AI4Agri

Developing green and digital skills towards AI use in agriculture

Erasmus+

KA220-VET - Cooperation partnerships in vocational education and training

WP2: Connecting AI with Agricultural sector: current status and needs assessment

A2.1 Review on AI and Agriculture Technology

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Summary

This report, deliverable A2.1, "Review on AI and agriculture technology and analysis of farmer-driven innovations and best-practices in AI and agriculture technology'', was prepared as part of the co-funded European Erasmus+ Program, entitled "Developing green and digital skills towards AI use in agriculture'' and acronym AI4Agri. It's part of the deliverables of WP2," Connecting AI with Agricultural sector: current status and needs assessment ".

This report is a desk research and literature review in order to identify current practices, tools, and models in use at both national (in this case Cyprus) and European levels, shedding light on existing pathways towards AI integration and uncovering gaps in policies related to AI ethics and technology adoption, particularly among small farmers.

This research focus on:

1. Agriculture Policies in the EU: Analyses current EU policies related to agriculture, including any provisions for AI integration.

2. AI Policies in the EU: Examines existing EU policies and regulations concerning AI, with a focus on their impact on the agricultural sector.

3. Adaptation at National Contexts: Discusses how AI technologies are being adapted and implemented in Cyprus.

4. National Legislation Frameworks: Evaluates national legal frameworks and regulations governing AI use in agriculture.

5. AI Technologies & Applications in Agriculture Industry: Provides a comprehensive overview of AI technologies, methods, and tools currently employed in agriculture and highlights successful AI applications and their impact on agricultural productivity.

6. Pedagogical Practices and Trainings: Investigates pedagogical approaches and training programs that are addressing the digital literacy gap among agriculture workers and identify best practices and successful training initiatives.

1. Introduction

Cyprus is the third largest island in the Mediterranean, with a total area of 9251 km^2 and intense mediterranean climate.

The agricultural sector in Cyprus contributes around 1.65% to gross domestic product (GDP) in 2022. The main crop products are potatoes, citrus, vegetables, and grapes, whereas meat (pork, beef, poultry, sheep, and goat) and milk (cow, sheep, goat) are the most significant livestock products consumed. The main processed agricultural products are halloumi cheese with growing exports, followed by beverages such as "zivania" and local wines.

The main problems agriculture in Cyprus is facing, according to G.Adamides, are the prevalence of small and fragmented farm holdings, land degradation and water scarcity, the ageing of the rural population, the low education level of farmers, the lack of a skilled workforce, the high input costs (e.g., pesticides, fertilizers, irrigation), and various marketing and unfair trading practices. It is also projected that agriculture in Cyprus will be highly affected by climate change impacts, such as increased temperature and decreased precipitation. Furthermore, the Cypriot agricultural sector still lags in terms of the adoption of new smart farming technologies, as well as agriculture digitalization in general, which is a strategic goal of the next programming period (2021–2027). Another problem Cyprus is facing, indicated from the validator of this report, is that due to the high temperatures Cyprus has, insects have much more generations and Cypriot farmers must deal with larger populations of insects harmful to the crops. As a result, production costs are higher, agricultural products with higher percentages of drug residues and the risk of insect enemies developing resistance to specific active substances.

Agri-tech offers the potential to mitigate against some of these challenges and future-proof the agricultural sector by using technologies to optimise yields and quality as well as more efficient resource use and less carbon footprint of the sector.

According to the Smart Specialisation Strategy of Cyprus, agriculture and livestock are dominated by small farms, with the average size being between 3 and 4 hectares, while 81% of them have less than €8,000 of standard output. In addition, the available land for agricultural use is in decline, falling from 166,000 hectares in 2005 to 112,000 hectares in 2016.
Most farms (97.6%) are family farms, with more than 50% of the regular labour being family members. Farmers are relatively old (only 3.3% of farmers are under 40 compared to 10% of EU-28), and the share (3.3%) of young farm managers aged below 40 is the lowest in EU (EU average 10.6%). Among the farmers, only 0.6% of them have full agricultural training. There is a lack of digital skills and awareness of the contemporary approaches to cultivation and the opportunities offered by technology to increase productivity and cost-based competitiveness. The low capacity of the sector to absorb new knowledge and adopt new methods and technologies is also reflected in the investments in agriculture, which are the lowest in the EU. The above limitations in agriculture keep productivity very low, at around 0.27%.
Due to the very low absorptive capacity and the absence of economies of scale in the agriculture sector, the local market of innovative Cypriot companies providing solutions for agriculture, such as precision agriculture, automation, and robotics, is very small.

