crops or on agricultural operations in general, some of the functions, possible integration with other tools. They are useful examples of DSS for the technician/farmer);
- boxes about small insights useful for learners, educators, tips for better learning, environmental and economic benefits for users (these will be useful in expanding readers' education through additional information and external resources that can be assimilated through other training methods).

The usefulness of the boxes is explained below:

- "HINTS FOR EDUCATOR": this box is useful for educators because there will be insights (web sites, scientific research, digital materials) to share with other people as well as being useful for self-learning. Educators can deepen certain topics in such a way that they can include them in subsequent meetings with their learners. It is a way of increasing the possibilities for self-focused learning on specific topics and especially of creating links with topics outside this chapter.
- "EDUCATIONAL NEEDS": DSSs integrate weather trends, crop phenological development, and mathematical algorithms to provide the user with valuable information for crop management and defense treatments. However, the user (farmer, technician, agronomist) must be trained in both "Data input" and "Analysis and interpretation of results". To properly interpret DSS dashboard (histograms, time series, scatter plots or radar charts) one must have some knowledge: ability to filter information, ability to choose recommendations and ability to process and connect data.
- The manual is geared toward spreading specific skills in digital data management, sensoristics applied to agriculture and forestry, precision agriculture techniques, and management of information systems applied to land management. The European Union is geared toward Green Transition and Digital Transformation. The learner will be able

to deal with land management more effectively by adopting the most innovative technologies due to the strong innovative character and pronounced information in the manuals.

- "ENVIRONMENTAL and ECONOMIC BENEFITS": DSS constitute a valuable support for the farmer or technician in monitoring all the variables necessary to sift decisions (they provide short- or long-term forecasts; they offer the possibility of remote management; they store all the information creating an extremely rich database). Today, the use of DSSs assumes a role that is now commonplace in the field of defense, where in special and difficult environmental conditions and in high-income crops, its use is a guarantee of safeguarding production and sustainability of interventions. Some examples:
- the cost of using a DSS varies widely, but on average it provides savings compared to planning with traditional systems, which is around 30-35% in terms of both plant protection products and labor;
- one DSS can suggest the use of a fertilizer, rank a list for pest or weed control treatments or even suggest the integration of both chemical and non-chemical-based practices in favor of crop development and productivity[1];
- DSSs have been reported to assess the yield losses of important crops (winter wheat or soybean) due to weeds surviving herbicide treatments, some of them are able to estimate the herbicide residuals in soil water by means of several environmental indices[2];
- The usage of sensors that measure the soil water status is a key complement to modulate the water requirements of the crops. Soil variables, such as soil moisture content or soil matric potential, are considered by many authors as crucial part of scheduling tools for managing irrigation[3].

[1] Kanatas, P.; Travlos, I.S.; Gazoulis, I.; Tataridas, A.; Tsekoura, A.; Antonopoulos, N. Benefits and Limitations of Decision Support Systems (DSS) with a Special Emphasis on Weeds. Agronomy 2020, *10*, 548.

[2] Berti, A.; Zanin, G. Gestinf: A decision model for post-emergence weed management in soybean (Glycine max (L.) Merr.). Crop Prot. 1997, 16, 109–116

[3] Cardenas-Lailhacar and Dukes, 2010, Soulis et al., 2015

HINTS FOR EDUCATOR

Explanation of ET by FAO equation - https://www.fao.org/3/x0490e/x0490e06.htm

What is a weather station - https://ag.umass.edu/landscape/fact-sheets/what-is-weather-station-can-it-benefit-ornamental-growers#:~:text=A%20weather%20station%20is%20a,and%20soil%20bulk%20electrical%20conductivity

Precision Agriculture: Technology To Boost Crop Farming - https://eos.com/blog/precision-agriculture/ (Try now a high-tech agriculture tool to monitor your crops!)

Precision Agriculture in the Digital Era: Recent Adoption on U.S. Farms (USDA) - https://www.ers.usda.gov/webdocs/publications/105894/eib-248.pdf?v=8648.7

Use of DSS in modern agriculture - http://dps-promatic.com/docs/dss_in_agriculture.pdf

EDUCATIONAL NEEDS

Decision support systems for agriculture 4.0: Survey and challenges - https://www.sciencedirect.com/science/article/pii/S0168169919316497

Debeljak M et al(2019) A Field-Scale Decision Support System for Assessment and Management of Soil Functions - https://www.frontiersin.org/articles/10.3389/fenvs.2019.00115/full

Decision support system in Agriculture - https://www.youtube.com/watch?v=ormzL59kEZQ

ENVIRONMENTAL BENEFITS

Reduced input utilization (optimization on quantity of inputs and reduction chemical substances utilization)

Keep an eye on the soil health (by providing recommendations about: crop rotation, tillage practices, erosion, compaction, soil fertility)

Efficient water management (smart water management support enabled through a daily water balance)

Reduced waste and environmental impact (reduced greenhouse gas emissions)

You can help achieve the goals of New Green Deal and, specifically, Farm to Fork Strategy

ECONOMIC BENEFITS

Reduced input costs (defense, nutrition, irrigation and when to use them)

Reduced time to gather information and make decisions (risk management by providing warnings of potential crop failures due to weather events or disease)

Increased crop yields (optimization of quali-quantitative harvest index HI)

Improved resource management: reduce waste and lower costs (by providing information on when to plant, irrigate, fertilize, and harvest crops)

Some of the most successful DSS available on the market are described below.

The proposed solutions, based on prevention and optimization practices, allow a containment of interventions thanks to the predictive models and controlled input of products and irrigation volumes, thus reducing production costs and environmental impacts of the production process and increasing efficiency and productivity.

Today, the use of DSSs assumes a role that is now commonplace in the field of defense, where under particular and difficult environmental conditions and in high-income crops, its use is a guarantee of safeguarding production and sustainability of interventions.

3.3.6.1. CAL-FERT and Bluleaf

Bluleaf® Awareness in Agriculture

An example of DSS that provides suggestions on N_2O, P_2O_5 and K_2O's contribution for numerous horticultural crops is the Cal-Fert calculation sheet.

It calculates the dose of fertilizer on the basis to be made during the crop cycle and provides a measure of the items of the mineral budget of the crop.

It is based on a conservative approach, which tends to maintain an "optimal" level of nutrients in the root area of the crop, so as not to impoverish the soil of cultivation and at the same time not generate waste of fertilizer.

For the calculation of the doses of N_2O, P_2O_5 and K_2O to be made with fertilization, Cal-Fert requires: the content of organic substance, total nitrogen and minimum nitrogen, assimilable P_2O_5, exchangeable K_2O, the C/N ratio, the texture of the ground.

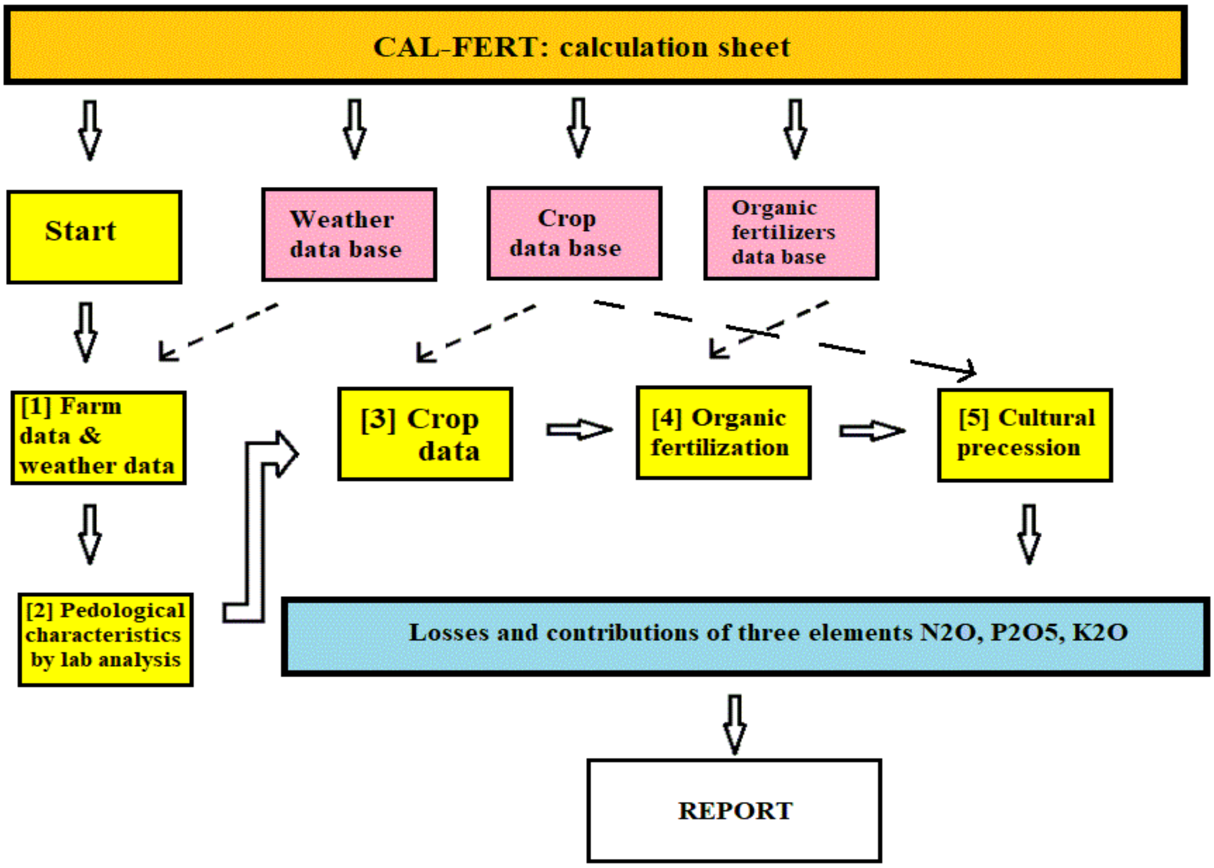

Figure 3.2. How the CAL-FERT software works

In the drafting of the fertilization plan, the user follows a path consisting of 5 consecutive windows where the inputs necessary for the calculation are inserted: farm data; ground and pedological characteristics; crop; cultural precession; organic fertilization.

The software proceeds to calculate the doses of N_2O, P_2O_5 and K_2O to be administered. The climatic data are used to estimate the quantity of limited nutrients with rains and/or irrigation, as well as for the calculation of the supply of nutrients deriving from the mineralization of the organic substance and the air cultivation residues.

Using the climatic data from your own climate database and an estimation of the potential evaporation of the crop, the electronic sheet constructs a water balance of the land in the time period between 3 months from the date of analysis until the date of the collection of the crop to fertilize after the user has entered the requested inputs.[1].

The sheet computes the losses and contributions for each period for the three nutritional components, counting the amount of organic material that has already broken down from crop

[1] Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration.

residues (and from any organic fertilizers), in order to determine how much is still in the process of breaking down at the time of analysis.

Cal-Fert is integrated on the Bluleaf platform[1]. Bluleaf allows careful and high technological impact management of agronomic crops. It is possible to manage irrigation, fertilization and defense. The Cal-Fert software is one of the tools that can be used for the programming and monitoring of fertilization.

The nutritional budget's many parts can all be checked in detail when all the parameters have been entered. The computer program consults its databases to determine the ideal amount of nutrient that must be present in the radical area. Based on the inputs entered, the program calculates the equipment of the soil at the moment 0 contributions and losses and then gives the user the total dose that needs to be administered for the individual elements (N-P-K), expressed in kg/ha.

HINTS FOR EDUCATOR
About the DSS: https://www.bluleaf.it/en/home-eng/

To better understand how DSS works: https://www.bluleaf.it/en/bluleaf-app/

3.3.6.2. vite.net®

It is a decision support system for integrated and sustainable vineyard management. The system is available in real time on a web platform. An agro-meteorological network, a server that can store weather information as well as agronomic and operational data (such as the treatment log) pertaining to each individual vineyard, and a variety of mathematical models are the foundation of the DSS. These models use the data collected to produce information that is useful for tactical management of treatments and cultivation practices.

The DSS is made up of two main components: an integrated system for real-time monitoring of vineyard components (air, soil, plants, diseases, and insects) and storage of the corresponding data, as well as an online application that analyzes this data using advanced modeling techniques and outputs real-time alerts and information to aid in decision-making.

For vite.net® to work optimally, the vineyard is divided into production units (PUs). The management of a UP is uniform throughout the season and is defined at the beginning of the season. This operation involves the collection, organisation and integration of site-specific

[1] https://www.bluleaf.it/en/home-eng/

information that is both static (which does not change during the season and is entered into the system by the user only once) and dynamic (which changes during the season). For each UP, real-time data collected in the vineyard through sensors or monitoring is received; this data represents the input for the forecast models operating in the system.

The models' outputs contain data on important areas of managing vineyards, including protection, estimation of plant growth and production, canopy management, and stress from heat and water.

vite.net® provides for the static and dynamic information of each vineyard acquired by means of sensors (e.g. weather sensors) or monitoring activities (e.g. using handhelds) to flow in real time into a remote database. The DSS stores the information collected by the sensors, then checks and analyses it using mathematical models and finally interprets it by comparing it with so-called 'expert knowledge' and provides decision-making and warning aids that the user can use to make informed decisions about vineyard management. With the execution of an action (e.g. fungicide treatment), the state of the vineyard is changed (in the example, the disease risk is changed) and therefore - again by monitoring the vineyard environment - a new cycle of information is triggered: information therefore moves "from" and "to" the vineyard in a continuous cycle that begins with monitoring and ends with action.

HINTS FOR EDUCATOR
About the DSS: https://www.horta-srl.it/en/vite-net/
To better understand how DSS works: https://www.horta-srl.it/sito/wp-content/uploads/2021/10/vitenet_fascicolo_en.pdf
Tutorial, feedback and more details on DSS (set subtitles because the video is in Italian): https://www.youtube.com/watch?v=L820HpAo4go

3.3.6.3. GeoPard

GeoPard Agriculture

GeoPard Agriculture is an unbiased cloud-based Analytics Powerhouse for precision agriculture.

Any collection of geospatial data can be processed using the platform core. It supports client integration with both their applications and business processes. The DSS's advantages are:

- excellent quality: Maps are exact, accurate, based on trustworthy natural zones, and sourced from dependable geospatial data.
- Affordability: New technologies for precision farming, user-friendly mapping tools, and an accessible user interface are supplied for simple decision-making. The outcomes are based on the most recent researches available and computed by highly qualified people. Despite the available technologies, the price is extremely affordable;

- Keep all relevant information (both online and offline) concerning scouting on a mobile device, including soil sampling planning and execution, tissue (plant) sample, and visualization of all data layers.

With the release of the Equation-based analytics module, the GeoPard team has taken a big step forward in empowering farmers, agronomists, and spatial data analysts with actionable insights for each square meter. The module includes a catalogue of over 50 predefined GeoPard precision formulas that cover a wide range of agriculture-related analytics.

The precision formulas have been developed based on multi-year independent agronomic university and industry research and have been rigorously tested to ensure their accuracy and usefulness. They can be easily configured to be executed automatically for any field, providing users with powerful and reliable insights that can help them to optimize their crop yields and reduce input costs.

The Equation-based analytics module is a core feature of the GeoPard platform, providing users with a powerful tool to gain a deeper understanding of their operations and make data-driven decisions about their farming practices. With the ever-growing catalogue of formulas and the ability to customize formulas for different field scenarios. The GeoPard can meet the specific needs of any farming operation (https://geopard.tech/blog/).

Figure 3.3. How GeoPard works

HINTS FOR EDUCATOR
About the DSS: https://geopard.tech/
Tutorial: https://docs.geopard.tech/geopard-tutorials/product-tour-web-app/getting-started

To better understand how DSS works: https://help.geopard.tech/web/

Overview webinar about GeoPard: https://www.youtube.com/watch?v=OHXJCd9g3-g&t=239s

3.3.6.4. Agrisim

The Agrisim model simulates the structural conditions of a market in which the management choices of a company in the agricultural sector are made, i.e. a market in which the companies taking part in the simulation compete with each other and with existing competitors, producing and selling agricultural products. The objectives of the model are:

- to represent the interactions of decision-making processes within the management of a farm over a fairly long period of time (at least two years);
- to highlight the operational, economic and financial results of the decisions made by the managers of the virtual farm and the interactions with the environment, market and institutions;
- provide an educational tool that offers the opportunity to study and verify the effects of the decisions taken in a short time.

Through a simulated process, the Agrisim model aims to address the environmental, operational, economic, capital and financial issues typical of a modern farm with the aim of

- improve the production process by optimising the use of the resources employed (soil, crops, inorganic and organic fertilisers, fodder, herbicides, machinery, equipment, etc.) that go into the production process, with the primary objective being the current and future profitability of the crops with a view to environmental protection,
- to test their planning and decision-making skills (soil rotation, choice of crops, time organisation of activities, use of production resources) in an operating environment that is very close to production reality.

The ultimate mission of Agrisim is to realistically represent a virtual environment of the agricultural sector in which participants can test their planning and decision-making skills.

The simulation is carried out with the aid of software that processes the decisions made by each company in each of the management areas, producing results that take into account the choices of competing companies operating in the same market.

HINTS FOR EDUCATOR:
About the DSS: https://www.agrisim.com/

Short tutorial (I): https://www.youtube.com/watch?v=yeBiDYhlFb8

Short tutorial (II): https://www.youtube.com/watch?v=VjDDpRsY2mA

3.3.7. Advantages and disadvantages of DSS

The following box represents some of the important considerations about DSS utilization. The reflections surrounding DSS topic include benefits and also barriers to widespread adoption of them among farmers. The goal is to increase knowledge about DSS and their characteristics. The learners need to know the strengths and weaknesses, pluses and minuses so that they can create their own idea about the tool. The table is a brief summary of the general properties of DSS that have emerged during the use of them by numerous users. The main advantages of using a DSS include examination of multiple alternatives, better understanding of the processes, identification of unpredicted situations, enhanced communication, cost effectiveness, and better use of data and resources[1]. About barriers, we can discuss: limited skills of users, wrong data entry or disadvantages in the management.

[1] Michele Rinaldi, Zhenli He - Decision Support Systems to Manage Irrigation in Agriculture (Cereal Research Centre, Italy, 2014).

Field	***Benefits***	***Disadvantages and risks***
Economics	Changes in costs Changes in revenues Cash flow Time saving services availability	Changes in costs
Management	Data acquisition and analysis Support on decisions Time saving Automation Efficient Services availability	Limited skills Machine dependent Wrong data entry
Environment	Decrease input losses Target nutrient Uptake efficiency Environmental protection awareness	Wrong data entry Evaluation of outputs

Table 3.3. Issues affecting adoption of DSS in agriculture management

An increased awareness, knowledge, participation, and capacity are keys to sustainable development of agriculture. The farmers and learners will be the bridge between theory and practice and they will balance the challenges and complexity of a sustainable development of modern agriculture - social, ecological, economical and technological (Jessica Lindblom, Christina Lundström and Magnus Ljung, 2015).

In addition, the agricultural sector is supposed to fulfill several goals and societal values simultaneously; producing food, fiber and energy, reaching environmental goals, preserving and developing cultural heritage, and recreational values, etc., while at the same time being economically viable on a long-term basis. No single actor can manage these challenges themselves, why there is a need for an increased collaboration between farmers, and other actors, in order to reach objectives especially on a collective level.

The DSS must be adaptable, flexible, and user-centred. Additionally, it must support farmers and policy makers in the continuous monitoring of the effects of sustainable practices within agriculture. Enabling an ever-growing possibility to gather production and environmental data through new technologies enables farmers and other actors to make more informed decisions, but it will also make it possible to evaluate the consequences of taken actions and policies in an early stage of implementation.

Speaking of the benefits and limitations that DSSs bring to agriculture, one can mention:

- change in cost and efficiency of input use (Efficient weed control has been recorded at over a 30% decreased herbicide use in cereals by applying herbicides according to the suggestion of a DSS, whereas in sugar beet, the advice from a DSS decreased the herbicide input up to 20%. Rydahl, P. 2003);
- environmental protection and efficient use of water: DSS are helpful in controlling water resources but exert drastic effects on plant growth rate and yield. DSS analyzes different parameters to identify water-deficient sites and reports them to farmers or generates an alarm. This system possesses a user-friendly interaction environment that makes it easy to use (R. Khan, I. Ali, M. Zakarya, M. Ahmad, M. Imran and M. Shoaib);
- lack of technology knowledge in users (some users are afraid of exploring and learning new things and getting out of the comfort zone);
- difficulty in collecting all the required data: As a decision maker, you must realize that it’s not possible to capture all of the related data mechanically. While some data is difficult to record, some cannot be recorded at all. Therefore, the value presented by a DSS may not be 100% true.

3.3.8. How to use

This section is full of links and tutorials on how to use different DSS. It is dedicated to farmers and field workers who want to learn and learn more about the subject so that they can choose the best DSS for their farm or business.

The DSS provides support because it examines multiple alternatives, identifies unpredictable situations (using weather and other data), and makes efficient use of data and resources available to the farmer or technician. This section provides a small overview where the functions of some globally used DSS are explained in detail.

Crop operations such as crop protection and diagnosis, crop nutrition and fertilisation, crop irrigation, crop growth and canopy management, and harvesting can be accompanied by the use of DSS. Some examples:

- Crop diagnosis and protection:
    - Plantix (https://plantix.net/en/): send a picture of the crop on WhatsApp and a Crop Doctor will help you to solve the problem;
    - ADAMA Bullseye (https://apps.apple.com/it/app/adama-bullseye/id1350551410): it will help you identify insects, weeds, diseases and nematodes attacking your crop.

- Crop nutrition and fertilisation:
    - Dropleaf (https://play.google.com/store/apps/details?id=upvision.dropleaf&hl=en_US): it measures the efficacy of spraying methods and nozzles using images of water-sensitive papers (WSP) either captured from a smartphone.
- Growing and canopy management:
    - OneSoil (https://onesoil.ai/en/): it helps remotely monitor crops, increase yields, and reduce seed and fertilizer costs;
    - PocketLAI (https://cassandratech.it/en/pocketlai-en/): it is an Android mobile application allowing the estimation of leaf area index (LAI) using any smartphone.
    - VISCA DSS Tutorial: https://www.youtube.com/watch?v=Xh6sAl6WFM8
    - ExactFarming (farm management DSS) https://www.youtube.com/watch?v=W1lAejVVKuY
    - Land Support DSS (https://www.landsupport.eu/) : DSS reconciles agriculture, environmental sustainability and policy implementation and it contributes to the development and implementation of land use policies in Europe, and it will promote an integrated and participatory approach towards rural development and environmental policies allowing, among others, evaluation of trade-offs between different land uses.

We want to inspire users to engage with the content in a non-academic way. It can also be defined as a set of activities and processes to solve problems by using or applying the characteristics of game elements. Specifically:

- Gamification is adding game mechanics into nongame environments, like a website, online community, learning management system or business' intranet to increase participation. The goal of gamification is to engage with consumers, employees and partners to inspire collaborate, share and interact;
- Business Games stimulate comparison and teamwork. Unlike academic teaching, in which one is often required to passively assimilate a series of notions, the Business Game places the individual at the centre of the training process, initiating a process of guided self-education that guarantees a rapid and easy perception of business problems. The immediate confrontation with business reality and the freedom of reasoning, however driven by competition and the desire to establish one's own company, allows inductive and spontaneous learning according to the well-known logic of learning-by-doing.

More help for educators is available through the use of these two free online simulators. They are useful for showing how a DSS works around the creation of agricultural graphs and advice. You need to create an account and start the trial.

WiForAgri is a solution for advanced monitoring and management of agricultural crops. It consists of an agro-meteorological survey station and a series of sensors that measure soil and environmental parameters in real time. The data is transmitted to a web platform to be processed and visualized through common PCs, smartphones or tablets providing decision support in terms of crop management, pest and climate risk. It also provides for greenhouse monitoring for protected crop management.

It is useful for several operations:

- pesticide use reduction,
- optimal protection from pathologies,
- response to climate change,
- optimize the abuse of water and fertilizers,
- agricultural fields are always under control.

Rationalization of pest management and consequent containment of expenditure on herbicides, pesticides and fungicides. Optimization of irrigation and fertilizer and savings in labor costs and increased labor performance thanks to remote monitoring. Useful indications to the producer about the optimal time for harvesting and improvement of the average quality of production.

Ultimately though, success relies on the capacity of the farmer to make good decisions at the right time. The mixed farming program has been at the forefront of understanding and developing skills and products to help in decision making. Below are some pictures of the DSS WiForAgri dashboard.

Figure 5. Weather forecast and details

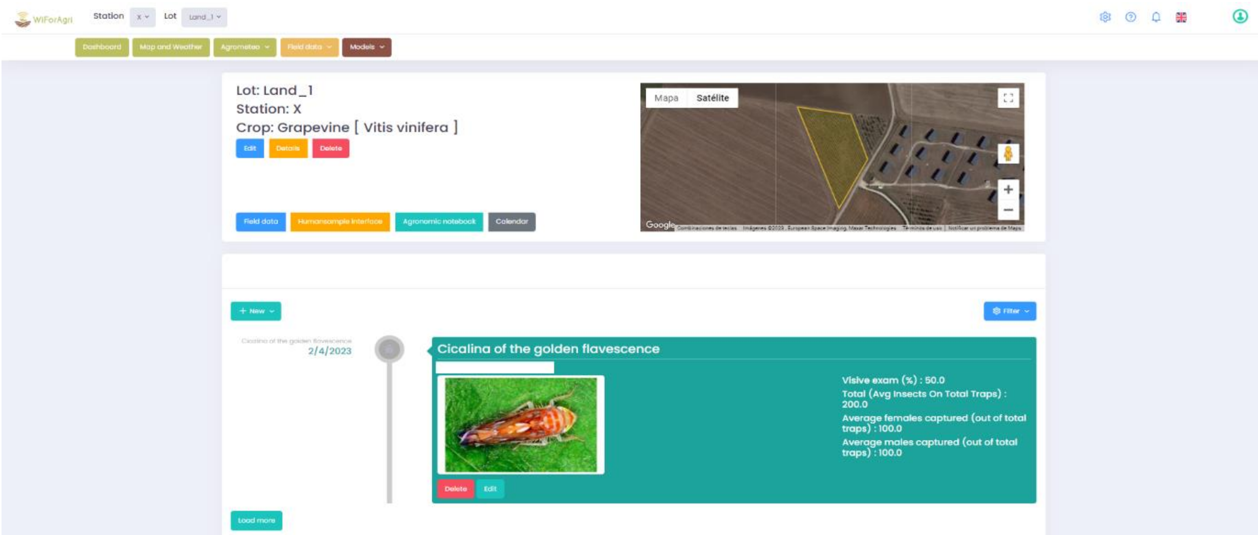

Figure 3.6. Details about Lot, Station, Crop and Pests

HINTS FOR EDUCATOR

Decision support tools (EIP-AGRI Network): https://ec.europa.eu/eip/agriculture/en/digitising-agriculture/developing-digital-technologies/decision-support-tools.html?country%5B0%5D=145&page=0%2C0%2C1

Using data to manage environmental impact of livestock farming: https://ec.europa.eu/eip/agriculture/en/news/inspirational-idea-using-data-manage-environmental.html and https://cap2er.eu/

Free trial of WiforAgri: https://www.wiforagri.com/en/home/

3.3.9. Future trends

According to the environmental issues we will face in the upcoming years, for instance:

- water resources are under severe stress, and more than 40% of the world's rural population lives in water-prone areas;
- soil erosion is brought on by improperly managed fallow, crop rotation, and livestock overgrazing;
- the unbalanced application of fertilizers to restore yields causes nutritional imbalances;
- greenhouse gas emissions.

The majority of the world's methane and nitrous oxide emissions are caused by agriculture, and because middle-class populations are expanding at the same rate as the world's population, there is typically a rise in the demand for meat over cereals, legumes, and wheat.

Modern farms and agricultural operations will work differently, primarily because of advancements in technology, including sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advances will let businesses be more profitable, efficient, safer, and environmentally friendly.

Agriculture 4.0 will no longer have to depend on applying water, fertilizers, and pesticides across entire fields. Instead, farmers will use the minimum quantities, or even completely remove them from the supply chain. They will be able to grow crops in arid areas and use abundant and clean resources such as the sun and seawater to grow food (Matthieu De Clercq, Anshu Vats, Alvaro Biel - 2018).

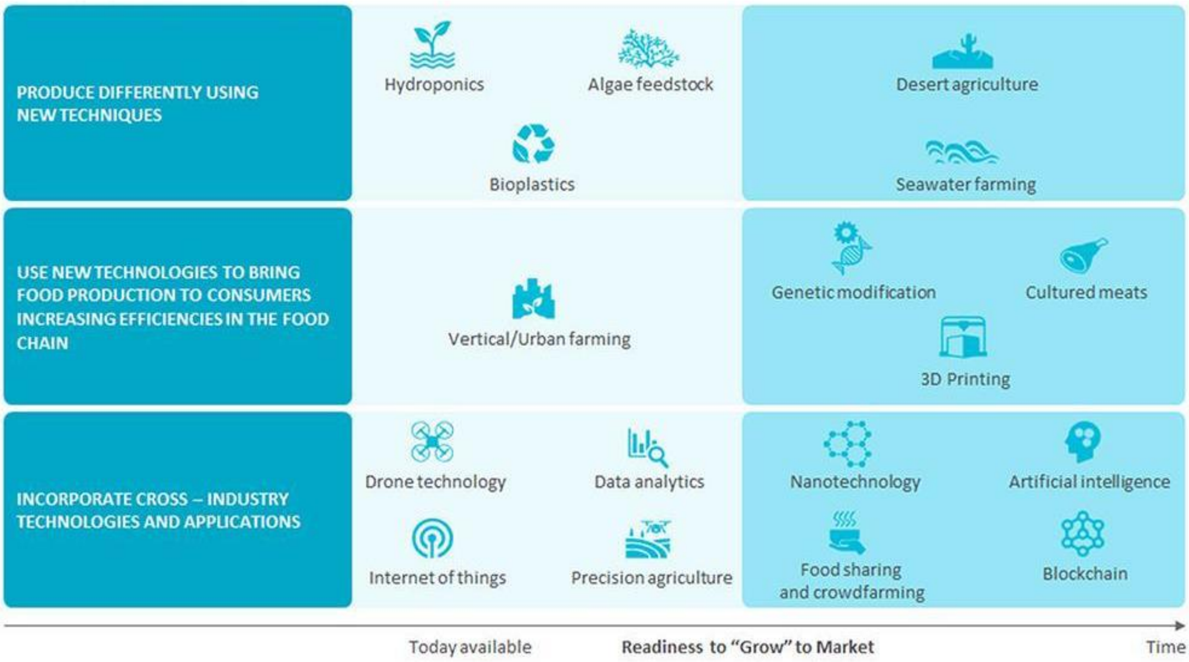

Figure 3.4. Map of technologies and maturity[1]

Here, it is described which are the most important future trends in agriculture:

- increased use of aerial imaging: growers will turn to aerial imaging to better manage their crops. Drone technology and satellite imaging allow farmers to see crop variations;
- Accurate yield forecasting is possible because to various agricultural methods, which enable farmers to do so before crops are harvested. Farmers will be able to sell all of their produce, preventing food waste and boosting revenues;
- data integration: data management software will allow growers to leverage this data to inform their decision-making. Also, this data can be used in real-time to make adjustments;

[1] Matthieu De Clercq, Anshu Vats, Alvaro Biel, 2018

- Technology used in livestock production includes genetics, digital technology, nutritional science, and more. There are several benefits of sensor and data technologies for the livestock business today. By carefully identifying unwell animals and discerning areas for improvement, it can raise cattle productivity. Computer vision primarily enables us to have a variety of objective facts that will be condensed into useful, practical insights;
- precision agriculture: temporal variability of the field leading to the field areas with common characteristics and these are called management zones. Management zones can also be used to apply the appropriate inputs to achieve the best management to increase profitability and reduce environmental impact.

Some of the future trends in agriculture that are prominent in the post-liberalization period include the rising productivity, diversification of the sector, development of horticulture, application of modern methods, a growing volume of exports, and development of the food processing industry.

3.4. Conclusions

Today, the use of DSSs plays an ordinary role in precision agriculture, where in particular and difficult environmental conditions and in high-yield crops, their use is a guarantee of safeguarding production and the sustainability of interventions.

In conclusion, on the basis of the results obtained and their potential, they constitute a sector that has been growing strongly in recent years, allowing the following advantages to be achieved:

- they constitute a valid support for the farmer or technician in monitoring all the variables needed to weigh up decisions;
- they provide short- or long-term forecasts
- they offer the possibility of remote management;
- they store all the information creating an extremely rich database.

At the basis of DSS, there is a concept of forecasting, but there are also other benefits that derive from their implementation: carrying out data-driven interventions leads to an increase in production capacity, in terms of quantity and quality, and to a rationalisation of resources, reducing the company's environmental impact and economic balance sheet.

There is a better use of resources, a prompt response based on the requests of the plant and a minimization of waste, which translates into lower environmental impact and greater profit for the entrepreneur.

In this regard, the transfer of knowledge and innovation in the agricultural sector has been identified as a "transversal priority" within the new rural development programs to be combined with the priority of promoting an efficient use of resources.

In conclusion, it can be said that in a global scenario aimed at environmental sustainability and an increasingly "green" and "smart" agricultural sector, technology appears to be an essential tool for accurate management of fertilization and resources in general, among which also water and soil.

We are witnessing one of the most anomalous climatic trends in recent years. With the alternation of rain, frost and drought, it is now essential to be able to predict the behavior of crops in relation to each scenario and to act promptly to stem possible damage.

In order to make rational decisions, disciplines such as statistics, economics and operational research have developed various methods, which have recently been enhanced by various techniques originating from Information Science, Cognitive Science, Artificial Intelligence (AI) and Pattern recognition. These methods have been implemented in the form of computer programs either as stand-alone systems or complex computing environments for complex decision making. Such environments are often given the common name of Decision Support Systems (DSSs).

The aim of these technologies, applied to the agricultural sector, is to offer the most extensive and precise support to farmers in the decision-making process related to their activity and the relationship with other parties in the supply chain. The ultimate goal is to increase economic, environmental, and social sustainability – as well as profitability – of agricultural processes.

The decisions of each farmer have impacts on sustainability and are made in a complex world of contradictious interests and values. Agricultural decision support systems (AgriDSS) will be a major contributor in the realization of a viable farm economy with less negative environmental impact, but it must not only provide current and relevant information. On the other hand, current DSSs available to farmers, advisors, experts, and policy makers are not used to their full potential. One reason is that they fail to capture the actual needs of the farmers and to understand their decision-making in practice. They are not adapted to the high complexity characterizing sustainable land use decision-making. Among farmers the acceptance of these systems is low, partly because existing DSS are based on what scientists and system developers consider as necessary (Jessica Lindblom, Christina Lundström and Magnus Ljung - Next Generation Decision Support Systems for Farmers: Sustainable Agriculture through Sustainable IT, 2014)

DSS will becoming more and more capable as it becomes an essential part of sustainable agriculture. The gathering and storing of data is being fueled by the expanding interconnectedness of technology and the proliferation of smart devices in the field. The acquired data will be combined and analyzed to improve the accuracy and dependability of DSS. Companies currently provide user-friendly mobile interfaces for smartphones and tablets that can be accessed in the field in real time. Since farmers are the ultimate customers and users of the new technologies that will revolutionize agriculture, these advancements make it possible for more farmers to use DSS.

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CHAPTER 4

Blockchain Technologies

CHAPTER 4 Blockchain Technologies

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WHAT WILL WE LEARN IN THIS CHAPTER?

What is blockchain technology?
What are the types of blockchain technology?
How can blockchain technology be applied in agriculture?
What are the benefits?

Keywords: Agriculture 4.0; Agricultural innovations; Smart farming, Blockchain technologies; Innovative technology; Digital technology; Digitalisation.

4.1. Glossary and abbreviations

In the following table, some words/abbreviations/definitions useful for understanding the chapter have been reported.

Industry 4.0	Industry 4.0 refers to the fourth industrial revolution that is characterized by the integration of digital technologies into manufacturing and other industries. It is also known as the "smart factory" or "digital factory" and represents a new era of industrial production that is highly automated, interconnected, and data driven. Industry 4.0 is based on the integration of various technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, cloud computing, and cyber-physical systems (CPS). By leveraging these technologies, companies can create highly efficient and flexible production systems that can respond quickly to changing market demands and customer needs. Industry 4.0 offers many potential benefits, including increased productivity, improved quality control, better supply chain management, and reduced costs. It is expected to transform manufacturing and other industries in the coming years, leading to new business models and opportunities, as well as significant changes in the way we work and live.
IoT - Internet of Things	IoT is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity that enables these devices to connect, collect and exchange data.
Ledger	A ledger is a book or electronic system used to record financial transactions. It is a fundamental component of accounting and provides a detailed record of all the financial activities of a business, organization or individual.
Distributed Ledger Technology (DLT)	Distributed ledger technology (DLT) is a digital system that enables secure, transparent, and decentralized record-keeping of transactions or data. It uses a network of computers, known as nodes, to maintain and synchronize a shared database, or ledger, across multiple locations, without the need for a central authority or intermediary. Each node in the network maintains a copy of the ledger, and any changes made to the ledger are validated and verified by the entire network through a consensus mechanism, such as proof-of-work or proof-of-stake. This ensures the integrity and immutability of the data, as any attempt to alter the ledger would require a consensus of the network, making it extremely difficult to hack or manipulate. DLT is the underlying technology behind cryptocurrencies such as Bitcoin and Ethereum, but it has many other potential applications, including supply chain management, voting systems, and identity verification.

Table 4.1. Glossary and abbreviations

4.2. Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter.

