smart skills

smart sustainable agriculture

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Literature Review
Agro-Tech

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contents

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01

Introduction

WHY WE ARE CARRYING OUT THIS RESEARCH

The purpose of this literature review is to critically evaluate and synthesize existing research on agro-tech approaches and technologies in agriculture. This review aims to provide a comprehensive understanding of how agro-tech can enhance sustainability, productivity, and efficiency within the agricultural sector. This involves:

1. **Identifying Key Agro-Tech Approaches:** The review seeks to identify and categorize the various agro-tech methods and tools currently employed in modern agriculture, including digital technologies, automation, sustainable practices, and data-driven decision-making.
2. **Analysing Effectiveness and Challenges**: The review examines the effectiveness of these agro-tech approaches in achieving optimal agricultural outcomes, such as increased productivity, reduced environmental impact, and resource efficiency, as well as the challenges and limitations associated with implementing each approach in diverse agricultural settings.
3. **Mapping Trends and Gaps**: It aims to map the current trends in agro-tech adoption globally and highlight any gaps in the existing research, including areas requiring further investigation to fully understand the implications of agro-tech on sustainability and climate resilience.
4. **Supporting Policy and Practice**: This literature review establishes a foundation for recommendations on how agro-tech approaches can be adapted and improved to support farmers' needs and address the growing demand for sustainable and efficient food production.

This review serves as a critical basis for our research, outlining what is already known about agro-tech and identifying opportunities for further exploration and improvement within the agricultural sector to inform the Smart Skills project and similar initiatives aimed at advancing sustainable agriculture.

02

What is Agro-Tech?

WHAT IS AGRO-TECH?

Definitions:

Agro-tech, short for Agricultural Technology, combines traditional farming practices with modern technologies such as drones, IoT, and data analytics. These connections lead to more efficient farming methods, reduced environmental impact, and increased productivity in the agricultural sector.

Key Technology Skills

- **Digital Literacy:**
  Digital literacy in agriculture includes the ability to effectively use technologies such as IoT (Internet of Things), various analytical tools and farm software. IoT devices that monitor conditions such as soil temperature, moisture or crop health provide farmers with accurate information about current conditions on the farm. This allows farmers to respond to changing conditions in real time and make adjustments that improve yields and sustainability. The ability to navigate these systems includes not only their use, but also understanding the data obtained and their effective interpretation for making decisions about key aspects of agricultural operations. (Kánská, et al., 2021)
- **Data management:**
  Data management is essential for using the information that comes from sensors, drones and satellites. These technologies collect large volumes of data on soil conditions, weather and crop growth. The ability to manage and analyze this data allows farmers to understand trends and predict future crop needs. For example, they can optimize irrigation based on current soil moisture or decide on fertilizer doses according to soil nutritional needs. Successful data management means the ability to combine information from different sources to create a comprehensive view of farm operations, which improves the accuracy and efficiency of decision-making processes. (Sekce digitální ekonomiky, 2013)
- **Automation and robotics:**
  Automation and robotics bring new possibilities to agriculture to make work more efficient and increase accuracy while keeping costs low. GPS systems, which are integrated into tractors and other agricultural machinery, enable precise navigation in the field without the need for human intervention. Tractors equipped with GPS can automatically follow precise routes and ensure even distribution of fertilizers or seeds. Drones are used to monitor crop health from a height, allowing for early detection of problems such as the presence of pests or the need for irrigation. In turn, harvesting robots enable more efficient harvesting of crops, especially those that require fine manipulation or precision. Automation and robotics thus help farmers reduce labor costs, increase efficiency and enable more sustainable farm management. (Lukáš, et al., 2020)

Sustainability and Green Agriculture

- **Water management**:
  Water is one of the most valuable resources in agriculture, so effective water management is key to sustainability. Precision irrigation systems, such as drip irrigation or sensor-controlled irrigation, apply water only where necessary, minimizing water loss due to evaporation and seepage. These systems monitor soil moisture in real time and adjust the amount of water, accordingly, ensuring that crops receive the right amount of moisture at the right time. The result is not only water saving, but also higher yields and crop quality, as they are optimally irrigated according to their needs. (Sukrati, et al., 2024)

