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## Literature Review Executive Summary



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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 key areas relevant to the Smart Skills project, focusing on Digital Skills, Vocational Education and Training (VET), Agro-Tech approaches, Essential Skills for Smart Agriculture, Sustainable Skills, and the Importance of Technology in Agriculture in the European Union. These interconnected themes aim to address the rapidly evolving demands of digitalization, sustainability, and innovation across education and agriculture sectors.

### 1. **Educational Approaches in VET:**

The review identifies and categorizes the various educational methods employed in VET across the EU, including traditional, modern, and emerging practices. It examines the effectiveness of these approaches, identifies challenges, and maps trends and gaps to provide recommendations for enhancing educational strategies in alignment with the needs of learners and labor markets.

### 2. **Digital Skills in Agriculture:**

With agriculture transforming through digitalization, this review explores the critical technical and digital literacy skills needed in Agriculture 4.0. It evaluates the state of farmers' knowledge and highlights disparities based on factors such as geography, farm size, and resources, while identifying areas for improvement and innovation.

### 3. **Agro-Tech and Sustainability:**

The review focuses on agro-tech methods, such as automation, data-driven decision-making, and sustainable practices, analyzing their effectiveness in achieving productivity, reducing environmental impacts, and enhancing resource efficiency. It identifies global trends, gaps in adoption, and the potential for further advancements.

### 4. **Essential Skills for Smart Agriculture:**

As Smart Agriculture increasingly relies on technologies like precision farming, AI, and sustainability practices, this review identifies the core competencies required for the agricultural workforce. It highlights gaps between current VET curricula and industry needs, proposing ways to align education with these demands.

### 5. **Sustainable Skills for Agriculture:**

Sustainable agriculture combines environmental stewardship with economic viability and social responsibility. This review identifies the skills required for effective soil management, sustainable water use, agroecology, precision farming, and organic production. Key competencies include rotational grazing, climate adaptation, and long-term planning for resource conservation. Emphasis is placed on the critical need for farmers to acquire skills in using digital tools, protecting biodiversity, and integrating sustainable practices into farming operations. These skills align with global efforts to address climate change and ensure long-term productivity.

### 6. **Importance of Technology in Agriculture:**

Digital and innovative technologies are transforming agriculture, enabling efficient resource management, reducing environmental impacts, and improving sustainability. This review examines the role of technologies such as IoT, blockchain, precision farming, and artificial intelligence in addressing challenges like climate change, food security, and rural development. Emphasis is placed on their alignment with Sustainable Development Goals (SDGs) and the opportunities they provide for optimizing agricultural processes, enhancing productivity, and supporting Smart Villages initiatives to improve rural livelihoods.

This comprehensive review serves as a critical foundation for the Smart Skills project by synthesizing existing knowledge, addressing key gaps, and providing actionable recommendations to advance education, workforce readiness, and sustainability in agriculture.

02

Agro-Tech



## | Agro-Tech

Agro-tech, a term that combines agriculture and technology, represents a revolutionary shift in farming practices by incorporating advanced tools to increase efficiency, reduce environmental impact, and boost productivity. The application of technology to agriculture addresses challenges such as climate variability, resource scarcity, and the need for sustainable practices while meeting the demands of a growing global population.

One of the central components of agro-tech is precision agriculture. This approach relies on technologies such as drones, IoT sensors, and GPS-guided machinery to collect real-time data about soil conditions, weather patterns, and crop health. For example, IoT sensors placed in fields can monitor soil moisture, enabling farmers to adjust irrigation systems in real time. This not only conserves water but also ensures optimal hydration for crops, improving yield quality and quantity. Drones equipped with multispectral cameras provide aerial imaging to detect stress in crops caused by pests, diseases, or nutrient deficiencies. Farmers can intervene early, applying targeted treatments to affected areas, thereby minimizing chemical use and enhancing sustainability.

Automation and robotics are also integral to agro-tech. Tractors equipped with GPS systems can perform tasks such as planting, fertilizing, and harvesting with unparalleled precision, reducing labor costs and errors. Harvesting robots, particularly useful for delicate crops like fruits, ensure consistent quality while minimizing damage. Furthermore, automated sorting and packaging systems streamline post-harvest processes, improving efficiency and reducing waste.

Despite its potential, agro-tech adoption faces significant barriers. Smallholder farmers, who constitute the majority of the agricultural workforce in many regions, often lack access to these advanced technologies due to high costs and limited technical expertise. Financial challenges include the initial investment in machinery, ongoing maintenance, and the training required to operate these tools effectively. Additionally, inadequate digital infrastructure in rural areas, such as poor internet connectivity, hampers the integration of IoT and cloud-based farm management systems.