The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives a value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	***Competences and skills***	***Duration time***	***Learning tools***
• Be able to explain Agriculture 4.0 and Blockchain technology in agriculture	• Knowledge of the practical application of blockchain technology in agriculture • Knowledge about its benefits • Define blockchain applications	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 4.2. Competence map

4.3. Blockchain technology

The world faces enormous challenges in providing food for an ever-growing population, especially due to climate change, floods, drought, desertification, biodiversity loss, pests,and diseases. Innovative agricultural practices are needed to address some of these challenges and make farming attractive and profitable for the small farmers who help feed the world.

The Sustainable Development Goals (SDGs) provide a vision for global development, and information and communications technologies (ICTs) can facilitate the much-needed acceleration of development to achieve many of these goals.

The growth of ICTs over the past decade has opened many opportunities to address some of the challenges in agriculture. Recent developments such as the increasing use of devices with mobile broadband access, the Internet of Things (IoT), drones, smart grids, Big Data analytics capabilities, and artificial intelligence have given agricultural stakeholders some important tools and technologies to improve production and marketing processes in agriculture and related sectors.

Blockchain technology is a new digital technological approach underpinned by Industry 4.0 to ensure data integrity and prevent tampering and single points of failure by providing fault tolerance, immutability, trust, transparency, and full traceability of stored transaction records for all agri-food value chain partners.

4.3.1. What is blockchain technology?

Prior to talking about the integration of this technology in the agricultural sector, we should first search for the meaning of 'blockchain'.

Distributed ledger technology (DLT), the technology that started the various cryptocurrencies in circulation today, has created quite a buzz in many areas in the last few years. Putting it simply, a DLT is a decentralized system for recording transactions with mechanisms for processing, validating and authorizing transactions that are then recorded on an immutable ledger. Blockchain is one implementation of DLT. It is also referred to as an “Internet of value”, meaning a secure way to store and transact value – anything from currency, stocks, contracts and even votes – from one entity to another. It is also the underlying technology powering cryptocurrencies such as Bitcoin and Ether[1]

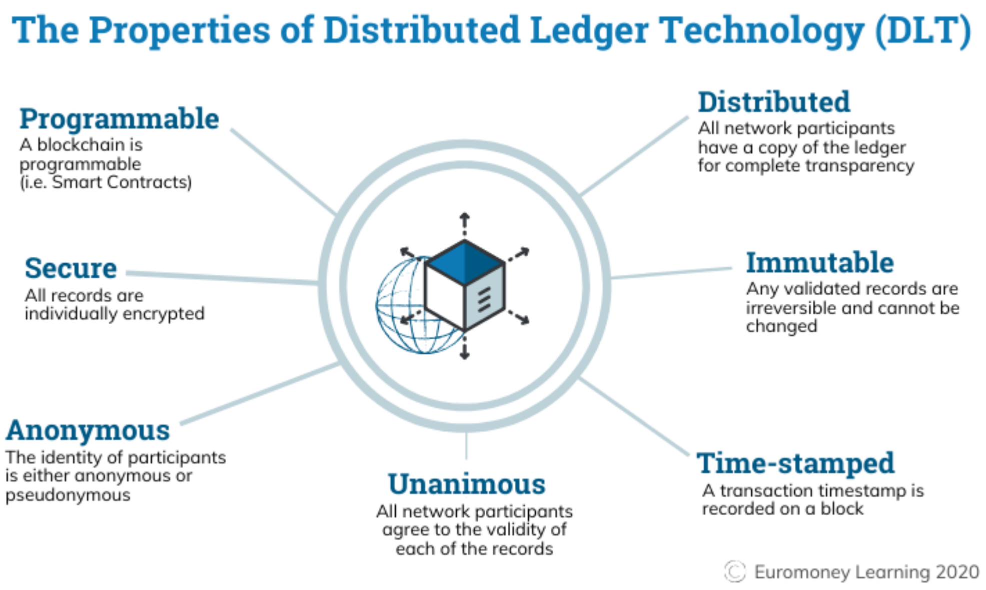

Figure 4.1. Distributed Ledger Technology
Source: https://www.euromoney.com/learning/blockchain-explained/what-is-blockchain

As it is described in the Figure 4.1, "A blockchain is a secure public ledger platform shared by all parties through the internet or an alternative distributed network of computers". Also, it is described as an open and secure method of storing and distributing information which operates without a central server. By extension, a blockchain is a database containing a record of every transaction between users from its creation onward. It is a secure, distributed database that is shared by the different parties without an intermediary, allowing each user to verify the validity of the chain. The 'blocks' in blockchain are batches of transactions. In computing, a transaction is an indivisible series of operations to go from State A to State B: a purchase, a payment, or to send a message, for example. A blockchain is therefore a database to which transactions, grouped together as blocks, are added in chronological order. It is like a ledger, where each line is a transaction. A key feature of this ledger is that it is written in indelible ink: every page can be consulted, lines can be added, but existing data cannot be deleted or changed. Users on the peer-to peer network receive identical copies of this ledger1. This means if one block in one chain was changed, it would be immediately apparent it had been tampered with.

[1] Pandey, P., Bansal, S., & Garg, D. (2019). E-agriculture in action: Blockchain for agriculture. Journal of Innovation in Digital Ecosystems, 6(2), 123-129.

If hackers wanted to corrupt a blockchain system, they would have to change every block in the chain, across all of the distributed versions of the chain.

Therefore, a blockchain consists of blocks, each block containing the data (anything of value), its own hash value (a unique cryptographic value containing characters and numbers generated through a complex computational algorithm), and a pointer to the hash of the previous block.

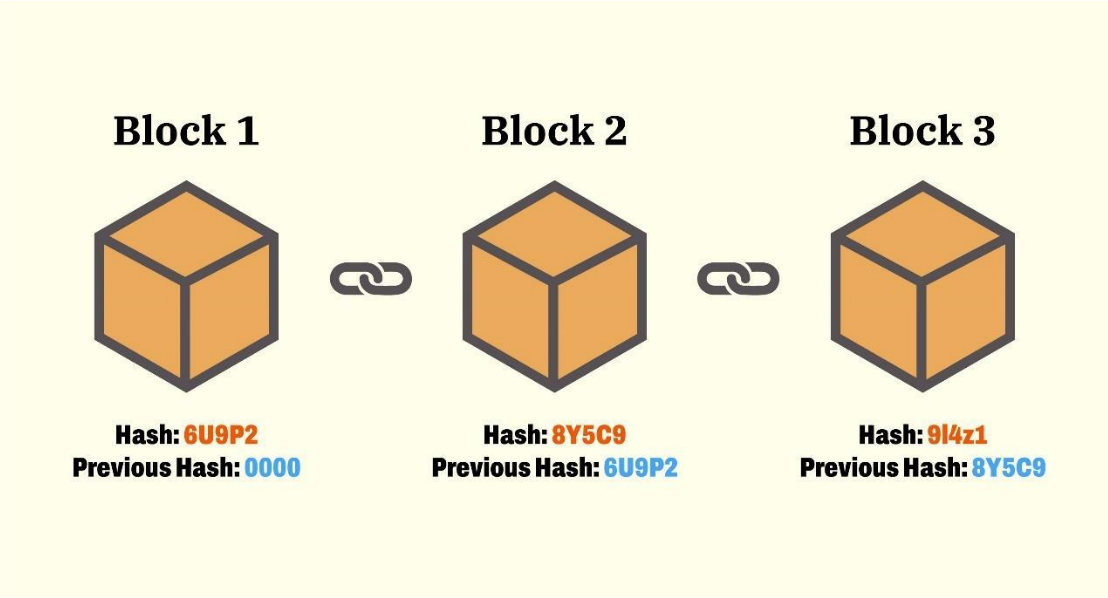

Figure 4.2. Explanation of Blockchain.
Source: https://money.com/what-is-blockchain/

Technologies around blockchain radically transform the way in which the economy functions, as they create a technological opportunity for the existence of a distributed form of trust. This is of great importance, as it can affect traditionally trusted authorities, transactions, and electronic services. With blockchain technology, the trust that has existed so far due to a contractual relationship is now built thanks to the distributed and secure way of storing, managing and exchanging information, and conducting online transactions. This results in radical changes in all the existing financial and business models that we all use every day. Blockchain technology can be applied in various sectors of the economy and society.[2]

[2] About blockchain technology. Retrieved from https://www.blockchain.org.gr/home/en/about-blockchain-technology/

4.3.2 Types of blockchain

Three major types of blockchain networks, each having their own characteristics are consortium blockchain, private blockchain, and public blockchain.

-Consortium: A consortium formed by a group of members that control this blockchain. Verifying and adding records to the blockchain is based on a consensus mechanism by a pre-selected set of nodes.

-Private: This is controlled by a centralized entity. Only people with specific authentication and permission can be part of this network and thereby can verify and add records to the 4 blockchains. However, the blockchain could be publicly viewable. Participants in this blockchain know and trust each other. Also known as a permissioned ledger.

-Public: Public or permissionless blockchain are decentralized and are visible to the public, anyone can join or leave the blockchain and anyone can verify and append transactions to the blockchain. This type of blockchain facilitates the dynamic collection of participants who may not know each other. Hence, stringent consensus mechanisms have to be implemented in this system [3].

Blockchain technology used in the agrifood value chain seems to be a promising research stream for future research, especially in the era of Industry 4.0[4].

4.4. Blockchain technologies in Agriculture and Food chain

While blockchain technology is gaining success and proving its functionality in many cryptocurrencies, various organizations, and other entities are trying to leverage its transparency and fault tolerance to solve problems in scenarios where numerous untrusted actors are involved in the distribution of a resource. Two important, highly relevant areas are agriculture and the food supply chain.

Agriculture and food supply chains are closely linked because the products of agriculture are almost always used as inputs in a distributed supply chain with multiple actors, in which the consumer is usually the end user. Blockchain technology has paved the way for its use in the food industry to improve traceability. Traceability is the ability to determine the history of data and associated movements of food before it is consumed.

[3] Blockchain for agriculture. Retrieved from http://www.fao.org/3/CA2906EN/ca2906en.pdf
[4] Zhao,G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chena, H., Boshkoska, B., M. "Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions".

A simplified example of the digitization of the food supply chain, supported by blockchain technology, is shown in Figure 4.3.

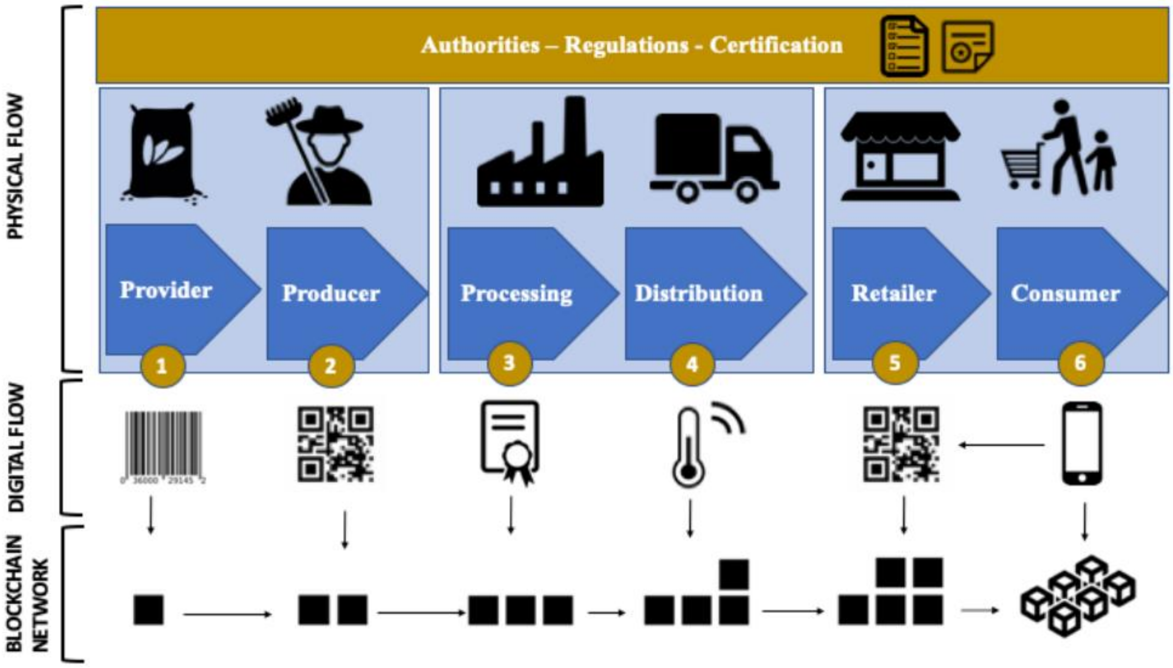

Figure 4.3. A simplified food supply chain system.
Source: Kamilaris, A.,Cole, F., X., Prenafeta-Boldú.“Blockchain in agriculture”. 2021.

According to this scheme the physical flow (top layer) is the digital flow layer (middle layer), which consists of various digital technologies (e.g., QR codes, RFID, NFC, online certification and digital signatures, sensors and actuators, cell phones, etc.). The Internet/Web serves as the connecting infrastructure. Every action along the food chain enabled by the use of the above digital technologies is recorded in the blockchain (lowest layer in Fig. 3), which serves as an immutable means of storing information accepted by all parties involved. The information recorded in each transaction is validated by the business partners in the food supply network, creating a consensus among all participants. After each block is validated, it is added to the transaction chain (see Figure 4.3), becoming a permanent record of the entire process. At each stage of the food flow (defined as numbers 1-6 in Figure 4.3), different technologies are involved and different information is written to the blockchain.

As a successful example, the company AgriDigital conducted the world's first settlement of the sale of 23.46 tons of grain via blockchain in December 2016. Since then, over 1,300 users and more than 1.6 million tons of grain have been transacted through the cloud-based system, with payments to farmers totaling $360 million. AgriDigitals' success served as inspiration for the potential use of this technology in the agricultural value chain. AgriDigital now aims to build trusted and efficient agricultural supply chains using blockchain technology. Another recent example is Louis Dreyfus Co (LDC), one of the world's largest food retailers, which partnered with Dutch and French banks to conduct the first agricultural commodity trade (i.e., a shipment of soybeans from the U.S. to China) based on blockchain. According to LDC, by automatically matching data in real time and eliminating duplication and manual checks, document processing was reduced to one-fifth the time[5].

4.4.1. Blockchain in Food Safety

Food safety is the condition of processing, managing, and storing food in hygienic ways, in order to prevent illnesses from occurring in the human population. Food safety and quality assurance have become increasingly difficult in times of growing global flows of goods.

With the help of this technology, consumers will be able to get all the information they need about food before they consume it, as it will provide consumers with a lot of data on tracking foodborne illnesses. Through this technology, consumers can get information such as the date of vaccinations and the use of antibiotics in the animals whose products they consume. Food data recorded and stored using blockchain technology cannot be altered or modified, making it a perfect way to ensure food safety for multiple consumers. Blockchain technology can be implemented in agricultural and food supply chain processes to capture all the necessary information based on the food. The information needed will keep the final consumers on the state of food products before consumption. Figure 4.3 indicates food information traceability with the help of blockchain technology. There is a flow of relevant information from different parties including distributors, factories, retailers, and the final consumers. Blockchain technology has the capability of informing the final consumers on the relevant information on food to keep them safe.

4.4.2. Blockchain in Food Integrity

Food integrity is about a reliable exchange of food in the supply chain. Each actor should deliver complete details about the origin of the goods. Food safety and integrity can be improved through better traceability. Using blockchain, food companies can mitigate food fraud by quickly identifying and tracing outbreaks to their specific sources.

[5]Kamilaris, A.,Cole, F., X., Prenafeta-Boldú."Blockchain in agriculture". 2021.

Some examples of blockchain technologies are:

Downstream beer6is the first company in the beer industry to use blockchain technology and disclose everything you want to know about the beer, i.e. its ingredients and brewing processes. Every aspect of this craft beer is recorded and written to the blockchain to ensure transparency and authenticity. Consumers can use their smartphone to scan the code QR on the front of the bottle and are then redirected to a website where they can find all the relevant information, from raw materials to bottling.

San Domenico roastery adopted blockchain technology to accompany its coffee product with reliable, unmodifiable documentation, and guarantee of absolute transparency. Thanks to the blockchain, each step until the sale was recorded and made unmodifiable before being launched to the next step, to ensure unequivocally the quality of the product and the entire production chain associating all the information concerning a coffee product with a univocal QR code. This permitted access to information, news, videos, certifications and images that trace the supply chain up to the final consumer. Figure 4 shows a snapshot of the mobile application after the QR code of an existing coffee product has been scanned, showing information about the origin of the coffee. Once the system was tailored to the company, the cost savings of certification ranged between 70% and 90%, according to Foodchain7. Foodchain is an Italian company that provides traceability services for food supply chains using blockchain technology.

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[6] Ireland Craft Beers. Downstream beer. (2017). Retrieved from http://www.down-stream.io in Kamilaris, A., Cole, F., & Prenafeta-Boldú, X. (2021). Blockchain in agriculture. Computers and Electronics in Agriculture, 182, 106016. doi: 10.1016/j.compag.2020.106016

[7] Foodchain, "San Domenico roastery: The first case of a coffee supply chain fullytraced with blockchain," 2019. [Online]. Retrieved from https://food-chain.it/public/case/san-domenico/ in Kamilaris, A., Cole, F., & Prenafeta-Boldú, X. (2021). Blockchain in agriculture. Computers and Electronics in Agriculture, 182, 106016. doi: 10.1016/j.compag.2020.106016

Figure 4.4. Foodchain
Source: Kamilaris, A.,Cole, F., X., Prenafeta-Boldú.“Blockchain in agriculture”. 2021.

4.4.3. Blockchain in Smart Farming

Different actors and stakeholders generate and manage data and information according to their needs and capacities. Smart agriculture is characterized by using ICT, the Internet of Things (IoT), and various modern technologies for data collection and analysis, including unmanned aerial vehicles (UAVs), sensors, and machine learning. A key issue in the adoption of smart agriculture is the development of a comprehensive security system that facilitates the use and management of data. Traditional methods manage data centrally and are vulnerable to inaccurate data, data distortion and misuse, and cyberattacks. For example, environmental monitoring data is typically managed by centralised government agencies that have vested interests.

Smart agriculture with blockchain does not lower, if not raise, the technological barrier for farmers to participate. Importantly, it is better motivated to collect trustworthy data from large farmers than from smallholders for uploading to the blockchain. Large farmers are more likely to be involved in blockchain-based smart agriculture and benefit from it. This thus can create or increase the discrepancy between large farmers and smallholders[8]

4.4.4. Blockchain and insurance

In the agriculture domain, self-executing smart contracts together with automated payments would be the game changer. The role of smart contracts especially in agricultural insurance, green bonds, and traceability could be very effective. Agricultural insurance built on blockchain with key weather incidents and related payouts drafted on a smart contract, linked to mobile wallets with weather data being provided regularly by sensors in the field and correlated by data from proximity weather stations would facilitate immediate payout in the case of a drought or flooding in the field.

Smart contracts are self-executing agreements that are triggered on the basis of predefined and agreed events (for example rainfall of more than 200 mm, the market price of the commodity more than USD 100). The “smart” in a smart contract comes from the fact that the clauses in the contract are evaluated and the appropriate code executed without human intervention. Settlements in smart contracts are automatically triggered if the pre-agreed conditions coded into the contract are met. Imagine something along the lines of the automatic debit used by merchants to take payment from your bank account, based on pre-agreed conditions (full payment, part payment, minimum amount etc.) on a pre-agreed day or date (first Wednesday of the month, every 10 May etc.)[9]

The idea behind the ARBOL project is via customized agreements, farmers can receive payments for droughts, floods, or other adverse weather outcomes that negatively affect their crop (ArbolMarket 2019)[10]

4.5. Blockchain applications

The Food and Agriculture Organization of the United Nations (FAO) has recognized the importance of blockchain to the agricultural sector. Because of these potential benefits, companies have already proposed blockchain-based solutions . blockchain applications in agriculture can provide various solutions such as:

[8] Xiong, H., Dalhaus, T., Wang, P., & Huang, J. “Blockchain Technology for Agriculture: Applications and Rationale” in Frontiers in Blockchain. 2020.
[9] Blockchain for agriculture. Retrieved from http://www.fao.org/3/CA2906EN/ca2906en.pdf
[10] Kamilaris, A.,Cole, F., X., Prenafeta-Boldú.“Blockchain in agriculture”. 2021.

- Product traceability and logging (e.g., IBM Food Trust, Ambrosus - https://ambrosus.io), and TE-FOOD (https://te-food.com): Consumers and regulators can verify the origin of products. They can also store product information from IoT devices and sensors.

- Ensuring trust between participants (e.g., TrustChain): With the transparency and immutability that blockchain can provide, supply chain participants can trust each other.

- Equal payment for producers (e.g., FairChain - https://fairchain.org): Blockchain can be used to reduce middlemen and transparently distribute profits to producers.

- Product insurance and indemnity claims (e.g., Etherisc - https://etherisc.com): Smart contracts can replace insurance documents and schedule insurance activation based on IoT sensors. All transactions are transparent and visible to other parties[11]

4.6. Conclusions

Blockchain technology is a decentralized system for recording transactions on an immutable ledger. It is a secure, distributed database shared by different parties without an intermediary, allowing each user to verify the validity of the chain. Blocks in blockchain are batches of transactions, each block containing data, its own hash value, and a pointer to the previous block's hash. Blockchain technology creates a technological opportunity for the existence of a distributed form of trust, affecting traditionally trusted authorities, transactions, and electronic services. It is a key feature of Industry 4.0 and can be integrated into the agricultural sector to ensure data integrity and prevent tampering, single points of failure, and improve the agri-food value chain.

Blockchain technology allows for the capture and storage of relevant information from different parties, including distributors, factories, retailers, and consumers, providing transparency and authenticity. With blockchain, food companies can mitigate food fraud by quickly identifying and tracing outbreaks to their specific sources. By recording every transaction on a tamper-proof and immutable ledger, blockchain can help ensure that all participants in the food supply chain have access to accurate and trustworthy information about the origin, quality, and safety of the products they are dealing with. This can enhance the efficiency and effectiveness of food safety and quality control measures, as well as enable consumers to make more informed choices about the food they eat. In addition to traceability, blockchain technology can also enable more efficient and secure transactions in the agrifood

[11] Sendros, A., Drosatos, G., P., Efraimidis, S., Tsirliganis, N., C. "Blockchain Applications in Agriculture: A Scoping Review". 2022.

value chain. For example, smart contracts can be used to automate and streamline the process of buying and selling agricultural products, reducing the need for intermediaries and enabling faster and more cost-effective settlements.

Examples of companies that have implemented blockchain technology include AgriDigital, Louis Dreyfus Co, Downstream Beer, and San Domenico Roastery. By implementing blockchain, food companies can improve food safety and integrity, increase transparency, and reduce certification costs.

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An AgroTIC Business Chair Study. (2017). Blockchain for agriculture and food supply chains. Retrieved from: https://www.agrotic.org/wp-content/uploads/2018/06/ChaireAgroTIC_Blockchain_English.pdf

Euromoney Learning. (n.d.). What is blockchain? A simple explanation. Retrieved from https://www.euromoney.com/learning/blockchain-explained/what-is-blockchain

Foodchain. (2019). San Domenico roastery: The first case of a coffee supply chain fully traced with blockchain. Retrieved from https://food-chain.it/public/case/san-domenico/

Ireland Craft Beers. (2017). Downstream beer. Retrieved from http://www.down-stream.io

Kamilaris, A., Cole, F., & Prenafeta-Boldú, X. (2021). Blockchain in agriculture. Computers and Electronics in Agriculture, 182, 106016. doi: 10.1016/j.compag.2020.106016

Pandey, P., Bansal, S., & Garg, D. (2019). E-agriculture in action: Blockchain for agriculture. Journal of Innovation in Digital Ecosystems, 6(2), 123-129.

Sendros, A., Drosatos, G., P., Efraimidis, S., Tsirliganis, N., C. (2022). Blockchain Applications in Agriculture: A Scoping Review.

Xiong, H., Dalhaus, T., Wang, P., & Huang, J. (2020). Blockchain Technology for Agriculture: Applications and Rationale. Frontiers in Blockchain.

FAO. (2019). Blockchain for agriculture. Retrieved from http://www.fao.org/3/CA2906EN/ca2906en.pdf

Blockchain.org.gr. (n.d.). About blockchain technology. Retrieved from https://www.blockchain.org.gr/home/en/about-blockchain-technology/

CHAPTER 5

NIR and Drones

CHAPTER 5 NIR and Drones

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WHAT WILL WE LEARN IN THIS CHAPTER?

What is the image processing?
What is the NIR?
Why we use drones?

Keywords: NIR, Drone; Image processing; Agriculture 4.0

5.1 Glossary and abbreviations

Near infrared (NIR)	Near-Infrared Light (NIR) is the section of electromagnetic radiation (EMR) wavelengths nearest to the normal range but just past what we can see.
Normalised difference vegetation index (NDVI)	The Normalized Difference Vegetation Index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, assessing whether the target being observed contains live green vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).
Near-infrared spectroscopy (NIRS)	Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from 780 nm to 2500 nm).
Infrared (IR)	Infrared (IR) is electromagnetic radiation with wavelengths longer than those of visible light and shorter than radio waves.
Internet of Things (IoT)	The Internet of Things (IoT) are the physical objects embedded with sensors and actuators allowing the physical world to be digitally monitored or even controlled.
Artificial Intelligence (AI)	AI is the ability of a machine to display human-like capabilities such as reasoning, learning, planning and creativity.
Geographic information systems (GIS)	A Geographic Information System (GIS) is a computer system that analyzes and displays geographically referenced information.
Unmanned Aerial Vehicles (UAV)	An unmanned aerial vehicle (UAV), is an aircraft without any human pilot, crew, or passengers on board.
Nanometer (nm)	A nanometer (nm) is a metric unit of spatial measurement that is one billionth (1×10-9) of a meter.
Remotely Piloted Aerial Systems (RPAS)	An aircraft where the flying pilot is not on board the aircraft

Table 5.1. Glossary and abbreviations

5.2 Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter. The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	***Competences and skills***	***Duration time***	***Learning tools***
• be able to explain the applications of the image processing • be able to explain the main application areas of drones	• Knowledge of the practical application of image processing used in agriculture • Identify the drones	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 5.2. Competence map

5.3 Introduction

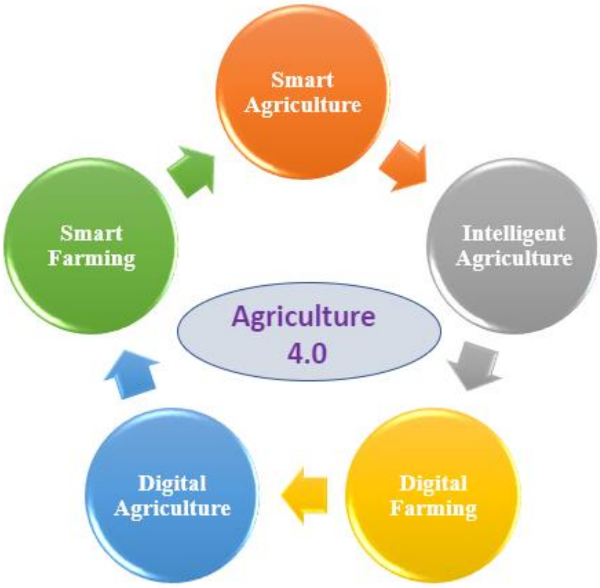

Figure 5.1. Agriculture 4.0 and other definitions

Agriculture 4.0 can be expressed in different forms such as "Smart Agriculture", "Intelligent Agriculture", "Digital Farming", and "Digital Agriculture" in different sources. In fact, they all include smart devices consisting of sensors, actuators, a digital brain, robotics, and communication technology using modern information technology tools[1].

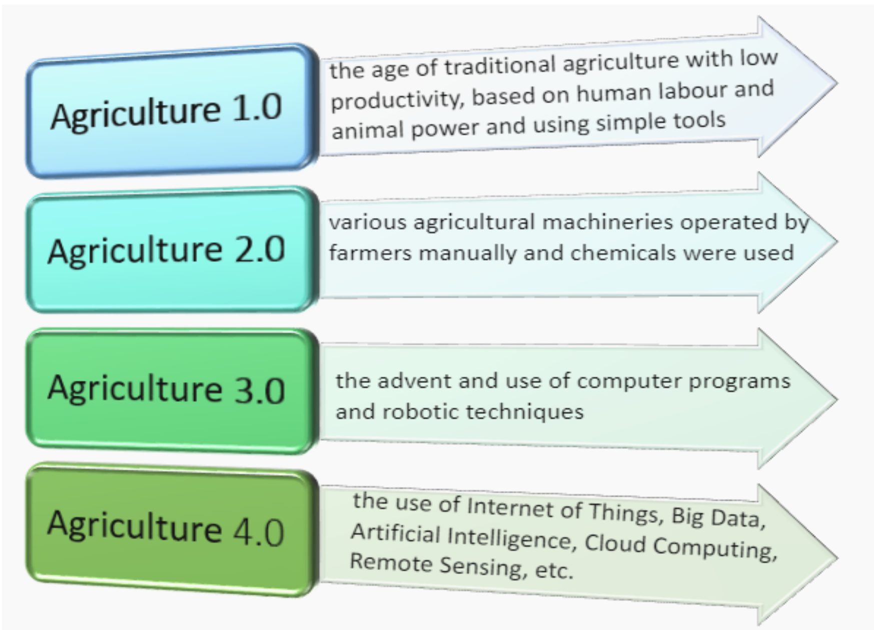

Figure 5.2. Agriculture 4.0 and its steps

[1] CEMA (2017) Digital Farming: what does it really mean? https://cema-agri.org/images/publications/positionpapers/CEMA_Digital_Farming_-_Agriculture_4.0__13_02_2017_0.pdf ((08.07.2020))

Agriculture 4.0 can combine various applications and tools to meet the different needs of producers, and mostly uses internet-based technologies. Various sensors placed on equipment, in the field, or in greenhouses can provide data to a platform (cloud-based) allowing an information system to be built[2].

With software developed using artificial intelligence, image processing, and machine learning, weeds can be detected, and the development of the plant can be followed. Thus, more effective and efficient irrigation, spraying, and fertilization operations can be performed. The amount of pesticide used can thus be reduced. Intelligent irrigation systems, developed using IoT-based devices, can irrigate by determining the weather conditions, the moisture requirement of the soil, and the type of crop. Turning the pump motor off and on according to the measured humidity rate compared to the threshold value helps both to use the water source efficiently, not waste the crop, and save electrical energy[3]. Reports can be received on the yield, operation, and related data of the past seasons, and weekly humidity, temperature, and soil analysis reports can be checked from mobile phones. Geographic information systems (GIS) is another Agriculture 4.0 tool characterized by the significant use of GPS technology and allow the mapping of lands. For example, mapping the nitrogen requirements of an area allows inputs to be adapted not only at the plot level but also for different regions defined by the satellite.

Near-infrared (NIR) spectroscopy can provide a real-time, rapid, and non-destructive crop nutrient monitoring, control, and decision support method for plants as a part of Internet of Things (IoT) and Artificial Intelligence (AI) based methods[4,5]. In agricultural operations, especially high-resolution plant images and image processing are of great importance in terms of irrigation, fertilization, and spraying. These images, which are costly to obtain with aircraft and satellites, can be obtained from cameras that are constantly fixed on the field, unmanned land, or unmanned aerial vehicles (UAV) with GPS systems and cameras. With these monitoring systems, problems of over-irrigation, soil erosion and crop-specific irrigation can be resolved[4]. In addition, the experience gained during the implementation of image processing studies has been evaluated together with machine learning, deep learning, artificial intelligence, modelling and simulation applications, paving the way for the development of real-time and

[2] https://arastirma.tarimorman.gov.tr/koyunculuk/Menu/76/Tarim-4-0

[3] https://tarfin.com/blog/tarim-40-nedir-getirdigi-yenilikler-nelerdir

[4] Hanumann, T., Swamy, N. V. V. S. N., Gowtham, P., Sumathi, R., Chinnasamy, P., & Kalaiarasi, A. (2022, January). Plant Monitoring System Cum Smart Irrigation using Bolt IOT. In *2022 International Conference on Computer Communication and Informatics (ICCCI)* (pp. 1-3). IEEE.

[5] Sarma, K. K., Das, K. K., Mishra, V., Bhuiya, S., & Kaplun, D. (2022). Learning Aided System for Agriculture Monitoring Designed Using Image Processing and IoT-CNN. *IEEE Access*, *10*, 41525-41536.

automatic expert systems, autonomous tractors or agricultural machines and agricultural robotic applications[6].

5.4 What is NIR/NIRS?

With the application of image processing techniques in agricultural activities, many analyses can be done remotely and quickly such as detection of plant diseases, plant pests, and weeds, determination of plant stresses, monitoring of crop growth, modelling of irrigation methods, determination of soil properties, monitoring of animal growth, detecting lameness, identifying pain points in animals[6].

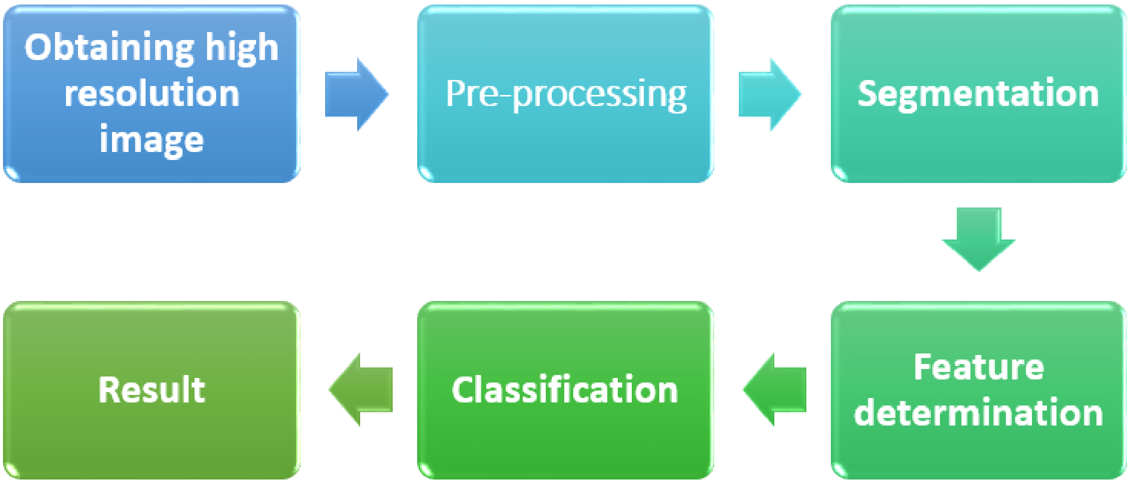

Figure 5.3. Image processing

Figure 5.4[6] shows the stages of disease detection by image processing from the leaf of the sugar beet plant. On the original leaf image of sugar beet taken from the field, each pixel was labelled with the cluster index. Using pixel tags, the pixels in the image are separated into colors (segmentation) resulting in three images. The disease image was selected from among the three clusters (brown segment). Disease severity was calculated at 48% as a result of image processing for the sugar beet leaf spot image.

[6] Altas, Z., Ozguven, M. M., & Yanar, Y. Use of Image Processing Techniques in Determination of Plant Disease and Pest Levels: The Case Study of Sugar Beet Leaf Disease.

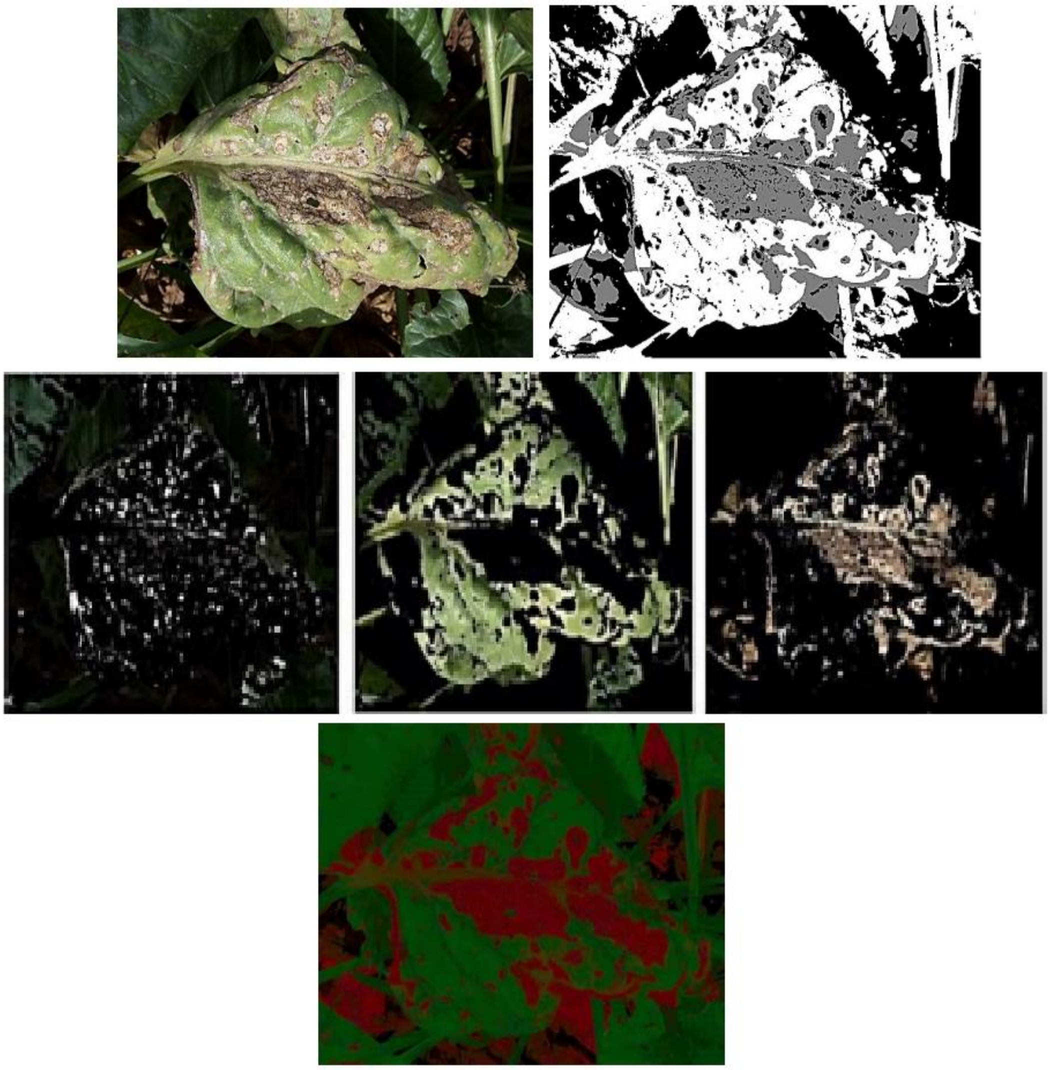

Figure 5.4. Disease detection from leaf of sugar beet plant by image processing[6]

In the example in Figure 5.5, image processing techniques were used to identify, and classify actual diseased areas in the detection of rice blight disease (Pyricularia oryzae Cav.). Artificial Neural Networks, one of the machine learning algorithms, have been applied to different data sets. In image processing, a clustering method was used for the segmentation of diseased parts, non-disease part and backgrounds. Rice blight disease images were taken from the cultivated fields both from the ground and remotely with the help of drones[7].

