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AI4AGRI

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Developing green and digital skills towards AI use in agriculture

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A.2.1: Review on AI and agriculture technology and analysis of farmer-driven innovations and best-practices in AI and agriculture technology

Developed by

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1. Agriculture Policies in the EU

Agriculture has long held a central place in the European Union's economic, social, and environmental landscape. From feeding its population and supporting rural livelihoods to protecting biodiversity and managing natural resources, agriculture intersects with numerous policy domains. The European Union has built one of the most comprehensive agricultural policy frameworks in the world, aimed at securing a sustainable and competitive agri-food sector. Over the decades, this framework has evolved from a focus on productivity and food security to broader goals that encompass environmental sustainability, digital transformation, rural development, and social equity.

At the heart of EU agricultural governance lies the Common Agricultural Policy (CAP), which has undergone multiple reforms since its inception in 1962. These reforms reflect the changing priorities of the Union—from post-war food self-sufficiency and market stabilization to environmental protection, innovation, and resilience in the face of global challenges like climate change and geopolitical instability. This report provides a detailed overview of the current EU agricultural policy landscape, with a focus on the CAP 2023–2027, sustainability and digital goals, the European Green Deal and Digital Europe Programme, and the mechanisms used to fund and support these initiatives.

1.1. The Common Agricultural Policy (CAP) 2023–2027

The Common Agricultural Policy was established in 1962 with the founding principles of increasing agricultural productivity, ensuring a fair standard of living for farmers, stabilizing markets, securing food supplies, and providing consumers with affordable food. In the decades following World War II, the CAP helped transform European agriculture from a fragmented and inefficient sector into a high-output, modern system. However, overproduction, budget pressures, and environmental degradation by the 1980s and 1990s led to successive waves of reform. The Agenda 2000 reform emphasized rural development, while the 2003 and 2013 reforms focused more on sustainability, cross-compliance, and greening measures. These changes laid the groundwork for the CAP 2023–2027, which is more performance-oriented, environmentally conscious, and tailored to Member State needs.

The CAP 2023–2027 represents a fundamental redesign rather than an incremental update. Its structure is more flexible and decentralised, allowing each Member State to implement a National Strategic Plan (NSP) that reflects their agricultural characteristics and socio-economic challenges while still adhering to EU-wide goals. These goals are centered on competitiveness, climate action, natural resource protection, generational renewal, rural viability, food security, and innovation.

One of the most transformative elements of the new CAP is the introduction of eco-schemes. These are voluntary programs that reward farmers who go beyond the basic legal requirements in adopting environmentally beneficial practices. To encourage uptake, Member States must allocate at least 25% of their direct payments budget to eco-schemes. Social conditionality has also been introduced for the first time, linking subsidies to labor rights and working conditions.

Furthermore, the CAP 2023–2027 strengthens support for young farmers, gender equality, and the adoption of digital and green technologies. It introduces more rigorous performance monitoring, relying on a new results-based framework that focuses on measurable outcomes rather than administrative compliance.

1.2. Sustainability and Digital Transformation Goals

Sustainability has emerged as a defining feature of EU agricultural policy, reflecting broader societal concerns about climate change, biodiversity loss, and resource depletion. Agriculture is both a victim and a contributor to climate change—while farming is impacted by extreme weather and changing ecosystems, it is also responsible for around 10% of the EU's greenhouse gas emissions. Recognizing this dual role, the EU has integrated sustainability deeply into the CAP and associated programs. Sustainable farming practices promoted under the CAP include crop rotation, cover cropping, organic agriculture, agroforestry, and precision farming. These methods enhance soil health, conserve water, and reduce chemical inputs. Special support is also given to carbon farming initiatives, restoration of wetlands, and protection of pollinators and natural habitats.

The digital transformation of EU agriculture is a parallel priority aimed at improving efficiency, transparency, and adaptability. Precision agriculture, enabled by satellite imagery, sensors, artificial intelligence, and machine learning, allows farmers to make data-driven decisions that enhance productivity while reducing environmental impact. Tools such as the Farm Sustainability Tool for Nutrients (FaST) help optimize fertilizer use and reduce runoff into waterways.

To support this shift, the EU is investing in digital infrastructure, such as broadband expansion in rural areas, digital skills training, and the development of farm data platforms. The CAP encourages the adoption of smart farming practices through funding, knowledge-sharing networks, and innovation hubs. These tools not only improve competitiveness but also make farming more attractive to younger generations.