To overcome these challenges, governments and industry stakeholders must collaborate to develop affordable financing models, such as subsidies, low-interest loans, and leasing programs for equipment. Demonstration projects showcasing the benefits of agro-tech can encourage adoption by reducing skepticism and building farmer confidence. Moreover, investments in digital infrastructure, particularly in rural areas, are essential to support IoT-enabled systems and real-time data sharing.

Agro-tech also plays a critical role in sustainability. Renewable energy sources, such as solar panels, are increasingly used to power farm equipment, reducing reliance on fossil fuels. Advanced water management systems, including precision irrigation and rainwater harvesting, optimize resource use while protecting natural ecosystems. By integrating these technologies, agro-tech promotes environmentally responsible farming practices that address climate change and ensure long-term agricultural viability.

# 03

## Digital Skills



## | Digital Skills

Digital skills are the backbone of modern agriculture, enabling farmers to harness the power of technology for precision farming, data management, and automated operations. In the era of Agriculture 4.0, these skills are no longer optional but essential for achieving efficiency, sustainability, and competitiveness.

At the basic level, digital literacy includes the ability to operate IoT devices, interpret data from farm management software, and use mobile applications for weather forecasting and market analysis. For instance, a farmer equipped with digital literacy can monitor soil conditions through smartphone apps connected to IoT sensors, enabling informed decisions about irrigation and fertilization schedules. Similarly, understanding weather data can help optimize planting and harvesting times, reducing the risk of crop losses due to adverse conditions.

Advanced digital skills go beyond basic literacy, encompassing competencies in data analysis, machine learning, and artificial intelligence (AI). These skills enable farmers to analyze complex datasets, such as satellite imagery and sensor readings, to identify trends and predict outcomes. For example, AI-powered predictive analytics can forecast pest outbreaks or crop diseases, allowing farmers to take preventive measures. Machine learning algorithms can optimize resource allocation, ensuring that water, fertilizers, and pesticides are used efficiently.

However, the distribution of digital skills across the agricultural sector is uneven. Smallholder farmers, particularly in developing regions, often lack access to training and resources, limiting their ability to adopt digital tools. Infrastructure challenges, such as limited internet connectivity and the high cost of digital devices, further exacerbate this divide. Even in developed regions, older farmers may resist adopting new technologies due to unfamiliarity or perceived complexity.

Addressing these gaps requires a multi-faceted approach. Governments and educational institutions must develop training programs tailored to the needs of farmers, emphasizing practical applications and hands-on experience. E-learning platforms that incorporate audiovisual content can make training more accessible, particularly in remote areas. These platforms should cover topics such as IoT device operation, data interpretation, and the use of AI tools in agriculture.

Policy interventions are also critical. Subsidies and tax incentives can reduce the financial burden of acquiring digital tools, while public-private partnerships can promote the development and distribution of affordable, user-friendly technologies. Renewable energy solutions, such as solar-powered devices, can address infrastructure limitations, enabling farmers in off-grid areas to access digital tools.



# 04

## Essential Skills



## | Essential Skills

Essential skills in modern agriculture extend beyond technical competencies, encompassing problem-solving, adaptability, and a deep understanding of sustainability principles. As the sector faces unprecedented challenges such as climate change, resource scarcity, and market volatility, these skills are increasingly vital for ensuring resilience and long-term success.

Problem-solving skills enable farmers to address complex issues, such as pest infestations or unpredictable weather patterns, with innovative solutions. For instance, a farmer facing a water shortage might implement precision irrigation systems to optimize resource use. Similarly, adaptability is crucial for navigating the rapid technological advancements that characterize Agriculture 4.0. Farmers must be willing to learn and adopt new tools, such as drones or AI-based decision-making systems, to remain competitive.

Sustainability awareness is another critical component of essential skills. Farmers must understand the environmental impact of their practices and adopt strategies that promote ecological balance. For example, maintaining soil health through crop rotation and organic fertilizers not only improves productivity but also reduces the risk of degradation. Integrating renewable energy sources, such as solar panels, into farm operations minimizes greenhouse gas emissions and enhances energy efficiency.

To develop these skills, educational programs must go beyond technical training, incorporating modules on critical thinking, environmental stewardship, and innovation. For example, vocational education and training (VET) systems can include case studies and simulations that encourage learners to apply theoretical knowledge to real-world scenarios. Collaborative learning models, where farmers share experiences and best practices, can also foster skill development.