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Agricultural Research Institute (ARI) of the Ministry of Agriculture, Rural Development and Environment (MARDE) of Cyprus in their Interim Progress Report on ICT (Information Society in Rural Areas: Informing Farmers through new Information and Communication Technologies, November 2023) mentions ''Continuous developments in technology prompt us to continue and strengthen research on the evaluation of the use of Smart Farming Technologies (SFTs) in main crops of Cyprus, conducting targeted experiments with based on the particularities and problems faced by Cypriot agriculture. It is considered necessary to write a new research proposal, within 2024, which will cover more broadly the SFTs issues and will be consistent with the Strategic Objective of the ARI, but also with the 2023-2025 Strategic Plan of the Ministry of Agriculture, Rural Development and Environment for the digitization of the rural sector. In this new proposal will also involve researchers from other branches of the ARI, thus following an integrated interdisciplinary approach.''

Artificial Intelligence (AI) has already revolutionized many industries, from healthcare to finance, and now it is poised to do the same for agriculture.

There is a global competition among large countries like the USA, China, Russia, and UK to win the AI race. The EU, fully aware of the need to stay ahead in AI, has already announced a great number of AI projects to be funded. In the period 2021-2027 digital technologies in agriculture will continue to be a high priority of the European Union. In this context, the EU's Horizon Europe research program will provide € 10 billion for research and development in the food industry, agriculture, rural development, and bioeconomy.

2. Agriculture Policies in the EU

Agriculture is the only sector of the European Union (EU) where there is a common policy. EU agricultural policy covers a wide range of areas, including food quality, traceability, trade and promotion of EU farm products. It seeks to ensure a sustainable future for European farmers, provide more targeted support to smaller farms, and allow greater flexibility for EU countries to adapt measures to local conditions.

Initiated in 1962, EU's Common Agricultural Policy (CAP) is a partnership between agriculture and society, and between Europe and its farmers aiming to:

1. support farmers and improve agricultural productivity, ensuring a stable supply of affordable food;
2. safeguard European Union farmers to make a reasonable living;
3. help tackle climate change and the sustainable management of natural resources;
4. maintain rural areas and landscapes across the EU;
5. keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sectors.

In its most recent version (2023–27), CAP relies on Member States' own strategic plans framed by 10 key objectives, which are:

1. to ensure a fair income for farmers;
2. to increase competitiveness;
3. to improve the position of farmers in the food chain;
4. climate change action;
5. environmental care;
6. to preserve landscapes and biodiversity;
7. to support generational renewal;
8. vibrant rural areas;
9. to protect food and health quality; and
10. fostering knowledge and innovation.

The CAP's main instruments include agricultural price supports, direct payments to farmers, supply controls, and border measures. Successive rounds of policy reforms in 2003, 2013, and up to the current version support the transition towards sustainable agriculture and forestry in the EU and requires farmers to comply more fully with environmental, animal welfare, food safety, and food-quality regulations to receive direct payments.

CAP 2023–27 builds upon the 2003 and 2013 reforms to provide Member States with greater autonomy over the application of CAP. Each Member State completed a national strategic plan that was subject to review and approval by the commission. This gave Member States greater flexibility to design and implement policies to address their unique needs and challenges while following the overarching principals and objectives of CAP.

The CAP 2023-27 is covered by three regulations, which generally apply since 1 January 2023:

- *Regulation (EU) 2021/2116*, repealing Regulation (EU) 1306/2013 (previous CAP 2014-20) on the financing, management and monitoring of the CAP;
- *Regulation (EU) 2021/2115*, establishing rules on support for national CAP strategic plans, and repealing Regulations (EU) 1305/2013 and 1307/2013 of previous CAP 2014-20;
- *Regulation (EU) 2021/2117*, amending Regulation (EU) 1308/2013 (previous CAP 2014-20) on the common organisation of the agricultural markets; Regulation (EU) No 1151/2012 on quality schemes for agricultural products; Regulation (EU) No 251/2014 on geographical indications for aromatised wine products; and Regulation (EU) No 228/2013 laying down measures for agriculture in the outermost regions of the EU.

For the years 2021-22, a transitional regulation (Regulation (EU) 2020/2220) was in force. The regulation laid down conditions for the provision of support from the European agricultural guarantee fund (EAGF) and European Agricultural Fund for Rural Development (EAFRD) during these years, extending and amending provisions set out in the preceding regulations. It remained in force until the new CAP began.

3. AI Policies in the EU

The use of Artificial Intelligence (AI) in the EU will be regulated by the *AI Act*, the world's first legislation on AI. With the growing influence of AI across various sectors, the EU, as part of its digital strategy, wants to regulate artificial intelligence seeks to strike a balance between fostering innovation and ensuring ethical and responsible AI development. AI can create many benefits, such as better healthcare; safer and cleaner transport; more efficient manufacturing; and cheaper and more sustainable energy.