[7] Soydan, O. Determination of rice leaf blight disease by using image processing techniques. Master's thesis, Ondokuz Mayıs University / Institute of Science and Technology / Department of Agricultural Machinery and Technologies Engineering, 2020.

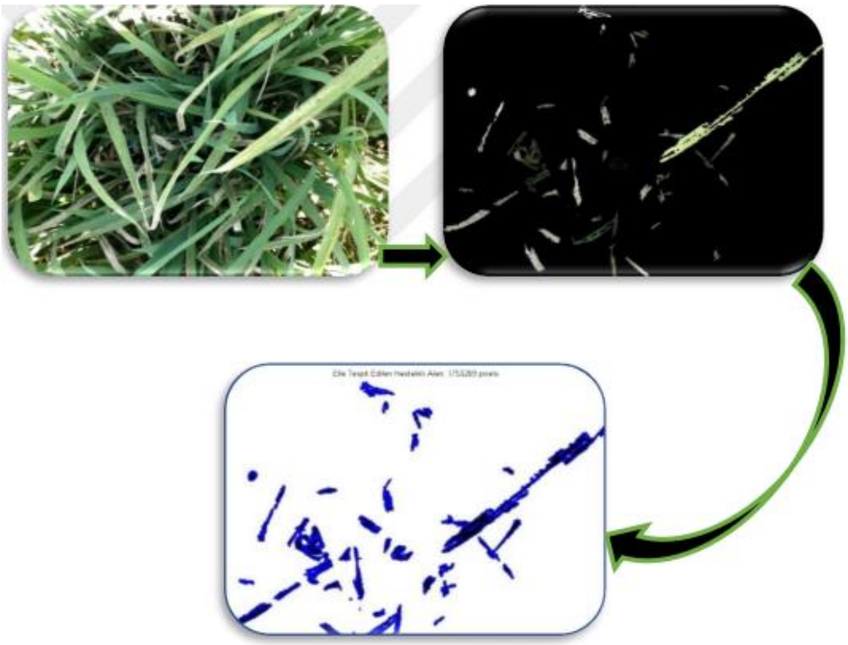

Figure 5.5. Identification of actual diseased areas of rice blight disease (Pyricularia oryzae Cav.)[7]

Another example, as can be seen in Figure 5.6, the damage caused by the leaf scabies pest was determined at the lowest 10% and the highest 87% damage rate among 50 images by using the image processing toolbox module of the MATLAB program. In the study, the damage levels determined by expert evaluation and image processing techniques were found to be close to each other[6].

In particular, sensors using infrared wavelength reflections are widely used in remote sensing studies. NIR spectroscopy can provide a real-time, rapid, and non-destructive crop nutrient monitoring, control, and decision support method for plants. While the light that the human eye can see is in the range of 400-700 nanometers (nm), the range of 700-2500 nm can be displayed in terms of the reflected or transmitted absorbance of electromagnetic energy with NIR[8].

The distinction due to the differences in the spectral signatures of the plants is obtained by using various indices. Some of the features that can be detected in plants from the differences in spectral indices are as follows[9]:

- healthy plant versus an unhealthy plant,
- cultivar with weeds,

[8] Prananto, J. A., Minasny, B., & Weaver, T. (2020). Near infrared (NIR) spectroscopy as a rapid and cost-effective method for nutrient analysis of plant leaf tissues. *Advances in Agronomy*, *164*, 1-49.
[9] Turkseven, S., Kizmaz, M. Z., Tekin, A. B., Urkan, E., & Serim, A. T. (2016). Digital Conversion in Agriculture; Unmanned Air Vehicle Use. *Tarım Makinaları Bilimi Dergisi*, *12*(4), 267-271.

- mature plant and an immature plant,
- the plant that is under water stress and the plant that does not need irrigation,
- nutrient-deficient and non-nutrient-deficient plants.

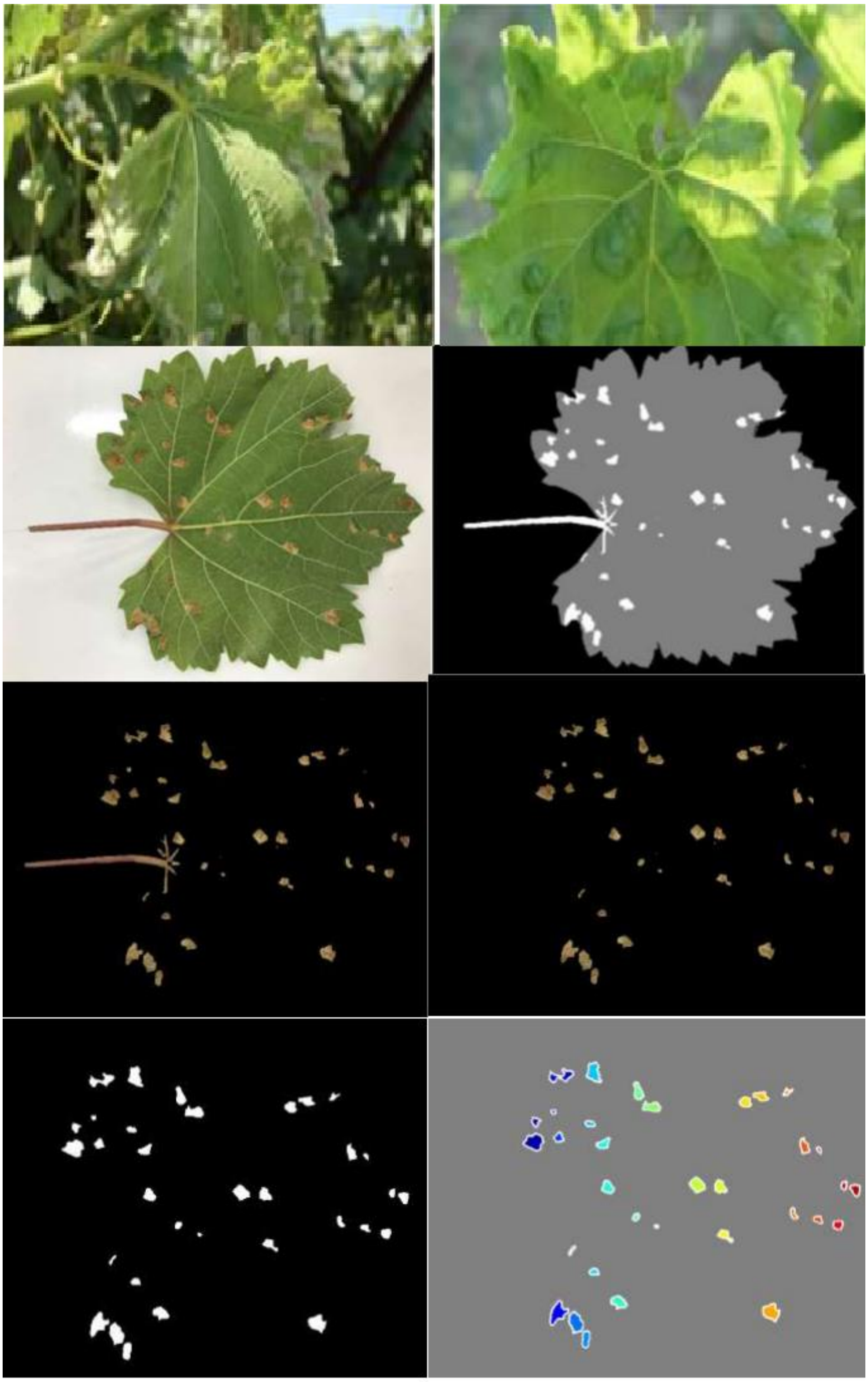

Figure 5.6. The damage caused by the leaf scabies pest monitoring using the image processing[6]

When the human eye perceives the changes/damages occurring in plants, it is quite late to carry out the necessary applications. However, with the data collected in the visible light spectrum and NIR spectrum, these differences can be detected long before the symptoms that can be perceived by the human eye occur[8].

Chlorophyll is a pigment that plays an important role in photosynthesis, is an indicator of plant health and plant stress, and provides the characteristic green color for healthy plants due to the absorption of blue and red chlorophyll[10,11]. Green reflection can be used for monitoring, but NIR and IR methods provide much better results in monitoring plant health and water stress. The normalized difference vegetation index (NDVI) is used as an important indicator for the health status and water content of plants. It is based on the difference between the red reflection due to pigment absorption by the chlorophyll of the plant and the NIR reflection due to the scattering of the cellular structure. NDVI has a linear relationship with precipitation, temperature and evapotranspiration as well as water stresses[12,13,14,15] . The vegetation indices are a combination of the percentage of refracted radiation in different specific bands[16].

Vegetation absorbs solar radiation at different frequency ranges and wavelengths, and reflects back a different percentage depending on plant health and water stress. As seen in Figure 5.7 and Table 5.3, the NDVI values vary between -1 and 1, and each value corresponds to a different agronomic situation, regardless of the crop[16].

Many indices have been developed for determining natural phenomena and observing the changes that occur by making use of measurements made with the help of white light and NIR sensors. With the help of these indexes, the vegetative vegetation is evaluated in terms of quality and quantity. Among these indices, NDVI is used the most. Index, the idea that other objects don't reflect in the region of the spectrum known as the near-infrared (NIR), where vegetation reflects a lot of light formulated on it. When plants are dehydrated or stressed, they reflect less light in the NIR, but the same amount of light in the visible wavelength. Therefore, when these

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[10] Steele, M., Gitelson, A. A., & Rundquist, D. (2008). Nondestructive estimation of leaf chlorophyll content in grapes. *American Journal of Enology and Viticulture*, *59*(3), 299-305.
[11] Blum, A. (2018). *Plant breeding for stress environments*. CRC press.
[12] Rouse, J. W. (1974). Monitoring the vernal advancement of retrogradation of natural vegetation. *NASA/GSFC, type III, final report, greenbelt, MD, 371*.
[13] Peñuelas, J., & Filella, I. (1998). Visible and near-infrared reflectance techniques for diagnosing plant physiological status. *Trends in plant science*, *3*(4), 151-156.
[14] Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote sensing of Environment*, *8*(2), 127-150.
[15] Chung, S., Breshears, L. E., & Yoon, J. Y. (2018). Smartphone near infrared monitoring of plant stress. *Computers and Electronics in Agriculture*, *154*, 93-98.
[16]https://www.agricolus.com/en/vegetation-indices-ndvi-ndmi/

two types of data are combined, besides detecting the presence of vegetation, it can also be determined whether it is healthy or not[8,17].

NDVI	***INTERPRETATION***
<0.1	Bare soil
0.1 – 0.2	Almost absent canopy cover
0.2 – 0.3	Very low canopy cover
0.3 – 0.4	Low canopy cover, low vigour or very low canopy cover, high vigour
0.4 – 0.5	Mid-low canopy cover, low vigour or low canopy cover, high vigour
0.5 – 0.6	Average canopy cover, low vigour or mid-low canopy cover, high vigour
0.6 – 0.7	Mid-high canopy cover, low vigour or average canopy cover, high vigour
0.7 – 0.8	High canopy cover, high vigour
0.8 – 0.9	Very high canopy cover, very high vigour
0.9 – 1.0	Total canopy cover, very high vigour

Table 5.3. The NDVI values for a different agronomic situation

[17] Tsuchikawa, S., Ma, T., & Inagaki, T. (2022). Application of near-infrared spectroscopy to agriculture and forestry. *Analytical Sciences*, 1-8.

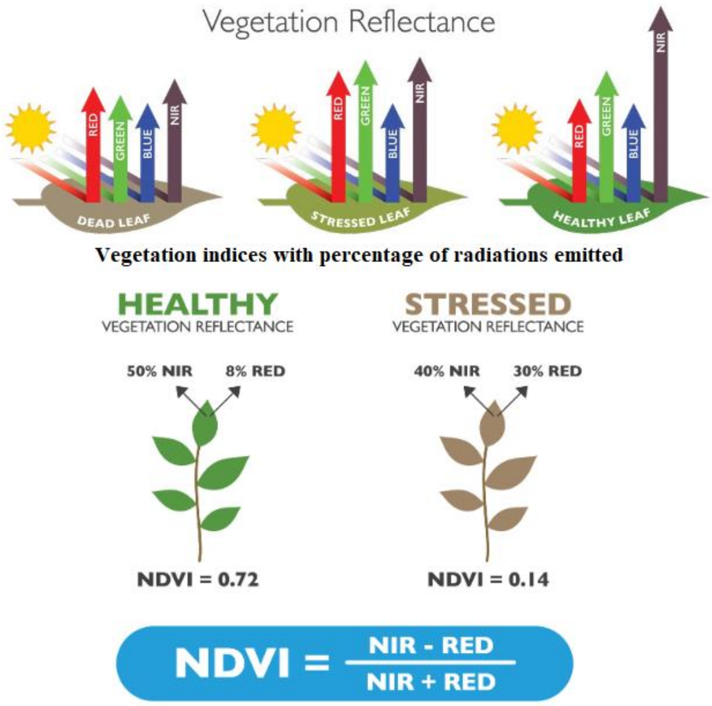

Figure 5. 7. The vegetation indices and NDVI formula

Pre-symptomatic infections can be monitored and determined using NIR. Figure 5.8a shows visible and NIR hyperspectral images of tomato leaves infected with Pseudomonas cichorii JBC1 and Figure 5.8b shows chlorophyll fluorescence images of tomato leaves inoculated with different densities of Pseudomonas cichorii JBC1 cells[18].

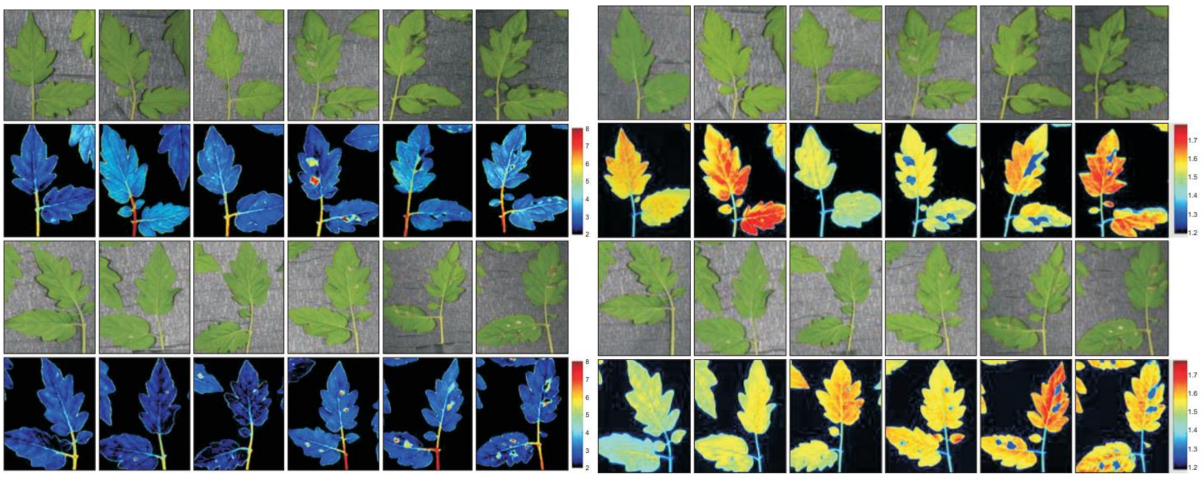

Figure 5.8. Visible and NIR hyperspectral images of tomato leaves infected with Pseudomonas cichorii JBC1 (a), chlorophyll fluorescence images of tomato leaves inoculated with different densities of Pseudomonas cichorii JBC1 cells (b)[17]

[18] Rajendran, D. K., Park, E., Nagendran, R., Hung, N. B., Cho, B. K., Kim, K. H., & Lee, Y. H. (2016). Visual analysis for detection and quantification of Pseudomonas cichorii disease severity in tomato plants. *The plant pathology journal*, *32*(4), 300.

5.5 Drones

A UAV (Unmanned Aerial Vehicle) or Unarmed Aerial System (UAS) is an aircraft that has no onboard, human pilot and drones are the most widely known among UAVs. It can fly on a predetermined route with the help of an autopilot and GPS coordinates. It also has normal radio controls and can be manually commanded in a malfunction or dangerous situation[19,20].

Figure 5.9. Remote control of drones[21]

Although the use of drones for military purposes has come to the fore, they have also been used for various purposes later in meteorological studies and recently in many civilian areas including environmentally oriented agricultural production[9].

Drones have become an essential tool for all manufacturers because of their ability to increase productivity and improve food safety. Drones offer many advantages for agricultural use due to their ability to capture high-resolution and low-cost images of agricultural production areas, plants, and animals using recording portable devices such as visible (RGB), infrared (NIR), and thermal sensors[22,23].

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[19] Ahirwar, S., Swarnkar, R., Bhukya, S., & Namwade, G. (2019). Application of drones in agriculture. International Journal of Current Microbiology and Applied Sciences, 8(1), 2500-2505.

[20] Clarke, R. (2014). Understanding the drone epidemic. Computer Law & Security Review, 30(3), 230-246.

[21]<ahref="https://www.freepik.com/free-vector/drones-quadrocopters-isometric-set_6883528.htm#query=drone&position=7&from_view=keyword">Image by macrovector on Freepik

[22] Turner, D., Lucieer, A., Malenovský, Z., King, D., and Robinson, S. (2014). Spatial co-registration of ultra-high resolution visible, multispectral and thermal images acquired with a micro-UAV over Antarctic moss beds. Remote Sensing, 6(5), 4003-4024.doi:10.3390/rs6054003.

[23] Demir, S., & Başayiğit, L. (2020). Sorunlu Gelişim Gösteren Bitkilerin İnsansız Hava Araçları (İHA) ile Belirlenmesi. Türk Bilim ve Mühendislik Dergisi, 2(1), 12.

Figure 5.10. A drone[24]

Main application areas of drones

Military drones or RPAS (Remotely Piloted Aerial Systems), are used in situations where manned flight is considered too risky or difficult. Drones are also used in inspection, surveillance, intelligence, chemical, biological, nuclear and radiological activities. Delivery services could save a lot of manpower and shift unnecessary road traffic to the sky. For security and law enforcement, they help with the surveillance of large crowds and ensure public safety. Drones are able to discover the location of lost people in harsh conditions or challenging terrains. The film and television industries use them to capture footage that requires expensive helicopters and cranes. It is also used in wildlife monitoring, as a deterrent to poachers, for animals protection, disaster management, and agriculture applications[18].

Figure 5.11. Drone quadcopter with high resolution digital camera on green corn field[25]

[24]<ahref="https://www.freepik.com/free-photo/white-drone-hovering-bright-blue-sky_6659454.htm#query=drone%20camera&position=4&from_view=keyword">Image by ArthurHidden on Freepik
[25]<ahref="https://www.freepik.com/free-photo/drone-quad-copter-with-high-resolution-digital-camera-green-corn-field_10141248.htm#query=drone%20camera&position=6&from_view=keyword">Image by standret on Freepik

Figure 5.12. Drone spraying fertilizer on vegetable green plants agriculture technology farm automation[26]

The advantages of UAVs can be listed as follows[27]

- Fast setup time
- Low acquisition costs
- Live data capture

In addition to the many advantages of UAVs, there are also disadvantages as listed below [28]:

- Low flight time
- Battery efficiency
- Communication distance
- Load issues

Drones used in agriculture are classified according to rotor and wing structures:[29]

- Multi-Rotor UAVs,
- Fixed Wing UAVs,
- Single Rotor UAVs and
- Hybrid Vertical Take-off and Landing (VTOL).

[26] https://www.freepik.com/free-photo/drone-spraying-fertilizer-vegetable-green-plants-agriculture-technology-farm-automation_21544380.htm#query=drone%20plant&position=9&from_view=search&track=sphlution-digital-camera-green-corn-field_10141248.htm#query=drone%20camera&position=6&from_view=keyword

[27] Maddikunta, P. K. R., Hakak, S., Alazab, M., Bhattacharya, S., Gadekallu, T. R., Khan, W. Z., & Pham, Q. V. (2021). Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges. *IEEE Sensors Journal*, *21*(16), 17608-17619.

[28] Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021). A review of applications and communication technologies for internet of things (Iot) and unmanned aerial vehicle (uav) based sustainable smart farming. Sustainability, 13(4), 1821.

[29] Kim, J., Kim, S., Ju, C., & Son, H. I. (2019). Unmanned aerial vehicles in agriculture: A review of perspective of platform, control, and applications. Ieee Access, 7, 105100-105115.

Multi Rotor drones can be used in the field of photography and surveillance and can have 3, 4, 6, or 8 rotors. Their speed and flight time are limited. It can be preferred due to its cheap and easy production according to its intended use. The average flight time of fixed-wing drones flying with thrust and aerodynamic lift is 2 hours. They can work long distances. They need a runway for flight. They are expensive, larger than rotor models, and require good training. Single rotor drones are helicopter-like thanks to the large rotor and small rotor in the tail but have longer flight times compared to multi rotor drones. They are costly and complex in structure.

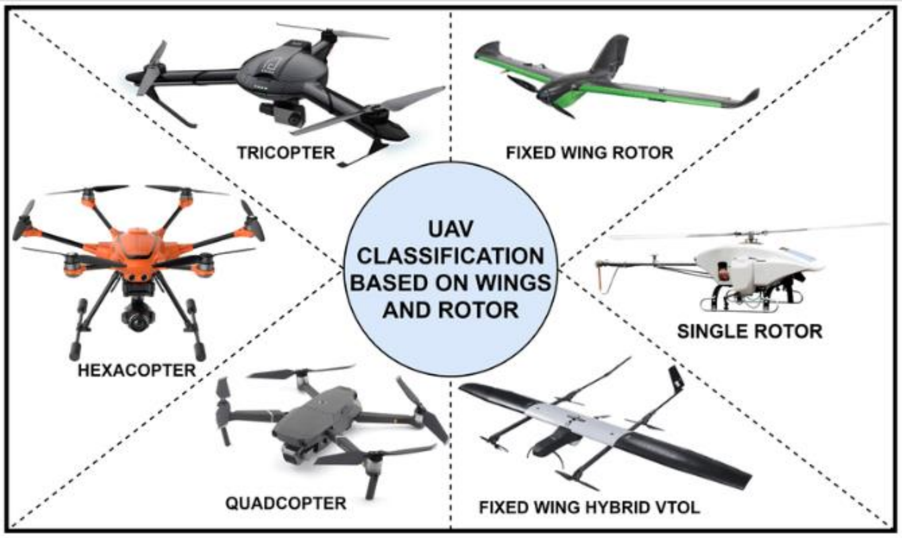

Figure 5.13. Classification of UAV based on wings and rotors[30]

Hybrid Vertical Take-off and Landing (VTOL) has a hybrid structure and rotor, and fixed wing UAVs systems are used. Using the advantages of the fixed wing, this vehicle can also stay stationary in the air[27,28]. The fixed wing, however, is designed for very specific purposes, which makes it less versatile in its use. Its main disadvantage is the issue of landing and take-off. Not being able to land and take off vertically means that someone must mark out a fairly large area of land (around 60 m^2); that must be flat and unobstructed. On the other hand, a fixed-wing drone does not allow a stationary flight, which prevents us from being able to carry out a wide range of operations. It also has a reduced payload capacity in relation to its size. Therefore, the fixed wing is an indispensable tool for some specific operations, but it is not the ideal tool if we are looking for versatility.

Drones (UAVs) can also be classified by their weight[29]:

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[30] Chamola, V., Kotesh, P., Agarwal, A., Gupta, N., & Guizani, M. (2021). A comprehensive review of unmanned aerial vehicle attacks and neutralization techniques. *Ad hoc networks*, *111*, 102324.

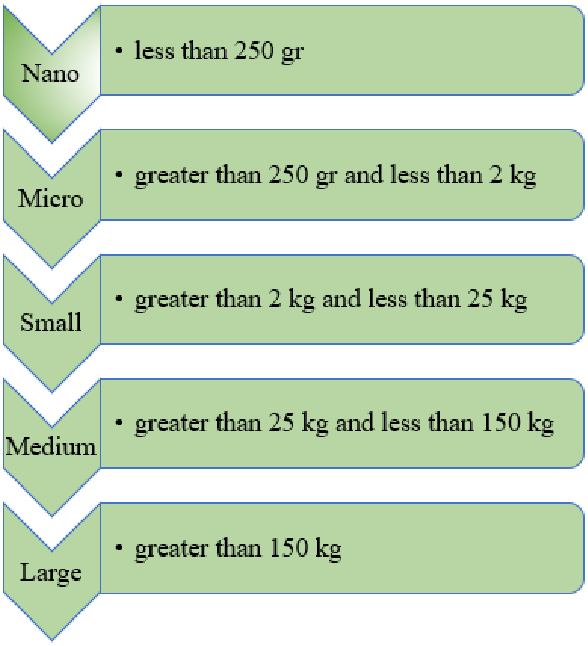


Figure 5. 14. Drone classified on the basis of weight[29]

Drones can be of seven different types according to their base on altitude and range (Table 5.4) [29]:

Type of UAV	Altitude	Range
Hand Held	<600 m	<2 km
Close	<1500 m	<10 km
NATO	<3000 m	<50 km
Tactical	<5500 m	<160 km
Medium Altitude Long Range	<9100 m	<200 km
High Altitude Long Range	>9100 m	NA
Hypersonic	<15200 m	>200 km

Table 5.4. Classification of UAV based on altitude and range[29]

Based on application, UAV can be personal (used for applications such as videography and entertainment), commercial (used for applications such as infrastructure monitoring, product delivery, and aerial imaging), government and law enforcement (used for applications such as firefighting and patrolling), or military (used for applications such as surveillance and combat attacks)[29].

5.6 Future Trends

Although UAVs find applications in many fields, from agriculture to the military, from the film industry to natural disasters, there are still many obstacles to fulfilling the tasks they are asked to perform[31]:

- A UAV's battery capacity is the most important factor affecting its energy consumption and airtime. As the battery capacity increases, the weight of the battery increases, causing it to consume more energy. Battery management involves the planning, scheduling, and replacement of a battery to accomplish required missions. Battery systems consisting of a landing platform, battery charger, battery storage, and microcontroller can be changed while the UAV is working. Some other applications have potential: Solar-powered UAVs, wireless charging, recharging UAVs from power lines during the inspection process, and an automatic charging station system for UAVs distributed on the UAV's given path consists of a solar panel, a wireless charging pad, a battery, and a power converter.
- Collision avoidance for UAVs is crucial to avoiding accidents. Along the flight path, they may encounter fixed or moving obstacles and may collide. In order to avoid a collision, a geometric approach that takes into account geometric analysis and a vision-based approach that captures images from cameras mounted on the UAV can be used to avoid the collision problem with the help of in-flight snapshot processing operations.
- Various attacks by intruders can target communication links between different pieces of equipment in the UAV system and create cyber security problems.

Future research topics and directions for UAVs[31].

- Swarm UAV systems, where each UAV has a small task that is part of a larger task, are promising for smart agriculture applications as well as the military field.
- Machine learning and deep learning algorithms can be used for UAVs in different applications such as obstacle avoidance, tracking, path planning, battery scheduling, and computing power improvement. It will also help design nano-UAVs that are much smaller, lighter, and smarter than current UAV models.
- Wireless connectivity and limited computational capabilities are essential parameters for the security and safety of UAVs. Blockchain and physical layer security can be used for the required quality and reliability.

[31] Elmeseiry, N., Alshaer, N., & Ismail, T. (2021). A detailed survey and future directions of unmanned aerial vehicles (UAVs) with potential applications. *Aerospace*, *8*(12), 363.

- The potential to use a multi-objective optimization algorithm and heuristic algorithms to develop tracking and path planning techniques to avoid collisions, minimize the energy consumption of flights, and optimize the mission path of UAVs is very high.
- Recent advances in battery technologies, such as advanced lithium-ion batteries, hydrogen fuel cells, and green energy sources have been used to extend flight times.
- Optical Wireless Communications (OWCs) are widely adopted in UAV communication, and they are expected to be used in the 6G mobile network.

In addition, drones are becoming more and more popular in agriculture. Because[32]:

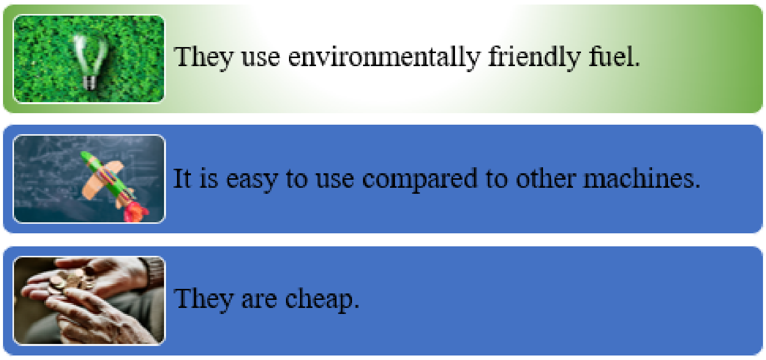


Figure 5. 15. Advantages of Drones

What are the benefits of NIR Spectroscopy in agricultural applications?[33,34,35]

NIR has been applied to look for bruising not visible to the human eye, in fruits and vegetables, meats and fish, beverages and dairy, cereals and grain stocks, grapes, and olives, as well as areas regarding production factors like soils and manures and environmental applications. Currently, hybrid models are being created that can take the best parts of various techniques and combine them to address biological variations to a certain extent. Challenges remain in addressing assortment, data collection, analysis, and model optimization.

[32] https://cropaia.com/blog/drones-in-agriculture/

[33] https://www.avantes.com/applications/cases/nir-spectroscopy-in-agricultural-production/

[34] https://www.novuslight.com/applications-for-nir-spectroscopy-in-agriculture-and-food-production_N10153.html

[35] Pandiselvam, R., Prithviraj, V., Manikantan, M. R., Kothakota, A., Rusu, A. V., Trif, M., & Khaneghah, A. M. (2022). Recent advancements in NIR spectroscopy for assessing the quality and safety of horticultural products: A comprehensive review. *Frontiers in Nutrition, 9.*

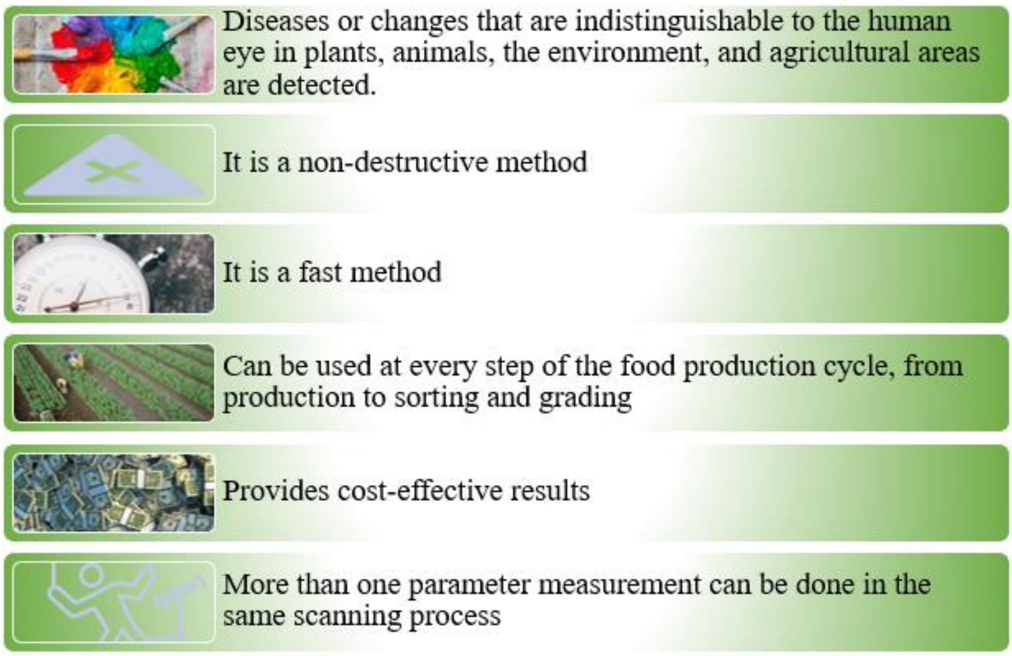


Figure 5. 16. The benefits of NIR Spectroscopy in agricultural applications

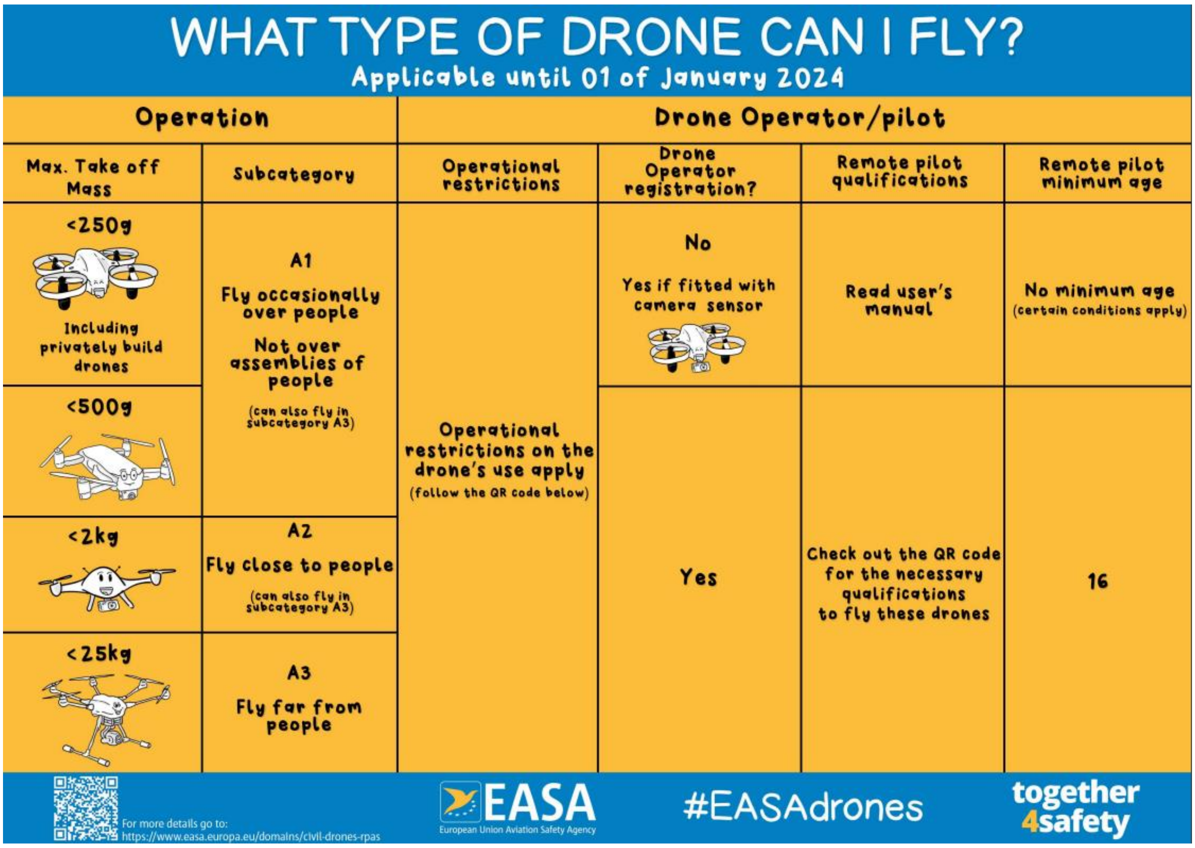
5.7 Training needs

NIR technology can be used in many different situations in agriculture. If the training is about analyzing agricultural crops and soil using near-infrared (NIR) spectroscopy, the content can be[36]:

- Review agriculture applications for spectroscopy
- Example NIR spectral signatures in agriculture
- Water spectrum
- Soil spectrum
- Soil organic carbon spectrum

There are various laws, regulations, and procedures for drone use/piloting that differ from country to country. According to European Aviation Safety Agency (EASA)37, the drone pilot needs to complete the necessary online training, pass a pilot exam, and get a valid remote pilot competency certificate (valid for 5 years). Figure 5.16 gives a good overview about who can fly what drone in what subcategory under what conditions.