- **Soil health:**
  Maintaining soil health is the foundation of long-term sustainable agriculture. Soil condition monitoring technologies such as sensors measuring pH, moisture and nutrient content allow farmers to better understand the needs of their soil. These sensors provide information that allows farmers to more accurately dose fertilizers and other inputs according to the current needs of the soil, thus preventing excessive use of fertilizers and minimizing the risk of soil degradation. Healthy soil supports higher crop productivity, improves water retention and reduces erosion, contributing to the long-term sustainability and quality of agricultural soils. (Sukrati, et al., 2024)
- **Energy efficiency:**
  Modern agriculture increasingly includes technologies that contribute to reducing energy consumption and ecological footprint. Solar panels are increasingly being used to power farm equipment and machinery, helping to reduce dependence on fossil fuels. Automated machines such as GPS-controlled tractors also contribute to energy efficiency by minimizing unnecessary trips and overlaps when applying fertilizer or irrigation. Such machines not only reduce fuel consumption, but also reduce working time and ensure precision, which leads to a lower environmental impact. This increases the efficiency of the farm while reducing greenhouse gas emissions. (Sukrati, et al., 2024)

Problem Solving and Innovation

- **Adaptation to climate change**:
  Agriculture is increasingly affected by extreme weather events, such as drought, torrential rains or unexpected frosts, which can seriously threaten crops. Precision agriculture provides farmers with tools and technologies to help them better adapt to these climate fluctuations. For example, systems based on predictive weather models and soil sensors allow farmers to predict when they will need to increase irrigation or apply frost protection measures. (Jarolímek & Vaněk, 2003) In addition, farmers can introduce drought-tolerant crops and use irrigation techniques that minimize water use during dry periods. These technologies contribute to better planning and reduce the risk of losses associated with unpredictable weather, allowing farms to remain productive even in times of climate change. (Sekce digitální ekonomiky, 2013)
- **Innovative technology**:
  Innovative technologies such as sensors and drones that use advanced data analysis allow farmers to monitor the health of their crops and detect potential problems, such as the appearance of pests or the spread of diseases, in time. These systems often use artificial intelligence to analyze the image and identify areas where there is a likely risk of infection or pest infestation. With this information, farmers can immediately intervene and apply appropriate conservation measures, reducing the need for widespread pesticide use. Such technology helps protect crops and minimize losses, leading to higher yields and greater efficiency. In addition, it reduces the ecological burden by allowing targeted interventions only where they are really needed. (Kánská, et al., 2021)
- **Collaboration and knowledge sharing**:
  In modern agriculture, cooperation between farmers plays a vital role, especially thanks to the availability of online platforms and advisory services. These digital tools allow farmers to share their experiences, best practices and solutions to problems with others, helping to spread innovative approaches and best practices across the industry. In addition, farmers can receive up-to-date information on weather, market trends and new technologies, which supports their decision-making processes. Online forums, mobile applications and specialized consultations provide access to knowledge and support, which increases the efficiency of their work and enables them to face the challenges of modern agriculture more effectively. This form of cooperation also strengthens the farming community and enables them to better adapt to changing conditions. (Šimek, et al., 2017)