The objectives of the EU AI Act are to create a regulatory framework for AI technologies, mitigate risks associated with AI systems, and establish clear guidelines for developers, users, and regulators. The act aims to ensure the responsible use of AI by protecting fundamental rights and promoting transparency in AI applications.

The legal framework for AI, has a clear, easy to understand approach, based on four different levels of risk: minimal risk, high risk, unacceptable risk, and specific transparency risk. It also introduces dedicated rules for general purpose AI models.

Minimal risk: Most of AI systems currently used or likely to be used in the EU fall into this category. Minimal risk applications can be developed and used subject to the existing legislation without additional legal obligations, as these systems present only minimal or no risk for citizens' rights or safety. Voluntarily, companies may choose to apply the requirements for trustworthy AI and adhere to voluntary codes of conduct.

High-risk: AI systems identified as high-risk will be required to comply with strict requirements, including risk-mitigation systems, high quality of data sets, logging of activity, detailed documentation, clear user information, human oversight, and a high level of robustness, accuracy and cybersecurity. Regulatory sandboxes will facilitate responsible innovation and the development of compliant AI systems.

Examples of such high-risk AI systems include certain critical infrastructures for instance in the fields of water, gas and electricity; medical devices; systems to determine access to educational institutions or for recruiting people; or certain systems used in the fields of law enforcement, border control, administration of justice and democratic processes. Moreover, biometric identification, categorisation and emotion recognition systems are also considered high-risk.

Unacceptable risk: AI systems considered a clear threat to the fundamental rights of people will be banned. It includes AI systems or applications that manipulate human behaviour to circumvent users' free will, such as toys using voice assistance encouraging dangerous behaviour of minors or systems that allow ‘social scoring' by governments or companies, and certain applications of predictive policing. In addition, some uses of biometric systems will be prohibited, for example emotion recognition systems used at the workplace and some systems for categorising people or real time remote biometric identification for law enforcement purposes in publicly accessible spaces (with narrow exceptions).

Specific transparency risk: For certain AI systems specific transparency requirements are imposed, for example where there is a clear risk of manipulation, such as chatbots, users should be aware that they are interacting with a machine. Deep fakes and other AI generated content will have to be labelled as such, and users need to be informed when biometric categorisation or emotion recognition systems are being used. In addition, providers will have to design systems in a way that synthetic audio, video, text and images content is marked in a machine-readable format, and detectable as artificially generated or manipulated.

General purpose AI: The AI Act introduces dedicated rules for general purpose AI models that will ensure transparency along the value chain. For very powerful models that could pose systemic risks, there will be additional binding obligations related to managing risks and monitoring serious incidents, performing model evaluation and adversarial testing. These new obligations will be operationalised through codes of practices developed by industry, the scientific community, civil society and other stakeholders together with the Commission.

The regulations prohibit the following:

- Biometric categorisation systems that use sensitive characteristics such as political, religious, philosophical beliefs, sexual orientation, race.
- Untargeted scraping of facial images from the internet or CCTV footage to create facial recognition databases.
- Emotion recognition in the workplace and educational institutions.
- Social scoring based on social behaviour or personal characteristics.
- AI systems that manipulate human behaviour to circumvent their free will.
- AI used to exploit the vulnerabilities of people due to their age, disability, social or economic situation.

The final legislation is expected to go into force early this year (2024) and apply in 2026.

The proposed EU AI act's high-risk AI list does not explicitly mention AI applications in agriculture. However, it could be argued that several actual or foreseeable AI applications in agriculture would fall within the scope of that list, especially since that list is neither exhaustive nor fixed.

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4. Adaptation at National Context

A *National Artificial Intelligence strategy of Cyprus* has been conducted in 2019 and approved by the Council of Ministers in 2020 with an implementation goal of 2026. According to the AI Strategy Report, Cyprus will focus on the following priority areas:

- Cultivating talent, skills and lifelong learning.
- Increasing the competitiveness of businesses through support initiatives towards research and innovation and maximising opportunities for networking and partnerships.
- Improving the quality of public services through the use of digital and AI-related applications.
- Creating national data areas.
- Developing ethical and reliable AI.

Cyprus has already established several Digital Innovation Hubs (DIHs) such as the CYRIC Digital Innovation Hub, the KIOS Innovation Hub, the Robotics Control and Decision Systems (RCDS) Lab at the University of Technology, and the Entrepreneurship Centre at the Cyprus University. These DIHs are active in various market segments (e.g. health, construction, transport, manufacturing, agriculture and energy) and in a wide range of technological areas, including AI, Big Data, cloud computing and cybersecurity.