1.3. European Green Deal and Digital Europe Programme

The European Green Deal, announced in 2019, is the EU's overarching roadmap to sustainability and climate neutrality by 2050. Agriculture features prominently in this strategy through the Farm to Fork Strategy and the Biodiversity Strategy. These initiatives call for a systemic transformation of the food system—from production and processing to distribution and consumption.

The Farm to Fork Strategy sets ambitious targets: reducing the use of pesticides and antimicrobials by 50%, cutting fertilizer use by 20%, increasing organic farming land to 25%, and halving food waste. These goals are intended to make food systems fair, healthy, and environmentally friendly. The strategy also focuses on enhancing food labelling, traceability, and nutrition standards.

The Biodiversity Strategy complements these efforts by promoting the restoration of ecosystems, protection of pollinators, and conservation of genetic diversity in crops and livestock. Farmers are encouraged to integrate biodiversity-friendly practices, and protected areas are expanded under the Natura 2000 network.

The DEP is a €7.5 billion funding program that supports the deployment of digital technologies across the EU. In agriculture, this includes investments in artificial intelligence, cybersecurity, high-performance computing, and digital skills. The program supports the creation of common data spaces for agriculture, enabling the secure exchange of information between farmers, advisors, researchers, and policy makers.

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1.4. Funding Mechanisms and Support Tools

To accelerate the adoption of AI in agriculture, the EU has established several funding instruments and support networks. The European Agricultural Fund for Rural Development (EAFRD) offers co-financing for investments in digital infrastructure, training, and the acquisition of precision farming tools. Another key mechanism, the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI), promotes collaboration between farmers, researchers, businesses, and advisory services. EIP-AGRI's operational groups serve as platforms for experimenting with and scaling up AI applications, such as autonomous tractors, smart dairy systems, and integrated pest management software. Additionally, digital innovation hubs and Living Labs across the EU function as testing grounds for new technologies, providing technical assistance, user feedback, and pathways to commercialization. These mechanisms collectively create a robust ecosystem for integrating AI into the European agricultural sector.

The *European Agricultural Fund for Rural Development (EAFRD)* is the financial engine of CAP's Pillar II, which focuses on rural development. For the 2021–2027 period, the EAFRD is allocated approximately €87 billion, including national co-financing from Member States. This fund is essential for ensuring a balanced territorial development of rural areas, improving competitiveness, and promoting social inclusion.

EAFRD supports a wide array of interventions including:

- **Agri-environment-climate measures** that encourage farmers to adopt practices beneficial to biodiversity, soil conservation, water management, and carbon sequestration.
- **Support for young farmers** entering the agricultural sector, including startup aid, training, and advisory services.
- **Rural infrastructure development**, such as renewable energy projects, broadband expansion, and basic services in remote areas.
- **Community-led local development (CLLD)** via the LEADER initiative, which empowers local action groups to design and implement bottom-up strategies tailored to regional needs.

Each Member State prepares a Rural Development Programme (RDP) under the EAFRD, aligned with EU priorities such as competitiveness, innovation, climate action, and social well-being. The EAFRD is also aligned with the EU's Green Deal and digitalization objectives, ensuring that rural areas are not left behind in the twin green and digital transitions.

The *EIP-AGRI* is a flagship initiative under Horizon Europe and the CAP that promotes innovation as a tool to enhance agricultural productivity in a sustainable manner. Launched in 2012, EIP-AGRI connects farmers, researchers, advisors, businesses, and NGOs to co-create and disseminate practical solutions that address real-world challenges in agriculture and forestry.

Key features of EIP-AGRI include:

- **Operational Groups (OGs):** Multi-stakeholder consortia formed around specific themes or problems. These groups receive funding from the EAFRD to develop and test innovative practices or technologies.

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- **Thematic Networks and Focus Groups:** These aim to collect and share knowledge on specific topics (e.g., climate-smart farming, soil management, or digital tools) and identify good practices and policy recommendations.
- **Innovation support services:** Facilitate matchmaking between project partners, navigate funding opportunities, and support knowledge transfer.

EIP-AGRI bridges the gap between research and application, ensuring that innovation is farmer-driven, context-specific, and aligned with EU sustainability goals. It supports the CAP's performance-based approach by linking innovation to measurable outcomes in productivity, environmental quality, and economic resilience.

The *LEADER approach* (Liaison Entre Actions de Développement de l'Économie Rurale), supported by the EAFRD, embodies a bottom-up, participatory development model. It enables Community-Led Local Development (CLLD), where local action groups (LAGs) composed of public, private, and civil society stakeholders create and execute area-specific development strategies.

LEADER projects foster economic diversification, heritage conservation, cultural tourism, and local entrepreneurship. They are particularly valuable in preserving the social fabric and identity of rural communities, while also contributing to green and digital transformations.