Implementation of Agro Tech

- **Farmer Network:**
  Networking among farmers has proven to be a very effective way to share knowledge and experience. This mutual assistance allows farmers to solve problems faster and more efficiently, as they can be inspired by the successful examples and best practices of their colleagues. (UITPA, 2024) Within farmer networks, individual members can share information about new technologies, farming methods and environmental measures. Such platforms also provide a space to discuss current trends in agriculture and solve problems together, which helps overall innovation in the industry. Thanks to this collaboration, farmers not only increase their productivity, but also find solutions that reduce their operating costs and contribute to a more sustainable agriculture. (Šimek, et al., 2017)
- **Benefits for the economy and ecology:**
  The implementation of agro technologies has significant economic and ecological benefits. On an economic level, it brings increased revenues due to better use of resources and higher efficiency. Technologies such as precision irrigation systems and sensors make it possible to optimize water consumption, leading to lower costs and sustainability. Similarly, energy-efficient technologies such as solar panels and GPS-controlled machines help reduce energy consumption. Thanks to technologies for the targeted application of pesticides, it is also possible to reduce their use to only the necessary minimum, which contributes to healthier crops and environmental protection. These environmental benefits include a reduction in chemical pollution of soil and water and an overall reduction in the farm's carbon footprint. The result is a more sustainable and efficient way of farming that ensures long-term productivity and protection of natural resources. (Lukáš, et al., 2020)

View to the Future

- **The arrival of new technologies**:
  The future of agriculture brings new technologies such as artificial intelligence (AI), advanced drones and autonomous machines that are fundamentally changing the way farms operate. Artificial intelligence enables farmers to predict yields, analyze large volumes of crop data and make fast decisions based on advanced analytics. For example, AI can detect early signs of disease in crops and immediately recommend interventions, helping to minimize losses and optimize stocks. Autonomous machines can perform routine tasks such as sowing, harvesting or irrigation, reducing the need for human labor and increasing productivity. (Singh, et al., 2024)
- **A new era of agriculture**:
  Efficiency, sustainability and access to information Agro tech moves agriculture into a new era, where efficiency, sustainability and transparency become key values. Technologies enable farmers to access accurate information about field conditions and support better data-driven decision-making. At the same time, they provide ways to use resources more efficiently and promote environmentally responsible practices. This shift is towards agriculture that is not only more productive, but also more environmentally friendly. As a result, farms in the future will be better able to respond to climate challenges, growing food demand and pressure for sustainability, which is essential for the long-term preservation and improvement of the quality of farmland and natural resources. (Singh, et al., 2024)

IDENTIFYING KEY APPROACHES:

To categorize the key agro tech skills commonly used in Europe today, we can divide these skills into three main categories: technological, environmental and operational competencies. Each of these categories represents a necessary area in which knowledge and skills need to be developed for agriculture to effectively respond to current challenges and transition to a more sustainable production model.

These competencies include both the ability to work with advanced technologies and digitized tools, as well as skills related to the sustainable use of natural resources and optimization of farm operations. (Eger, 2013) Thanks to this, farmers can meet the requirements for greater efficiency, cost reduction and minimization of environmental impacts, thereby contributing to the long-term sustainability of European agriculture.

Digital literacy and technology for precision agriculture

The ability to work with digital tools is the basis for implementing modern agro tech solutions. Farmers today use IoT devices to monitor soil, climate, and crop growth, while analytics tools help interpret data from these sources. Precision farming technologies such as GPS-controlled tractors, drones and automation systems help with planning and efficient farm management, reducing losses and enabling more precise application of inputs (fertilizers, pesticides) only where necessary. (O. Ejemeyovwi, et al., 2021)

Sustainable use of natural resources

Ensuring long-term soil productivity and efficient management of resources such as water and energy are essential in agro tech. Precision irrigation systems minimize water wastage and ensure that water is applied only where it is needed. Soil monitoring technologies that track nutrients and moisture enable targeted fertilization and conserve resources, which is key to protecting soil from degradation. In addition, the use of renewable sources, such as solar panels, to power farm equipment is becoming more widespread.

Solving problems using predictive and preventive technologies

Thanks to advanced sensors and AI systems, farmers can detect problems such as pests, diseases or soil deficiencies in time. Artificial intelligence and predictive models enable them to make interventions that prevent yield losses and reduce the need for chemicals. The ability to quickly respond to environmental changes through predictive analytics allows farmers to better adapt to climate fluctuations and changing conditions.

Collaborative approach and knowledge sharing

Agro tech promotes collaboration between farmers through online platforms and networks where they can share experiences, best practices and problem-solving approaches. This increases the success rate of introducing new technologies and allows farmers to learn from the successes and failures of their colleagues. These platforms also provide access to training and expert information on the latest innovations in agriculture.