In the *Cyprus Recovery and Resilience Plan 2021 – 2026* there are a series of projects regarding the use of Smart Agriculture technology.

The plan proposes "Specifically, the measures on primary sector focus on developing a competitive agriculture sector primarily through agri-tech and strong collaboration with business, higher-education institutions and research centres to excel. The measures regarding the secondary section focus on developing a competitive light manufacturing sector that includes production in areas of green-tech, agri-tech, etc.,"

The plan proposes investments specific to agriculture, but there are also investments planned for areas like water management that would have a direct effect on the sector.

To modernise and expand infrastructure supporting the agriculture, farming, horticulture, and aquaculture of Cyprus, the plan suggests reforms such as:

- Move agricultural practices from the 20th century to the 21st century by investing in a national centre for excellence in agri-tech.
- On-line, cloud-based platform for improving the trade and information in the fresh produce supply chain.
- Genetic Improvement of the sheep and goat population.

The main objectives aimed to be achieved through the reforms and investments are the following:

- To establish a centralised resource for best practices relating to agricultural/ agri-tech practices, animal husbandry and environmental protection.
- To improve the uniqueness, and competitiveness of the primary sector with aim of improving the yield, efficiency, and profitability of the sector.

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- To build a close and active partnership between the farming community and universities, ultimately aiming to upskill and future-proof the community through alignment of curriculums, degrees, and graduates of local universities to the sector.

In the last years, Cyprus has introduced several initiatives to boost the agricultural sector in areas such as water and waste management, smart farming, environmental protection and new measures to ensure better animal welfare. But still, Cyprus agriculture practices are more 'traditional' with a limited implementation of 'Smart' practices with a small number of individual cases where Hydroponics and Aquaponics systems have been created (presented in Section 7 of this report) and the Research Stations of the Agricultural Research Institute (ARI) which are focused on experimental work.

5. National Legislation Frameworks

In line with EU priorities in digital transformation and following the EU's AI Act, the government of Cyprus will develop legislative framework to ensure the availability of data with transparent regulations, in particular on data protection. This legislative framework will consider EU directives on the free flow of data and general data protection and will facilitate the interoperability of data. To this purpose, it is important that the new legislative framework enables digital services to use up-to-date and high-quality information at the right moment, while taking into account the protection of personal data. With respect to ethics, the government of Cyprus is currently developing guidelines to ensure ethically sound and reliable developments in AI, i.e. by defining measures of transparency, responsibility, privacy, equality, diversity and safety among others. The developed guidelines should preserve human rights and social values. To coordinate the development of ethical guidelines, the Cyprian strategy advocates the creation of a National Committee on Ethical and Reliable AI. This Committee will continuously and systematically monitor and analyse issues or problems related to the usage or development of AI technologies and provide recommendations for legal and ethical interventions. To successfully conduct this exercise, the Committee will take into account the Ethics Guidelines for Trustworthy Artificial Intelligence as prepared by the High-Level Expert Group on Artificial Intelligence. Cyprus is also active in developing international standards for AI to foster and facilitate industrial and economic developments in this field. The Cyprus Organisation for Standardisation (CYS) will establish a National Commission constituting of technical experts from the public and private sectors to monitor and evaluate the work of International and European Committees on AI. It will also be responsible to apply and introduce AI standards in all sectors of the economy of Cyprus.

The Common Agricultural Policy (CAP) of the European Union is implemented in Cyprus through the CAP Strategic Plan 2023-2027, which has been prepared by the Ministry of Agriculture, Rural Development and Environment (MARDE) and has been approved by the Council of Ministers and the European Commission.

The Cypriot CAP Plan will provide an opportunity to renew the agricultural potential of Cyprus, creating a robust primary sector. It aims to respond to the concerns of producers and consumers, to attract younger generations, maintain social cohesion and promote a sustainable rural development. In parallel, it intends to protect the environment in which farmers operate. The Plan will work with a view to shift towards a new agricultural model, which respects the use of natural resources and commits to preserving and improving them.

Cyprus aims to increase the sustainability and resilience of the agricultural sector by expanding the production of high-quality agricultural products while improving the economic viability of small and medium-sized holdings.