# 05

## Sustainable Skills



## | Sustainable Skills

Sustainability is at the heart of modern agricultural practices, addressing the urgent need to balance productivity with environmental stewardship. Sustainable skills encompass a range of competencies that enable farmers to adopt practices that conserve resources, protect ecosystems, and enhance resilience to climate change. These skills are critical for ensuring the long-term viability of agriculture and meeting global food security goals.

Water management is a cornerstone of sustainable farming. Precision irrigation systems, such as drip irrigation and sensor-controlled sprinklers, minimize water wastage by delivering water directly to the root zones of plants. These systems rely on real-time data from soil moisture sensors, which allow farmers to adjust irrigation schedules based on crop needs. This approach not only conserves water but also improves crop yields by ensuring optimal hydration.

Soil health management is another critical aspect of sustainability. Healthy soils are essential for productive farming, as they support nutrient cycling, water retention, and plant growth. Technologies such as soil sensors and remote sensing tools provide valuable insights into soil conditions, including pH levels, nutrient content, and moisture. By using this data, farmers can apply fertilizers more precisely, reducing chemical runoff and preventing soil degradation. Practices such as crop rotation, cover cropping, and organic amendments further enhance soil fertility and resilience.

Energy efficiency is integral to sustainable agriculture. Renewable energy sources, such as solar and wind power, are increasingly used to power farm operations. For example, solar panels can supply energy for irrigation pumps, reducing dependence on fossil fuels and lowering greenhouse gas emissions. Automated machinery, such as GPS-guided tractors, also contributes to energy efficiency by optimizing fuel use and minimizing operational overlaps.

Climate resilience is a key focus of sustainable agriculture, as extreme weather events and shifting climate patterns pose significant risks to farming. Predictive analytics, powered by AI and machine learning, enable farmers to anticipate and prepare for climate-related challenges. For instance, weather models can predict droughts or frost events, allowing farmers to implement protective measures, such as adjusting planting schedules or using frost-resistant crop varieties.

Training and education are essential for equipping farmers with sustainable skills. VET programs must incorporate modules on resource conservation, renewable energy use, and climate-smart agriculture. Hands-on workshops and field demonstrations can help farmers understand and adopt best practices, such as precision irrigation and integrated pest management. Collaborative learning platforms, where farmers share experiences and solutions, further promote the dissemination of sustainable techniques.

Despite the benefits of sustainable practices, adoption remains limited due to financial and technical barriers. Smallholder farmers often lack the resources to invest in advanced technologies, such as soil sensors or renewable energy systems. Inadequate access to training and information further hinders the implementation of sustainable practices, particularly in rural and low-income regions.

To address these challenges, targeted policies and funding mechanisms are needed. Subsidies and grants can lower the cost of adopting sustainable technologies, while public-private partnerships can facilitate the development and distribution of affordable solutions. Expanding access to digital infrastructure and e-learning platforms can provide farmers with the knowledge and tools to implement sustainable practices effectively.

# 06

## VET Educational Approaches



## | VET Educational Approaches

Vocational Education and Training (VET) is essential for equipping the agricultural workforce with the skills needed to meet modern challenges. The agricultural sector, heavily influenced by technological advancements, requires a combination of traditional knowledge and modern, practice-oriented education. VET plays a crucial role in bridging this gap by preparing both young and adult learners for careers in agriculture and related industries.

Traditional VET approaches, such as classroom-based learning and apprenticeships, have long served as the foundation of agricultural education. Classroom-based instruction focuses on theoretical knowledge, providing students with an understanding of scientific principles related to farming, such as soil chemistry, crop cycles, and pest control. Apprenticeships, on the other hand, offer hands-on experience by pairing learners with experienced professionals in the field. This approach helps students acquire practical skills and fosters a deeper understanding of daily agricultural operations.

However, traditional methods alone are no longer sufficient to meet the demands of modern agriculture, which requires skills in technology, data analysis, and sustainability. Modern VET approaches, including blended and modular learning, have emerged as effective solutions. Blended learning combines in-person instruction with online resources, allowing learners to access course materials at their convenience. For example, a farmer participating in a blended learning program might attend in-person workshops on irrigation techniques while also completing online modules on IoT device management.

Modular learning divides curricula into smaller, focused units, enabling students to learn specific skills relevant to their career goals. This flexibility is particularly valuable in agriculture, where diverse specializations—such as crop management, livestock care, and agri-tech—require tailored training. Competence-based education further enhances VET by emphasizing the mastery of practical skills. Assessments are designed to test real-world applications, such as using drone technology to monitor crop health or calibrating automated irrigation systems.