Economic and ecological optimization of farming practices

The key goal of agro tech is to improve the economic and ecological aspects of agriculture. By using modern technologies, farmers can achieve higher yields with less input costs. Reducing the use of water, energy and chemicals not only reduces costs, but also minimizes the impact on the environment, contributing to a more sustainable agriculture.

These approaches represent a fundamental shift towards sustainable and technologically advanced agriculture that responds to current challenges in climate, efficiency and conservation of natural resources.

Within the SmartSkills project, aimed at developing key skills for smart agriculture, several key approaches and categories have been identified across the EU. These skills are closely linked to the broader goals of digital transformation, climate protection and sustainability. The following approaches show how these key skills can be effectively categorized and developed:

1. Promoting digital literacy and technology skills:

- Development of digital skills necessary for effective use of modern technologies in agriculture.
- Teaching farmers to work with digital tools such as sensors, drones and data analytics.
- Optimizing farm operations and more efficient use of resources thanks to digital literacy.
- Increasing decision-making accuracy and supporting sustainability through better technology mastery.

2. Dissemination of sustainable and environmentally friendly agricultural practices:

- Helping farmers acquire skills for managing water, soil and energy resources.
- Promoting best practices such as precision irrigation and soil monitoring.
- Use of renewable energy sources to reduce water consumption and costs.
- Protecting the environment through environmentally friendly practices.

3. A micro-learning platform for flexible learning:

- A digital learning platform allowing access to micro-learning modules.
- Covering key topics such as agro tech and climate change adaptation.
- Flexible study tailored to the individual needs of farmers.
- Increasing the availability of education even for farmers from remote areas.

4. "Train the Trainer" program to spread knowledge:

- Training of experts and advisors from rural areas who pass on their knowledge.
- Fostering community collaboration and knowledge sharing at the local level.
- Faster implementation of innovative procedures thanks to the exchange of experience.
- Effective dissemination of new practices and knowledge among farmers.

5. Support for adaptation to climate change

- Developing farmers' skills to adapt to climate change.
- Use of predictive technologies to prevent losses caused by changes in weather.
- Implementing climate-friendly practices such as maintaining soil health.
- Use of resistant crop varieties for better adaptation to climatic conditions.

Analysis: The article examines the role of information and communication technologies (ICT) in Czech agriculture, emphasizing that digital tools, such as the Internet, IoT and social networks, significantly increase the efficiency and competitiveness of agricultural enterprises. It describes the use of social networks for marketing and knowledge sharing and identifies obstacles such as high costs and lack of skilled labor.

The research includes an automated data collection methodology that is important for the application of ICT in the future. The paper recommends further research into sustainability and the introduction of innovations such as drones and analytics tools to reduce environmental impacts and support rural development.

The findings from the article on the role of ICT in agriculture are highly relevant to the SmartSkills project, as they underscore the importance of digital competency, sustainable practices, and innovative technology adoption in the agricultural sector.

Key insights include:

1. **Digital Literacy and Efficiency:** Digital tools (IoT, internet, social media) boost efficiency in agriculture, aligning with SmartSkills' aim to enhance farmers' digital competencies.

2. **Social Media for Knowledge Sharing:** Social media is key for marketing and information exchange; SmartSkills can provide training on using these platforms for community engagement and product promotion.

3. **Addressing ICT Adoption Barriers:** High costs and lack of skills are obstacles. SmartSkills can offer affordable educational resources to help smaller farms overcome these challenges.

4. **Data Collection for Decision-Making:** Automated data collection is crucial for informed decisions. SmartSkills can help farmers develop basic skills in data gathering and analysis.

5. **Sustainability and Innovation:** Emphasis on sustainable practices and tech (drones, analytics) aligns with SmartSkills' goal to support eco-friendly and innovative farming methods.

These insights strongly support the goals of the SmartSkills project and contribute to the overall advancement of sustainable and technologically equipped agricultural communities.