In addition to grants, the EU promotes financial instruments such as **loans, guarantees, and blended finance** to support agriculture-related investments. These are often administered by the European Investment Bank (EIB) or national development banks, with support from the CAP or InvestEU.

Such instruments are crucial for:

- Modernizing farm infrastructure and machinery.
- Facilitating land acquisition or generational renewal.
- Investing in climate-resilient and precision farming technologies.
- Supporting agri-food SMEs and cooperatives.

These financial tools help overcome credit constraints, especially for young farmers and smallholders, and are increasingly used to fund projects aligned with EU climate and digital goals.

2. AI Policies in the EU

Artificial Intelligence (AI) has been identified as a transformative technology that holds significant promise for driving innovation, enhancing productivity, and tackling societal challenges across sectors. Recognizing both its opportunities and risks, the European Union (EU) has taken a proactive approach to shaping AI policy that balances innovation with fundamental rights and safety. The EU's AI strategy is deeply rooted in its values of transparency, human-centricity, and accountability. This approach aims to ensure that AI systems developed and used within the Union are trustworthy, lawful, and ethically aligned. The development of these policies began in earnest with the 2018 "European Strategy on Artificial Intelligence" and has since evolved into a robust regulatory and strategic framework encompassing legal, ethical, economic, and geopolitical dimensions.

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2.1. The EU AI Act

The Artificial Intelligence Act, proposed by the European Commission in April 2021, represents the world's first attempt to comprehensively regulate AI systems. The Act introduces a horizontal, risk-based regulatory approach, categorizing AI applications into four risk levels: unacceptable, high, limited, and minimal. Unacceptable-risk AI systems—such as those involving real-time biometric identification in public spaces or social scoring—are banned outright. High-risk systems, including those used in critical sectors like healthcare, education, law enforcement, and border control, are subject to rigorous requirements. These include conformity assessments, mandatory risk management protocols, robust data governance, human oversight mechanisms, and transparency obligations.

Importantly, the AI Act is designed to be future-proof, applying to both current AI applications and emerging technologies like generative AI and foundation models. Recent amendments have proposed specific obligations for providers of large-scale general-purpose AI models, requiring documentation of training data, risk mitigation strategies, and compliance with EU fundamental rights. The Act also foresees the creation of an EU AI Office, tasked with monitoring implementation and coordinating among national competent authorities. Once adopted, the AI Act will become a key pillar of Europe's digital regulation framework, comparable in influence to the GDPR.

2.2. The EU AI Pact

In anticipation of the AI Act's full enforcement, the European Commission launched the EU AI Pact in 2023. This voluntary initiative encourages companies, developers, and public institutions to start aligning their AI systems with the forthcoming regulatory requirements ahead of time. Participants in the AI Pact commit to proactively adopting the ethical and procedural safeguards outlined in the AI Act, including documentation practices, algorithmic transparency, and human oversight.

The AI Pact serves several strategic purposes. It fosters early compliance and reduces future regulatory friction, encourages knowledge sharing and best practices across sectors, and signals strong market readiness. Furthermore, the Pact is seen as a testbed for regulatory implementation, offering valuable feedback to policymakers as they finalize the legal text. It strengthens the EU's capacity to transition smoothly into a fully regulated AI ecosystem while encouraging international actors to adapt to EU standards.

2.3. White Paper on Artificial Intelligence

The EU's regulatory ambition began with the publication of the White Paper on Artificial Intelligence in February 2020. This document laid the conceptual groundwork for the AI Act and provided a blueprint for a "European approach to excellence and trust." The White Paper outlined two main pillars: fostering an ecosystem of excellence to support innovation and creating an ecosystem of trust through regulatory intervention. It identified key challenges including lack of data access, fragmented research efforts, and ethical concerns such as bias and lack of transparency in AI systems.

In response, the White Paper proposed coordinated investment in research, skills, and infrastructure, alongside the development of a legislative framework to address high-risk AI applications. It also emphasized the need for public-private cooperation and cross-border initiatives to strengthen the EU's AI ecosystem. The proposals within the White Paper triggered wide public consultation and formed the backbone of the AI Act, underscoring the importance of participatory policymaking in EU digital strategy.

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2.4. Testing and Experimentation Facilities (TEFs)

To translate AI research into real-world applications, the EU has invested in AI Testing and Experimentation Facilities (TEFs). These are large-scale, cross-border infrastructure projects designed to enable the testing, validation, and fine-tuning of AI systems in realistic environments. TEFs focus on key sectors such as healthcare, agriculture, smart cities, and manufacturing, offering controlled settings where developers can evaluate their systems against regulatory standards and ethical benchmarks.