Cyprus will enable the set-up of a system for agricultural knowledge and innovation (AKIS) in order to promote innovation in the agri-food sector. The Cypriot Plan aims to provide relevant education and training to producers. It also foresees advice and cooperation to facilitate the transfer of knowledge and promote new technologies in the primary sector. Farmers may keep their farms modern and innovative, for example, by investing in digital technologies and/or by forming operational groups to develop innovative solutions and practices. In Cyprus there is a low share of farmers with vocational education in agriculture. According to the latest available data, 94.3% of the farmers registered as farm heads in Cyprus only have practical experience but have not received any vocational training. There is a need to focus more on entrepreneurship, rural economics, processing, and marketing.

No regulations, or any are foreseen in the future for the use of AI in agriculture, in Cyprus.

6. AI Technologies & Applications in Agriculture Industry

In the next years to come, the field of agriculture and especially the farming industry will play a key role in shaping everyone's lives. In today's agriculture, modern technology has played a huge part in the development of the agriculture industry, hi-tech systems such as robot, humidity, and temperature sensors, aerial imagery, and GPS-technology are constantly being used. These progressive technologies, along with precision farming and robotics, enable businesses to be more clean, efficient, profitable, and safer.

Some innovative farming methods and agriculture technologies that are playing a significant role in changing the agricultural sector along with their benefits are:

1. *Farm Automation:* Automation is already a major part of the farming process, but it will become even more important in the coming years. Farmers are already using drones to monitor their crops, and advanced sensors can tell them exactly when they need to water or fertilize their fields. These devices can also be used to monitor soil quality and ensure that crops aren't affected by drought or other environmental factors.
   The increased level of automation will allow farmers to focus more on other aspects of their business than traditional manual labor tasks like watering, seeding, and harvesting.
2. *IoT Technologies:* IoT is used as a smart farming solution for monitoring the crop field from anywhere. It involves using sensors to track soil moisture, crop health, livestock conditions, temperature, etc.
   IoT technologies make it possible to create automated irrigation structures where water resources can be managed efficiently. By collecting crop data such as moisture and temperature, IoT technologies can help determine the right amount of water for crops every season.
3. *Geographic Information Systems (GIS):* it relies on technology such as drones and satellites to understand crop position and types, fertilization level, soil status, and related information. With data generated from GIS remote sensing devices and software, farmers can determine the best location for crop planting in the field and make informed decisions on how to improve soil nutrition.
   In livestock rearing, GIS software monitors the movement of animals. This, in turn, will help farmers track animals' health, fertility, or nutrition.
4. *Blockchain technologies:* used to track plant information from the farms to the shelf. Powered by a decentralized database, this technology helps regulate the quality of food and its shelf life. The auditable database allows growers and marketers to monitor farm produce throughout the supply chain.
5. *AI/ ML & Data Science technology:* Agricultural forecasting is made easy when farmers deploy AI/ML & data science technology. The use of 3D laser scanning and spectral imaging/spectral analysis, for example, can help farmers predict weather scenarios and optimize the use of resources required for irrigation, fertilization, and pest control.
   Through AI/ML & data science technology, farmers can analyze their fields for the best locations for planting seeds. They can use computer vision to recognize plants' optimal

height, width, and spacing. This data can then be used to optimize their growing methods.

6. *Controlled Environment Agriculture (CEA)*: is a method of cultivating plants in a fully regulated environment. It is also known as 'vertical farming or indoor farming.' In this type of cultivation, all the plant's needs are met by artificially providing them with water, nutrients, and light using hydroponic, aquaponic, and aeroponic techniques.
   CEA has proven to reduce some of the challenges faced in conventional farming. For example, it greatly reduces water consumption depending on the farm setup. In fact, some vertical farms use 70% to 95% less water than what's typically required in traditional outdoor farms.
   In addition to optimal water usage, CEA protects plants from adverse weather conditions and helps maximize the use of space for cultivation.
7. *Robotics:* The need to meet the increasing global food demand is one of the major driving forces for the wide application and adoption of agriculture robotics.
   Many farming activities performed by humans can now be done by agricultural robots (agribots), maximizing productivity and saving enormous resources. Today, agribots are used in seed planting, crop harvesting, weeding, sorting and packaging, livestock management, etc.
8. *Drones:* Drones are increasingly becoming useful in crop and livestock management. For example, farmers can use sensor-equipped drones to monitor the growth of plants, detect disease stress, monitor field temperature, and spray pesticides or fertilizers at desired locations on the field.
   In animal husbandry, drones are used to observe grasslands and track animal movements on big ranches. Some drones have thermal imaging cameras to detect sick animals with high body temperatures.
   The inherent benefits and the rise of drones in farm operations lie in their ability to help farmers acquire comprehensive data to make timely decisions.
9. *Precision Agriculture:* The increase in the global population has led to increased food production per capita. However, this has also led to water shortages due to irrigation purposes. To combat these issues, farmers are turning towards precision agriculture as it can save them both time and money.
   Precision agriculture is a rapidly evolving farm management system that involves the use of sensor technology, AI, GIS, and IoT to collect and analyze data about the soil, plants, and animals. It allows for more targeted use of inputs such as water, fertilizer, plant nutrients, pesticides, seeds, and labor. Precision agriculture deviates from conventional agriculture practices, where a uniform method is employed over a large area regardless of soil quality or topography variations.
10. *Big Data & Analytics:* The farm is becoming a data factory, with sensors and other technology collecting thousands of data points about everything from soil quality to humidity and crop yields. Big data & analytics can help farmers decide when to plant and harvest, how much water or fertilizer to use, and how much seed they should sow.