[36] https://training.ti.com/analyzing-agricultural-crop-and-soil-using-near-infrared-nir-spectroscopy
[37] https://www.easa.europa.eu/en/light/topics/drone-operators-pilots#:~:text=The%20drone%20pilot%20needs%20to,correct%20licence%20to%20be%20issued.



WHAT TYPE OF DRONE CAN I FLY?
Applicable until 01 of January 2024

Operation		Drone Operator/pilot			
Max. Take off Mass	Subcategory	Operational restrictions	Drone Operator registration?	Remote pilot qualifications	Remote pilot minimum age
<250g Including privately build drones	A1 Fly occasionally over people Not over assemblies of people (can also fly in subcategory A3)	Operational restrictions on the drone's use apply (follow the QR code below)	No Yes if fitted with camera sensor	Read user's manual	No minimum age (certain conditions apply)
<500g			Yes	Check out the QR code for the necessary qualifications to fly these drones	16
<2kg	A2 Fly close to people (can also fly in subcategory A3)				
<25kg	A3 Fly far from people				

Figure 5. 17. The schematic view about who can fly what drone in what subcategory under what conditions[38]

Users/pilots are required to comply with the rules in their country. In these legislations, in which situations drones can be used, training conditions, and training contents and training hours are specified. For example, in Turkiye, obtaining a drone license is mandatory for devices weighing 500 gr and above. The drone license is the only document that can be obtained from the General Directorate of Civil Aviation (GDCA) or from any of the organizations authorized by the GDCA and that law enforcement officers will demand from the user during drone flights. This printed document can be just like a vehicle license or be in the form of a certificate[39]. Sporting licenses are given free of charge. Licenses to be used for commercial activity may be subject to fees. In order to get permission to fly a drone, it is necessary to enter the SHGM website and apply from the permission menu. It is obligatory for those who sell, buy, produce, import, and fly UAVs with a weight of 500 g and above to register in this system. In all regions other than the free zone (green), it is obligatory to obtain a flight permit to fly a UAV. Must be

[38] https://www.easa.europa.eu/en/light/topics/operators-guidance-drone-pilots

[39] https://iha.shgm.gov.tr/public/index

at least 12 years old for a class UAV0 pilot license and at least 15 years old for a class UAV1 pilot license. Must be at least 18 years old for UAV2 and UAV3 class pilot licenses.

5.8 Conclusions

Considering the importance of the subject and its contribution to the future agriculture, environment, natural resources and economy, this section includes basic information about image processing technologies and basic application areas of drones. To summarize the chapter, we can ask the following question:

What are the benefits of image processing ***technology*** and drones for the farm?[40]

- Near infrared (NIR) spectroscopy provides non-destructive and accurate quality parameters analysis.
- NIR helps to evaluate the development and health status of the crop and to identify problems related to irrigation, spraying, and fertilization.
- NIR has the potential to make food production sustainable with real-time analysis onsite.
- NIR spectroscopy applications are becoming increasingly common in the field.
- Drones can be used quickly and easily.
- Drones assist in imaging, spraying, and monitoring.

In conclusion, for farmers, smart farming methods and tools, including drones, can qualify as the path to financial success and better resource management[41]. While even having an aerial view of farmland was of great value when drones were first used to capture aerial images in agriculture, today farmers can fly drones as often as they want to pinpoint problems with irrigation leaks, leaf discoloration, or pests. The resulting images help farmers plan better by highlighting where these problems occur[42]. Drones can also plant seeds in remote locations, reducing equipment and labor costs for farmers. It is reported that drones can generate value between $85 billion and $115 billion by reducing costs and improving returns[43].

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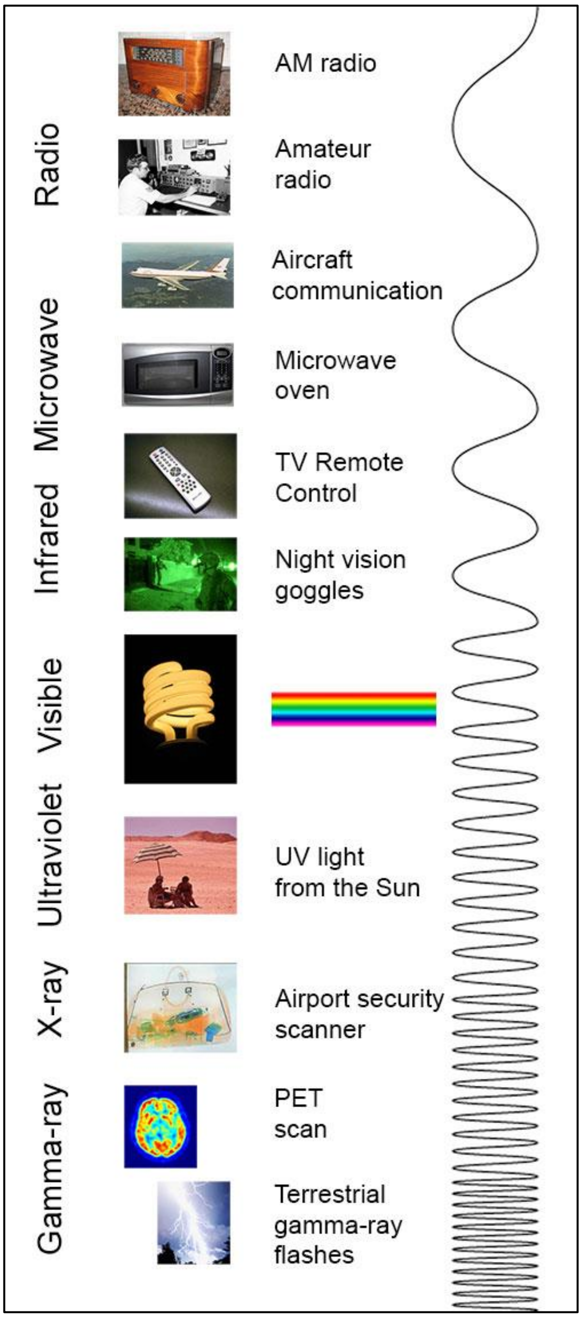
[40] https://felixinstruments.com/blog/nir-applications-in-agriculture-everything-you-need-to-know-for-2020/
[41] https://www.farmprogress.com/technology/smart-farming-drones-agriculture-s-high-flying-future
[42] https://agfundernews.com/the-next-generation-of-drone-technologies-for-agriculture
[43] https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth

HINTS FOR EDUCATOR:



The Electromagnetic Spectrum:

Radio: Your radio captures radio waves emitted by radio stations, bringing your favorite tunes. Radio waves are also emitted by stars and gases in space.

Microwave: Microwave radiation will cook your popcorn in just a few minutes, but is also used by astronomers to learn about the structure of nearby galaxies.

Infrared: Night vision goggles pick up the infrared light emitted by our skin and objects with heat. In space, infrared light helps us map the dust between stars.

Visible: Our eyes detect visible light. Fireflies, light bulbs, and stars all emit visible light.

Ultraviolet: Ultraviolet radiation is emitted by the Sun and are the reason skin tans and burns. "Hot" objects in space emit UV radiation as well.

X-ray: A dentist uses X-rays to image your teeth, and airport security uses them to see through your bag. Hot gases in the Universe also emit X-rays.

Gamma ray: Doctors use gamma-ray imaging to see inside your body. The biggest gamma-ray generator of all is the Universe.

https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html#:~:text=The%20Electromagnetic%20Spectrum,two%20types%20of%20electromagnetic%20radiation.

HINTS FOR EDUCATOR:

Drone operator and drone pilot – what is the difference?

A drone operator is any person, or organization, who owns or rents one or more registered drones. A drone pilot is the person actually flying the drone, without necessarily owning or renting the drone.

https://www.easa.europa.eu/en/light/topics/drone-operators-pilots#:~:text=The%20drone%20pilot%20needs%20to,correct%20licence%20to%20be%20issued.

National aviation authority (NAA) drone website reference:
https://www.easa.europa.eu/en/domains/civil-drones/naa

Some useful links:https://felixinstruments.com/blog/nir-applications-in-agriculture-everything-you-need-to-know-for-2020/ https://training.ti.com/analyzing-agricultural-crop-and-soil-using-near-infrared-nir-spectroscopy https://www.mdpi.com/1424-8220/22/13/4721 https://www.startus-insights.com/innovators-guide/5-near-infrared-spectroscopy-startups-impacting-agriculture/

https://www.fossanalytics.com/en/news-articles/technologies/nir-technology
https://gyiad.org.tr/haberler/gyiad-akilli-tarim-teknolojileri-online-egitimi-

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<ahref="https://www.freepik.com/free-photo/white-drone-hovering-bright-blue-sky_6659454.htm#query=drone%20camera&position=4&from_view=keyword">Image by ArthurHidden on Freepik

<ahref="https://www.freepik.com/free-photo/drone-quad-copter-with-high-resolution-digital-camera-green-corn-field_10141248.htm#query=drone%20camera&position=6&from_view=keyword">Image by standret on Freepik

https://www.freepik.com/free-photo/drone-spraying-fertilizer-vegetable-green-plants-agriculture-technology-farm-automation_21544380.htm#query=drone%20plant&position=9&from_view=search&track=sphlution-digital-camera-green-corn-field_10141248.htm#query=drone%20camera&position=6&from_view=keyword

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https://www.easa.europa.eu/en/light/topics/operators-guidance-drone-pilots

https://iha.shgm.gov.tr/public/index

https://felixinstruments.com/blog/nir-applications-in-agriculture-everything-you-need-to-know-for-2020/

https://www.farmprogress.com/technology/smart-farming-drones-agriculture-s-high-flying-future

https://agfundernews.com/the-next-generation-of-drone-technologies-for-agriculture

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CHAPTER 6

Farmbot

CHAPTER 6 Farmbot

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Ramazan Çağrı KUTLUBAY, Mine SULAK

Organizations: Pamukkale University and Acción Laboral

WHAT WILL WE LEARN IN THIS CHAPTER?

What is the FARMBOT?
What is the sensor technology?
What can we do with sensors?
What are the smart machines?
What are the Autonomous vehicles?
What are the educational/training needs?

Keywords: Farmbot; smart machine; sensor; drone

6.1 Glossary and abbreviations

Precision agriculture (PA)	Precision farming is an agriculture method that uses information technology (IT) to ensure that crops and soil get exactly what they need for optimum health and productivity.
Computer Numerical Control (CNC)	It is a manufacturing method that automates the control, movement, and precision of machine tools in production through the use of pre-programmed computer software.
Computer Aided Design (CAD)	CAD (computer-aided design) is the use of computer-based software to aid in design processes.
Sensor	A sensor is a device that measures physical input from its environment and converts it as an output signal into data. Sensors are to measure temperature, gauge distance, detect smoke, regulate pressure and a myriad of other uses.
Unmanned Vehicle	An uncrewed vehicle or unmanned vehicle is a vehicle without a person on board.
Free and open-source software (FOSS)	It is a term used to refer to groups of software consisting of both free software and open-source software where anyone is freely licensed to use, copy, study, and change the software.
Open Source	Open source is a code source that is available to everyone who wants to access, modify it and reproduce it. This model fits in with decentralized software development that fosters open collaboration. Free and open-source software (FOSS) is a term also used to refer to a suite of software consisting of both free software and open-source software where software is freely licensed for anyone to use, copy, work on, and modify the software in any way1.

Table 6.1. Glossary and abbreviations

[1] https://en.wikipedia.org/wiki/Free_and_open-source_software

6.2 Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter. The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	***Competences and skills***	***Duration time***	***Learning tools***
● be able to explain the applications of sensors ● be able to define the unmanned vehicles	● -Knowledge of the practical application of sensors used in agriculture ● ● -Identify the unmanned vehicles	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 6.2. Competence map

6.3 Introduction

Precision farming/agriculture (PA), also known as smart farming, is important as it allows for reducing inputs and increasing and optimizing outputs while conserving resources. To investigate and improve PA strategies, test mechanisms such as farmbot can be used to reproduce the technology's use on scale farms prior to implementation[2]. Farmbot is an open-source precision agriculture CNC consisting of a Cartesian coordinate farming machine, software, and documentation, including a data repository[3]. It can also be defined as a robotic system that allows farmers or anyone who wants to use their backyard to farm efficiently and easily[4].

It is estimated that the world population will reach 7-9 billion by 2050. The required food production should also increase by 60%. In this context, the Farmbot project has been developed considering the potential of precision agriculture to reduce the environmental impact of farming by reducing water use, energy, and transportation. The project was started in 2011 by Rory Aronson[5], a mechanical engineering student at the California Polytechnic State University. Rory attended an organic agriculture course. In this course, Aronson learned about a tractor that used machine vision to detect and remove weeds, reducing the use of herbicides and manual labor. The cost of the tractor was 1 million dollars. Later, in 2013, Aronson wrote a white paper labeled "*Grow a community that produces free and open-source hardware plans, software, data, and documentation enabling everyone to build and operate a farming machine*." The main aim of the paper was the need to increase the production of food to feed the population expected in 2050[1]. In 2014, Aronson started to work full time on the project funded by a grant conceded from the Shuttleworth Foundation. The Shuttleworth Foundation was founded by Mark Shuttleworth and seeks to promote open-source and open educational projects. Often linked with ecological issues. In 2015 the project held finalist positions on the Hackday Prize. In 2016 the first commercial version of farmbot was launched.

Farmbot is capable of growing in small box different types of crops, watering them and treating each one according to their needs. The whole processes is automatized. The interface to operate farmbot is handy and it can be operated by smartphones and laptops. CAD models are free to download. Users can assemble their own farmbot, when they have the proper means. The second option is to buy the assembled device.Farmbot is used for domestic self-production. Currently, there are two models of farmbot: Farmbot Genesis and Farmbot Express. Farmbot Genesis is the advanced form of the device, Farmbot Express is a simplified version of it[6].

Farmbot Genesis includes tools like;

- Rotary tool

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[2] Murcia Vargas, V. A., & Palacios Sánchez, J. F. (2020). Farmbot simulator: towards a virtual environment for scale precision agriculture.
[3] https://laughingsquid.com/farmbot-genesis-an-open-source-automated-farming-machine-for-home-garden-use/
[4] Barakat, M., & Mousa, A. (2018). Farmbot.
[5] https://agfundernews.com/farmbot-founder-aronson-on-open-source-tech-and-encouraging-consumers-to-farm5832
[6] https://farm.bot/

- Watering Nozzle
- Weeder
- Soil Sensor
- Camera
- Seed Injector
- Seed thoughts
- Seed bin
- Seed tray

At this point, many assistive technologies can be used, including IoT and AI. Artificial Intelligence (AI), specifically deep learning, can be used for object, plant, insect, or disease recognition by making use of computer vision[7]. The IoT can help design systems that can transmit and monitor all data received over a network that can be assigned a smart station or an IP address to monitor a plant disease, plant growth, soil moisture, or air pollution[8].

Figure 6.1. Farmbot Genesis

Various sensors and automatic or manual machines are used to collect data, transfer it to the AI and IoT systems, and make the necessary interventions. In this section, basic information about all these machines and sensors and suggestions for basic training methodology for trainers are presented.

For more information:

[7] Singh, K., Rawat, R., & Ashu, A. (2021). Image segmentation in agriculture crop and weed detection using image processing and deep learning techniques. *International Journal of Research in Engineering, Science and Management*, *4*(5), 235-238.

[8] Suciu, G., Marcu, I., Balaceanu, C., Dobrea, M., & Botezat, E. (2019, June). Efficient IoT system for precision agriculture. In 2019 15th International Conference on Engineering of Modern Electric Systems (EMES) (pp. 173-176). IEEE.

https://farm.bot/pages/genesis
https://farm.bot/pages/genesis#
http://software.farm.bot/v15/docs/intro

6.4. Sensors

A ***sensor*** is an easy, small tool that measures or detects natural world conditions such as motion, heat or light and converts that state into an analog or digital representation. There are many types of sensors used in agriculture and in smart agriculture structures. Smart sensors in agriculture provide data that helps farmers monitor and optimize their crops and stay up to date with changing environmental and ecosystem factors. Aside from identifying heat, monitoring health, and weeding out and treating sick cows, smart farming sensors help find and track herds. With smart sensors in agriculture, farmers can understand their crops and productivity, conserve resources, and prevent or control crop damage from environmental impact or disaster[9,10,11].

What is the Role of Sensors in Agriculture?

The sensors used in agriculture are sensors known for smart agriculture. These sensors provide data that helps farmers monitor and optimize their crops, along with environmental conditions and challenges. These sensors used in agriculture are installed and fixed on meteorological stations, drones, and robots used in the agricultural industry. The sensors can be controlled with the developed mobile applications. Agri sensors based on wireless connections can be controlled directly using Wi-Fi or via cellular towers with the help of cell phone apps.

Which sensor type to choose for agricultural work?

Depending on the agricultural application, it is necessary to select the sensors for the device. The choice is made depending on the types of information you want to collect and the purpose of your solution in general. The quality of your sensors is critical to the success of your product and will depend on the accuracy and authenticity of the data collected. Based on the work to be done, the probability of flying with one or more camera types will be evaluated.

Agricultural sensors, which have many privileges, have many advantages. Smart sensors used in agriculture are easy to use and maintain; the sensors are cheaper in price and of good quality. They can be used to measure pollution and global warming for their fields and crops. They can be remotely controlled.

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[9] Keleş, A., Keleş, A. (2018). Nesnelerin internetinin getirdiği yenilikler ve sorunlari. *Electronic Turkish Studies*, *13*(13).
[10] Narain, A. (2017,07,06). Internet of Things (IoT) system for data-driven agriculture. Geospatial world. https://www.geospatialworld.net/blogs/internet-of-things-system-for-agriculture.
[11] Khattab, A., Abdelgawad, A., & Yelmarthi, K. (2016, December). Design and implementation of a cloud-based IoT scheme for precision agriculture. In *2016 28th International Conference on Microelectronics (ICM)* (pp. 201-204). IEEE.

6.4.1 RGB (red, green, blue) sensors

These are traditional compact cameras that take pictures in the light visible spectrum. Some studies state that the best spatial resolutions are taken from cameras such as the S.O.D.A and Sony-WX, which are mounted on the drones as they have a larger image size than thermal or multispectral cameras[12].

Type of work:

- These cameras are used when a detailed and highly accurate image is needed. They can be very useful for volume or biomass calculations as they provide almost real 3D representations.
- All types of agricultural surveys that require RGB images for a clear identification of the problem, e.g., damage to maize by wild boar.
- Counting of objects; nowadays, with advanced artificial intelligence techniques, we can obtain the production of a plot of land in certain crops by simply collecting photos of it and applying algorithms that are already defined, e.g., lettuce counting.
- The topography of the plots is one of the best working tools nowadays as it allows for reduced delivery times and much more detail than with traditional GPS equipment (Fig. 6.2) [13].

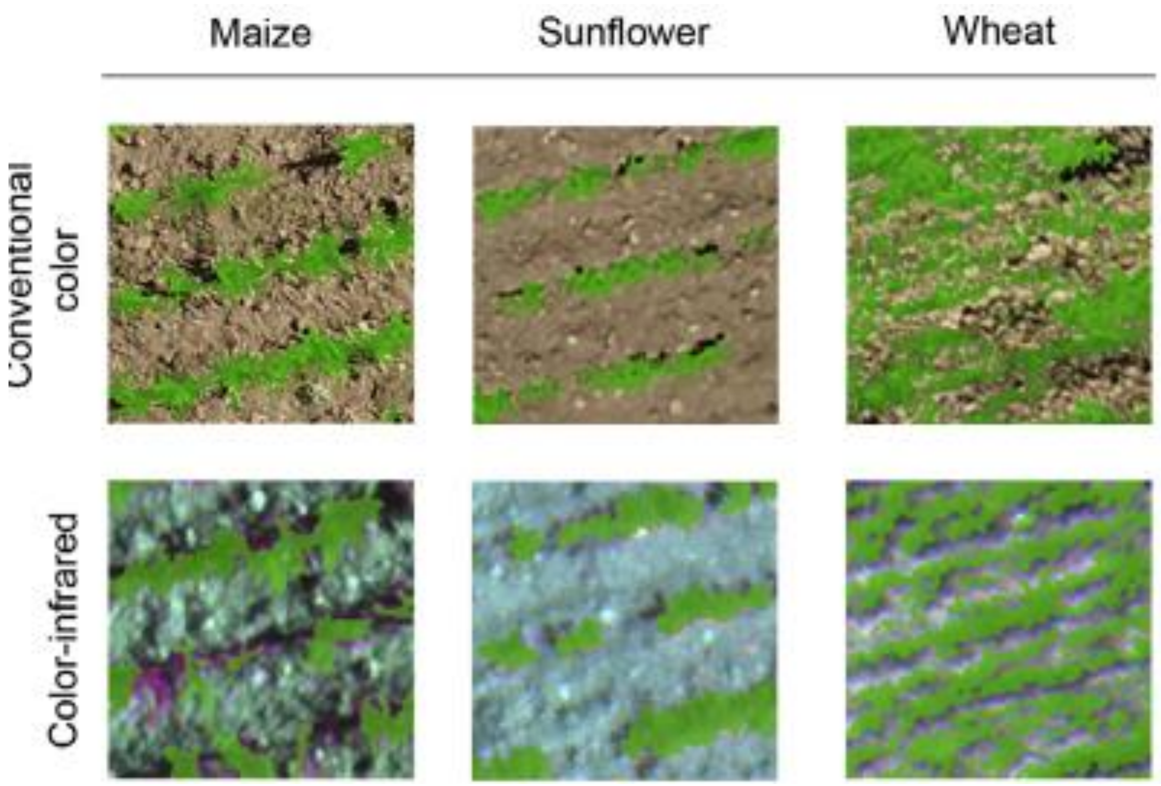

Figure 6.2. Classification outputs for the best scale parameter for different crop and sensor[12]

[12] Pazzi, B. M., Pistoia, D., & Alberti, G. (2022). RGB-Detector: A Smart, Low-Cost Device for Reading RGB Indexes of Microfluidic Paper-Based Analytical Devices. *Micromachines*, *13*(10), 1585.
[13] Torres-Sánchez, J., López-Granados, F., & Pena, J. M. (2015). An automatic object-based method for optimal thresholding in UAV images: Application for vegetation detection in herbaceous crops. *Computers and Electronics in Agriculture*, *114*, 43-52.

6.4.2. Multispectral Sensors (MultiSPEC and Sequoia)

These are cameras that capture information in ranges of the non-visible light spectrum, generally in the length that corresponds to the Near Red-Near Infrared limit. These cameras have been the most widely used to analyze crops, as it is in these ranges where vegetation presents the greatest spectral differences depending on its state (Fig.6.3. and Fig.6.4).

Figure 6.3. UAV platforms to perform multispectral and hyperspectral sensing[14]

MultiSPEC and Sequoia are two multispectral sensors that can be fitted to the drones. Their main advantage is that they both correct for reflectivity directly. With a calibration gray, the camera is adjusted before each flight. In addition, a luxmeter records the brightness at the time of each photograph, so it also makes corrections for possible differences in radiation during the flight[13]. The jobs that require these sensors are:

- Monitoring of the crop and how it is at vigor level.
- Fertilization works with variable doses and zoning of areas in plots.
- Obtaining different agronomic indices for the specific study of a crop, such as LAI, NDRE, NVDI, etc.

[14] Di Gennaro, S. F., Toscano, P., Gatti, M., Poni, S., Berton, A., & Matese, A. (2022). Spectral Comparison of UAV-Based Hyper and Multispectral Cameras for Precision Viticulture. *Remote Sensing*, *14*(3), 449.

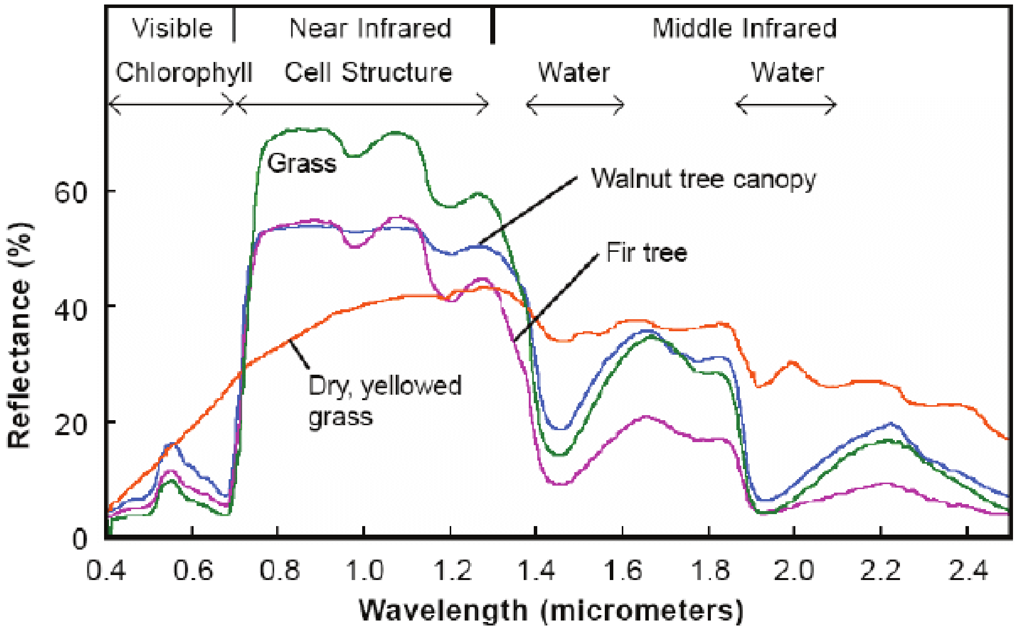

Figure 6.4. Reflectance spectra of different types of green vegetation compared to a spectral signature for senescent leaves[15,16]

In short, this sensor allows us to capture the image where the human eye cannot, which is important because of the greater range of information it offers us about the crop.

6.4.3. Thermographic Sensors

All objects emit infrared radiation (heat), and this emission is greater the hotter they are. The wavelength of this energy ranges from a few microns to thousands of microns, i.e., it is much longer and completely outside the range visible to the human eye (450-750 nanometers). Thermal cameras can capture these radiations, those used in drones are usually calibrated to work in the thermal infrared, between 8 and 14 micrometers. These same sensors are capable of capturing differences of tenths of a degree Celsius, so precision is important. The processing of thermographic images is somewhat more complex than of visible spectrum images. While RGB cameras can have sensors with more than 20 megapixels, thermal cameras usually do not exceed one megapixel. A maximum resolution of 640x512 is a common resolution. Although the most successful cameras in precision agriculture are multispectral cameras, thermographic cameras are also important. Leaf temperature is an indicator that can indirectly measure the level of water stress in a plant. Some insect pests cause the temperature to rise by tens of

[15] Govender, M., Chetty, K., & Bulcock, H. (2007). A review of hyperspectral remote sensing and its application in vegetation and water resource studies. *Water Sa*, *33*(2), 145-151.
[16] Smith RB (2001) Introduction to hyperspectral imaging. www.microimages.com

degrees[17]. Examples of thermographic sensor set up and examples of thermal sensor image processing can be seen in Figure 6.5 and Figure 6.6 view [18].

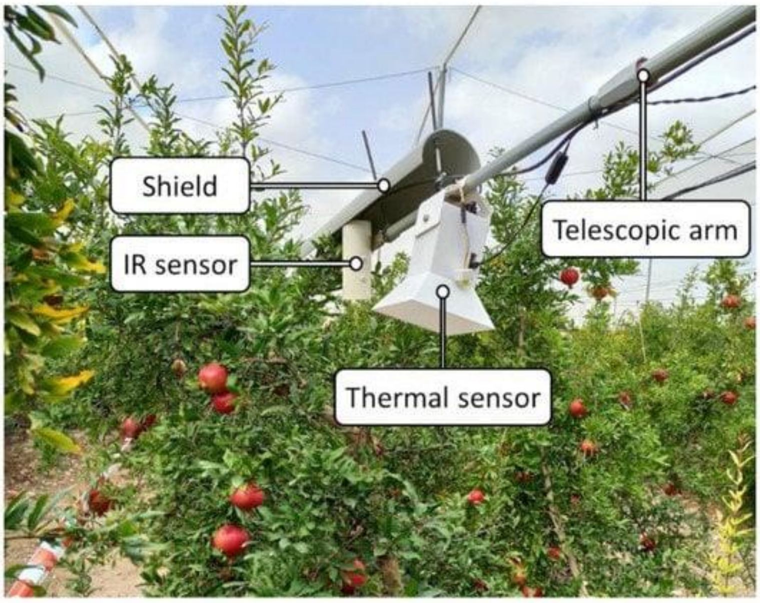

Figure 6.5. An example of thermal sensor and IR set-up detail view [19]

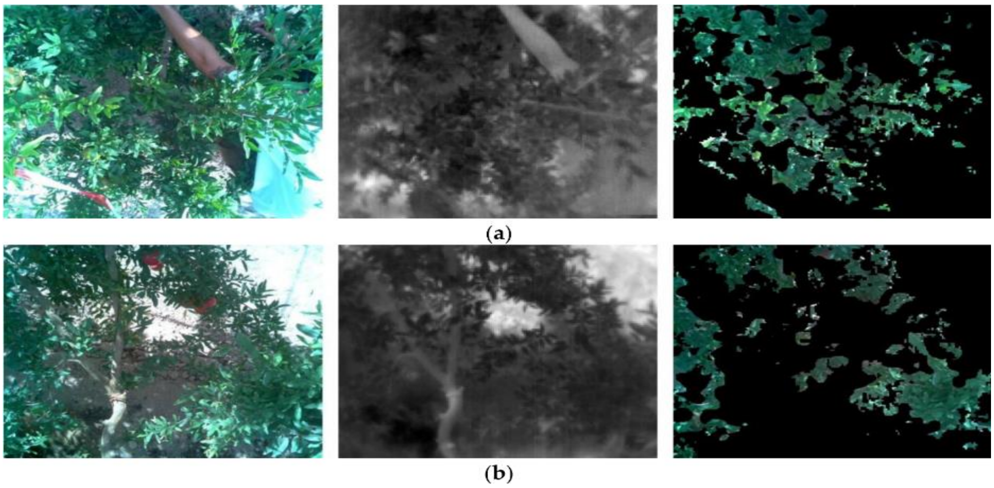

Figure 6.6. Examples of thermal sensor image processing: (a) date: 22 July 2021 (DOY 203) and (b) date: 16 September 2022 (DOY 259). From left to right: visible image, thermal image, and mask overlaid on visible image[20].

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[17] Ishimwe, R., Abutaleb, K., & Ahmed, F. (2014). Applications of thermal imaging in agriculture—A review. *Advances in remote Sensing*, *3*(03), 128.

[18] Giménez-Gallego, J., González-Teruel, J. D., Blaya-Ros, P. J., Toledo-Moreo, A. B., Domingo-Miguel, R., & Torres-Sánchez, R. (2023). Automatic Crop Canopy Temperature Measurement Using a Low-Cost Image-Based Thermal Sensor: Application in a Pomegranate Orchard under a Permanent Shade Net House. *Sensors*, *23*(6), 2915.

[19] Giménez-Gallego, J., González-Teruel, J. D., Blaya-Ros, P. J., Toledo-Moreo, A. B., Domingo-Miguel, R., & Torres-Sánchez, R. (2023). Automatic Crop Canopy Temperature Measurement Using a Low-Cost Image-Based Thermal Sensor: Application in a Pomegranate Orchard under a Permanent Shade Net House. *Sensors*, *23*(6), 2915.

[20] Giménez-Gallego, J., González-Teruel, J. D., Blaya-Ros, P. J., Toledo-Moreo, A. B., Domingo-Miguel, R., & Torres-Sánchez, R. (2023). Automatic Crop Canopy Temperature Measurement Using a Low-Cost Image-Based Thermal Sensor: Application in a Pomegranate Orchard under a Permanent Shade Net House. *Sensors*, *23*(6), 2915.

6.4.4. Optical Sensors

When assessing soil properties, measuring various light frequencies uses light. With these sensors placed on vehicles or unmanned aerial vehicles, soil reflection and plant color data are collected and evaluated (Figure 6.7). Optical sensors determine the clay, organic matter, and soil moisture content[21].

Figure 6.7. Optical Sensors in Agriculture[22]

Optical sensors measure soil properties by detecting different light reflections in the near and mid-infrared and polarized light spectrums. Organic materials are an important source of nitrogen in the soil, and the more organic matter present in the soil, the more nitrogen the soil produces. As the organic matter concentrations change, the nitrogen availability in the soil changes drastically. Optical sensors can monitor crop viability and determine nitrogen ratio based on plant biomass and nitrogen content[23,24]. The ultraviolet sensor is another type of optical sensor and can be used for pest and disease control in the cropland, especially to detect the presence of certain fungal species that cause crop diseases or even to monitor the level of fungal spores in the air. Optical sensors are also generally less expensive than other sensing/sensor systems. Most optical sensors need to be mounted on a stable platform such as a tripod, mast or even a drone to function properly[24].

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[21] Hu, P., Chen, Y., & Sonkusale, S. (2015, March). Low cost spectrometer accessory for cell phone based optical sensor. In *2015 IEEE Virtual Conference on Applications of Commercial Sensors (VCACS)* (pp. 1-5). IEEE.
[22] https://testsite.quantumobile.com/case-studies/plant-smart-monitoring-system/
[23] https://www.automate.org/blogs/improving-soil-management-with-agricultural-optical-sensors
[24] https://www.agrifarming.in/importance-of-optical-sensors-in-agriculture-advantages-and-working-principles#:~:text=In%20agriculture%2C%20optical%20sensors%20are,light%20reflected%20off%20the%20soil.

Figure 6.8. An optical sensor applicationcontent[24]

6.4.5. Electrochemical Sensors

It helps in collecting soil chemical data. Electrochemical sensors provide information for nutrient detection in the soil (Fig. 6.9). Soil samples are sent to a soil testing laboratory and specific measurements, particularly pH determination, are performed using an ion-selective electrode. These electrodes measure the activity of certain ions such as nitrate, potassium, or hydrogen[25]. Plant species and growth stages differ, and ions interact in complex ways in plant roots through various absorption mechanisms. These ions, which are among the essential nutrients required for plant metabolism, are[26]:

- carbon, hydrogen and oxygen (can be absorbed from water and carbon dioxide)
- macronutrients (for example, nitrogen, potassium, calcium, phosphoric acid, sulfur and magnesium)
- micronutrients (for example, chlorine, boron, iron, manganese, zinc, copper, nickel and molybdenum).

[25] Yew, T. K., Yusoff, Y., Sieng, L. K., Lah, H. C., Majid, H., & Shelida, N. (2014, May). An electrochemical sensor ASIC for agriculture applications. In *2014 37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 85-90). IEEE.

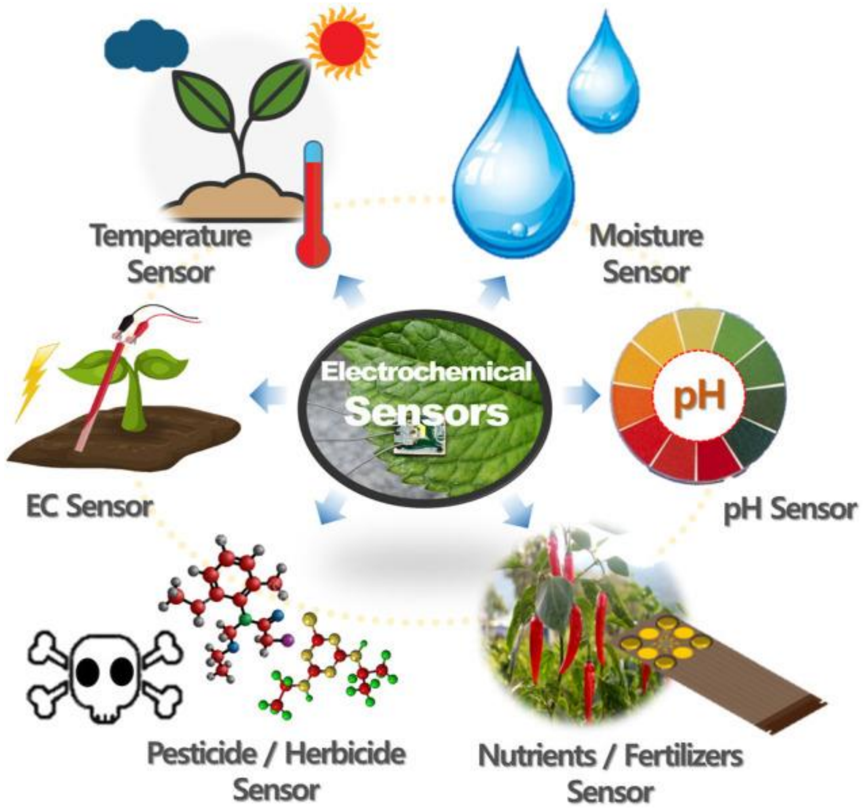

Figure 6.10. The electrochemical sensor for monitoring plant health in precision agriculture[26]

Figure 6.11. Types of essential nutrients needed for plant growth[26]

[26] Kim, M. Y., & Lee, K. H. (2022). Electrochemical Sensors for Sustainable Precision Agriculture—A Review. *Frontiers in Chemistry, 10*.