03

Research Analysis

ANALYSIS OF KEY APPROACHES TO THE ADOPTION OF ICT AND INNOVATIVE TECHNOLOGIES IN AGRICULTURE:

Traditional Educational Approaches

1. Current state of ICT integration and digital literacy

Current competences:
Digital literacy of farmers, especially smaller entrepreneurs, is limited. Many farmers use basic digital tools such as mobile phones but lack the skills to use advanced technologies such as IoT sensors, drones and specialized farm management software. This lack of digital skills has limited the adoption of advanced agricultural technologies, leading to lower productivity and efficiency compared to businesses that actively use digital technologies.

Future requirements:
With the development of precision agriculture, the need for skills in the use and interpretation of data analysis from digital platforms is increasingly urgent. Digital literacy, including knowledge of farm management software platforms and analytical tools for data-driven decision making, is becoming key. Education programs should focus on practical skills such as managing data from IoT devices and using software to improve management.

2. Sustainable agricultural practices and environmental literacy

Current competences:
Part of the farmers already practice basic methods of sustainable agriculture, such as crop rotation or organic farming. However, these approaches often lack systematicity and are not always based on up-to-date soil or climate data. In areas with less access to information and training, only traditional conservation methods are often used without the support of technology, which has limited the effectiveness and sustainability of these practices.

Future requirements:
Growing demands for sustainability and climate resilience of agriculture require advanced knowledge in precision irrigation, renewable energy sources and soil health monitoring. Key sustainable skills of the future will be knowledge of efficient resource management and carbon footprint reduction through precision fertilization, renewable energy (eg. solar panels) and waste minimization.

3. Innovation and automation in agricultural processes

Current competencies:
Advanced technologies such as GPS-guided machines, drones and automation systems are currently only being used to a limited extent, especially on smaller farms. Many farmers prefer traditional methods and find the technology expensive or complex to manage and maintain. This attitude persists despite the benefits that automated systems can bring, such as increased efficiency and reduced labor costs.

Future requirements:
To fulfill the potential of automation in agriculture, it will be necessary to develop the skills associated with the operation and maintenance of these technologies. The future agricultural workforce will require expertise in robotics, automation and precision control of agricultural machinery to optimize production and use resources efficiently. These technologies will enable smaller farms to reduce labor costs and increase yields, improving their economic sustainability.

4. Blended Learning

Current Competencies:

The dissertation shows that the increasing use of social media supports communication and information exchange among farmers. Social networks are becoming a tool for sharing knowledge, marketing products and developing community relationships, helping farmers spread green practices and innovative approaches. However, access to these platforms is limited, especially in less developed rural areas with poorer digital infrastructure.

Future requirements:

As digital communication becomes increasingly important, there is a need to develop skills focused on effective communication and networking. Fostering collaboration through digital platforms will enable farmers to better share best practices and access innovations that will enhance productivity and sustainability. Also, creating online networks to connect farmers with agronomic experts and technology companies should be one of the key goals of modern agricultural education.

5. Modular Learning

Financial barriers:

The acquisition cost of advanced agricultural technologies is one of the most significant factors limiting their adoption, especially among smaller farmers. Small farmers often do not have access to finance or cannot take advantage of subsidies intended to support technology. This lack of funding significantly hinders the faster implementation of innovative procedures.

Infrastructure challenges:

The limited availability of stable and fast internet connection in remote rural areas also hinders the effective use of technologies such as IoT or cloud platforms for farm management. Without sufficient infrastructure, the efficiency of modern agricultural technologies decreases, which makes the wider use of data-intensive systems impossible.

The need for technical support:

Even after the acquisition of technology, it is essential to ensure ongoin technical support. Many farmers face difficulties in maintaining and managing the technologies, which can lead to inefficient use of these tools or even their abandonment. There is therefore a need for affordable technical facilities and training to help farmers use and maintain the technology effectively.