TEFs play a crucial role in ensuring that AI innovations are safe, effective, and market-ready. They provide access to shared datasets, computing infrastructure, and domain expertise, thereby lowering the barrier to innovation, particularly for startups and SMEs. Additionally, TEFs support the objectives of the AI Act by enabling providers to assess compliance with safety and performance requirements before market deployment. These facilities are funded under the Digital Europe Programme and operated through partnerships between research institutions, private companies, and public agencies across the EU.

3. Adaptation of AI at the National Contexts

In Poland, the integration of AI technologies into agriculture represents a monumental leap forward, ushering in a transformative era of innovation, productivity, and sustainability within the sector. Across various facets of agricultural practices, AI-driven applications are being meticulously adapted and strategically implemented to confront specific challenges while optimizing every aspect of farm management processes. This concerted effort is propelling Polish agriculture into a new epoch characterized by precision, efficiency, and resilience, positioning the sector for sustained growth and competitiveness in the global market. (Loon, 2023).

Precision agriculture stands as a cornerstone domain profoundly impacted by the advancements in AI technology. Through the strategic deployment of AI-powered sensors, drones, and satellite imagery, Polish farmers are empowered to collect and analyse intricate datasets pertaining to soil conditions, crop health, and environmental parameters with unprecedented accuracy and granularity. This wealth of data serves as the cornerstone for informed decision-making, allowing farmers to optimize resource allocation, implement targeted interventions for irrigation, fertilization, and pest control, and ultimately, amplify crop yields while minimizing input costs. By embracing precision agriculture methodologies augmented by AI, farmers across Poland are not merely maximizing productivity but also spearheading efforts towards a more sustainable agricultural ecosystem, where efficiency and environmental stewardship go hand in hand. (Nayak, 2024).

Moreover, the advent of predictive analytics fuelled by AI technologies has emerged as a game-changer for Polish farmers in mitigating risks associated with pests, diseases, and adverse weather conditions. By harnessing historical data alongside real-time environmental indicators, AI algorithms generate precise forecasts and timely alerts, empowering farmers to proactively implement preventive measures. Whether it's adjusting planting schedules, deploying targeted pest management strategies, or optimizing crop rotations, AI-driven predictive analytics plays a pivotal role in safeguarding crop yields and ensuring the overall health of agricultural operations throughout Poland.

In the realm of livestock farming, AI-driven monitoring and management systems are spearheading a revolution in traditional husbandry practices. Through the strategic deployment of AI-powered sensors and monitoring devices, farmers gain invaluable insights into critical parameters such as feed intake,

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activity levels, and health indicators among their livestock in real-time. This enables early detection of health issues and facilitates prompt intervention, thereby enhancing animal welfare and optimizing production outcomes. Furthermore, AI-driven analytics are revolutionizing breeding programs, improving feed efficiency, and bolstering overall farm profitability in livestock operations across Poland, contributing to the sector's competitiveness and sustainability. (CABI, 2024). The deployment of autonomous farming machinery equipped with AI capabilities is gaining rapid momentum across Polish farms, heralding a new era of labour efficiency and operational optimization. These AI-powered robots, adept at executing a diverse array of tasks with remarkable precision and efficiency, are revolutionizing farm operations. By diminishing the reliance on manual labour, autonomous farming machinery not only amplifies productivity but also addresses labour shortages within the agricultural sector, thereby fostering heightened farm efficiency and profitability. (ibid.)

Furthermore, smart farming systems, underpinned by AI and the Internet of Things (IoT), are fostering seamless integration and interoperability of farm equipment, sensors, and data analytics platforms. This interconnectedness facilitates real-time monitoring and control of agricultural processes, optimizing resource utilization, enhancing decision-making, and elevating operational efficiency across the entire agricultural value chain. Additionally, AI-driven decision support systems provide Polish farmers with invaluable insights and recommendations to fine-tune farm management practices, ensuring optimal yields, minimal risks, and enhanced profitability. (ibid.)

Beyond operational enhancements, AI technologies are playing a pivotal role in catalysing data-driven research and innovation within Poland's agricultural landscape. Research institutions, agricultural organizations, and governmental bodies are leveraging AI to analyse vast datasets, uncover patterns, and develop novel technologies and practices to address emergent challenges and seize untapped opportunities within the sector. This concerted effort in AI-driven innovation is pivotal in propelling Poland's agricultural industry onto the global stage while effectively meeting the evolving demands of consumers and stakeholders alike. (Loon, 2023).