Emerging technologies are transforming VET, providing innovative ways to deliver education. Virtual and augmented reality (VR/AR) create immersive training environments where learners can simulate farming operations without the risks associated with real-world experimentation. For instance, students can practice operating heavy machinery or experiment with crop rotation strategies in a virtual setting, gaining confidence before applying these skills on actual farms.

Gamification is another emerging trend in VET, incorporating game-like elements into learning. By rewarding achievements and creating competitive challenges, gamification enhances engagement and motivation. AI-driven adaptive learning platforms further personalize the educational experience, analyzing individual progress and tailoring content to address specific knowledge gaps.

Despite these advancements, challenges remain in implementing modern VET approaches. Rural areas often lack the digital infrastructure needed to support online learning platforms and VR/AR technologies. Additionally, aligning VET curricula with industry needs requires close collaboration between educational institutions and agricultural businesses. Policymakers must also address the financial barriers that prevent smallholder farmers from accessing advanced training programs.

To overcome these obstacles, investments in digital infrastructure, such as high-speed internet and renewable energy solutions, are critical. Partnerships between government, industry, and educational institutions can ensure that VET programs are relevant, accessible, and responsive to the needs of the agricultural workforce. Expanding funding for scholarships, subsidies, and low-cost training options can further enhance participation, particularly among underserved populations.

# 07

## Practical Application of Technologies



## | Practical Application of Technologies

The practical application of agricultural technologies is a key driver of innovation and efficiency in the sector. Technologies such as automation, robotics, IoT, and AI are transforming traditional farming methods, enabling farmers to achieve higher productivity while reducing environmental impact. However, their successful implementation requires not only access to these tools but also the skills and infrastructure to use them effectively.

Automation and robotics streamline labor-intensive processes, reducing the need for manual intervention. GPS-controlled tractors, for example, ensure precise planting and fertilization, minimizing waste and optimizing resource use. Drones equipped with imaging technology provide detailed maps of crop conditions, enabling targeted interventions. These technologies not only save time and labor but also improve the accuracy and efficiency of farm operations.

IoT devices are integral to modern agriculture, connecting sensors, machinery, and data platforms to create smart farming ecosystems. Soil sensors monitor moisture, pH, and nutrient levels, providing real-time data that informs irrigation and fertilization decisions. Weather stations collect localized climate data, helping farmers plan activities such as planting and harvesting. These interconnected systems enhance decision-making and reduce the risk of crop failure.

AI and machine learning offer powerful tools for predictive analytics and decision support. AI algorithms analyze vast datasets, such as satellite imagery and sensor readings, to identify patterns and forecast outcomes. For instance, AI can predict pest outbreaks based on weather conditions and crop health data, allowing farmers to take preventive measures. Machine learning models optimize resource allocation, ensuring efficient use of water, energy, and fertilizers.

While the benefits of agricultural technologies are clear, their practical application is often hindered by challenges such as high costs, limited access, and technical complexity. Smallholder farmers, in particular, face barriers to adoption due to financial constraints and lack of training. Furthermore, inadequate digital infrastructure, especially in rural areas, limits the effectiveness of IoT and cloud-based systems.