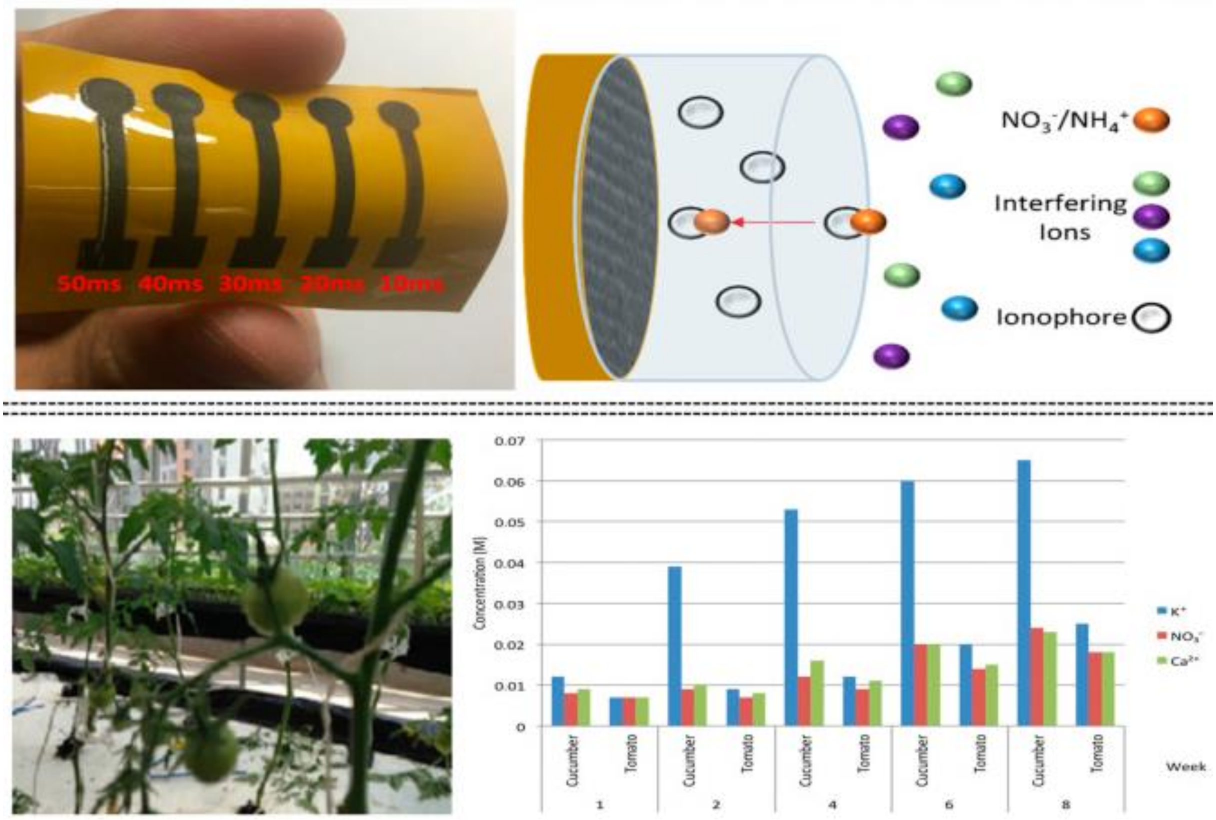

Figure 6.12. An example of detecting nutrients in plant sap, soil and nutrient solutions[26]

Unlike spectroscopic methods, electrochemical sensors do not require the installation of optical systems and can be used directly in soil for nutrient measurements. However, they need an electronic circuit, which is necessary for the sensor reading and the battery[27].

6.4.6. Mechanical Soil Sensors

These sensors use a mechanism that cuts through the soil and documents the force measured by pressure gauges or load cells. Mechanical soil sensors (Fig. 6.13) record the holding forces from shearing, breaking, and displacement of the soil when the sensor cuts into it. The mechanical resistance of the soil is measured in units of pressure and represents the ratio of the force required to penetrate the soil to the front area of the tool engaged with the soil[28].

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[27] Ali, M. A., Dong, L., Dhau, J., Khosla, A., & Kaushik, A. (2020). Perspective—electrochemical sensors for soil quality assessment. *Journal of The Electrochemical Society*, *167*(3), 037550.

[28] Yurui, S., Qingmeng, Z., Zhaolong, Z., & Lammers, P. S. (2007, May). Measuring soil physical properties by sensor fusion technique. In *2007 2nd IEEE Conference on Industrial Electronics and Applications* (pp. 142-146). IEEE.

Figure 6.13. Mechanical Soil Sensors for Agriculture[22]

Existing soil compaction sensor systems operate on the basis of soil strength sensors, liquid permeability sensors, water content sensors or combinations thereof. These sensors are operated at a constant depth bulk strength measuring sensors and/or a changing depth vertically actuated[29]. A penetration resistance system connected to a GPS antenna can be mounted on the tractor to estimate soil compaction variability across the field. Soil compaction restricts root and crop growth of plants and crops and reduces crop yields. Information gathered about soil compaction can help explain crop and yield variability, and plan tillage operations[31].

Figure 6.14. Operation of mechanical Soil Sensors[30]

[29] Hemmat, A., & Adamchuk, V. I. (2008). Sensor systems for measuring soil compaction: Review and analysis. *Computers and electronics in agriculture*, *63*(2), 89-103.
[30] https://agroflowsystem.com/product/soil-research-logger/

Figure 6.15. The instrumented tractor with mounted soil penetrometer – shearometer unit[31]

6.4.7. Dielectric Soil Moisture Sensors

The moisture level in the soil is extremely important for the growth of crops. Humidity sensors (Fig. 6.16) are used with rain control throughout the farm[32].

Figure 6.16. Dielectic Soil Sensors for Agriculture[22]

Dielectric soil moisture sensors is used to conserve water in agricultural applications. These sensors provide farmers with accurate information about the soil moisture of their fields, allowing them to reduce water consumption by reducing over-irrigation[33].

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[31] K. NAGENDRA , A. SURVANSHI and MARUTI. Studies on Sensors for Measuring Soil Compaction for Effective Crop Production-A Review and Analysis. International Journal of Research in Agricultural Sciences Volume 5, Issue 1, ISSN (Online): 2348 – 3997. https://ijras.org/index.php/issue?view=publication&task=show&id=291

[32] Hanson, B., & Peters, D. (2000). Soil type affects accuracy of dielectric moisture sensors. *California Agriculture*, *54*(3), 43-47.

[33] David Spelman; Kristoph-Dietrich Kinzli, P.E., M.ASCE; and Tanya Kunberger, Calibration of the 10HS Soil Moisture Sensor for Southwest Florida Agricultural Soils. J. Irrig. Drain Eng. 2013.139:965-971.

Figure 6.17. An application of dielectic soil sensors[34]

6.4.8. Location Sensors

These sensors determine the range, distance, and altitude of any location within the required area (Fig. 6.18). For this, they get help from GPS satellites[35]. It signals comes from GPS satellites to determine latitude, longitude, and altitude to within feet. Minimum 3 satellites are required to triangulate a position[36].

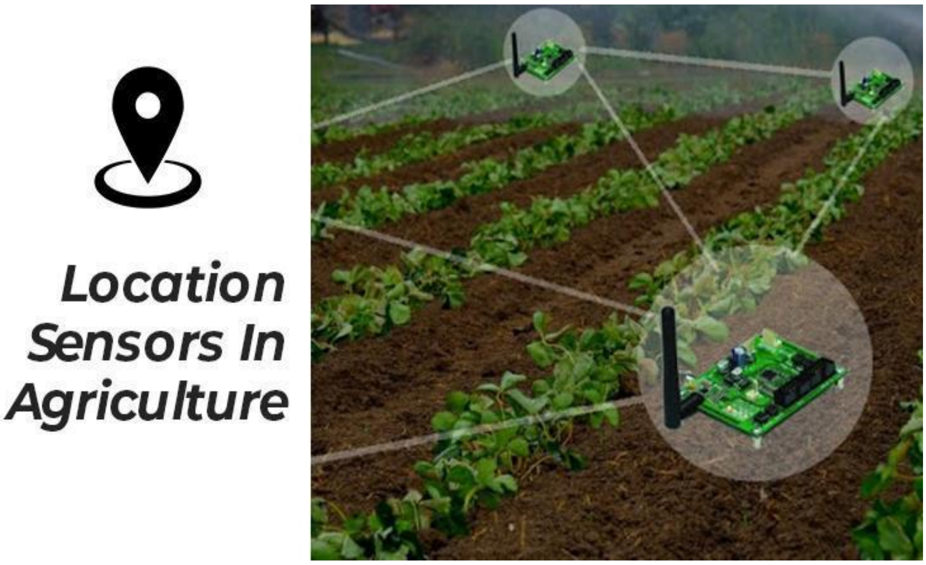

Figure 6.18. Location Sensors for Agriculture[20]

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[34]https://justagriculture.in/files/magazine/nov/020%20Application%20Of%20Soil%20Moisture%20Sensors%20In%20Agriculture.pdf

[35] Math, R. K. M., & Dharwadkar, N. V. (2018, August). IoT Based low-cost weather station and monitoring system for precision agriculture in India. In *2018 2nd international conference on I-SMAC (IoT in social, mobile, analytics and cloud) (I-SMAC) I-SMAC (IoT in social, mobile, analytics and cloud)(I-SMAC), 2018 2nd international conference on* (pp. 81-86). IEEE.

[36]https://justagriculture.in/files/newsletter/052.%20Agricultural%20Sensors%20A%20Step%20towards%20Smart%20Agriculture.pdf

Crop harvesting and farming works have recently adopted GPS technology in highly accurate vehicle guidance systems. Data received via location sensors can be used for optimization in many farming applications (such as plowing a field), the use of automated guided systems, and their orientation in the field. This can reduce process conflict and reduce the time required to complete a task[37]. Crop monitoring and yield prediction are two important applications of location intelligence in agriculture. In addition, location intelligence is also being used to improve the agricultural supply chain, pest, water, and disease management[38].

The data provided by location sensors is used to locate sensitive technologies where they are needed most. The global agriculture sensor market size was valued at USD 1.34 billion in 2020 and is expected to expand at a compound annual growth rate (CAGR) of 13.6% by 2028. The location sensor segment accounted for the largest revenue share of more than 13.0%, contributing revenue of USD 183.59 million in 2020[39].

Figure 6.19. Location Sensors[40]

6.4.9. Electronic Sensors

It is mounted on tractors and other field equipment to control the operations of the trimming equipment. Cellular and satellite communication systems are used to transmit data instantly to computers or by email to people[41] (Fig. 6.20).

[37] https://www.arrow.com/en/research-and-events/articles/top-5-sensors-used-in-agriculture

[38] https://www.geospatialworld.net/prime/business-and-industry-trends/role-of-location-intelligence-in-agriculture/

[39] https://www.grandviewresearch.com/industry-analysis/agriculture-sensor-market-report

[40] https://www.ictworks.org/how-can-sensor-technologies-and-precision-farming-improve-agriculture/

[41] de Freitas Coelho, A. L., de Queiroz, D. M., Valente, D. S. M., & de Carvalho Pinto, F. D. A. (2018). An open-source spatial analysis system for embedded systems. *Computers and Electronics in Agriculture*, *154*, 289-295.

Figure 6.20. Electronic Sensors for Agriculture[20]

Most digital networks combine existing wireless communication standards with an array of active electronic sensors in the field. Most IoT sensors carry onboard batteries and electronic chips, which increases the cost of manufacturing and assembly, placing a limit on the number of nodes that can be deployed in the field. To overcome the disadvantages of on-chip sensors, chipless wireless sensors are widely used as they do not require the operation of electronic chips or batteries[42].

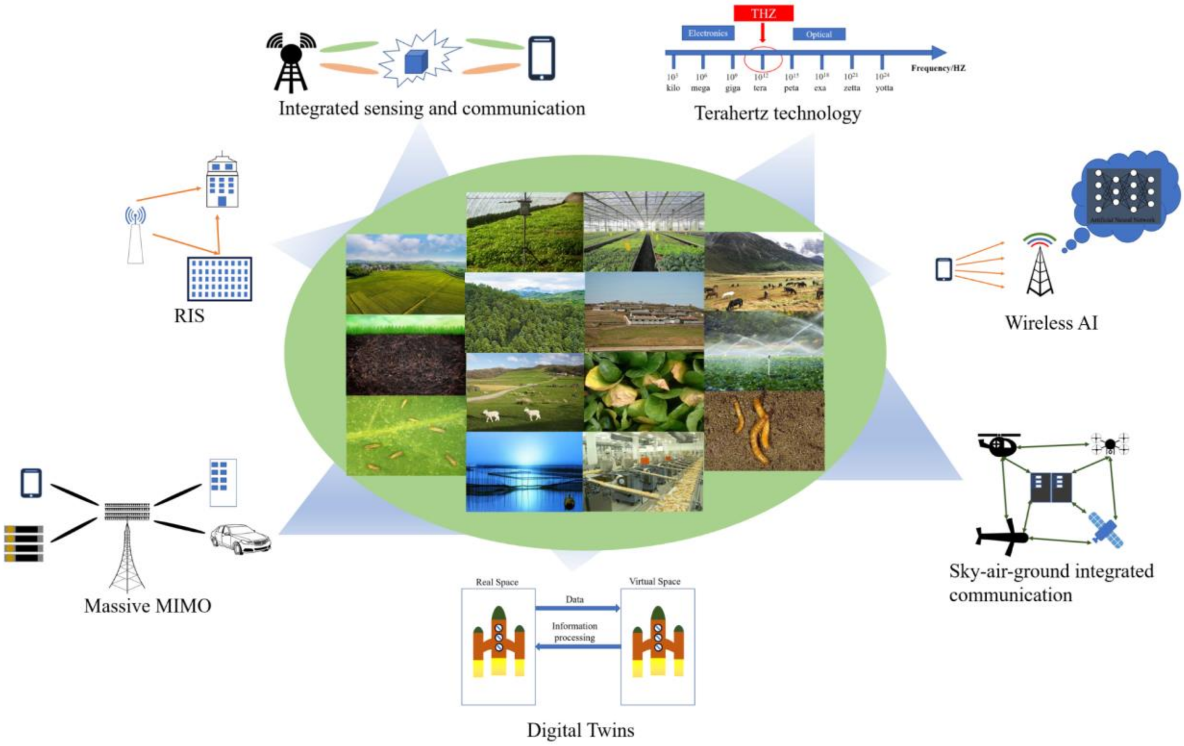

Figure 6.21. E-nose based soil sensing station[43]

[42] Gopalakrishnan, S., Waimin, J., Zareei, A., Sedaghat, S., Raghunathan, N., Shakouri, A., & Rahimi, R. (2022). A biodegradable chipless sensor for wireless subsoil health monitoring. *Scientific Reports*, *12*(1), 1-14.
[43] Zhang, F., Zhang, Y., Lu, W., Gao, Y., Gong, Y., & Cao, J. (2022). 6G-Enabled Smart Agriculture: A Review and Prospect. Electronics, 11(18), 2845.

6.4.10. Air Flow Sensors

Measurements can be made at specific locations while on the move. The desired output is the pressure required to push a certain amount of air into the ground at a predetermined depth. Various soil properties, including compaction, structure, soil type, and moisture level, create a distinctive defining signature[44]. They are also used to determine the air permeability of the soil. Measurements are made in real time in specific areas or on the go. Thus, farmers have real weather data and can monitor weather changes. Agricultural sensors can help conserve water. It also provides real-time data to help farmers reduce labor, lowering costs, and reduce environmental impact[45].

Figure 6.22. Air Flow Sensors for Agriculture[22]

6.4.11. Current and Future Trends in Sensor Technology

In this section (Section 6.4), the most commonly used types of sensors in agriculture and their applications are examined under separate headings:

- RGB sensors
- Multispectral Sensors
- Thermographic Sensors
- Optical Sensors
- Electrochemical Sensors
- Mechanical Soil Sensors
- Dielectric Soil Moisture Sensors
- Location Sensors
- Electronic Sensors
- Air Flow Sensors

[44] Schriber, S. (2019). Smart agriculture sensors: helping small farmers and positively impacting global issues, Too. *Mouser Electron http://www. sciencedirect. com/science/article/pii/S016719871500029X, 4.*
[45] https://www.avirtech.co/what-are-the-types-of-sensors-used-in-agriculture

In Table 6.3, the benefits, disadvantages, and risks of these sensors from an economic, management, and environmental point of view are summarized.

Field	***Benefits***	***Disadvantages and risks***
Economics	• Changes in costs • Changes in fertilizer, water, pesticide, and energy costs • Time saving • Raising productivity • Increased profits	• Initial investment costs • Need for advanced program and interface
Management	• Easy to use and maintain • Monitor and optimize of crops • Stay up to date with changing environmental and ecosystem factors • Help find and track herds	• Limited skills • Selection of suitable technology or solutions
Environment	• Conserve resources • Decrease input losses • Environmental protection • Less harm to the environment • Reduced food contamination • Reduction of the need for water and chemicals for crops	• Evaluation of outputs

Table 6.3. The benefits, disadvantages, and risks of sensors from an economic, management, and environmental point of view

Recently, nanotechnology and its advantages have begun to revolutionize all agricultural applications. Nanotechnology research has the potential to improve all aspects of current agriculture. As designed nanofertilizers can strengthen the growth of plants by improving nutrient uptake, it is also possible to monitor plant and soil conditions through nanosensors, and to detect pathogen and toxin residues in the food we eat through bionanosensors[46]. Nanobiosensors are sensors that can easily operate at low cost and function at a wide range of sensing scales[47]. The potential of agricultural nanobiotechnology is very high. In fact, environmental sustainability can be contributed by using green agronomic techniques from agricultural waste. The potential of agricultural nanobiotechnology is very

[46] Abdel-Aziz, H. M., & Heikal, Y. M. (2021). Nanosensors for the detection of fertilizers and other agricultural applications. *Nanosensors for Environment, Food and Agriculture Vol. 1*, 157-168.
[47] Mahmoud, A. E. D., & Fawzy, M. (2021). Nanosensors and nanobiosensors for monitoring the environmental pollutants. *Waste Recycling Technologies for Nanomaterials Manufacturing*, 229-246.

high. In fact, using green agronomic techniques from agricultural wastes can contribute to environmental sustainability (Figure 6.24).

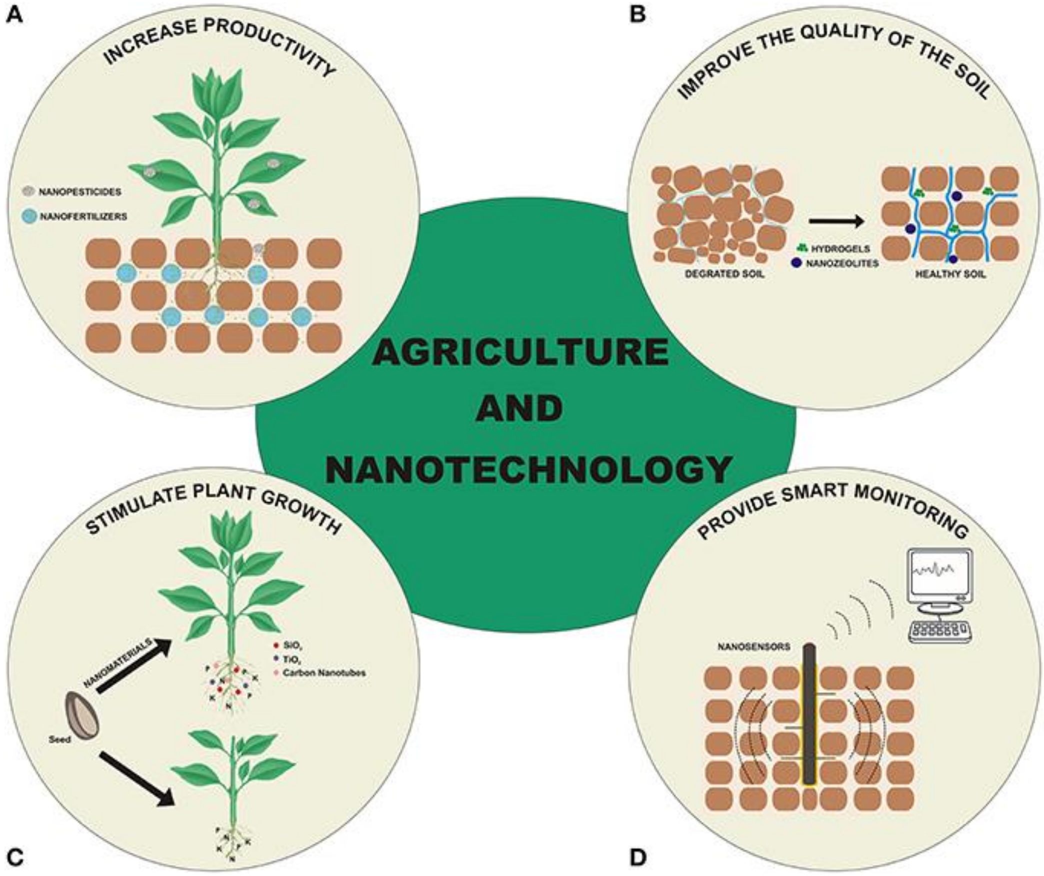

Figure 6.23. Potential applications of nanotechnology in agriculture: (A) Increase the productivity using nanopesticides and nanofertilizers; (B) Improve the quality of the soil using nanozeolites and hydrogels; (C) Stimulate plant growth using nanomaterials (SiO_2, TiO_2, and carbon nanotubes); (D) Provide smart monitoring using nanosensors by wireless communication devices[48].

[48] https://www.frontiersin.org/articles/10.3389/fenvs.2016.00020/full?tag=makemoney0821-20

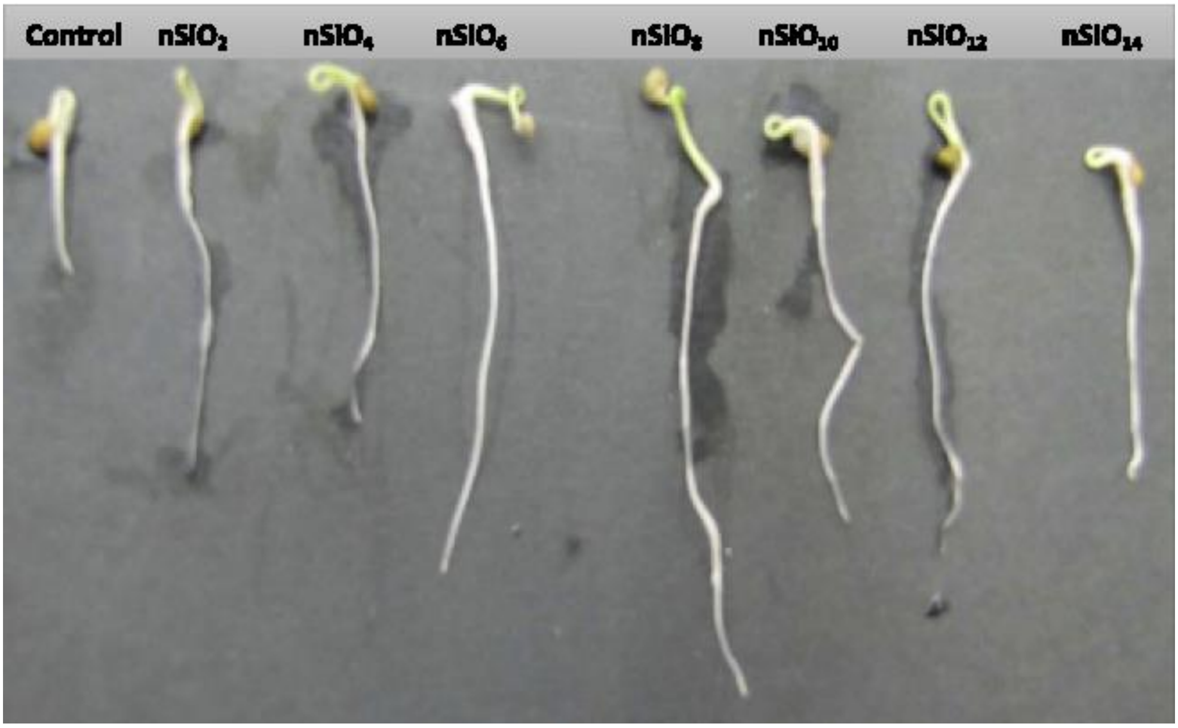

Figure 6.24. Effect of nano-SiO_2 on seeding growth of tomato.

for MORE INFORMATION

Johnson, M. S., Sajeev, S., & Nair, R. S. (2021, March). Role of Nanosensors in agriculture. In *2021 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)* (pp. 58-63). IEEE.

Chhipa, H., & Joshi, P. (2016). Nanofertilisers, nanopesticides and nanosensors in agriculture. *Nanoscience in food and agriculture 1*, 247-282.

Srivastava, A. K., Dev, A., & Karmakar, S. (2018). Nanosensors and nanobiosensors in food and agriculture. *Environmental Chemistry Letters*, *16*, 161-182.

Dubey, A., & Mailapalli, D. R. (2016). Nanofertilisers, nanopesticides, nanosensors of pest and nanotoxicity in agriculture. *Sustainable Agriculture Reviews: Volume 19*, 307-330.

https://www.frontiersin.org/articles/10.3389/fenvs.2016.00020/full

6.5. Autonomous Vehicles

With the rapidly increasing world population, nutritional needs are also increasing. In 2050, it is foreseen that production should be increased by 70% to meet this need. In addition, with the increasing population, urbanization will increase and the labor force in the field of agriculture will decrease[49]. With the technology used today, advanced research can be done, and this situation saves us time, labor, cost, data collection convenience, etc. These systems,

[49] Saygılı, F., Kaya, A. A., Çalışkan, E. T., & Kozal, Ö. E. (2018). Türk tarımının global entegrasyonu ve tarım 4.0. *İzmir Ticaret Borsası, Yayın No: 98, İzmir*.

which started to be used for military purposes, will bring about changes in the agricultural sector with the development of technology [50]. In 2010, a new process started with Agriculture 4.0. This process also includes Digital Farming, Smart Farming, etc. With this technology, agricultural fields and agricultural vehicles are in communication with each other. The sensors are used to collect and analyze the necessary information from the agricultural field. Satellite images can be combined with this analysis. With the help of unmanned aerial vehicles, necessary information is obtained from agricultural areas and processed. Thanks to the GPS system, information about the agricultural area and various negatives can be detected and spraying, irrigation, etc. transactions can be done more effectively. The robots used in the agricultural field increase efficiency in production and harvesting[28,51].

The word "Autonomous" is of French origin and means independent. Autonomous vehicles, on the other hand, are systems that collect data, analyze it, and make decisions as a result of the tasks assigned to them by using various technologies and do not require human beings to a large extent. Thanks to these decisions, they perform the tasks given by performing the necessary operations with the minimum error. Autonomous vehicles, which are widely used in today's technology, can be seen in exemplary applications such as automotive, health, clothing, military, agriculture, manufacturing, service robots, robot arms, and armed and unarmed aerial vehicles.

As investors and companies turn to agricultural production, high technology has been used in this sector and thus the production capabilities of farmers have improved[52]. Today, there is an increase in the use of UAVs. Especially high-resolution images are of great importance in agricultural processes but obtaining these images by plane and satellite is costly. UAVs with GPS systems and cameras provide an advantage in this regard[29]. One of the issues of interest in terms of precision agriculture is planting trees and managing fruitful orchards. For these operations, trees must be identified and numbered one by one. In this process, it can be done with high resolution images, which are obtained with unmanned aerial vehicles[53]. Thanks to the vehicles used during production, efficient production is ensured by reducing the waste of chemical substances and giving the plants enough nutrients[54].

Harvesting by workers using ladders, reaching, and plucking the product, etc., cause serious labor and energy losses and work accidents. In addition, the cost of collecting for agricultural workers increases. It was stated that the manual apple harvesting process in the USA in 2016 was more than 7 million tons. Considering the difficulty of the work, the

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[50] Akkamiş, M., & Çalişkan, S. (2020). Insansiz hava araçlari ve tarimsal uygulamalarda kullanimi. *Türkiye insansiz hava araçlari dergisi*, *2*(1), 8-16.
[51] Reis, M. (2014). İnsansız Hava Araçları ile Bitki Koruma ve Tarım Uygulamaları. In *International Symposium on Innovative Technologies in Engineering and Science, Proceeding Book* (pp. 1443-1449).
[52] Güzey, A., Akinci, M. M., & Altan, Ş. (2020). Otonom Kara ve Hava Araçları ile Akıllı Tarım: Hasat Optimizasyonu Üzerine Bir Uygulama. *Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 207-220.
[53] Csillik, O., Cherbini, J., Johnson, R., Lyons, A., & Kelly, M. (2018). Identification of citrus trees from unmanned aerial vehicle imagery using convolutional neural networks. *Drones*, *2*(4), 39.
[54] Türkseven, S., Kizmaz, M. Z., Tekin, A. B., Urkan, E., & Serim, A. T. (2016). Tarımda dijital dönüşüm; insansız hava araçları kullanımı. *Tarım Makinaları Bilimi Dergisi*, *12*(4), 267-271.

increasing hourly wages create serious problems in terms of cost[31]. In addition, it has been reported that one of the goals of smart agriculture is to reduce the environmental footprint[55].

The following applications can be carried out in the agricultural field with unmanned vehicles used in agriculture[28,29,30,31,32,33,34].

- Examination of climatic conditions
- Examination of the current state of the soil
- Examination of the soil for the next period
- Obtaining 3D topographic images
- Examination of weather conditions.
- Wild animal damage
- Description and numbering of trees
- Soil erosion
- High-definition imaging with low flight.
- Disease and pest detection.
- Carrying out necessary agricultural activities in cases where life safety is endangered due to land conditions
- Effective realization of the irrigation process
- Performing imaging operations in agricultural areas
- Flowering and fruit formation follow-up
- Harvesting operations
- Yield analysis
- Appropriate pesticide use and low volume spraying at the appropriate time.
- Separation and packaging
- Determination of plant species.
- Examination of plant status and plant protection activities.
- Performing fertilization processes
- Service platforms
- Water stress detection
- Surveillance of workers
- Location of grazing animals and detection of harmful gases from feces
- Controlling the growth conditions of the offspring on the farms

6.5.1. Unmanned aerial vehicles (UAVs)

UAVs, also called drones, are aerial vehicles that can be remotely controlled by an operator and can fly without a pilot (Figure 6.25). They are widely used in smart agriculture applications because they provide great advantages[34,56]. They are inexpensive compared to other agricultural machines and easy to use. It has good mobility and can move in variable weather conditions. They can take high resolution photos at altitudes between 50-100 m. They are used in many different areas such as the analysis of agricultural areas, mapping, seed

[55] Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021). A review of applications and communication technologies for internet of things (Iot) and unmanned aerial vehicle (uav) based sustainable smart farming. *Sustainability*, *13*(4), 1821.

[56] Maddikunta, P. K. R., Hakak, S., Alazab, M., Bhattacharya, S., Gadekallu, T. R., Khan, W. Z., & Pham, Q. V. (2021). Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges. *IEEE Sensors Journal*, *21*(16), 17608-17619.

planting, productivity analysis and spraying operations (Fig. 6.25-26). It also provides great advantages in conditions where transportation is difficult. Thanks to the data obtained through the analyses they will make in the agricultural field, the software used in smart devices from cloud-based platforms can bring together farmers and other stakeholders on different subjects[34,35,57].

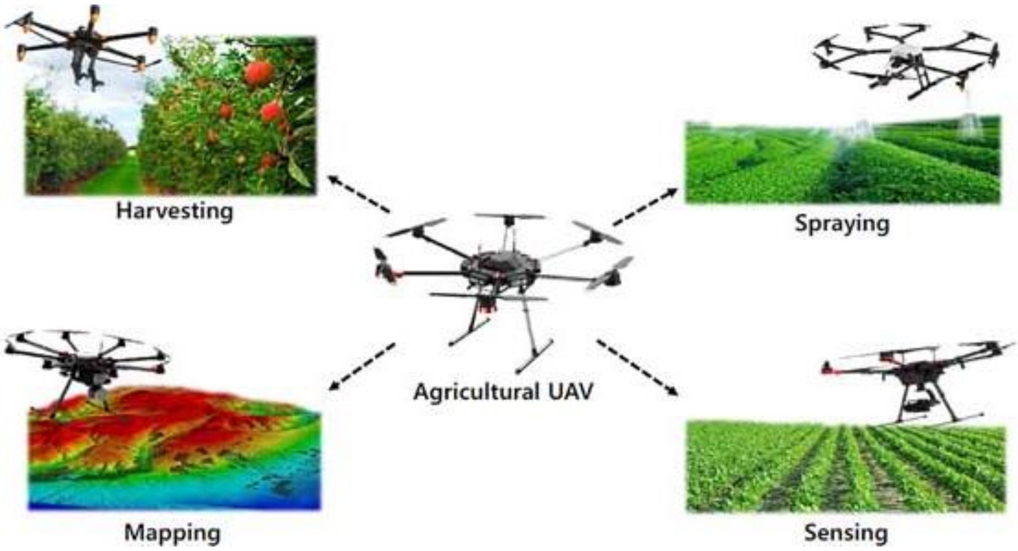

Figure 6.25. Different applications by different unmanned aerial vehicles[58]

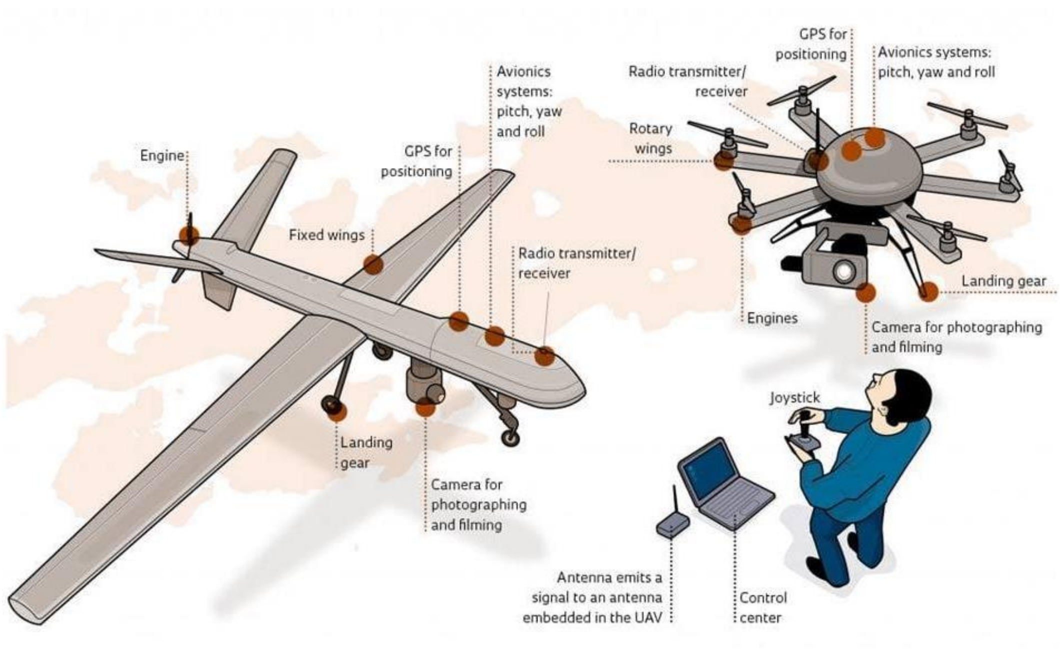

Figure 6.26. Operating principle of unmanned aerial vehicles[59]

[57] Kim, J., Kim, S., Ju, C., & Son, H. I. (2019). Unmanned aerial vehicles in agriculture: A review of perspective of platform, control, and applications. *IEEE Access*, *7*, 105100-105115.

[58] J. Kim, S. Kim, C. Ju and H. I. Son, "Unmanned Aerial Vehicles in Agriculture: A Review of Perspective of Platform, Control, and Applications," in *IEEE Access*, vol. 7, pp. 105100-105115, 2019, doi: 10.1109/ACCESS.2019.2932119.

[59] https://kautilyatech.in/sensitive-uav-solutions/

Fast setup time, low acquisition costs, and instant data capture can be counted as the advantages of UAVs. However, they have disadvantages such as short flight time, battery efficiency is a problem to be solved, and communication distance is not sufficient in most cases.

We can divide the types of UAVs used in agriculture into four categories according to their structure (Fig. 6.27)[54]. These are called Multi Rotor UAVs, Fixed Wing UAVs, Single Rotor UAVs and Hybrid Vertical Take-off and Landing (VTOL). Multi Rotor UAVs can be used in the field of photography and surveillance, and can have 3, 4, 6, or 8 rotors. Their speed and flight time are limited. It can be preferred due to its cheap and easy production according to its intended use. The average flight time of Fixed Wing UAVs flying with thrust and aerodynamic lift is 2 hours. They can work long distances. They need a runway for flight. They are expensive, larger than rotor models, and require good training. Single Rotor UAVs are helicopter-like thanks to the large rotor and small rotor in the tail but have longer flight times compared to Multi Rotor UAVs. They are costly and complex in structure. Hybrid Vertical Take-off and Landing (VTOL) has a hybrid structure and rotor, and Fixed Wing UAVs systems are used. Using the advantages of the fixed wing, this vehicle can also stay stationary in the air.