Conclusion and recommendations

This analysis points to key areas where skills need to be developed for wider adoption of ICT and sustainable practices in agriculture. To achieve these goals, the following is recommended:

1. Targeted training and education:

Investments in the development of digital literacy, especially while working with data and using modern agricultural technologies, are essential. The training should include practical skills to use IoT, drones, software and analytical tools to increase the efficiency and sustainability of agricultural processes.

2. Promoting sustainable agriculture:

Expanding programs focused on environmental education and promoting climate-friendly agricultural practices such as precision irrigation, soil restoration and the use of renewable energy sources is essential. Such measures will help reduce the environmental impact of agriculture and increase its long-term sustainability.

3. Improving access to technology and financing:

For smaller farmers, the availability of financial support focused on innovation and technology is key. The development of grant programs and low-interest loans would enable the wider use of modern technologies even for smaller businesses, which would lead to greater efficiency and competitiveness of these entities. In this way, one can help to overcome the high initial investments associated with the implementation of advanced technologies such as autonomous machines, IoT devices or sophisticated monitoring systems.

4. Strengthening the digital infrastructure in the countryside:

A stable and fast Internet connection is a prerequisite for the use of most modern ICT tools in agriculture. Investing in digital infrastructure in remote areas will allow farmers to fully exploit the potential of technology and facilitate access to online learning platforms that will allow farmers to share their experiences and acquire the necessary knowledge and skills.

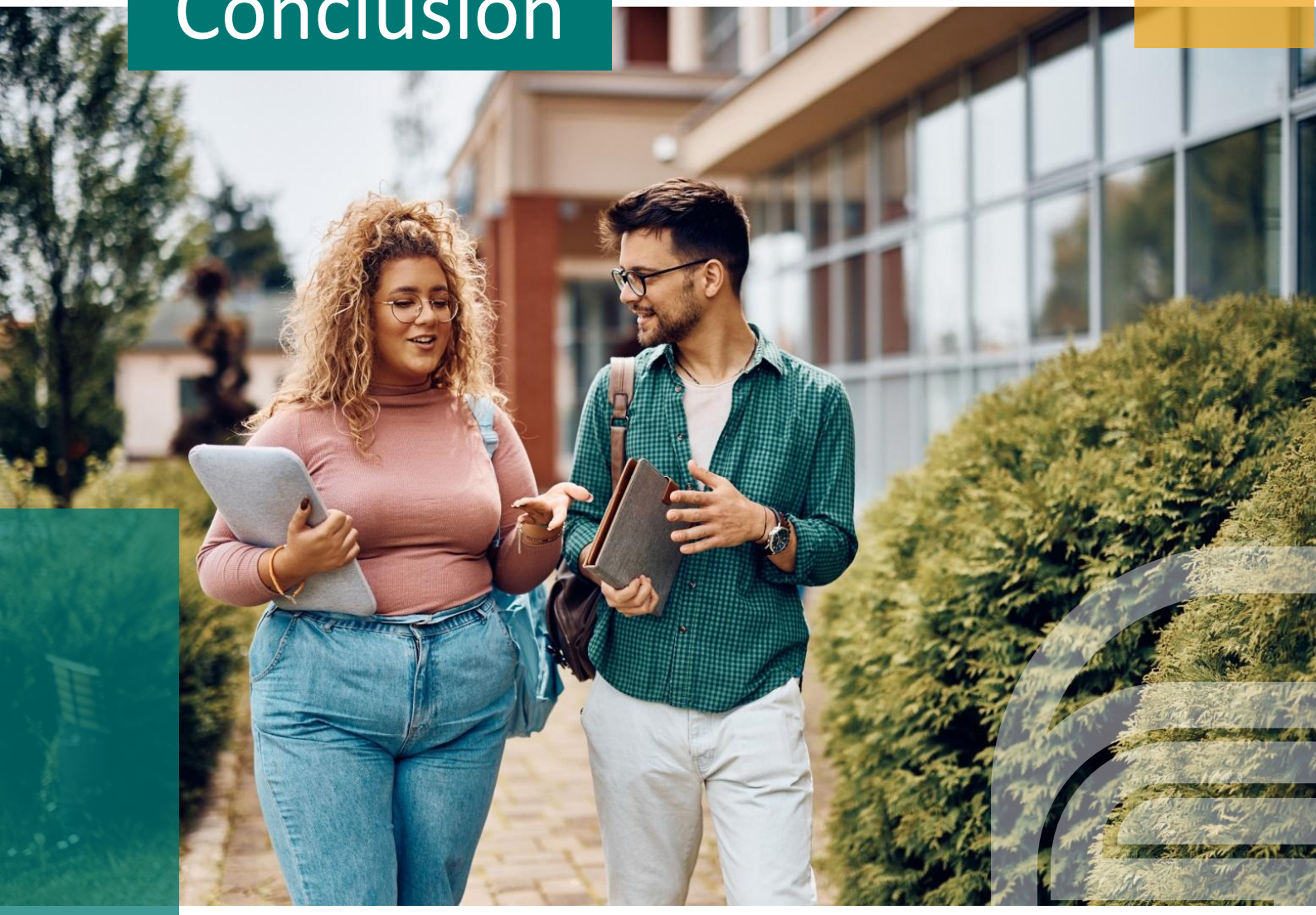
5. Ongoing technical support and training:

Even after the implementation of technologies, support in their maintenance and management is essential for farmers. Establishing regional technical centers or providing ongoing training can greatly increase the effective use of technology. This will ensure that farmers have long-term access to information on new technologies and are able to maximize the benefits these technologies bring to them.

These recommendations underline the need for systematic support for the implementation of ICT in agriculture and the transition to sustainable and efficient agricultural practices. Investments in training, infrastructure and financing are key steps for achieving long-term sustainability and competitiveness in the Czech agricultural sector.

04

Conclusion



CONCLUSION:

This analysis of key approaches to the adoption of ICT and innovative technologies in agriculture highlights the critical need to develop digital skills, environmental literacy and accessibility of modern technologies among farmers to effectively face the current challenges of sustainability and efficiency. The results of the analysis point to several key areas:

1. **Lack of digital literacy among farmers**, especially those from smaller holdings, has limited the ability to effectively use modern technology, reducing the productivity and efficiency of farming operations compared to larger businesses that have invested in ICT.

2. **The adoption of sustainable practices** is essential for the long-term conservation of soil and water resources. To develop sustainable skills, it is important to consider new technologies aimed at efficient use of resources, such as precision irrigation and the use of renewable energy sources.

3. **Financial and infrastructural barriers** to implementing advanced technologies remain a major challenge. Smaller farms in particular lack access to the subsidies and support needed to purchase and maintain modern equipment, and rural areas often lack the internet coverage necessary to effectively deploy digital tools.

4. **The need for ongoing technical support and training** is important to ensure effective and long-term use of new technologies. Technical support and access to training will enable farmers to better utilize the potential of these tools and ensure their smooth operation.

Recommendations for supporting the adoption of ICT in agriculture

Based on the established facts, it is recommended:

1. **Invest in targeted education** focused on farmers' digital and technical skills, especially in the areas of data analytics, IoT and the use of advanced software tools that can support effective decision-making.

2. **Support programs for ecologically friendly agriculture** with an emphasis on techniques such as precision irrigation, soil restoration and the use of renewable energies that can increase the sustainability of the sector in the long term.

3. **Expand the availability of financing and facilitate access** to technology subsidies, thereby supporting the implementation of innovative technologies even among smaller farmers.

4. **Improve digital infrastructure** in remote areas to enable farmers to fully exploit the potential of digital tools, including the ability to share knowledge and experience within community networks.

5. **Provide technical support** and regular training focused on the maintenance and effective management of technologies that will ensure long-term benefits from their implementation.

These recommendations underline the need for systematic support for the implementation of ICT and the transition to sustainable and more efficient agricultural practices. Investments in education, infrastructure and financing are key to the long-term sustainability and competitiveness of the agricultural sector.

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