Farming operations are subject to weather and environmental changes, which are difficult to access, especially for large farms. Applying big data and analytics in agriculture help farmers predict water cycles or rainfall patterns.

11. *Connectivity Technologies:* In today's information-driven world, agriculture production should be based on a knowledge- and data-driven approach. Farmers need to be able to communicate with each other, vendors, and customers to produce more food efficiently. This can be done through connectivity technologies.
    Connectivity technologies, such as mobile devices, satellite technology, and internet-based platforms, allow farmers to share information to make better decisions about how they grow their crops or raise their livestock. These technologies also enable farmers to reach out to potential buyers or sell directly to consumers.

During 2010–2020, in Cypriot agriculture there were only two robotic applications, a semiautonomous agricultural robot sprayer used in two vineyard fields. Given that pesticides and fertilizers are widely used in agriculture to enhance crop protection and production, the use of robotics for targeted spraying in terms of climate-smart agriculture can lead to reduced pesticide application, thus improving sustainability and overcoming environmental concerns, as well as reducing material costs, human labor, and medical hazards. However, other robotic applications such as harversting, which also involves a substantial labor cost, have not been examined in Cyprus. Also, no scientific works on robotic applications in animal production are reported, even though statistical data from the Department of Agriculture (DoA) of Cyprus show that such robotic systems (e.g., dairy robotic milking systems) do exist and are in operation in dairy cow farms in Cyprus.

Smart farming techniques and IoT technologies are applied in Cypriot agriculture. Cypriot farmers are learning to change their currently used farming techniques (e.g., water management, pest management) to respond suitably to the challenges of sustainability and climate change. Two pilot studies (CYSLOP and IoT4Potato) engage farmers, which supported the extraction of additional results, facilitated the identification of the best practices towards the large-scale realization of smart farming in Cyprus. These works offer opportunities for innovation in agriculture and climate change adaptation options and could help farmers to achieve sustainable optimization of agricultural production and reduce their ecological footprint. No scientific works were found in relation to IoT applications in animal production farms. This is even though 96 dairy cow farms use an automated electronic system for the detection of oestrus, as reported in DoA.

Similarly, to robotics and IoT, no remote sensing applications were found in the literature for animal production and climate-smart agriculture (CSA) technologies are applied to only certain crops.

There seems to be limited or no research works on ICT and digital farming, leading animal production farmers to find and apply such technologies on their own, thus creating a gap between scientific knowledge and practice.

In Cyprus, in recent years, there has been an increase in the use of hydroponics, especially in the greenhouse sector due to the promotion of hydroponics through the Rural Development Plan, but also due to its more efficient use of the rest of greenhouse equipment. However, hydroponics is still used to a limited extend and where it is applied, its potential is usually not fully exploited.

7. Pedagogical Practices and Trainings

The Agricultural Research Institute (ARI), a Department under the Ministry of Agriculture, Rural Development and Environment, of the Republic of Cyprus, is the foremost body for the evaluation, consolidation, improvement and maintenance of the genetic base of crop and livestock production in Cyprus.

ARI's research programs promote the National Strategy for Smart Specialisation in the field of agriculture and contribute to the reform and strengthening of the competitiveness of the rural economy. In 2014, it opened up the Hydroponics Education Centre, offering Vocational Education to agriculture professionals.

The "Cyprus Agro Industry Center" (2020) organise 1-day theoretical and practical trainings about the basics of Hydroponics and Aquaponics.

On academic level, no specific training programmes have been found. The Institute of Professional Studies of UCLan Cyprus, in its Agriculture – Agribusiness course, in 2020 was offering a course in Hydroponics but currently it doesn't exist on their module list.

Best Practices in Cyprus:

1. CypruSaves

CypruSaves project was aiming to motivate farmers in using modern technology and tools, address current and future water shortages, and manage their cultivation in terms of soil, yield, nutrients, and pesticide use.