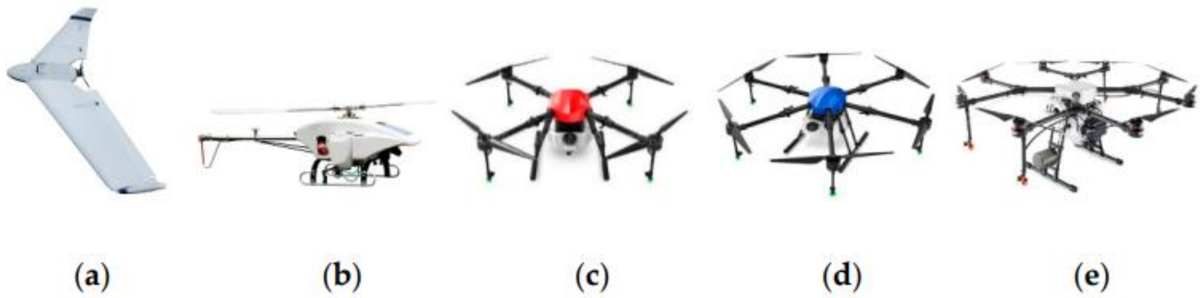

Figure 6.27. Different types of UAV: (a) Fixed Wing, (b) Single rotor, (c) Quadcopter (d) Hexacopter, and (e) Octocopter[60]

6.5.2. Unmanned land/ground vehicles

It is thought that unmanned land vehicles have a vital role in eliminating the problems predicted for the coming years. There are two topics discussed in unmanned ground vehicles. One of them is the automation of traditional tools. The other is the development of specially designed mobile platforms. Agricultural machinery is used for agricultural operations such as fertilizing, pruning, tillage, sowing, soil sampling, irrigation, harvesting, mechanical weeding, animal feeding, and spraying. Harsh weather conditions, heavy duties in production, exposure to chemicals during spraying, and repetitive processes are among the problems faced by agricultural workers. In addition, food safety is one of themost important issues in agriculture. Every year, 48 million Americans become ill due to food diseases, and 3000 of these patients

[60] Hanif, A. S., Han, X., & Yu, S. H. (2022). Independent Control Spraying System for UAV-Based Precise Variable Sprayer: A Review. *Drones*, *6*(12), 383.

have been reported to die. To prevent this problem, studies are carried out on land vehicles that investigate focal contamination between rows of planted spinach[61,62,63,64].

Figure 6.28 shows the cycle of unmanned land vehicles for precision agriculture. The right side of the figure shows analysis and planning. The left side of the figure is the activities based on providing movement.

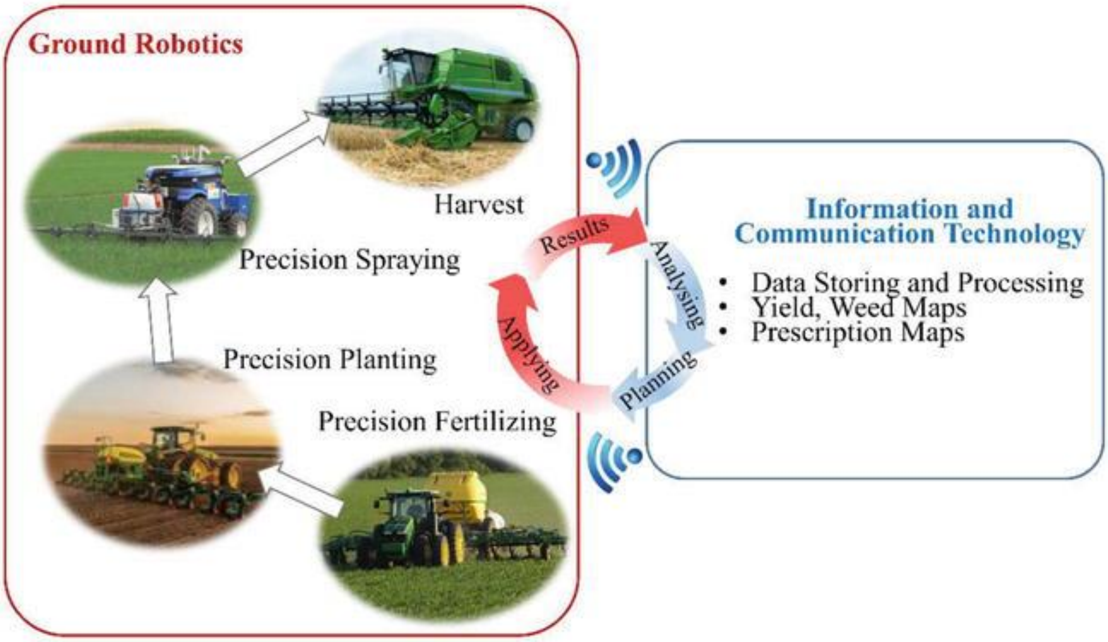

Figure 6.28. Cycle of unmanned ground vehicles for precision farming[58]

They can be classified as tracked and wheeled land vehicles; tracked vehicles provide an advantage in difficult terrains because the load distribution in tracked systems is distributed over a wider area (Figure 6.29). Track tractors are tractors do not have wheels (Figure 6.30).

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[61] García-Pérez, L., García-Alegre, M. C., Ribeiro, A., & Guinea, D. (2008). An agent of behaviour architecture for unmanned control of a farming vehicle. *computers and electronics in agriculture*, *60*(1), 39-48.
[62] Bonadies, S., Lefcourt, A., & Gadsden, S. A. (2016, May). A survey of unmanned ground vehicles with applications to agricultural and environmental sensing. In *Autonomous air and ground sensing systems for agricultural optimization and phenotyping* (Vol. 9866, pp. 142-155). SPIE.
[63] Fernandes, H. R., Polania, E. C. M., Garcia, A. P., Mendonza, O. B., & Albiero, D. (2021). Agricultural unmanned ground vehicles: A review from the stability point of view. Revista Ciência Agronômica, 51.
[64] Gonzalez-De-Santos, P., Fernández, R., Sepúlveda, D., Navas, E., & Armada, M. (2020). Unmanned ground vehicles for smart farms. In Agronomy-Climate Change and Food Security (p. 73).

Figure 6.29. An off-road vehicle from a combination of old Volvo personnel carrier and Defender 90[65]

Figure 6.30. A track Tractor[66]

Wheeled vehicles move faster than tracked vehicles. Structures of wheeled robots can be categorized as[58]:

- Number of wheels (most field robots are based on four wheels)
- Wheel orientation type

[65] https://www.fwi.co.uk/machinery/4x4s/farmer-mashes-volvo-and-defender-to-create-tracked-land-rover
[66] https://lemonbin.com/types-of-farm-vehicles/

    - Fixed wheel (the wheel is perpendicular to the platform and its angle (orientation) cannot change)
    - Orienting wheel (using an orientation actuator, the wheel plane changes its orientation)
    - Castor wheel (the wheel can rotate freely and its orientation can change)
- Wheel power type
    - Passive wheel (the wheel rotates freely around its shaft and does not provide power)
    - Active wheel (to provide power, an actuator rotates the wheel)
- Wheel arrangement
    - Coordinated steering scheme (one advantage of this system is that a single actuator can steer both wheels)
    - Skid steering scheme (the two wheels on one side can be powered independently or by a single actuator)
    - Independent steering scheme (the coordination of driving and steering results in more efficient maneuverability and reduces internal power losses caused by actuator fighting. The independent steering scheme requires eight actuators for a four-wheel vehicle)

For each wheel arrangement type the usage in digital farming, advantages, and disadvantages can be seen at Table 6.3[58].

Terrain conditions are one of the problems encountered by land vehicles and stability is important at this point. Due to the terrain conditions, problems such as overturning vehicles and the inability to fulfill the given task may be encountered. Coffee fields and forests have low regularity, while fields and greenhouses have high regularity. Soil cohesion is one of the other important substances in field conditions. Ground conditions can cause sinking, skidding, poor traction, etc., which can cause problems. Land slope, which is one of the main factors, can cause rollovers as it affects the position of the center of gravity and the distribution of force on the wheels. With the various suspension types used, these problems are reduced or eliminated. Examples for systems with rigid suspensions in Figure 6.31 and passive suspensions in Figure 6.32 are given[57].

Wheel arrangement	Characteristics
Coordinated	**Use in smart farms:** New mobile robotic designs are abandoning this scheme, which only offers simplicity. Hence, such steering control is not expected to be used in smart farms.
	Advantages: Simplicity, Few actuators (2) if based on the Ackermann device, Good turning accuracy if the front wheels are steered independently.
	Disadvantages: Large turning radii, Ideal rotation in only three steering angles if based on the Ackermann device, Requires three actuators and more complex control algorithms if based on front wheels steered independently, *Steering control on loose grounds, e.g., after plowing, is difficult.
Skid	**Use in smart farms:** This **steering** scheme is simple and robust, but not very precise in loose terrain; hence, it could be used in smart farms, e.g., for indoor tasks, but not for infield tasks.
	Advantages: Compact size, robustness, few parts, Agility (motion with heading control and zero-radius turns), Few actuators (2).
	Disadvantages: The maximum forward thrust is not maintained during turns, Terrain irregularities and tire-soil effects demand unpredictable power supply, Vehicle rotations erode the ground and wore the tires.
Independent	**Use in smart farms:** This steering scheme is the more versatile of the schemes, but it is also more complex and expensive. However, most of the engineering systems evolve by increasing their sophistication and robustness while decreasing their cost; hence, this scheme will be intensively used in smart farms.
	Advantages: Full mobility (including crab motion).
	Disadvantages: Many actuators and parts (eight for a four-wheel robot), Complex control algorithms.

Table 6.4. Characteristics of wheeled structures

Figure 6.31. Examples for land vehicles with rigid suspensions[42]

Figure 6.32. Examples for land vehicles with passive suspensions[42]

Unmanned land vehicles can be operated manually using tools like tablets, wireless controllers, or mobile devices. They can also be driven automatically using a variety of control strategies when manual operations is not preferred. Thanks to the sensors, processors and actuators attached to the vehicles, efforts are made to automate traditional vehicles, thus reducing labor costs in agriculture. Figure 6.33 shows a vehicle designed as an agricultural robot[40,41].

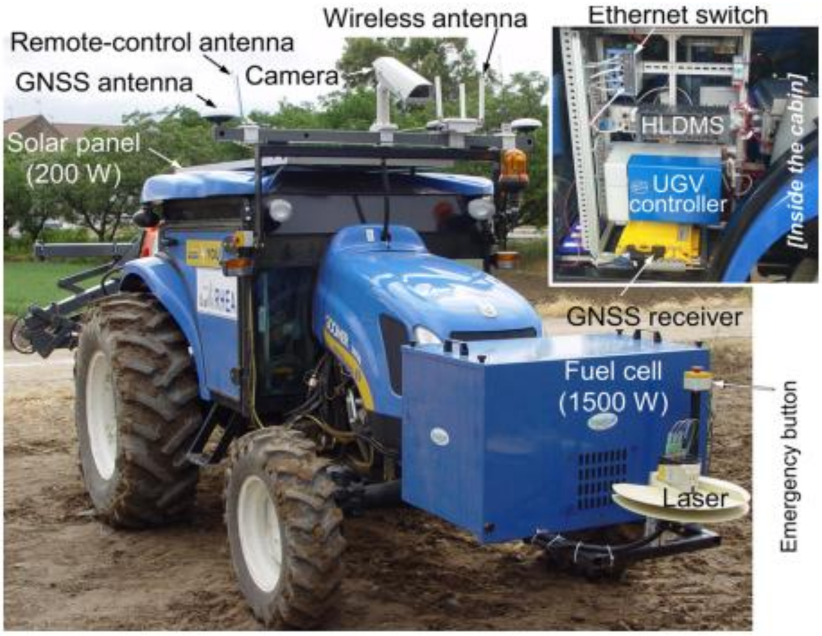

Figure 6.33. A vehicle designed as an agricultural robot[67]

6.5.3. Unmanned aerial boats (UA airboats) (Airboats)

It has been reported that the first version of airboats, whose history goes back a long time, was produced in 1905. This vehicle, made by Alexander Graham Bell and his team, is called "Ugly Duckling". Water vehicles are divided into two groups according to their working environments. Underwater vehicles (UV) are generally used for underwater exploration, while surface vehicles (SV) are used in aquaculture. Surface vehicles with aerodynamic propulsion (SV) are also called airboats. With the development of technology, unmanned airboats have been produced. An airboat to be used for agricultural operations is shown in Figure 6.34[68].

Figure 6.34. Agricultural airboat[45]

[67] Gonzalez-de-Santos, P., Ribeiro, A., Fernandez-Quintanilla, C., Lopez-Granados, F., Brandstoetter, M., Tomic, S., ... & Debilde, B. (2017). Fleets of robots for environmentally-safe pest control in agriculture. *Precision Agriculture*, *18*(4), 574-614.
[68] Liu, Y., Wang, J., Shi, Y., He, Z., Liu, F., Kong, W., & He, Y. (2022). Unmanned airboat technology and applications in environment and agriculture. *Computers and Electronics in Agriculture*, *197*, 106920.

In addition, as shown in Figure 6.35, a hybrid version of the vehicle (Amphibious Hybrid Unmanned Aerial Vehicle (AHUAV)) has been developed[69].

Figure 6.35. Hybrid version vehicle[46]

UAs, which are used in water analysis, mud measurement, mapping, examination of plankton communities, weeding (Figure 6.34), spraying and feed casting, are preferred in aquaculture and paddy fields where land vehicles have difficulty entering. Since the paddy row spacing is 25-30 cm in paddy fields, fertilization and spraying operations are difficult for tractors. In addition, wide roads should be built for tractors to enter the paddy field. These wide roads to be built will cause waste of planting areas. If not done, tractors can damage the paddy. Most of the UAs used in agriculture are still in the experimental stage, and their usage rates in agricultural areas are low due to the complexity of the agricultural area, load, stability, suitable sensors, durability, and navigation problems[70].

6.6. Robots and Robotic Arms

Today, robots and robotic arms are used in many fields such as health, production, assembly, agriculture, service, and the military, and they are preferred especially in repetitive, dangerous, and sensitive works. Systems used as semi-autonomous and fully autonomous have advantages and disadvantages compared to each other.

Although many studies have been done on automation and fully autonomous, it has been seen that a single robot cannot perform some tasks efficiently. Therefore, it is thought that humans and robots should work together, and studies are being carried out on robot-human technologies. In these systems, operators perform additional verification and correction of robot perceptions, while robots act as an assistant, helping with challenging and dangerous tasks. On

[69] Manoharan, D., Rajesh, S., Vignesh, S., Bhuvaneshwaran, G. D., Mohammed, T., Gunaseelan, J., ... & Padmanabhan, M. K. (2021). Water Body Survey, Inspection, and Monitoring Using Amphibious Hybrid Unmanned Aerial Vehicle. *SAE International Journal of Aerospace*, *14*(01-14-01-0003), 63-79.
[70] Liu, Y., Noguchi, N., & Liang, L. (2019). Development of a positioning system using UAV-based computer vision for an airboat navigation in paddy field. *Computers and Electronics in Agriculture*, *162*, 126-133.

the other hand, in autonomous systems,the key component is navigation, because many agricultural operations require the robot to move. In cases where the navigation processes are not performed correctly, other tasks that the robot should perform will fail[71,72].

In the example given in Figure 6.36, the robot controlled by an operator in the same place helps a farmer during the strawberry harvest[73].

One of the areas where robots and robot arms are used in smart agriculture technology is greenhouses. Greenhouses are used to maximize production and plant growth rates and are conducive environments for the spread of diseases. In the period between sowing and harvesting, disease controlling is necessary because early diagnosis is important to control the disease. Manual disease control has problems such as low sample sizes and high monitoring costs[74]. Figure 6.37 shows the robotic disease detection system.

Figure 6.36. Robot helping with strawberry harvest[50]

6.7. Current and future trends of unmanned agricultural vehicles

In sections 6.5 and 6.6 the most commonly used types of unmanned vehicles in agriculture and their applications are examined under separate headings:

- Unmanned aerial vehicles (UAVs)
- Unmanned land/ground vehicles
- Unmanned aerial boats (UA airboats) (Airboats)

[71] Lytridis, C., Kaburlasos, V. G., Pachidis, T., Manios, M., Vrochidou, E., Kalampokas, T., & Chatzistamatis, S. (2021). An Overview of Cooperative Robotics in Agriculture. *Agronomy*, *11*(9), 1818.

[72] Rahmadian, R., & Widyartono, M. (2020, October). Autonomous Robotic in Agriculture: A Review. In *2020 third international conference on vocational education and electrical engineering (ICVEE)* (pp. 1-6). IEEE.

[73] Sharkawy, A. N. (2021). Human-Robot Interaction: Applications. *arXiv preprint arXiv:2102.00928*.

[74] Schor, N., Bechar, A., Ignat, T., Dombrovsky, A., Elad, Y., & Berman, S. (2016). Robotic disease detection in greenhouses: combined detection of powdery mildew and tomato spotted wilt virus. *IEEE Robotics and Automation Letters*, *1*(1), 354-360.

- Robots and Robotic Arms

In Table 6.5, the benefits, disadvantages, and risks of these unmanned agricultural vehicles from an economic, management, and environmental point of view are summarized.

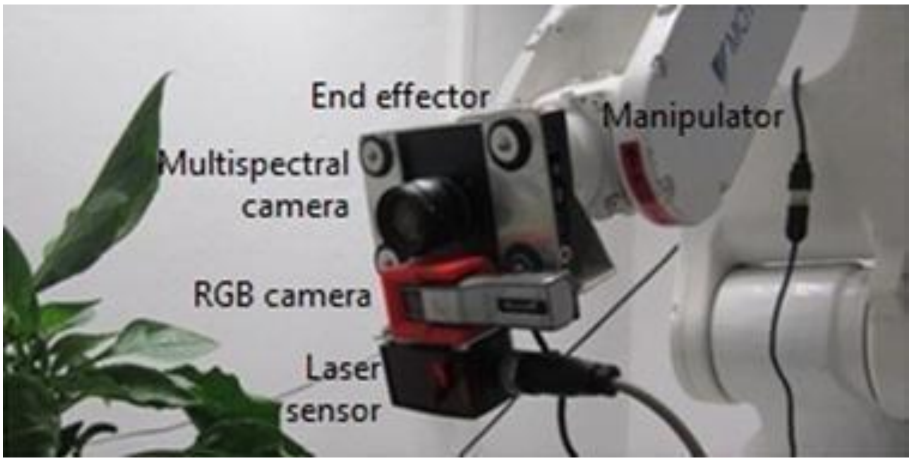

Figure 6.37. A robotic disease detection system[75]

With the developing technology, the use of vehicles and robots consisting of unmanned land, air, water and their combinations will increase gradually. Considering that energy, input, and employee costs are increasing day by day, it is important to reduce input and operating costs. In addition, sustainable resource management and environmental impacts should be minimized. Considering all these conditions, we can list some of the topics that are seen as the trends of the future[76]:

- The use of more efficient, more reliable, and lighter electric motor tractors with zero carbon emissions, very large torque at low speeds, in agricultural applications,
- Large spraying drones with an all-electric drive with replaceable lithium-ion batteries and equipped with a flexible and standardized payload attachment system in the frame,
- Thanks to the electric drive, the autonomous electric tractor has no carbon emissions, extremely low noise levels, low wear and maintenance costs,
- Autonomous drone sprayer that significantly reduces the amount of pesticides used and ensures precise application,
- Plant-specific treatment with the help of high-resolution cameras and artificial intelligence that capture 20 images per second.

[75] Schor, N., Berman, S., Dombrovsky, A. *et al.* Development of a robotic detection system for greenhouse pepper plant diseases. *Precision Agric* **18**, 394–409 (2017). https://doi.org/10.1007/s11119-017-9503-z
[76] https://www.deere.co.uk/en/agriculture/future-of-farming /

Field	***Benefits***	***Disadvantages and risks***
Economics	• Changes in costs • Changes in fertilizer, water, pesticide, and energy costs • Time saving • Raising productivity • Increased profits • Reducing labor cost	• Initial investment costs • Need for advanced program and interface
Management	• Fast spraying and irrigation • Fast crop processing and picking • Move faster than humans • Access to areas that are difficult for people to access	• Limited skills • Selection of suitable tools and infrastructures
Environment	• Conserve resources • Decrease input losses • Environmental protection • Reduced food contamination • Reduction of the need for water and chemicals for crops	• Evaluation of outputs

Table 6.5. The benefits, disadvantages, and risks of unmanned agricultural vehicles from an economic, management, and environmental point of view

for MORE INFORMATION

https://ati.ec.europa.eu/sites/default/files/2021-04/Technological%20trends%20in%20the%20machinery%20industry.pdf

https://ec.europa.eu/research-and-innovation/en/horizon-magazine/futuristic-fields-europes-farm-industry-cusp-robot-revolution

https://www.deere.co.uk/en/agriculture/future-of-farming/

https://www.economist.com/technology-quarterly/2016-06-09/factory-fresh?utm_medium=cpc.adword.pd&utm_source=google&ppccampaignID=18151738051&ppcadID=&utm_campaign=a.22brand_pmax&utm_content=conversion.direct-response.anonymous&gclid=Cj0KCQjwyLGjBhDKARIsAFRNgW9qPM3dqj8jDi94x6siZwiiK5yVT8UYpqxsXG-FRVS_NRZdut0G26UaAkT6EALw_wcB&gclsrc=aw.ds

https://www.forbes.com/sites/bernardmarr/2022/01/28/the-biggest-future-trends-in-agriculture-and-food-production/?sh=70586822107a

https://cema-agri.org/publications/19-brochures-publications/992-cema-presents-the-european-agricultural-machinery-industry-report

6.8. Conclusions

Autonomous vehicles are rapidly developing as a technology trend in which the independent movement of many vehicles without human interaction, from drones to robots, gains importance. Agriculture automation technology **addresses** key issues such as global populations, farm labor shortages, and changing consumer preferences. The market for agricultural equipment is expected to increase, rising from $168.30 billion in 2022 to $272.36 billion by 2029[77].

The increase in mechanization in the agricultural sector and the increase in the income of the farmers are expected to be the primary factors driving the growth in the market. Increasing use of autonomous tractors, agricultural robots, unmanned vehicles, drones, sensors, and software to help farmers produce food at low costs to meet growing food demand offers better prospects for market growth over the forecast period[78]. While the high initial cost of farm equipment is predicted to be one of the challenges in adopting farm equipment, especially for small income farmers, renting these vehicles is expected to help overcome such challenges.

[77] https://www.fortunebusinessinsights.com/agriculture-equipment-market-102665
[78] https://www.grandviewresearch.com/industry-analysis/agriculture-equipment-market

HINTS for EDUCATOR-1

Farmers face important challenges and require education and training to ensure their success. Training helps farmers to incorporate the latest scientific advances and technology tools into their daily operations. The results of enhancing their operations with these tools increases efficiency and can also lead to[79]:

- Less harm to the environment
- Reduced food contamination
- Reduction of the need for water and chemicals for crops
- Increased profits

In order to achieve these, it can be said that there is a need for training in basic concepts such as basic internet and computer skills, open source programs, internet of things, artificial intelligence, desicion support system (DSS), image processing, drone, unmanned vehicles, blockchain, and e-commerce platform.

Students can complete their training in detail on the implementation of sensors, their operation, the technical characteristics, advantages, and disadvantages of each one of them, data downloading, the type of soil recommended, and, most importantly, the evaluation and interpretation of the results[80]. In the training content, learners should first be given basic sensor information. Moreover, the training may also contain the following topics[81]:

- Knowledge of local ecosystems
- How can the appropriate technology or solutions be chosen?
- Sense of solidarity and responsibility for the community
- Working with processed data

Some online resources that can be used:

Tiwari, P. S., Chandel, E. N., Agrawal, K. N., Singh, K., Tripathi, E. H., & Golhani, K. (2014). TRAINING MANUAL: National Training on Sensors and Actuators for Precision Farming. https://www.researchgate.net/profile/Prem-Tiwari/publication/281112982_TRAINING_MANUAL_National_Training_on_Sensors_and_Actuators_for_Precision_Farming/links/57be7c9208aeb95224d08713/TRAINING-MANUAL-National-Training-on-Sensors-and-Actuators-for-Precision-Farming.pdf

https://www.futurelearn.com/info/courses/innovation-in-arable-farming/0/steps/160450

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[79] https://www.nifa.usda.gov/topics/farmer-education

[80] https://library.iated.org/view/MORALESRODRIGUEZ2021TRA

[81] Bournaris, T., Correia, M., Guadagni, A., Karouta, J., Krus, A., Lombardo, S., ... & Vieri, M. (2022). Current Skills of Students and Their Expected Future Training Needs on Precision Agriculture: Evidence from Euro-Mediterranean Higher Education Institutes. *Agronomy*, *12*(2), 269.

HINTS for EDUCATOR-2

Given the rapid change and development of smart agriculture, and the current trend towards accelerated knowledge exchange, precision agriculture educators face the challenge of keeping up and providing quality training programs[82]. Smart agriculture training programs need to reflect these dynamics of change. Smart agriculture training programs should consider how to remove barriers to smart agriculture adoption, how the learning process of these technologies and methods can be improved, and what the needs of different agricultural actors are.

Six learning steps involved in the adoption and application of smart agriculture can be listed as[53]:

Step 1: Learning and understanding the concept of spatial data management.

Step 2: Learning the proper use of sensors.

Step 3: Learning to use a computer and software for mapping.

Step 4: Make improved crop production decisions by assessing yield variation and narrowing down potential causes.

Step 5: Development of site-specific management (SSM) plans with relevant information collected, summarized, and interpreted.

Step 6: Optimizing management with strategic sampling and on-farm trials.

Producers, agribusinesses, and educators will learn the most pertinent information smart farming as they progress:

1) agronomic knowledge and skills,
2) computer and information management skills, and
3) to understand precision agriculture as a system for increasing knowledge.

[82] Kitchen, N. R., Snyder, C. J., Franzen, D. W., & Wiebold, W. J. (2002). Educational needs of precision agriculture. *Precision agriculture*, *3*(4), 341-351. https://link.springer.com/article/10.1023/A:1021588721188

HOW TO USE?

The "Autonomous tractors market in Europe: Major Driver and Trend" report indicates that the autonomous tractors market in Europe is expected to grow by USD 862.86 million by 2026. The report extensively covers the autonomous tractors market in Europe segmentation by component (sensors, GPS, vision system, and others) and application (harvesting, seed sowing, and irrigation). In addition, Solar energy-powered tractors is anticipated to boost the growth of the Autonomous Tractors Market in Europe. **Autonomous tractors market in Europe: Major Vendor Offerings**[83].

- **AgJunction Inc.:** The company offers advanced guidance and autosteering solutions for precision agriculture applications. https://www.agjunction.com/
- **AgXeed BV:** The company offers a wide range of solutions that give farmers more time to make the right decisions. https://www.agxeed.com/
- **Autonomous Solutions Inc.:** The company offers independent vehicle automation systems for mining, agriculture, automotive, government, and manufacturing industries with remote control. https://asirobots.com/
- **Autonomous Tractor Corp.:** The company offers an electric drivetrain system to improve tilling, harvesting, and hauling services. https://autonomoustractor.com/
- **Deere and Co.:** the company offers manufacturing and distribution of machines and service parts used in construction, earthmoving, road building, material handling, and timber harvesting. https://www.deere.com/en/

[83] https://www.prnewswire.com/news-releases/autonomous-tractors-market-in-europe-to-grow-by-usd-862-86-mn-by-2026--increase-in-the-profits-generated-from-farming-to-boost-market-growth---technavio-301653482.html

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CHAPTER 7

E-Commerce Software, Marketing and Advertising Platforms

CHAPTER 7 E-Commerce Software, Marketing and Advertising Platforms

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Organisation(s):
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WHAT WILL WE LEARN IN THIS CHAPTER?

What is e-Commerce Software?
What are digital platforms?
How to use e-Commerce software, Marketing and Advertising platforms in agriculture (techniques and methodologies)?
Which are the future trends of digital marketing in agriculture?

Keywords: e-commerce software, digital platform(s), marketing platform, advertising platform, competency map, digital marketing strategy, digital techniques & methodologies, agriculture

7.1. Glossary and abbreviations

In the following table, some words/abbreviations/definitions useful for understanding the chapter have been reported.

e-commerce software	E-commerce software is a tool that drives all online store processes, helping owners manage inventory, add or remove products, process payments, compute taxes, and fulfil orders, among many others. It offers all the things needed to run a retail site, effectively simplifying online store management.
digital platform	A tech-based business model with the mission to connect interests and people as well as to promote valuable interactions between those involved.
commerce platform(s)	The technology enables a transaction for selling products or services online or across various channels. A commerce platform can also connect and manage different aspects of a retail or restaurant business as well as provide data and insights for better decision making.
marketing platform	The online software or solution that helps digital marketers manages their digital marketing activities.
advertising platform	Any online space where advertisers can monetize visitor traffic through the products or services they offer.
competency map	Illustrates the notions, information, skills that learners will acquire through reading and studying the chapter
MOOC – Massive Open On-line Course	A course of study made available over the internet without charge to a very large number of people. Anyone who decides to take a MOOC simply logs on to the website and signs up.
SEO – Search Engine Optimisation	The process of improving your website to increase its visibility on search engines whenever people search for product, services, information.
Digital Marketing Strategy	Using online resources to reach the target customer. Identifying where, why, and how a company makes a profit is one of the building blocks of a digital marketing strategy. It helps formulate a marketing plan that aligns with the business goals and customer requirements

CRM - Customer Relationship Management	Assists in marketing automation. CRM systems allow contacts to be segmented based on their information enabling email flows for interaction with leads and customers, in an automated and personalized manner.
CMS – Content Management System	A computer software or an application that uses a database to manage all content, and it can be used when developing a website.
ERP – Enterprise Resource Planning	The simplest way to define ERP is to think about all the core business processes needed to run a company: finance, HR, manufacturing, supply chain, services, procurement, and others. At its most basic level, ERP helps to efficiently manage all these processes in an integrated system. It is often referred to as the system of record of the organisation.

Table 7.1: Glossary and abbreviations

7.2. Competency map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter.

The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives a value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	***Competences and skills***	***Duration time***	***Learning tools***
• be able to use various types of Advertising and Marketing platforms in agriculture • be able to use E-Commerce Software in agriculture	• knowledge of the practical application of marketing and advertising platforms in agriculture • Knowledge about advantages and disadvantages of digital/e-commerce platforms • knowledge about trends of marketing and advertising platforms in agriculture	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Learning outcomes	*Competences and skills*	*Duration time*	*Learning tools*
	• ability to collect, manage, process and use various data		

Table 7.2: Competency map

7.3. E-commerce Software, Marketing and Advertising Platforms

Generally, agribusiness and farming businesses still tend to rely more on non-digital and established business growth strategies making digital marketing more of an accessory.

Thus, digital marketing in the agriculture industry has not been so popular, but agricultural industry businesses are missing out on the golden opportunity to market their products not only to local and national but also to a global market.

Why is the agriculture industry lagging behind the digital age? There are many reasons for it.

One of the main reasons is because the businesses are not willing to try the new method of marketing or in fact, some might even not have a marketing plan for agricultural products outside their town or city but just the local market.

There is also a lack of education or lack of knowledge on how digital marketing will help their business to thrive through the new age of marketing.

Despite these facts, digital marketing has, in the meantime, become the best way to reach the modern farmer.

Also, the best way to reach a farmer's audience is now online. It is to remember that to get the most out of online advertising, it is basically necessary to bring back potential customers to a professional, modern website that is optimised to convert casual visitors into paying customers.

Whether somebody is looking to launch a new agricultural product to the market or is just looking for a new way to promote its services, we've created this helpful introduction to the world of online advertising for the agricultural industry.

7.3.1. E - Commerce Software – with reference to the agricultural sector

E - Commerce software[1] is a tool that drives all online store processes, helping owners manage inventory, add or remove products, process payments, compute taxes, and fulfil orders, among many others. It offers all the things needed to run a retail site, effectively simplifying online store management.

[1] Source: https://financesonline.com/e-commerce-software-analysis-features-benefits-pricing/

An online store consists of many intricate components and processes, which ecommerce software streamlines through an easy-to-use interface that even non-tech persons can operate. Further facilitating things is the ability of the system to integrate with other platforms and services such as CRM, CMS, ERP, payment gateways, email marketing tools, accounting software, fulfilment services, and social media networks.

7.3.1.1 Agriculture businesses sales growth through digital marketing and social media - Benefits of digital marketing in the agriculture sector

- Digital marketing enables creating personalized messages towards targeted groups to reach the interested group of audience effectively.
- It helps determine the demographics, psychographics, and customer profiles of the respective customer audiences.
- It helps in the blooming and sharing of knowledge in agriculture with various aspiring marketers.
- It helps to achieve a high return on investment by tracking the digital marketing campaigns to promote agricultural products or services.

At creating great website content, it can also be shared in email newsletters for subscribers who are interested in your business. Newsletters can keep the brand in people's minds and remind them of the quality products/services you provide. While email marketing comes with its own set of challenges (research best practices in this area, as well), it can be an extremely effective way to grow the audience and increase traffic to the website, which will ideally lead to more sales.

When dealing with digital marketing, one of the most important things to remember is that the landscape is always changing, and it never gets less competitive. It is strongly recommended to consult with people who dedicate their professional lives to digital marketing.

Search is one of the most important online channels for any business hoping to grow their sales. For starters, it is necessary to focus on the local aspect of search engine marketing, which means claiming and verifying the business on Google, and implementing local search engine optimization (SEO) strategies and paying for Google search ads (AdWords).

Beyond that, it's also a good idea to use general SEO best practices so that your business frequently appears in search results when consumers are Googling. There are many tactics and tips to keep in mind (which is why one should consult with an SEO expert), the best advice here is to create great content for the website that the search engines can index and show users who search relevant queries.

Social media

Generally, most businesses have come to the conclusion by now that social media is not to be ignored. For agriculture businesses, it also represents a vital part of the marketing landscape. Whether they're conscious of it or not, customers are going to form their opinion on what they see – or don't see – on social media. If we want them to have a positive impression of a certain brand, products or services, then time has to be invested in cultivating a healthy online community and high-quality, valuable content.[2]

It is necessary to use the major social platforms, including Facebook, Twitter, and Instagram. These help with visibility and connection with other farmers, consumers, or whomever you are trying to reach. Agriculture businesses can strongly benefit from YouTube, as well. Upload compelling videos that further help to boost your brand and reputation. As an added bonus, Google likes YouTube videos and often shows them to its users in search results.

Social media can be especially used in the marketing phase of agricultural production. Social networks assure access to a wide audience and thus promotion campaigns for the farming brand and its products can be very helpful in the sales of products as the final phase of the agricultural process. An attractive and clear message / product offer can be prepared and posted by the farmer itself or, even better, by a digital marketing expert.

7.3.1.2 Vital techniques and methodologies used in digital marketing and social media with reference to the agriculture sector

Email Marketing

With all the new inventions, social platforms, and rise of video content around, it may be weird to say email marketing is the cheapest and most effective way of marketing. There is much more to explore in email marketing like personalization, putting out the right content in the email, automated email, and implementing the different strategies3.

Once you have a number of customers' email addresses, you can start sending them promotional emails (sometimes called nurture emails). As each person you're emailing has already expressed interest in your product or service, you're going to get a much warmer reception (and higher success rate) than if you were contacting random people in the industry. It is recommended that the person, that you've already been in contact with, receives an email content with the highest level of personalisation i.e. very personal addressing of such person and especially detailed description of your products that must include all and same details/values that have already been communicated at the previous occasion. The result? Your emails are going to get more opens, clicks and conversions.

With email marketing automation software, you can now prepare customized and personalized emails months in advance and schedule them to send out at set times of the year.

[2] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online

[3] Source: https://www.webfx.com/industries/industrial/agriculture/

Email Newsletter

Email marketing is an excellent digital marketing strategy that helps achieve a high return on investment. As per reports, email marketing is 40 times more effective in acquiring new customers than various social media platforms or channels[4].

An email newsletter helps to stay in contact with potential customers. It helps provide relevant information regarding your agricultural business and achieve a high conversion rate compared to other channels. It helps to deliver relevant updates in customer content.

By the focused newsletter content the targeted customers are currently informed about the activities and events on the farm like harvest of certain grains, vintage in the vineyards and and especially about the availability of seasonal fruits and vegetables. Of course all new extensions of the farm framework are to be communicated with appropriate attention to the potential and already regular customers. This way the market absorption capacity is widened and the steady growth of sales is supported.

Web design

Development of an e-commerce website helps to promote the agribusiness to the next level. It helps boost sales and enables prospects to explore your business offerings. It helps to display the whole range of agricultural products, agricultural accessories, food processing equipment, and many more. It is recommended that the mission and the vision of the farm, upgraded with strong slogans is visibly presented on the site as well. This way the unique image of certain agribusiness is built up. The promotion of the agri-brand through e-commerce websites represents a powerful digital tool5.

The modern website for marketing the agricultural products must include clean, focused content about the agriproducts since people visit the site to take action and not see just the web art. So the design itself is important but should not prevail. In general a site that is easy to use will have more website traffic and potentially it will boost the sales.

Content marketing

Content Marketing is a long-term strategy, which focuses on building a strong relationship with the targeted audience and delivering them high-quality content which is useful to the audience regularly

It is essential to create content that helps to address customer queries or questions to improve user engagement. It involves the creation of content assets like blogs, articles, videos, and infographics that help provoke the brand's interest in the minds of consumers. Content marketing helps to aid the SEO strategy and drive better results. It helps to educate the audience on various aspects of the agricultural sector6.

[4] Source: https://alokbadatia.com/digital-marketing-of-agricultural-products/
[5] Source: https://www.webfx.com/industries/industrial/agriculture/
[6]Source: https://thinkshiftinc.com/blog/digital-advertising-benchmarks-all-agrimarketers-should-know

It will help you generate organic traffic to your website and help enhance your business expertise. Engaging content will help to improve online visibility and rank higher in the SERPs. It will help you showcase your business expertise or skills and enable users to explore your agricultural business online. Content marketing is a core part of digital marketing and helps attract high-quality leads and drive more traffic. It is related to almost all other digital techniques like website, e-mails, videos ... and contributes to the focusing and well targeting the potential buyers of the farm products.

Video Marketing

Videos are becoming the most attractive way of marketing in the near future. Video marketing is an essential form of marketing and thus should be implemented in the field of agricultural products as well. It represents one of the best ways to promote the agri-contents[7].

Social Media platforms like Instagram, Facebook, YouTube, Snapchat, and more promote video content, and the potential clients or customers are on these platforms, which enable them to consume the video content.