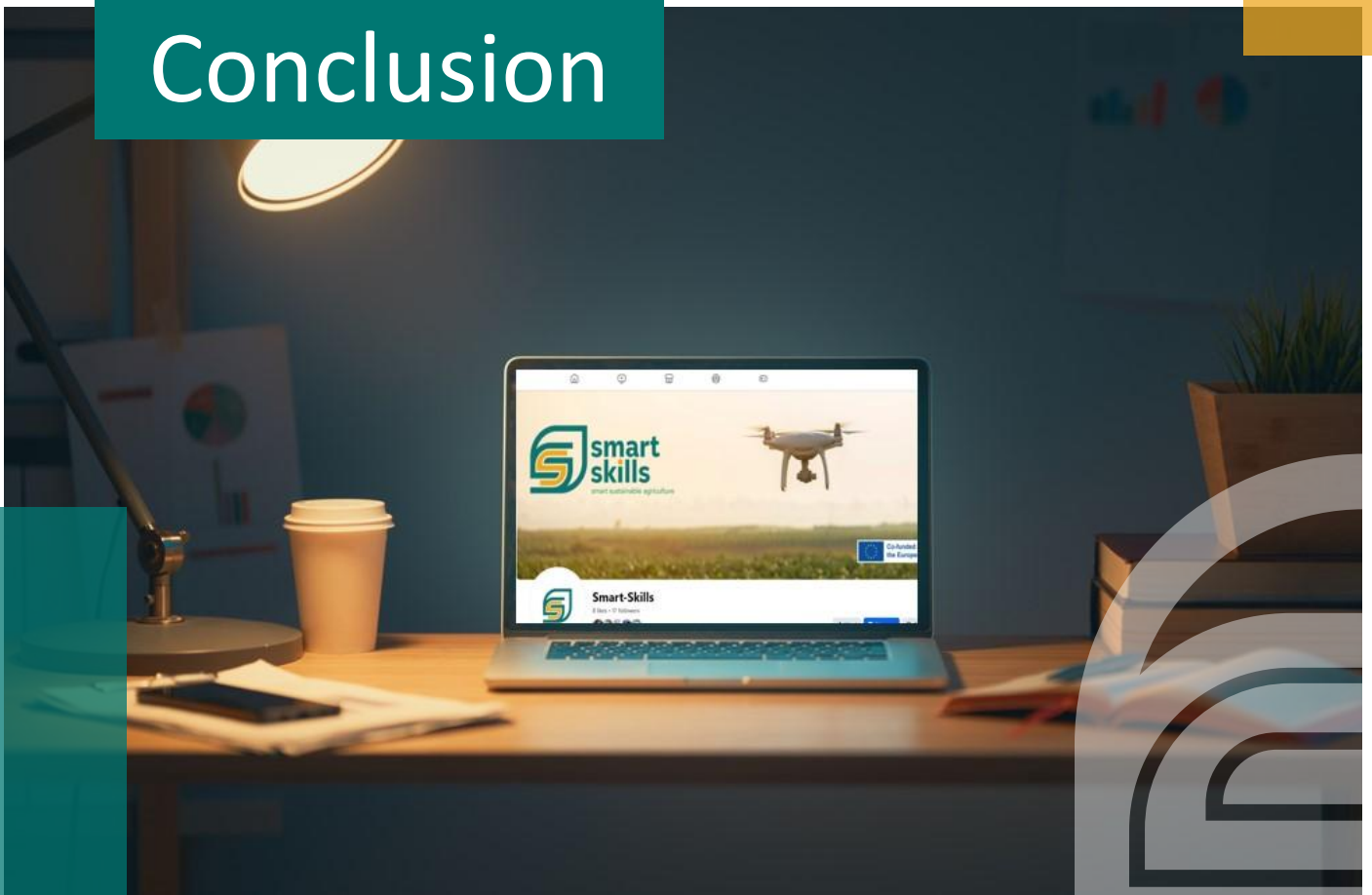
To address these issues, targeted interventions are needed. Governments and industry stakeholders must collaborate to develop affordable financing models, such as leasing programs and microloans, to make technologies accessible to smaller farms. Training programs should focus on building practical skills, emphasizing hands-on experience with tools and systems. Investments in digital infrastructure, such as broadband internet and renewable energy solutions, are essential to support the deployment of smart farming technologies.

In conclusion, the practical application of technologies is transforming agriculture, offering solutions to some of the sector's most pressing challenges. By addressing barriers to adoption and investing in skills development and infrastructure, stakeholders can unlock the full potential of these innovations, driving sustainable and efficient agricultural practices.



# 08

## Conclusion



## | Conclusion

The Smart Skills literature research underscores the importance of equipping the agricultural sector with the knowledge, skills, and technologies required to meet the demands of a rapidly evolving world. Through this literature review, key areas of focus—digital skills, vocational education and training (VET), agro-tech, essential skills for smart agriculture, sustainable skills, and the integration of technology—have been critically analyzed and synthesized.

The findings highlight the transformative potential of digital and innovative technologies in improving productivity, sustainability, and resource efficiency across agricultural systems. By leveraging tools such as IoT, blockchain, artificial intelligence, and precision farming technologies, farmers can address the challenges posed by climate change, resource scarcity, and food security. These advancements, however, require a parallel focus on education and training to bridge skill gaps, especially among smallholder farmers and underserved communities.

Sustainability emerges as a central theme, emphasizing the need for practices that balance environmental conservation with economic viability. Skills in water management, soil health, agroecology, and renewable energy are critical for fostering resilience and addressing global sustainability goals.

While the integration of these skills and technologies offers promising opportunities, significant barriers remain, including financial constraints, inadequate infrastructure, and resistance to change. Addressing these challenges requires concerted efforts from policymakers, industry stakeholders, and educational institutions. Investments in digital infrastructure, targeted training programs, and affordable technology solutions are essential to ensure equitable access and participation.

Ultimately, this review provides a comprehensive foundation for the Smart Skills project, offering actionable recommendations to advance workforce readiness, sustainability, and technological integration in agriculture. By aligning educational strategies with industry needs and global challenges, the project paves the way for a smarter, more resilient agricultural future.