During the project, 10 Meteorological stations were installed and two gateways in vineyard fields, in Limassol and Paphos region, along with soil sensors for measuring soil moisture and electrical conductivity. Data were feeding the digital tools developed by the project for the estimation of water footprint and pests outbreaks for the benefit of local grape producers.

CypruSaves was one of 5 pilots/proposals, selected to join the H2020 DEMETER, an EU-funded project aiming at facilitating the deployment of inter-operable, data-driven and smart farming solutions. It was a consortium of 3 partners, Omnia and Zambartas wineries from Cyprus and Benaki Phytopathological Institute of Greece. The duration of the project was 1 year from May 2022 until May 2023.

2. SPACE4GREEN – Trusted and GREEN traceability through EU Space technologies

SPACE4GREEN project aims to develop a technological solution that enables Trusted Digital Data Sharing. This solution will enable stakeholders to obtain automated certification for various activities, which means stakeholders will have irrefutable knowledge that a specific activity took place at a particular time and location, eliminating the need for human certification from a third party. By making it easier to verify that a specific activity is happening at a certain place and time, the project could help to improve food safety, sustainability, and transparency.

The project combines cutting-edge technologies, including Galileo OSNMA**,** Blockchain and a project-specific SDK. Satellite Technology Helps Farmers Monitor and Respond to Field Data.

With Galileo OSNMA and Copernicus services, farmers can now monitor and respond to almost real-time data from their fields. Sensor technology detects crucial factors like water**,** nutrient, and pesticide levels, guiding farmers to deliver targeted solutions where they're needed most.

Earth Observation (EO) and accurate positioning are key to planning and monitoring sustainable agricultural practices and complying with the Common Agricultural Policy (CAP).

In Cyprus, the pilot vineyards of the CypruSaves project (mentioned above) are included as pilot case in SPACE4GREEN project.

The project is funded by Horizon 2020. It's a consortium of 8 partners from 5 European countries. Coordinator is the Spanish company Integrasys and OMNIA is within the partners. The project started in November 2022 and is still ongoing.

3. *ECONUTRI - Innovative concepts and technologies for ECOlogically sustainable NUTRIent management in agriculture aiming to prevent, mitigate and eliminate pollution in soils, water, and air project:*

The general objective of the innovative project ECONUTRI is to optimize, validate, and demonstrate nature-based novel solutions adapted into a holistic concept, which contribute to reduction of nitrates and phosphorous leaching, control of nitrogen losses through ammonia volatilization, and mitigation of GHG emissions originating from the agricultural sector, including both plant and animal production. To achieve this objective, the project aims further to disseminate and scale up the application of these novel technologies, and support EU farmers and scientists through training and education to implement nature based nutrient management tools that would improve air, soil and water quality in Europe and China, and contribute to mitigation of global climate change. The Econutri project uses smart agriculture systems.

The project is funded by Horizon 2020. It's a consortium of 30 partners, 26 from Europe and 6 from China. Coordinator is the Agricultural University of Athens. Within the partners is the Agricultural Research Institute (ARI) of Cyprus. The project started in November 2022 and is still ongoing.

4. *IoT4Potato - Data-Driven Potato Production project:*

This project combines IoT technology with earth-surveying data, to help farmers reduce the cost of potato production and improve product quality, while at the same time reducing their environmental footprint. The project employs a network of telemetric IoT stations (agro-environmental stations called Gaiatrons through NEUROPUBLIC's gaiasense smart farming system), installed in potato fields to automatically collect atmospheric and soil data, which are combined with satellite data as well as information about agricultural activities provided by the producers themselves.

The use case innovation is offered as an inexpensive service with no technology related investment for end-users, making it accessible even to small farmers. Gaiatrons are specially designed to adopt to the operational requirements of the area they are installed in, ranging from a dense installation network under the canopy or large-scale deployment.

The aim of this use case's research activity was the support of potato production in Poland, Ukraine and Cyprus, three countries with significant tradition in potato production.

In Cyprus, two pilot fields located in Liopetri and Paralimni villages in Kokkinochoria area were chosen, due to the importance of the region in potato cultivation. One station was installed in each field.

The results indicate a potential reduction of up to 25% on water consumption, 15% on pesticides use and 19% on the total input costs. Furthermore, the experts agreed on the usefulness, ease of use, and the reliability of the gaiasense solution. Also, they identified the provision of real time and accurate data as well as the presentation of information with comprehensive tables and graphs, as the important features of the proposed smart farming system.

The project was a case study of the European program "Internet of Food and Farm 2020' (IoF2020) funded by Horizon 2020 (Horizon 2020 - Industrial Leadership). Coordinator was the Greek company Neuropublic in partnership with the Agricultural Institute of Research (ARI, Cyprus) and organizations from Poland (Delphy Poland and FFP2), Ukraine (AgroLV) and the Netherlands (Wageningen University & Research). The project started in January 2019 and completed in March 2021.