The contents showing the strong sides of the farm activities and results-products can include inserts of the agri-production on the fields when using the modern machinery and technologies and up to the final products like fresh vegetables and fruits as well as vine from the sunny vineyards,

Mobile Optimization

Optimizing to mobile-friendly is one of the most crucial marketing strategy for agricultural products. In this sense the website should be adapted to its presentation on mobile phones. Especially the videos and pictures of the agriproducts have to be reconsidered design and size-wise. Mobile optimization is an integral core part of SEO services and enables the website content to be accessed by users on mobile. Optimized content flows easily through mobile and desktop services. It helps to enhance the user experience[8].

Tracking KPI data with Google Analytics

It helps agricultural businesses to determine and fragment the traffic from websites, search engines, social media, and referrals. It measures website development, website traffic for certain agribusiness. It helps a farmer to trace which farming activities, products and related commercial offers were mostly viewed and thus gives precious information on what is the most interesting subject of the potential customers. Google Search Console data, helps to fine-tune digital marketing strategies, achieves CTR, and performs better in search results[9].

It is essential to understand how users drive to the website to improve the website plan and change SEO campaigns in the long run. It helps fine-tune the areas and improve user

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[7] Source: https://alokbadatia.com/digital-marketing-of-agricultural-products/

[8] Source: https://echovme.in/blog/digital-marketing-strategies-for-agriculture-industry/#9_Mobile_Optimization

[9] Source: https://www.webfx.com/industries/industrial/agriculture/

engagement, rankings, and conversion rate. Google Analytics helps to determine the page views, advertising performance, conversion rate percentage, and a lot more.

Search Engine Optimisation - SEO

SEO is a digital marketing strategy that helps your website appear in relevant search results in search engines like Google, bringing more qualified traffic to your website. It involves various techniques, from using keywords on your pages to earning links to your site.

Implementing an effective SEO strategy optimizes your website to rank higher in the search engine results. A responsive and engaging website will help you achieve more leads, conversions, and relevant website traffic. Implement long-tail keywords to match industrial technology.

SEO is putting relevant keyword of the business and ranking a particular page on the search engine which gives your business recognition in the online market and increases you web traffic which gives your business credibility in the market and this involves a lot more effort and time to rank on top of the page but it gives you a long-term reward which will directly benefit your business in terms of sales and revenue[10].

Search engine optimization as a part of digital marketing strategy for the agricultural sector is ideal for:

- Connecting the right customers for certain agri products
- Finding the supply sources and services that correspond the needs of the farmers production
- Choosing the appropriate machinery – optimised for individual farming surfaces and other conditions
- Selecting the best financial sources and insurance services for different types of farms
- Growing market share
- Gaining authority reliability through page linking and back-linking growth
- Promoting brand recognition and enhancing brand awareness

Retargeting Adverts (aka Programmatic Ads)

When someone visits your website, they're assigned a tracker ID that will display your ads to them repeatedly when they visit other sites. You might have noticed after researching something online that you keep seeing adverts for that exact item or similar products. This is retargeting ads in action.

The average customer will namely interact with a company seven times before actually purchasing from them. By repeatedly reminding them of your amazing products and services, you're touching base with them, building that relationship - without having to put any time or effort in.

This programmatic tool is thus accelerating the process of perception of potential customers and additionally upgrades the impact of other digital tools used parallel. Of course

[10] Source: https://seodesignchicago.com/digital-marketing-industries/agriculture-marketing/

the content of such repeated messages must be precisely reconsidered in order to attract and not reject the viewers' attention. The use of this tool is recommended especially in the time of seasonal sales of different agri products like the new wine is to be advertised in late autumn and beginning of winter[11].

PPC Advertisements

Running a PPC campaign is an effective digital marketing strategy that helps to increase conversions and leads. With the help of digital marketing, modern farming equipment, which has been an evolution, can be promoted widely to people. PPC advertisements will help enhance the organic search results and enhance the rankings in SERPs. You need only pay when a user clicks on the ad in PPC advertising[12].

You can bid on various keywords or phrases so that your ad appears in the top search engine results. Digital marketing strategies can play a significant game-changer when the concern is about generating sales or leads. It helps scale up the agricultural products, thereby increasing the followers' engagement. PPC ads help increase brand awareness around 80%, and you can use online means of growing your agricultural business.

The use of this digital tool is recommended especially for the agri products that have the top sales and financial priority of certain farms and it should be implemented at the time of their seasonal peak.

Google AdWords

When most people hear 'online advertising' they think of Google AdWords - and for good reason! According to Internet Live Stats, there's around 5.5 billion Google searches per day. That's around 63,000 search queries per second. A true staple of online advertising, Google AdWords potentially gives you access to the millions of people searching for information on your industry.

The key to AdWords success is narrowing down who your ads appear to. If you sell John Deere tractors in the USA, you don't want to waste money on someone from France clicking on your ad to figure out where their nearest tractor dealership is.

Getting the best return on your investment in Google AdWords means fine-tuning who your ads appear to. You want to know exactly who you're marketing to: where they live, what they do and what they're searching for. When you can pinpoint exactly who your customers are, you can choose to target them and pay to showcase your details above your competitors[13].

This digital tool can help a farmer to find the optimal way to the most appropriate and geographically closest customers by attracting them through the placement of the right words into the AdWords system which serves the farm's offer of its agri products to the potential customers.

[11] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online
[12] Source: https://www.webfx.com/industries/industrial/agriculture/
[13] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online

Google Shopping

A sub-sector of Google AdWords, Google Shopping is a very good way of showing off your farm products to people that are searching for the big brands and names in the agriculture industry. Rather than appearing for generalised searches, Google Shopping ads are best used for specific agricultural products[14].

A great aspect of Google Shopping ads is they allow you to appeal to potential customers with more than a couple of lines of text. They show users a photo of the product produced at your farm, a title and description, a price, your store name and more. Google Shopping is a great way to promote your online and local inventory, boost traffic to your website (or local store) and outperform your competitors on Google.

Advertising on Industry Experts' Websites

For years, the agriculture industry has relied on placing ads in local newspapers, farming magazines and farming directories. With the shift from traditional to digital a lot of the places companies used to buy ad space have gone online15.

This is exactly the same premise as before, just instead of a paper ad being printed, the newspaper/magazine will add the required advert to their website.

The benefit of advertising on the websites of industry's biggest names means to have access to all of their subscribers and visitors but on the other hand the advertisement has to get noticed amongst all those other companies advertising too.

It is recommended that firstly you make a selection of the right and most experienced and successful experts for your agri products (vegetables, fruits, wine, meat etc.) and then the specialised advertisements with strong promotional content should be elaborated. If there is no sufficient knowledge at the farm itself then the appropriate external consulting advice is needed in order to implement the whole process of successful advertising.

Social Media Marketing – Creating Social Media Pages

Young farmers are still more likely to use social media to promote their businesses, but older farmers are quickly catching up. Keep farmers engaged with your company by advertising on the likes of Facebook, Twitter, Instagram and LinkedIn. Figure out where your target audience likes to hang out and implement an ad campaign on that platform.

The great thing about advertising on social media is your audience can be as broad or specific as you would like. You can hit every farmer in your region or just those in your town. You can even narrow it down to their income levels too. When you choose to advertise on social media, each platform gives you measurable and quantifiable statistics on what's working and what's not - helping you to invest your money in adverts that actually work16.

[14] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online
[15] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online
[16] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online

When creating pages for advertising on social media it should be first reconsidered which segment of potential customers is mostly using a certain media. Then their age and needs must be identified. This data should match or at least generally correspond your offer on vegetables; meat etc. so that finally the optimal and strong content and connection is established by publishing your brand on selected social media.

Promotional Item Giveaways

Essentially, a promotional item giveaway (or a free product giveaway) is where you choose to giveaway an item in exchange for people giving you their contact details (most likely on your website) or by liking and sharing your social media post. After a set period, a winner is chosen and they receive a free item.

Promotional giveaways can potentially bring you a huge amount of brand awareness. Depending on the item you choose to give away, they can continue to have a beneficial effect on your company long after you have stopped promoting them. Although the agri products have rather short time of use it is worth to include this kind of promotion into the wider promotion actions, especially those published via social media17

Things like t-shirts, bags, pens and rucksacks may enter daily use amongst your target audience. The most popular (and most shared) items are usually free products given away - but so far in the field of nutrition and farming this is relatively rare practice. This means that farmers can widely use this opportunity and stamp their brand, slogans and pictures from agri production process and final products.

7.3.2 Digital platforms

A **digital platform** is the software and technology used to unify and streamline business operations and IT systems. A digital platform serves as a company's backbone for operations and customer engagement. We live in a world that blends the real and the virtual. Nowadays, we no longer think of creating businesses that cannot be managed in these two environments.

As a result, there are many different types of digital platforms, each of which meets the different needs of its users within different contexts – **marketing and advertising**. This allows products and services to be made available digitally.

Marketing platforms are the online software or solution that help digital marketers manage their digital marketing activities.

Advertising platforms represent any online space where advertisers can monetize visitor traffic through the products or services they offer.

7.3.2.1 Marketing and Advertising platforms

In technical terms, an online digital platform can be described as a software-based "site" that enables interactive exchanges among independent parties. These platforms act as

[17] Source: https://www.agtivation.com/best-ways-to-advertise-agricultural-products-online

intermediaries or facilitators between these parties, often referred to as the "sides" of the market or platform. They are not merely technical systems or neutral arbitrators but also encompass governance structures.

For a platform to succeed, it needs to attract participants. For instance, in the agricultural sector, a company manufacturing agricultural machinery must attract farmers and app designers to create a successful platform. Platforms meet the needs of participants by providing resources and services like APIs, software development kits, payment systems, and access to a market of users. When properly designed, a digital platform can attract complementors, forming an ecosystem of organizations that operate through the platform and create value for both the platform itself and its users.

Successful platforms, whether in agriculture or other industries, grow by attracting users and service providers, triggering network effects. As the value of the platform increases, it can generate and capture more value. These network effects often result in winner-takes-all dynamics. Additionally, platform users may experience lock-in effects, making it challenging to switch to alternative platforms. Finally, successful platforms benefit from long-tail markets, as complementors offer users a wide range of choices.

As an intermediary, the platform has a comprehensive view of all activities taking place on it. The platform's power lies in its ability to "tax" ecosystem participants for using its services. This power is not necessarily negative, as the platform provides numerous benefits to those within its ecosystem. However, the ecosystem metaphor overlooks the influence wielded by the platform owner.

When a platform has strong lock-in effects, participants face difficulties in leaving the platform. Profit-oriented platforms aim to monopolize the market and extract maximum value from transactions, within the limits of preventing complementors from abandoning the platform. In agriculture, the adoption of a single digital platform could lead to significant efficiencies and various benefits, including environmental advantages.

Data generated or captured by one actor may have limited value to that actor but can be valuable to others. Encouraging actors to share their data encounters significant challenges. For instance, sharing precise farming data could expose intimate details about the generator's operations. Determining how actors will be compensated for the data they generate is a common challenge. Ownership and usage rights for data are even more complex to establish, considering that data is not static but continuously generated.

Farms generate vast amounts of data, including various types of data from farm machinery. In most cases, ownership of all the data created by the machinery is conferred to the manufacturer through contracts with farmers. While farmers may willingly share operational data for the machinery manufacturer's diagnostic purposes, they may be reluctant to share data related to their business profitability or yield, as it may not be relevant to the manufacturer.

On the other hand, marketing and advertising platforms focus on reaching a wide audience and potential customers. Participating farmers are interested in dispersing and widely showcasing technical and commercial data related to their agricultural products. However, the data published on these platforms are primarily aimed at sales purposes, lacking specific production details.

Every platform aims to attract as many users as possible, as they contribute data that initiate same-side network effects. Increasing the proportion of farmers on the platform leads to more comprehensive and valuable data, improving the accuracy of predictions. Adding other data sources like weather information, commodity prices, and remote sensing can further enhance the platform's value.

Similarly, input specifications from the chemical and seed industries could provide even greater value. For example, optimizing chemical applications or correlating yields with specific seeds could be achieved. Standardizing and analyzing this vast pool and flow of data has the potential to drive more efficient and sustainable farming practices.

7.3.2.2 Financial and environmental benefits of marketing, advertising and other digital platforms in agriculture

THE SPECTER of AGRICULTURAL AREAS COVERED:

- livestock,
- secure food,
- organic farming,
- landscape,
- publications on agriculture,
- machine-equipment,
- agricultural real estate,
- agri-tourism, agricultural software

NEW MARKETING and OTHER OPPORTUNITIES:

- services like buying, selling and advertising
- bringing together buyers and sellers by publishing the product information
- finding possible buyers and sell their products directly to them
- reaching alternative markets by bypassing traditional intermediary structures.
- enabling faster sale, with higher value and without commission
- establishing a virtual centre and marketplace to meet with other farmers, agricultural engineers, veterinarians, agricultural companies and exporters.

DIGITAL MARKETING EDUCATION OPPORTUNITIES / POSSIBILITIES:

- e-sale/e-learning/e-commerce platforms who bring farmers and buyers together
- education in e-learning and e-commerce media that meet other farmer’s needs.
- on integration of mobile phones and the internet
- education on 'how to sell agri products online’ included explaining credit card usage

PROVISION of OTHER INFROMATION:

- information on trainings on the concepts of growing products
- up-to-date information, know-how, skills and professional development
- access to the information about protecting their products in sense of intellectual property
- information on agricultural production methods and tools, plant diseases and protection, soil analysis and fertilization, solar energy in agriculture.
- information on reaching the world markets through specialised global marketing platforms

7.3.2.3 Practical cases and useful links

	Type of market-place	Description	Key interactions	Examples
PRODUCT MARKET-PLACES	1. Supplies market-place	Digital marketplace for farm supplies and inputs (Supplying seeds, herbs, vegetables and fruits) Web page as digital tool	Purchase of production inputs and farm supplies (Intermediary for agricultural production supplies)	AgroStar www.agrostar-group.com/
	2. Product market-place	Retail trading platform that connects farmers with consumers and small retailers on basis of **on-line shopping**	Sales of farm products via web shop	izyshop www.izyshop.com
	3. Combined supplies and product market-place	Digital marketplace for facilitating take-off as well as access to farm inputs (i.e., farmer sales and buys) **On-line shop** for farm supplies and SME retailers for food products	Enabling farmers, the access to markets of production inputs and farm supplies Sales of farm products – providing processed food to the world markets	farmcrowdy www.farmcrowdy.com
	4. Trading market-place	Wholesale trading platform that connects buyers and sellers of agricultural products – **on line trading platform**	Sales and purchase of farm products on basis of on-line collection of bids and enquiries	grãodireto www.graodireto.com.br

	Type of market-place	Description	Key interactions	Examples
PRODUCT AND SERVICE MARKET-PLACES	5. Integrated farm services market-place	Integrated farm support marketplace which provides a combination of supplies, production support, finance and take-off services. **Web page** that includes quotation of supporting services and products for farmers on the field of agricultural production, marketing, finance and insurance. **Communication via e-mail**, purchase of products partially through **on-line shop**	Purchase of production inputs and farm supplies Support services for agricultural production Farm finance and insurance Sales of farm products	www.limalinks.co.zm
SERVICE MARKET-PLACES	6. Farm services rental market-place	Marketplace that connects distributed asset owners and farmers to support on-farm production. Used digital tools: **web page and e-mail, also social networks**	Support services for agricultural production. A platform for hiring the mechanization for processes of farming	www.trotrotractor.com/
	7. Transport and logistics market-place	Marketplace that connects transport and logistics companies with farmers **Web page and e-mail** communication, also **includes** a **platform** with bids and enquiries on transport services	Transport of farm products	www.tanihubgroup.com
	8. Insurance market-place	Marketplace for insurance (typical multi-sector) Using a hybrid business model = mobile technology & traditional brokerage. Digital tools include **web page, e-mail and mobile applications** for concluding the insurance	Agricultural production related insurance, covering diversified types of insurance	www.gramcover.com

	Type of market-place	Description	Key interactions	Examples
PUBLIC PROCUREMENT FOR SUPPLY OF FOOD FOR PUBLIC	9. Food supplies market-place	**On-line catalogue** of food available in the territory of one state, intended for purchase by the governmental (public) institutions. Beside the offer of different agri-products It also includes all necessary data of available products, the support with measuring quantities, **advice for public procurement** etc.	Purchase of food from farmers and other suppliers of food, vegetables, fruits, meat etc. that are offering their products in the catalogue.	https://www.katalogzivil.si/ https://www.kgzs.si/novica/vabljeni-k-vpisu-v-katalog-zivil-za-javno-narocanje-2020-03-27 https://agrobiznis.finance.si/section/630/Javna-narocila-zivil

Table 7.3. Types of advertising platforms for marketing of agricultural products and services - worldwide[18]

7.3.2.4 Eager to learn more? Advertising and marketing platforms & agencies in some EU countries

Advertising and marketing platforms are online or offline platforms that businesses can use to promote their products or services to target audiences. These platforms may include search engines like Google, social media platforms like Facebook, Twitter, LinkedIn, or other media channels such as television, radio, or print media.

Advertising and marketing agencies, on the other hand, are companies that specialize in providing advertising and marketing services to businesses. These agencies may offer a range of services, including advertising campaign planning, creative development, media buying, market research, and digital marketing. They work with businesses to create effective marketing strategies that will help them reach their target audiences and achieve their marketing goals.

In the European Union (EU), there are many advertising and marketing platforms and agencies that operate in various countries, offering a range of services to businesses of all sizes. These platforms and agencies use a variety of channels and techniques to help businesses connect with their target audiences and achieve their marketing objectives.

Some useful links:
https://www.agrobridges.eu/project/airfield-estate/ - EU project
https://advertising.agriland.ie/ - Ireland
https://www.agridirect.eu/ - Netherlands
https://www.nieuweoogst.nl/ - Netherlands

[18] Source: https://isfadvisors.org/wp-content/uploads/2021/03/ISF_RAFLL_Agricultural_Platforms_Report.pdf

https://nutriman.net/farmer-platform - Netherlands
https://www.agrio.nl/home/ - Netherlands
https://gmc-marketing.eu/ - Germany
https://www.transagro.com/ - Germany
https://sabmadigital.com/fr - France
https://miimosa.com/ - France
https://www.agropress.pt/ - Portugal
https://www.portugalventures.pt/portfolio/agrimarketplace/ - Portugal
https://www.numidio.com/web-marketing-per-aziende-agricole/ - Italy
https://www.imagelinenetwork.com/portali-web-community-agricoltura.cfm - Italy
https://www.cru.agency/blog/social-media-marketing-locale-eventi - Italy
https://marketingrolniczy.pl/marketing-cyfrowy-dla-sektorow-rolnictwa/ - Poland
https://www.fwi.co.uk/mediacentre/2015/12/16/7-of-the-best-ways-to-advertise-agricultural-products/ U.K.

7.3.3 Future trends in e-commerce in agriculture

Global e-commerce sales are expected to total $6.3 trillion worldwide in 2023. This number is expected to continue growing over the next few years, proving that ecommerce is becoming an increasingly lucrative option for businesses (it also marks a 10.4% annual increase in the forecast period between 2021 and 2026). Global E-commerce of agriculture products market was US$ 9,714.6 Mn in 2021. It will reach US$ 17,308.3 Mn by 2031.

Even now, after the pandemic, with stores reopening their doors, online retail sales are continuing to rise but at a much steadier pace.

The majority of retailers who find themselves resisting e-commerce at this juncture will soon find themselves embracing it, and this is due to necessity. This will happen primarily due to the evolution of business. We need to look at the world from our customer's eyes and we will realize this trend is not going away and we can never go back to how we were.

The e-commerce will carve out a loyal following of farm customer participants and probably sooner than later. These more “transactional” farming operations will be less concerned about breaking ties with traditional retailers who currently provide application services and/or crop management expertise as the centrepieces of their product/service bundle.

Continuing their influence on the future of e-commerce, younger consumers are the main drivers behind the rise in social commerce – always seeking the technologies that will make their shopping experiences as seamless as possible.

The social commerce industry involves promoting and selling products and services using social networking sites like Facebook, Instagram, and Twitter. For example, shoppable ads, organic shoppable posts, in-app purchases via social media and social networks, shoppable influencer content, and shoppable videos and media leading to e-commerce sites are examples of social commerce. The degree and magnitude of consumer participation in the organization’s marketing through likes, retweets, and shares determines the overall effectiveness of a social commerce effort. Social commerce has become popular recently (as per the study published on

Twitter, 97.2 million people purchased through various social networks worldwide. In 2021, social commerce sales in the United States of America were expected to increase to USD 36.62 billion, with more than a 35% increase19).

In 2022, it was expected that the global social commerce market will grow by 23% to reach $585 billion20, with on average around 30% of 18–34-year-olds having already made at least one purchase through social media.

Because of the growing competition in the space of e-commerce, it is important for the farmers to remain ahead of the ascendant curve. To move forward, it is necessary to have a strong understanding of the trends, challenges and opportunities within e-commerce. The top agri e-commerce trends include:

- **The growth of online sales**. Online shopping continues to grow in popularity. Websites are more customer-friendly than ever and the trust of buyers in online transactions is higher than ever.

- **An increase in mobile shopping in agriculture**. Data shows that sales made via mobile devices has increased by 15-percent since 2016. By the end of 2023, it is projected that more than 80-percent of e-commerce sales will take place on mobile devices. Improving e-commerce strategies to strengthen mobile components is a large opportunity for future growth.

- **The shift in the role of social media**. Social media is rapidly becoming a favourite tool of online shoppers. Agribusiness brands now have the opportunity to revitalize their social strategies to increase the chance of being viewed by their target audience. There are now tools to link online stores with social media sites and the technology will only become more user-friendly.

- **Environmental concerns drive buying decisions**. Green consumerism is on the rise across all industries and the calls for sustainability and traceability within agriculture have never been stronger. Online agribusinesses must now put safe, sustainable practices at the forefront and demonstrate their commitment to environmental responsibility.

- **Making a commitment to personalization**. A personalized online shopping experience will improve customer satisfaction and create brand loyalty. E-commerce sites are already committed to this truth and have employed a variety of personalization tactics to improve the customer experience.

[19] Source: https://www.strategicmarketresearch.com/market-report/social-commerce-market

[20] Stephanie Chevalier, *Social commerce revenue worldwide 2022-2030*, published on Statista, September 16, 2022.

- **Increasing use of digital payments.** Restrictions on meetings and social distancing measures have accelerated smallholder farmers' openness to digital payments, as well as consumer use of online payments.

7.3.4 Future market opportunities

The pandemic COVID-19 has created a stimulating environment for many companies. The pandemic has enhanced changes in consumer behaviour and opened new markets for agricultural e-commerce platforms. E-commerce has increased the resilience of supply chains, and e-commerce models are predicted to continue to grow post-pandemic. Agricultural e-commerce players are seeking to retain these new customers by gaining consumer trust, ensuring seamless and hassle-free online experiences, and delivering on their promise of quality products. Investors have the opportunity to help companies capitalise on these changes and growing demand by providing them with investments that will enable them to overcome the challenges they currently face. These include: Logistics, warehousing and the development of consumer-facing platforms to increase customer loyalty COVID.

Food E-commerce is growing at a staggering pace in most Member States of Europe. A new market has formed, offering all types of food (ever-increasing variety of food supplements is being made available). These include products that regularly raise serious health concerns. There is an opportunity to significantly improve the enforcement of EU food chain legislation in online sales through much closer cooperation between food control authorities, responding comprehensively to the challenges of the borderless online world (DG SANTE, 2020).

The Commission proposes few actions to improve the enforcement of EU food law in online food sales and to explore possible improvements to the current control regime. This will allow consumers to buy food online with a high level of safety and increase consumer confidence in e-commerce, as well as promote information to consumers and food chain actors. The measures are:

- training for the staff of food control authorities through 'Better Training of Safer Food' programme
- web shops and traders on e-platforms which are officially controlled
- have been established and collaboration reinforced for food control authorities of MS with all major ePlatforms offering food (eBay, Amazon, Alibaba, Facebook) and some Payment Service Providers (PayPal, Mastercard) (DG SANTE, 2020).

The European Union has allocated 182.9 million euros for the promotion of EU agricultural and food products inside and outside the Union (EC, 2020). This policy aims to strengthen the competitiveness of the sector by taking advantage of the development of global agri-food markets and drawing attention to the high standards in agriculture in terms of sustainability and quality.

Farmers can sell: fruits and vegetables, dairy products, meat and seafood, bakery products, organic food products.

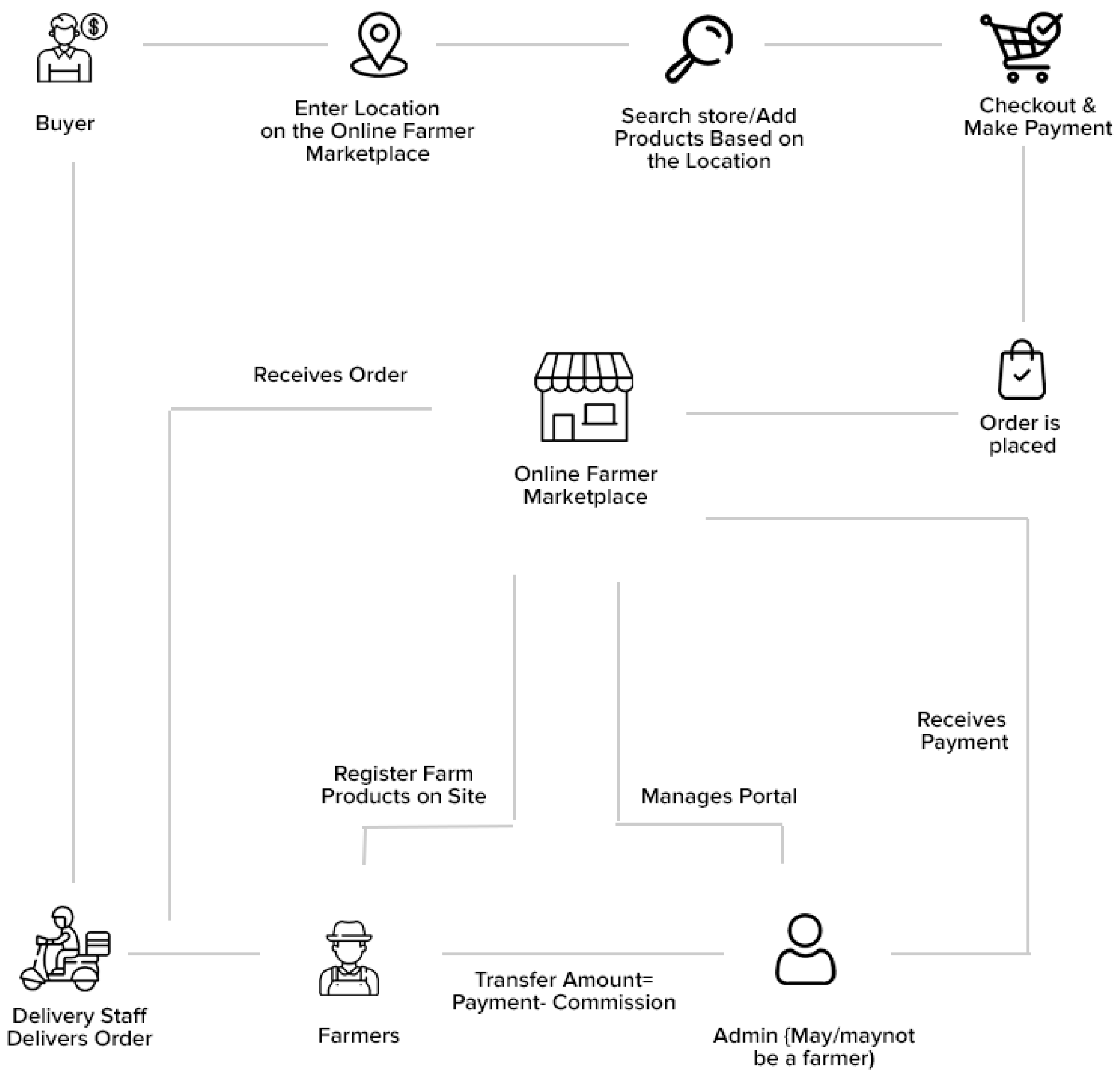

Figure 1: Business Model of an online farmers' marketplace

This model can be used for fresh products and other items (grains, spices, tea, coffee) because it links producers directly to markets or the buyers.

After the collection of agri-products from the fields, the farmers need to take care about marketing and distribution steps. Farmers and buyers are connected through the widespread use of mobile phones or PCs. This solution enables direct communication between customers and sellers, as well as simple and quick purchase and delivery processes. While not all farmers and buyers have access to the internet, most of them have a phone, and e-commerce platforms try to facilitate the communication process.

Regarding farmers, there will be 3 categories:

- family farming, where social media, e-commerce and marketing are done at a basic level, depending on everyone's knowledge.
- medium organizations, where there is the possibility of higher financial resources and then also the possibility of hiring a man to do a little bit of each in order to increase the brand and position it on the market.
- large organizations, where there is a whole marketing department, experts in social media and e-commerce, who will dictate both the trends in the online agri areas, as well as the increase in their sales.

At the level of teaching staff, these digital transformation trends and access to them depend a lot on the developed educational system, but also on the environment they come from. But the estimate is that in no more than 10 years, all teachers will use digital tools to the greatest extent, both for the part of the courses and for taking the exams.

7.3.5 Risks and opportunities

The spread of e-commerce is an important factor to develop the economy, as it has helped to increase the efficiency and productivity of enterprises and bring benefits to consumers. E-commerce is developing rapidly and has penetrated almost all sectors. Agriculture is identified as being promising due to its high level of fragmentation. This new reality can effectively promote the development of the rural economy. On this basis, it is discussed about the advantages and disadvantages of agricultural e-commerce and agri-food marketplace.

The main benefits of e-commerce platforms are different for farm-managers as for customers.

farm-managers	*customers*
*To increase the incomes of enterprises through online sales (spread of electronic transactions, reduction of deliveries of raw materials and semi-finished products, fast delivery of information to customer) *To enable smoother communication and better experiences *Competitiveness has also been positively influenced by the impact of e-commerce: geographically distant companies can easily compete with local companies. *To boost the circulation of agricultural products and development, *To promote market transparency and price discovery. *Market Outlet Diversification: different products have different traffic period and if you have product availability year-round, it also offers a stable presence	*Product Details and Suggestions: detailed descriptions and photos for each products are always available on the e-commerce platforms *Convenience to visit the website when the customers don't have the time

Table 7.4. The main benefits of e-commerce platforms

Now, some disadvantages / defects / challenges if you would like to be the owner of Agro E-Commerce:

- not establish a relationship with the customer (Customer relationship management provides an opportunity to create loyal e-commerce consumers who make repeat purchases),
- some delay in receiving the item, risk of fraud,
- Attracting Customers (optimized web presence with a strategy for driving consumers from social media, email, and other promotions to your website and online store),
- Product Compatibility (Some products may not be suitable for online shopping: especially if delivery is the only way to get the product to the customer).

Action 23: The enforcement of EU agri-food legislation on internet sales and consumer information (new May 2017). Available at: https://futurium.ec.europa.eu/en/egovernment4eu/actions-dashboard/action-23-enforcement-eu-agri-food-legislation-internet-sales-and-consumer-information-new-may-2017?language=it

https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2436

HINTS for EDUCATOR

- focus on the e-commerce situation in the Member States and some information on Turkey: European E-Commerce Report 2022 - https://ecommerce-europe.eu/wp-content/uploads/2022/06/CMI2022_FullVersion_LIGHT_v2.pdf
- farm advertising and consulting services for agricultural businesses https://seodesignchicago.com/digital-marketing-industries/agriculture-marketing/
- 20 must know off-page SEO Techniques for 2023 https://echovme.in/blog/off-page-seo-strategies/
- 10 Essential Digital marketing Strategies for Agriculture Industry – optimization https://echovme.in/blog/digital-marketing-strategies-for-agriculture-industry/#9_Mobile_Optimization

7.4. Conclusions

When agriculture first took root around 12,000 years ago, it triggered a change in how people lived. Dubbed the "Neolithic Revolution", the promise of a reliable food supply enabled humans to give up their nomadic hunter-gatherer lifestyles. Out of these first settlements grew cities and complex civilizations, shaping the world as we know it. Agriculture has allowed the human population to grow explosively, and its industrialization over the past two centuries fuelled the jump from 1 billion to nearly 7.7 billion people. As a result, agriculture in its modern form has tested the limits of our environmental resources.

With a projected 2 billion more mouths to feed across the world by 2050, agriculture needs to simultaneously become both more productive and sustainable. That requires increased investment and adoption of productivity-boosting and other digital technology as well as the participation from young people and smallholder farmers.

As a primary sector that employs millions of people directly and throughout the supply chain, agriculture has lagged behind many other sectors in digitalization and application of digital technology. Luckily, however, it is not too late to catch up, but the sector needs more investment, more new ideas and greater participation.

One of the most important things with digital marketing is that the landscape is always changing, and it never gets less competitive. That's why it is recommended to consult with people who are highly specialised in digital marketing.

A new market has formed since food e-commerce is growing at offering all types of food which represents an opportunity to significantly improve the enforcement of EU food chain legislation in online sales through much closer cooperation between food control authorities, responding comprehensively to the challenges of the borderless online world. The EU food law will allow consumers to buy food online with a high level of safety and increase consumer confidence in e-commerce, as well as promote information to consumers and food chain actors.

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https://www.strategicmarketresearch.com/market-report/social-commerce-market
Stephanie Chevalier, Social commerce revenue worldwide 2022-2030, published on Statista, September 16, 2022

CHAPTER 8

Digital Traineeships Methodologies

CHAPTER 8 Digital traineeships methodologies

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WHAT WILL WE LEARN IN THIS CHAPTER?

What are methodologies / tools to implement digital traineeships?
What documents / websites are useful for a digital traineeship?
What are the benefits and barriers?
Some advice and recommendations

Keywords: digital traineeships; digitalisation, virtual work environment; trainee; supervisor; digitalisation.

8.1. Methodologies and tools on how to implement digital traineeships in agriculture

Digital traineeships (or e-traineeships) represent other work integrated as well as work-applied learning and skill development opportunities that create additional occasions (Debora Jeske and Carol Linehan, 2020). The goals are to increase learners' experience/skills with the process and techniques, values-based (e.g., confidence, teamwork, and independent learning) skills for their career (Hruska, Amy M., Alison Cawood, Katrina M. Pagenkopp Lohan, Matthew B. Ogburn, and Kimberly J. Komatsu. 2022. "Going Remote: Recommendations for Normalizing Virtual Traineeships." Ecosphere 13(3): e3961).

In addition to the flexibility granted by not having to travel, the intern under this modality enjoys greater autonomy in managing their time because it is a model that focuses on results and expected goals during the period of the traineeship, rather than attendance and on premises participation.

8.2. Before digital traineeships

Before the placement, a number of indicators have been defined for the implementation of digital traineeships. Here, we define clear instructions and documentations for all stakeholders with explicit expectations, goals and objectives. These parameters were chosen:

I. learner-company matching process and competences of the learners,

II. development of the learning plan, objectives and activities,

III. methodology to prepare the trainee.

I) Here is some useful information to start the process of matching learners and company. The first step is the selection process (or recruitment candidate).

A) Promotion and Attraction: it needs a plan to disseminate the call/program through promotional channels (Online Job Offers, Social Media Campaign, Links with Universities, ask Private Sector Partners to replicate the program).

B) Candidate Review: Review of the applications to the program and make a summary. Contact candidates and schedule the first virtual interviews with HR (explain clearly the virtual selection process steps).

C) Evaluation and Selection: Meeting with Line Manager for evaluation of pre-selected candidates and choosing the candidates.

Tips on how to write a job post are briefly described here:

- Write the job title with an engaging lead (to include up to three of the most enticing advantages of the job: remote work, mentorship program, opportunities for professional growth);

- Introduce your company (Outline all the information a potential candidate would want to know: core company values, work culture, year of creation of the company);
- Write the job description (Include two or three features of the job position that you believe are particularly enticing);
- Spell out the top benefits (List five points describing essential reasons why someone should apply to your job);
- Include location details (two sentences describing where the job is located, if the company offers relocation or housing assistance, if the job is remote or semi-remote);
- Finish with contact and application information (include a contact email and/or phone number and define steps for the application process, hyperlink to your application page);
- Re-read, edit and post.

The International Board of Standards for Training, Performance and Instruction (https://ibstpi.org/) has been developing the standards for professionals matching process between learners and companies. It provides guidelines for the competencies that all online learners need to exhibit. Before the traineeships, the organizations could adopt the following standards:

- provide a benchmark for individual professional growth and development;
- provide a basis for employers to hire professionals with the specific knowledge and skill required to satisfy organizational demands;
- provide a clear criterion for supervisors to assess work performance of established practitioners and to assist in upgrading their knowledge and skill;
- provide organizations with elements to judge the quality of the learners' services;
- establish a basis for organizations to select and educate new professionals.

About the learners, it could consider specific competencies and standards for the agricultural and agro-technology field. Here, the checklists for the learners:

- personal competencies: personal effectiveness, integrity, professionalism, initiative, dependability and reliability, adaptability and flexibility and lifelong learning;
- "academic" competencies: critical and analytic thinking, basic computer skills, basic knowledge of the subject of the traineeship, possible experience in the agricultural field;
- workplace competencies: teamwork, customer focus, planning and organizing, creative thinking and problem solving and decision-making (Jan Roy and Diane Sykes, A Review of Traineeship Opportunities in Online Learning: Building a New Conceptual Framework for a Self-Regulated Traineeship in Hospitality, 2017).