5. *CYSLOP - Digital Ecosystem Utilisation project:*

Another use case of the Internet of Food and Farm 2020 (IoF2020) project was the Digital Ecosystem Utilisation - (CYSLOP) that was aiming to demonstrate IoT solutions in vegetable farms in Cyprus and Slovenia. The use case objectives were i) to drive IoT uptake in countries where IoF2020 was not initially present, ii) prove the sustainability of those IoT interventions cost- and environmentally wise, and iii) unveil their potential for post-farm and/or consumer-oriented applications.

The selected pilot areas in Cyprus located in the mountainous Limassol district where the cultivations under study were aronia, goji berries and raspberries (four plots), and in coastal Ammochostos district with two plots of open-field strawberries and cherry tomatoes (under hydroponic cultivation).

The expected environmental, economic and social impacts involve efficiency improvement in terms of pesticide and water use reduction between 5 and 10%, respective cost reduction of 10%, reduction of farm visits by 20% and more than twenty newly deployed IoT devices. Last, by incorporating innovative traceability technology, this use case was among the first to integrate information from the entire food value chain (from farm to fork) to a marketplace, offering elaborate value propositions to users.

The coordinator of the project was the Greek company Future Intelligence (FINT) in partnership with organizations from Cyprus (Institute of Agricultural Research and University of Nicosia) and Slovenia (ITC Cluster). The project started in January 2019 and completed in March 2021.

6. *SmartFarmer – Improving skills for Smartfarming as an innovative tool for rural development and economic growth:*

This initiative was based greatly on adopting the principles and standards of smart specialization.

The main objectives of the SmartFarmer programme were to highlight the reasons for why the production and marketing of the superfoods is an alternative beneficial option for the bio-producers and the competitive advantages comparing to other bio-products.

The SmartFarmer project aimed to improve the skills and competences of people in the agricultural sector by introducing a training programme in five EU countries while at the same time encouraging rural development in project countries in particular and Europe in general. The project was based on the transfer of the results of ProudFarmer project that was completed in 2010 and provided innovative results that were successfully integrated in formal training programmes in partner countries. The objectives of SmartFarmer included the analysis of the MTTM training programme and materials, their adaptation to the requirements of the target group and project countries; sharing experiences in smart farming practices training and development of new e-learning contents; testing and evaluation; dissemination of information about the project and project results and preparation of appropriate mechanisms/processes for their further exploitation.

The SmartFarmer project has been recognized by the European Commission as a Good Practice Example and a Success Story.

The project has been implemented by a consortium of 7 partners from 5 EU countries. The Agricultural Research Institute was the project's Coordinator. Partners in the project were the Cyprus University of Technology, the Union “Farmers Parliament” (ZSA - Latvia), the Harokopion University of Athens (HUA - Greece), Greek Superfoods Cooperation (M.A.G.I.Efkapron - Greece), the Development and Innovation Network (RCDI - Portugal), and the Fundacion Maimona (FM - Spain). The program was funded by the Foundation for the Management of European Lifelong Learning Programmes (IDEP) under the Leonardo Da Vinci Transfer of Innovation Program and ended in October 2015.

Few companies using smart farming technologies, including hydroponics are:

- Mountain Berries

A family business, established in 2018, with farms in the mountainous villages of Agridia, Chandria and Kyperounta with blackberries, blackcurrants, honeyberries, gooseberries, blueberries and many other color raspberry variations. Mountain Berries were also implemented CYSLOP (above mentioned use case of IoF2020) meteorological and microclimatic data, developing smart farming and irrigation protocols for the reduction of expenditure and improvement in fruit quality.

- Vardakis Farm

Another family business located in Avgorou, at Kokkinochoria area. It cultivates strawberries and cherry tomatoes through hydroponic systems.

- HerbanLeaf Farms

A family start up business, located in Parekklisia, Limassol providing with better quality and healthier leafy greens and herbs using the latest sustainable farming techniques. Since 2017, they use hydroponic farming growing vertically in 40ft shipping container, that can produce the equivalent of 2 acres of land saving up to 95% of the water used in traditional farming.

- Planty Aeroponics Mediterranean Ltd.

Located in Psematismenos, Larnaca in January 2020 they launched the biggest horticultural greenhouse facilities and packaging factory in Cyprus suppling the market with premium horticultural and hydroponic products such as microleaves-microgreens, herbs and leafy vegetables, using the Nutrient Film Technique (NFT).

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