All these skills should be included in a CV[1] created specifically for the applications present on the job platform. A job board is a website used by employers to advertise their job vacancies to job seekers. Job seekers can use job boards to search for new job opportunities in their area and profession.

By way of example, some European job search platforms are listed:

- https://eures.ec.europa.eu/index_en
- https://eurojobs.com/
- https://www.eurojobsites.com/
- http://jobs.euractiv.com/

Many companies offer virtual traineeships. When using traditional job platforms like Handshake, LinkedIn, or Indeed, virtual traineeships may be advertised as remote positions. There are also websites dedicated to promoting virtual traineeships specifically:

- https://www.parkerdewey.com/
- https://www.zippia.com/job-search/remote-jobs/
- https://weworkremotely.com/
- https://remote.co/

II) A critical first step in designing a successful virtual traineeship experience is understanding the goals and needs of the intern. This is best done through virtual discussions with the intern prior to the start of their traineeship, ideally occurring as part of the selection process (Hruska, Amy M., Alison Cawood, Katrina M. Pagenkopp Lohan, Matthew B. Ogburn, and Kimberly J. Komatsu. 2022. "Going Remote: Recommendations for Normalizing Virtual Traineeships." Ecosphere 13(3): e3961).
The next list is designed to complement a virtual experience and intersect with applied organization experience. The stakeholders will need the necessary training and resources for an optimal experience.
A Virtual Model is described here to list the main features of the work plan and objectives (Roy & Sykes, 2017):

- clear purpose and learning objectives (Letter of Commitment should outline the job specific competencies that will be assessed. The critical part: the supervisor understands the role of the intern and provides appropriate supervision and feedback about the workplace learning experience);

[1] https://www.indeed.com/career-advice/resumes-cover-letters/cv-format-guide, this is one of many websites that can help.

- clarify roles (Job description specific to traineeship and Virtual introduction of student, traineeship coordinator, and host organization supervisor);
- quality assurance (Effectiveness measures of the work experience, Evaluation mechanisms and Standards of performance);
- pre-traineeship seminar and creation of Traineeship agenda (this part is useful for discussing the themes and tools that will be used, as well as the general goals that will be achieved. This can be conducted by telephone, Skype, virtual conference system or via webinar).

III) We would like to show a few steps for conducting a successful virtual traineeship program.

1. Understand everyone's goals and needs: by matching the needs of the interns with what can feasibly be offered by the advisors, a more fulfilling experience can be created for all participants.
2. Create clear expectations for all participants: the advisor should be clear about working hours, frequency of advisor–intern checks, times for quick consultations, communication platforms.
3. Develop a clear plan for virtual projects in advance and a schedule of project deadlines should be developed with the interns at the beginning of the traineeship.
4. Ensure a positive mentoring experience: by promoting a friendly research environment encouraging comments and questions from the intern (having a mentor can make a difference in the speed of the intern's adaptation to their new role, to the area, and to the company). Traineeships focus on providing knowledge, skills, and work experience for a specific job role needed to perform the tasks. On the other hand, mentoring also focuses on interpersonal skills such as leadership, commitment, etc., preparing students on an individual level. It is very important to make a focus on the role of the mentor:
    - Initial Mentoring (Introduce the trainee to the team and make sure the intern is comfortable with all tools/equipment related to the virtual job);
    - Continuous Mentoring (mentor designates the frequency of mentoring throughout the program according to its duration to verify performance, support the intern in the learning process, support needs, issues, questions related to tasks and objectives);
    - Final Mentoring (feedback on intern's results and performance).
5. Create a virtual work environment: can be created through the variety of virtual platforms now available, including virtual meeting spaces, cloud document sharing and storage, and messaging applications (virtual work environment, advisors, interns, and collaborators can share important documents, create schedules, and meet virtually).

6. Provide virtual training: advisors should consider the best methods to provide interns with the learning experiences necessary to develop and master a given skill (e.g., one-on-one virtual meeting, prerecorded materials, and written protocols).

7. Create in-person opportunities when possible (in-person activities, scientific conferences, conference travel opportunities)[2].

   Here are some useful tips to make the digital apprenticeship as effective as possible:

- the organization's policies and procedures will be disseminated to the student prior to initial contact among all parties,
- at student's first day at work, the host organization supervisor, the student and the traineeship coordinator need to have a live meeting,
- the host organization will implement the performance evaluations which students need to understand (the students will evaluate the experience via these forms and checklists).
- the supervisors have to keep aspects such as geographic separation, computer-mediated communications, experiences, and level of knowledge. If the supervisors consider these factors, it will be easier to create a positive experience.
- create a virtual work environment.

8.3. During digital traineeships

At this stage we want to emphasise the importance of: tools and techniques that can make the digital traineeships effective, parameters that can be used to monitor the progress of activities and the level of completion.

It is very important Identify the existing problems during the traineeship period and take action to eliminate them. Improving them will facilitate the achievement of educational goals and training skills and improve the quality of the agricultural sector.

Portfolio could be a tool that helps mentors and trainees in self-regulated learning. It shows documentation about: trainee's abilities and learning process, evidence of learning and achieving success, medium or long-term perspective about tasks and objectives. One of the most important and common uses of the portfolio is to develop self-assessment skills, assessment (with the aim of formative and summative assessment), showing current successes and academic advancement of learners, improving thinking skills and learning strategies, and selecting and validating competencies (Moeinzadeh F, Ayati SHR, Iraj B, Mortazavi M, Vafamehr V., 2021).

For example, the mentor can record the results of the tasks he has in common with the trainee, he can check the trainee's performance, they can plan and prepare activities (it is a real system for monitoring and evaluating the activities of interns).

[2] Hruska, Amy M., Alison Cawood, Katrina M. Pagenkopp Lohan, Matthew B. Ogburn, and Kimberly J. Komatsu. 2022. "Going Remote: Recommendations for Normalizing Virtual Traineeships." Ecosphere 13(3): e3961.

The portfolio-documents were developed for task evaluation and feedback sharing by trainees. This set of documents is based on different means: monitoring documents, evaluation documents and activities implementations documents. The table summarises the documents mentioned above.

MONITORING DOCUMENTS	***EVALUATION DOCUMENTS***	***ACTIVITIES IMPLEMENTATION DOCUMENTS***
Interviews (some useful questions must be defined in order to understand possible new needs, numerical feedback, degree of professional behaviour, opinions regarding activities); a virtual instructor facilitated discussion board (virtual blog for students to record experiences in public forum, virtual diary and logbook that are private between student and supervisor).	Intern's status (duties/tasks of job, employment status, registration of the intern's absence) tracked virtually Satisfaction test accuracy within the schedule; Interoperability and Sharing Information; Ability to analyse) Presentations on LMS allow learners to develop learning materials and present them in a virtual classroom. After presenting the topics, colleagues can provide comments and suggestions to improve online learning.	Virtual components diaries (host organization supervisor can track daily or weekly activities of the intern); Simulators: the power of video and simulations can help when there is difficulty learning from printed material. Simulations imply better knowledge retention because they are dynamic and inclusive.

Table 8.1. Useful documents to implement a digital traineeship

All the virtual activities that are mentioned in the table can be organised using different software or technological resources. For example:

- Face-to-Face Communication: GoToMeeting, Zoom, FaceTime, WebEx, Zoho
- Other communication tools: Slack, Email, Instant Messenger
- Free Project Management Tools: Asana, OpenProject, nTask, Monday
- Online file sharing: DropBox, Box, GoFile

Here are some useful tips to make the digital apprenticeship as effective as possible:

- the student and their supervisor (together and individually) will need to meet with the instructor,
- the engagement section of the plan will be a virtual component so that the student and the manager can easily insert the activities of the student (daily and weekly tasks),

- all the stakeholders will maintain a journal or log of activities. The student should also keep a reflective journal of their thoughts and experiences[3].

8.4. After digital traineeships

Finally, for the closure of the digital traineeships you should consider: certificates to evaluate the skills learned, self-assessment for students, post traineeship seminar and similar documents/events. Students will be asked to share their thoughts and experiences by building a virtual wisdom network. Finally, stakeholders will be interviewed so that the program can be continuously improved. The following list shows some recommendations for concluding the traineeship correctly and usefully for both parties (company and trainee):

- reflective paper: virtual blog useful to share feedback and reflections and also private diary reflection;
- evaluation certificates signed by supervisor and hosting organization;
- surveys and online questionnaires for students to share reflections and recommendations (the students will be asked to evaluate the organization and also the experience or ask for feedback to revise and optimize the approaches for next projects and students);
- exit interview: to discuss experience and receive more and specific feedback about supervisor's job performance (some topics to talk about: non-technical skills and hard skills, resume updating, reference letter, etc.).

At the end of the experience, all parties should evaluate each other and provide feedback on the challenges and successes of the online training. This feedback can be used to improve the operation of the program and for the ongoing professional development of trainees.

Students, and educators are increasingly becoming accustomed to online education and remote working modes, virtual traineeships are a good way to access talent across different countries before potentially recruiting them into research positions on-site. This has implications for future collaborations as past work has shown that 90% of interns who successfully completed virtual traineeships expressed an interest in taking on future virtual traineeship or career options[4].

Reference

https://www.indeed.com/career-advice/resumes-cover-letters/cv-format-guide , this is one of many websites that can help.

Hruska, Amy M., Alison Cawood, Katrina M. Pagenkopp Lohan, Matthew B. Ogburn, and Kimberly J. Komatsu. 2022. "Going Remote: Recommendations for Normalizing Virtual Traineeships." Ecosphere 13(3): e3961.

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[4] Jeske D, Axtell CM. Effort and Rewards Effects: Appreciation and Self-Rated Performance in e-Traineeships. Soc Sci. 2017; 6:1–14.

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CHAPTER 9

Conclusions

CHAPTER 9 Conclusions

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WHAT WILL WE LEARN IN THIS CHAPTER?

Which digital tools are used in agriculture?
What are the benefits of digital technologies used in agriculture?
What are the challenges of digital technologies used in agriculture?

Keywords: Information and Communication Technology (ICT); Cloud computing; Extended Reality

9.1 Glossary and abbreviations

Information and Communication Technology (ICT)	ICT is the storage of collected information, the transmission of stored information, the development, transmission, and management of information using computers[1].
Cloud computing	Cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the internet ("the cloud")[2].
Simulation	A model is used for simulation, and the model represents key features or behaviours of the selected system or process. Simulation represents the evolution of the model over time and computers are used to run the simulation.[3]
3D printing	3D printing or Additive manufacturing refers to the processes used to create a three-dimensional object of any desired shape and geometry using a wide variety of materials.
Extended Reality	Extended Reality (XR) is a term that encompasses all of augmented reality (AR), virtual reality (VR) and mixed reality (MR).
Metaverse	The Metaverse is a network of 3D virtual worlds focused on social and economic connections. Components of Metaverse technology are now available in online video games.

Table 9.1. Glossary and abbreviations

[1] https://unesdoc.unesco.org/ark:/48223/pf0000186547

[2] https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-cloud-computing

[3] J. Banks; J. Carson; B. Nelson; D. Nicol (2001). Discrete-Event System Simulation. Prentice Hall. p. 3. ISBN 978-0-13-088702-3.

9.2 Competence map

This "Competence map" illustrates the notions, information, skills that learners will acquire through reading and studying the chapter.

The first column indicates practically what will be the results/outputs related to this chapter, the second column indicates the skills that will be possessed after reading the chapter. The 'Duration time' column gives a value regarding the time it takes to study the entire chapter. Finally, the means that are used for the dissemination of knowledge and learning outcomes are listed in the fourth column.

Learning outcomes	*Competences and skills*	*Duration time*	*Learning tools*
• Become familiar with the • benefits of digital technologies used in agriculture • Understanding the challenges of digital technologies used in agriculture	• to explain challenges of digital farming • Learning the benefits of digital tools and applications	PER MOOC	Printed materials Online materials Videos Field applications Digital traineeships

Table 9.2. Competence map

9.3 Introduction

The ***Digital Farmer project*** is created to empower the VET trainer and develop new methodologies and content for digital traineeship in agriculture, including new and innovative technologies. You have completed one of the manuals of the Digital Farmer project named "Digital Traineeship in Agriculture" in this section.

Technology is developing in an unpredictable manner, and it affects everything from daily human life to space technologies. Information and communication technology (ICT), big data, robotics, simulation, blockchain technologies, artificial intelligence, machine learning, Internet of Things, augmented and virtual reality applications, and cloud computing can be listed as some applications of innovative technology in all areas of life. Technological developments bring global and radical changes. At the same time, these technologies have a great impact on vocational education and lifelong learning, also. Vocational education is the education that provides the individual with knowledge, skills and work habits related to a particular profession in business life and develops the individual's abilities in various aspects4.

Today, flexible education systems that encourage thinking and planning, open to individual development, and encourage teamwork and entrepreneurship need to be developed, and existing systems need to be updated.

The "***Digital VET Trainer in Agriculture***" manual was created within the scope of the ***Digital Farmer*** project. This manual includes a theoretical introduction of the topic covered EU policies and recommendations, pedagogical principles underlying the importance of the topic, fields of application, and some capacity-building methodologies and tools to improve teaching effectiveness in the relevant field of application such as self-learning materials, teaching and assessment platforms, references to deepen knowledge.

As a result, digitalization is currently one of the most important trends in the world, as it can be systematized individually, organizationally, industrially, and socially. When applied to agriculture, digitalization is particularly effective in increasing productivity as it enables precise mechanization, automation, and improved decision making[5]. In order to include all these innovative technologies, the ***Digital Farmer*** project has been developed to strengthen the vocational education trainer and to develop new methodologies and contents for ***Digital Internships in Agriculture***. This manual consists of 7 sections except Conclusions:

Chapter 1- Introduction focuses on digitalization in agriculture, digital tools, Industry 4.0, Agriculture 4.0, and digital agriculture education. It includes links to digitalization in agriculture and provides a brief overview of the concepts of digitalization in agriculture used globally, the importance of digitalization in agriculture, its advantages, opportunities, and the obstacles.

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[4]Ilkan, Cevat ve diğ., (2001) Mesleki ve Teknik Eğitimin Esasları, Nobel Yayın Dağıtım, Ankara

[5] Fielke, S., Taylor, B., & Jakku, E. (2020). Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. *Agricultural Systems*, *180*, 102763.

Chapter 2- Decision support system as a key component of sustainable agriculture includes a general overview of the DSS. The chapter has also the development of DSS, how DSS are used in agriculture, main functions of a DSS, and types of DSS sections. The use of DSS for nutrient management, insect and pest management, water resources management, and livestock management is explained. Additionally, some of the most successful DSS available on the market are described.

Chapter 3- Blockchain Technology discusses the technological opportunity for the agricultural sector to transform is discussed to ensure data integrity and prevent tampering, avoid single points of failure, and improve the agri-food value chain. It includes types and applications of Blockchain technologies in agriculture, food chain, food safety, and food integrity.

Chapter 4- Information and Communication Technologies provides an overview on Smart farming, Precision Agriculture, Agriculture 4.0, the financial benefits of ICT technologies in agriculture, and the environmental benefits of ICT in agriculture. The Internet of Things (IoT), Cloud, Edge and Fog Computing, Edge computing and IoT, Big Data, Artificial intelligence (AI), Augmented reality and Virtual reality, the 5G technology, and communication between sensors and actuators described in detail in this chapter.

Chapter 5- NIR and Drones explains image processing applications, drones, and theirs benefits for digital farming. Near infrared (NIR) phenomenon, normalised difference vegetation index (NDVI), unmanned aerial vehicles (UAV), remotely piloted aerial systems (RPAS), drone types, and drones' applications in smart farming are discussed in the chapter.

Chapter 6- Farmbot includes sensors and unmanned vehicles used in agriculture. Sensor definitions are made in this section, and after the introduction of sensors used in agriculture, unmanned aerial and land vehicles, aerial boats, robots, and robotic arms are explained in detail.

Chapter 7- e-Commerce Software, Marketing and Advertising Platforms describes e-commerce software, marketing and advertising platforms, and their usage and potential. The channels that can be used for e-commerce in agriculture are explained in detail in this chapter.

Chapter 8- Digital traineeships methodologies represent other work integrated as well as work-applied learning and skill development opportunities that create additional occasions.

This chapter is a combination of all chapters and summarizes all of them.

9.4 Which digital tools are used in agriculture?

Digital agriculture/farming includes everything a farmer needs from field management to finance and becomes more predictive so that better results can be achieved by the farmer. Digital tools can help farmers make year-to-year assessments and predictive analytics when making decisions, by analysing satellite images and other data captured throughout the year.

These tools enable farmers to proactively move from "wait and see" to "plan, monitor, adjust and maximize" and improve their business[6].

In the first use of digital agricultural tools, the objectives were[7]:

- make farmers' life easier (GPS guidance, herd monitoring sensors)
- help them optimize their farming practices at the environmental level (connected weather stations, crop models used to optimize input use)

Thanks to the increase in traceability and the development of social networks, farmers and producers have also strengthened their ties with the consumer[7]. We can list the most used digital agricultural tools currently as follows:

1. Robots: Small robots that can move under the canopy can facilitate seeding, diagnostics, site-specific fertilization, and mechanical weeding to reduce pesticide usage. Robotics in farming represents a global market of over $5 billion and is projected to double in the next five years[8]. Such machines, called "farmbot/agribot", are produced in many shapes and sizes by a variety of companies. You can find detailed information on the subject in Chapter 6.

Figure 9.1. A robot application in agriculture[9]

[6] https://www.globalagtechinitiative.com/digital-farming/with-digital-agriculture-farmers-become-proactive-not-reactive-decision-makers/
[7] https://www.europeanscientist.com/en/features/digital-agriculture-new-tools-for-science-on-the-farm/
[8] https://www.forbes.com/sites/forbestechcouncil/2022/04/26/10-digital-technologies-that-are-transforming-agriculture/?sh=3848606e7baf
[9] https://www.automate.org/blogs/agricultural-robots-the-future-of-job-creation

2. IoT and Sensors: They are tools of great value in many areas such as tracking products and livestock and detecting growth and health problems, real-time monitoring of the environment and products within the farm and monitoring the supply chain years[8]. You can find detailed information on the subject in Chapter 4 and Chapter 5.

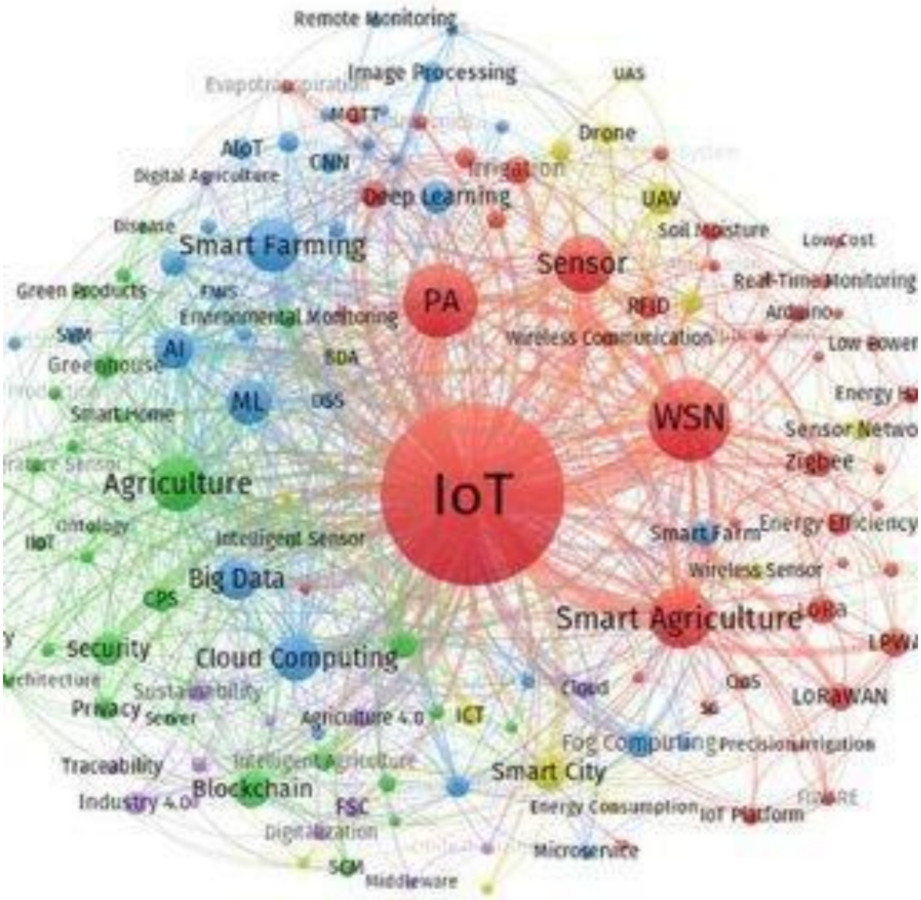

Figure 9.2. Schematic of IoT applications in agriculture [10]

Figure 9.3. Evaluating moisture content with soil moisture meters[11]

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[10] https://www.researchgate.net/figure/Keyword-co-occurrence-network_fig4_362088066
[11] https://www.flickr.com/photos/iita-media-library/7637264088

3. Artificial Intelligence (AI): While purely data-driven approaches will struggle to make a decisive breakthrough in agricultural decision support, artificial intelligence, as a combination of data-driven approaches and mechanical models, will lead to the change of agriculture-related professions[8]. AI can help farmers to produce the additional requirement of agricultural products. Crop disease, lack of irrigation, water management, the effect on the environment, low output, and improper soil treatment can be solved by the applications of AI. You can find detailed information on the subject in Chapter 4.

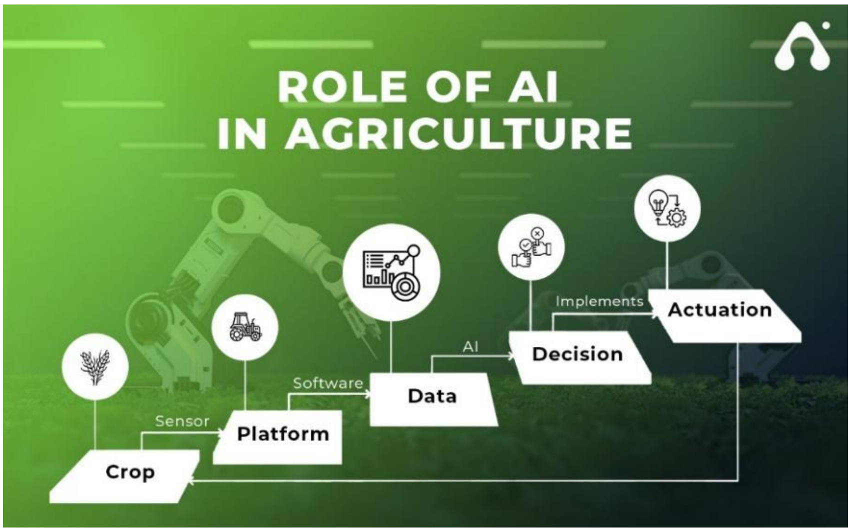

Figure 9.4. Role of AI in Agriculture[12]

4. 3D Printers: 3D printing, or Additive manufacturing, is a technology that is finding applications in almost all industries across the world. 3D printing is an emerging technology and is currently used for mainly developing prototypes. By offering the opportunity to manufacture parts for agricultural machinery and infrastructure, 3D printing has the potential to increase the efficiency of farm operations and produce essential products for the supply chain[8, 13].

[12] https://www.appventurez.com/blog/how-ai-is-transforming-agriculture-industry
[13] https://agrifutures.com.au/wp-content/uploads/publications/16-034.pdf

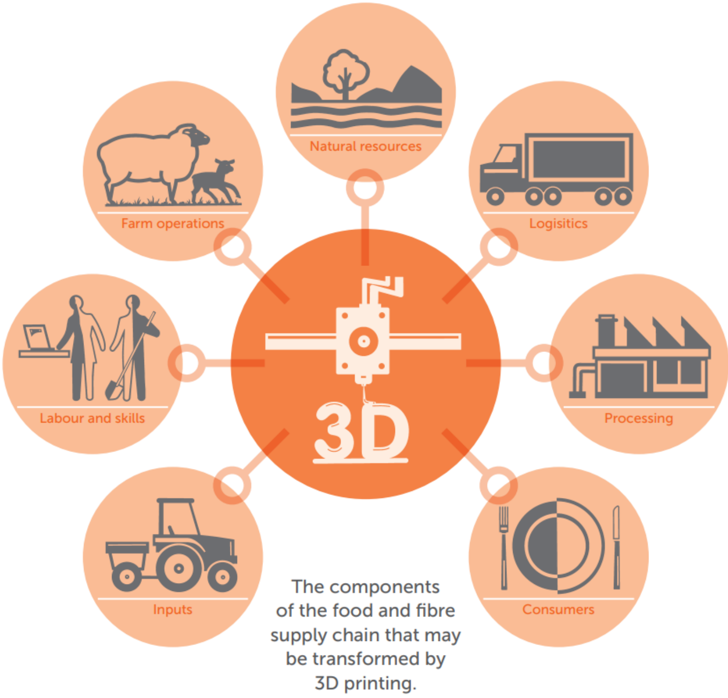

Figure 9.5. 3D printing, farm operations and the supply chain relationship[13]

5. Drones: Drones provide real information on pest control, fertilizer and pesticide application, irrigation and harvest timing, with the ability to see things that are not easily observed from the ground. In agriculture, drones can be rented or purchased per service and deployed on farms[14]. You can find detailed information on the subject in Chapter 5.

Figure 9.6. Spraying drones[14]

6. Extended Reality and The Metaverse: Extended reality (XR) applications can enable seeing with a wider spectrometer than visible light. This can be valuable in managing crops, animals and food production and contribute to the potential to improve health and food safety practices[8]. You can find detailed information on the subject in Chapter 4.

[14] https://www.cropin.com/digital-farming

Figure 9.7. Spraying drones[15]

7. Blockchain: Supply chain management in agriculture is more complex than other supply chains, as agricultural production depends on factors such as weather, pests, and diseases that are difficult to predict and control. Blockchain technologies can track any plant-related information, from the quality of the seed to how the crop is growing, creating a record of a plant's journey after harvest. Thanks to this data, the transparency of supply chains increases, and the problems associated with illegal and unethical production can be reduced[16]. You can find detailed information on the subject in Chapter 3.

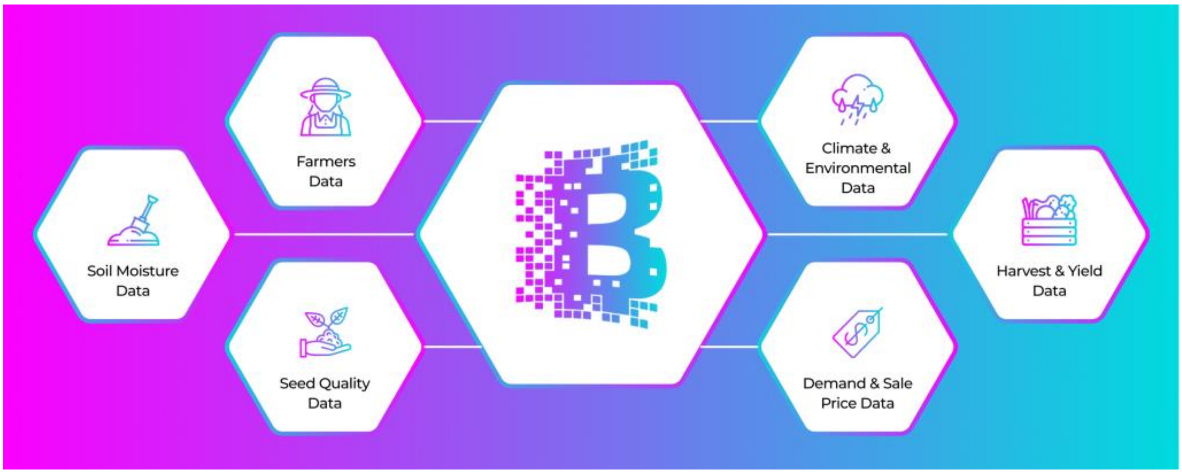

Figure 9.8. How Blockchain works in Agriculture[17]

8. E-commerce: Agricultural e-commerce, which buys and sells goods and services over an electronic network, offers agricultural producers and farmers an opportunity to streamline the agricultural value chain and reduce inefficiencies in the distribution of farm products. It provides new marketing and advertising platforms for farmers to sell their produce

[15] https://www.visartech.com/blog/how-virtual-and-augmented-realities-help-agriculture/
[16] https://www.edengreen.com/blog-collection/blockchain-technology-in-agriculture
[17] https://www.towardsanalytic.com/blockchain-in-agriculture-the-four-progressive-application-cases/

to a range of buyers, including agribusinesses, retailers, restaurants, and consumers[18]. You can find detailed information on the subject in Chapter 7.

Figure 9.9. E-commerce[19]

9. Cloud Connectivity: Cloud-based computing services use real-time internet connections. It is an information technology through which users can access shared pools of configurable system resources. There are good examples on data sharing and cloud-based applications to provide information and decision support to farmers using machinery data, satellite images, climate information, and data entered by the users[20]. You can find detailed information on the subject in Chapter 2 and Chapter 4.

Figure 9.10. Cloud computing in agriculture[21]

[18]https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/05/E-commerce_-in_agriculture_new_business_models_for_smallholders_inclusion_into_the_formal_economy.pdf

[19]https://www.businessworld.in/article/E-Commerce-In-Agriculture-Marketing-A-New-Frontier/04-10-2017-127543/

[20]https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_digital-tools-nutrient-management_final-report_2022_en.pdf_0.pdf

[21] https://www.sourcetrace.com/blog/cloud-computing-agriculture/

9.5 Benefits of digital technologies used in agriculture

When digital tools that are used in agriculture and have the potential to be used in the future are examined, in a summary, the use of digital technologies in agriculture can bring several benefits[22]:

1. Improved economic and environmental performance: Farmers using digitalization;

- can make better their decisions,
- can optimize their operations,
- they can earn higher profits due to increased productivity,

and

- all this could lead to a more sustainable agricultural sector.

2. Environmental protection and sustainability: Through the use of digital technologies and precision farming techniques;

- resource usage can be optimized,
- waste can be reduced,
- the environmental footprint of farmers can be reduced.

3. Improved and expanded working conditions for farmers: Digital technologies can help farmers have better working conditions by reducing their physical and mental workload.

4. Competitiveness of the EU digital supply industry: Digitization can help the European agriculture sector remain competitive in the global market, with innovative solutions and new business opportunities.

5. Increased transparency of the supply chain: Digitization helps consumers make more informed choices by increasing the traceability of agricultural products.

In addition, many more advantages that come with digital agriculture can be listed as follows[23]:

6. Streamlined Communication: Agricultural data can be easily collected in the field with mobile computing solutions and technologies. Collected data can be instantly sent to farm management and other supply chain partners.

7. Effective Monitoring: Technology can create solutions that allow farmers to better monitor the health of their crops;

- surveying fields with drones,

[22] https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture

[23] What is Digital Agriculture and What Are the Benefits? https://www.advancedmobilegroup.com/blog/what-is-digital-agriculture-and-what-are-the-benefits#:~:text=Digital%20agriculture%20is%20the%20integration,data%20collected%20in%20this%20sector

- assessing soil quality
- planning seed planting models
- monitor and manage weed and pest activities.

8. Better Documentation: Farmers can use mobile devices to document all stages of operation when they produce food that comes to consumers' tables.

9. More Informed Decisions: Successful agriculture results from the right choices. Digital technology provides farmers with the information they need to improve their performance and make more informed decisions.

10. Saving Time and Money: Using digital technologies such as GPS technology, a farmer can more effectively organize a field and increase productivity and reduce costs.

9.6 Challenges of digital technologies used in agriculture

Of the tools and applications mentioned above, farmers tend to choose tools that are easy to use, have a proven cost advantage, can be customized to local conditions, and reduce administrative burden by allowing them to share information with external consultants' as can be seen in Table 9.3[20].

Criteria for digital tools	Importance (Rank)
Simple, user-friendly, accessible	1
Cost-benefit (preferably free)	2
Reliable, accurate, scientifically sound, regularly updated, effective	3
Advisor-connected, direct assistance	4
Adaptable to local conditions and practices	5
Administrative documents production/Historical data	6
Compliance with law, Data security	7
Integrated management (environment, nutrients)	8
Compatible with other programmes	9
Broaden network/experiences	10

Table 9.3. Expert survey results, farmers' criteria towards digital tools[20]

Although many of smart farming technologies are becoming more widely used on large farms, with the advancement of technology and increased competition among technology providers, technology prices have dropped, or smart functions have defaulted to machines[20]. Also, with upgrade kits available from different manufacturers, it is not always necessary to purchase new machines to launch smart applications.

Despite the benefits of digital tools, there are also other several challenges that need to be addressed[24]:

Connectivity problems: Access to reliable and affordable internet is still difficult in many rural areas, hindering the adoption of digital technologies.

Limited benefits awareness: Many farmers may not be aware of the potential benefits of digitalization, as well as lack the necessary skills and resources to implement new technologies.

System interoperability: Different digital platforms that need to be used or interacted with may not be compatible with each other, making it difficult to share data and integrate different applications.

Farmers' skills: Many farmers may not have the necessary digital skills to take full advantage of digitalisation.

Benefit-cost ratio: The cost of implementing new digital technologies can be high, especially for smallholder farmers.

Reluctance to share data: Data sharing may be hindered due to concerns about data privacy and ownership among different actors in the agricultural sector.

Some Digital tools identified by experts[20]

Tool	***Description/Comment by farmer***
MarkOnline	Full-scale GIS-based Danish Farm Management Information System. Always up to date, clear output, visualisation of output.
Weather forecast	Of high revolution. From an agrometeorological station.
Fertilicalc	Application for calculating crop nutrient requirements and fertilizer amounts.
TUdi project	Tools to allow farmers, technicians, companies, and government agents to carry out strategies at farm level.
cropmanager.eu	Support system for managing nutrients and crop production.
e-mission/Element	Industry online tool to plan and track emission testing programs and trend data.

[24] https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture

FAST DSS	Decision-support system (mobile application and web-based solution). Incorporates soil data from the entire Europe.
LIFE AGROStrat tools	Strategies for the improvement of seriously degraded agricultural areas.
Farmstar	Scalable, satellite and crop model-based service that requires no investment.
N-tester/N-sensor	Quickly and easily measure the exact nitrogen requirements of developing plants, but hand-operated and thus not scalable.
Agricon/Agriport	Precision farming specialist for information-driven, knowledge-based, and automated crop production.
Verde Smart Nutritional kit	Consultancy and software applications for efficient use of water, fertilizer, and treatments.
Verde Smart Pro kit	Diagnosis of the concentration of N and K in the roots (and the leaching zone) and of balance of N and K in the plant.
Sativum	Computer development for farmers that allows access and management of information on agricultural plots.
NMP online	Online system for developing nutrient management plans for environment and regulatory purposes. Also available on the phone.
Farm Eye	Nutrient monitoring and planning application.
Manner/PLANET	Software tool that provides farmers and advisers with an estimate of crop available N, P, K supply.
SigAGROasesor	Platform with GIS support to provide customized recommendations for the sustainable management of extensive crops.
Terrazo	Web portal with maps.
NutriGuide/NutriZones	Online fertilisation planner.
Farmdok	Farm management software and digital field index.
Agrosmart	Farm process management program.
WatchITgrow	Online platform to support growers to monitor arable crops and vegetables.
Excel/Spreadsheet	Very flexible, but demands larger IT experience than farmers usually have.
BESyD	Accounting and recommendation system for fertilization.

SATAGRO	Flexible IT tool for nutrient management in the area of export to machine terminals. However, with very poor UI/UX.
Duengeportal NRW	Management of operating data, individual specialist information, implementation of fertiliser regulations.
atfarm	Tool to monitor the crop growth and to create application charts for fertilisers.
Fertimaps	Site specific application planning with the use of remote sensing

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ANNEX - A course about "Industry 4.0 for Agriculture"

01 INTRODUCTION TO INDUSTRY 4.0
- Industry 4.0: why 4.0 and what is it?;
- Definition of main components: Cyber-Physical Systems (CPS), Internet of Things, Big Data; Cloud computing; 3D Printing
- The future of automated agriculture

02 THE SIX INDUSTRY 4.0 DESIGN PRINCIPLES AND THEIR MEANING
- Interoperability;
- Virtualization;
- Decentralization;
- Real-Time Capability;
- Service Orientation;
- Modularity

03 THE MAIN TARGETS OF INDUSTRY 4.0 IN THE AGRICULTURE INDUSTRY
- Predictions based on Big Data;
- Energy efficiency;
- Real-time asset control;
- Production tracking;
- First steps necessary to make a agriculture company "Industry 4.0-ready"

04 APPLICATIONS OF THE INTERNET OF THINGS (IOT)
- The components of an IoT system;
- IoT in action: the connected farm;
- Machine to Machine (M2M) solutions;
- Consumer- and socio-economic impact

05 NEW BUSINESS MODELS FOR INDUSTRY 4.0
- Industry 4.0 requires innovative Business Models;
- The Blue Ocean strategy in the agriculture industry;
- The Virtual Farm;
- The Ecosystem;
- How ICT technologies can help;
- Supply Chain Management;
- The benefits of the connected enterprise

06 PLANT AND MACHINES SECURITY
- The challenges of an integrated environment;
- Security threats;
- Network and system security;

- Security Assurance;
- Risk management

07 FROM RESEARCH AND INNOVATION TO MARKET DEPLOYMENT
- Map out your Industry 4.0 strategy;
- Create initial pilot projects;
- Define the capabilities you need;
- Transform your idea into a digital enterprise;
- Focus on people and culture to drive transformation;
- Actively plan an ecosystem approach

08 HOW WORK IS CHANGING WITH INDUSTRY 4.0
- Creating new jobs in agriculture industries;
- Sustainability management;
- Trends in Industry 4.0

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