Moreover, the adoption of AI technologies in Polish agriculture bears profound implications for rural development, economic growth, and environmental sustainability. By augmenting productivity, reducing input costs, and optimizing resource efficiency, AI-driven agriculture holds the potential to bolster the economic viability of rural communities and spawn new avenues for employment and entrepreneurship within the agricultural sector. (Nayak, 2024). Additionally, by championing sustainable farming practices and curtailing environmental impact, AI technologies can play a pivotal role in conserving natural resources and mitigating the adverse effects of climate change, thereby ensuring the long-term sustainability of agriculture in Poland.

4. National Legislation Frameworks

The integration of artificial intelligence (AI) in Polish agriculture is underpinned by a comprehensive framework of legal regulations meticulously crafted to ensure the ethical, safe, and responsible use of AI technologies. These regulations serve to navigate the intricate intersection between technological innovation and agricultural practices, while also prioritizing the protection of farmers, consumers, and the environment.

Data protection legislation, notably the General Data Protection Regulation (GDPR) enforced by the European Union (EU), stands at the forefront of legal considerations governing AI adoption in agriculture in Poland. The GDPR establishes rigorous standards governing the collection, processing, and storage of personal data, including information generated by AI systems utilized in agricultural operations. Compliance with GDPR requirements is not just a legal obligation but a fundamental necessity for farmers and agricultural organizations in Poland to uphold the privacy and rights of individuals whose data is processed by AI technologies. Ensuring compliance with GDPR principles forms a crucial aspect of AI implementation strategies in the agricultural sector, where data privacy and security are paramount concerns. (EDPS, 2023).

Furthermore, intellectual property rights legislation plays a pivotal role in shaping the landscape of AI innovation within the agricultural domain in Poland. Farmers and agricultural companies are confronted with navigating a complex maze of patent rights, copyright protection, and trade secrets when developing or deploying AI technologies. Intellectual property laws provide essential legal safeguards to incentivize investment in research and development within the agricultural sector, fostering an environment conducive to innovation. Clear guidelines and robust enforcement mechanisms are essential to protect the intellectual property rights of innovators and developers, thereby promoting a vibrant ecosystem of AI-driven agricultural innovation in Poland. (Nayak, 2024).

Liability considerations constitute another significant facet of the legal frameworks governing AI adoption in Polish agriculture. As AI-powered agricultural machinery and systems become increasingly prevalent, questions regarding responsibility and accountability in the event of accidents or damages inevitably arise. Polish laws and regulations provide guidelines for determining liability in such cases, ensuring that farmers, manufacturers, and other stakeholders are held accountable for any harm caused by AI technologies in agriculture. Establishing a robust framework for risk mitigation and dispute resolution is essential to instil confidence in AI adoption among stakeholders, thereby fostering a climate conducive to innovation and growth in the agricultural sector. (ZG Legal, 2023).

Moreover, ethical considerations surrounding AI use in agriculture are addressed through a variety of legal frameworks aimed at promoting transparency, fairness, and accountability. Guidelines and codes of conduct may be established to govern the development, deployment, and use of AI technologies in agriculture, ensuring that ethical principles are upheld throughout the innovation process. These frameworks encompass provisions for ethical AI design, algorithm transparency, and stakeholder engagement, serving to mitigate potential risks and ensure that AI applications in agriculture align with societal values and expectations. Striking a balance between technological advancement and ethical considerations is paramount to fostering public trust and confidence in AI adoption in the agricultural sector. (Ryan, 2022).

Additionally, regulatory bodies and government agencies in Poland play a pivotal role in overseeing compliance with legal frameworks governing AI adoption in agriculture. These entities provide guidance, support, and oversight to ensure that AI technologies deployed in the agricultural sector adhere to applicable laws and regulations while promoting innovation, competitiveness, and sustainability. Through active engagement with industry stakeholders and continuous monitoring of technological developments, regulatory bodies endeavour to strike a delicate balance between fostering innovation and safeguarding public interests. Collaborative efforts between government agencies, industry stakeholders, and research institutions are essential to ensure that AI adoption in Polish agriculture is aligned with broader societal objectives, including economic growth, environmental sustainability, and social welfare. (EC, 2021).

In summary, the legal frameworks and regulations governing AI adoption in agriculture in Poland are multifaceted and continually evolving to keep pace with technological advancements and changing societal needs. By establishing clear rules and guidelines, Poland aims to promote responsible AI adoption in agriculture, ensuring that AI technologies contribute to the advancement of the agricultural sector while upholding ethical standards, protecting data privacy, addressing liability concerns, and fostering innovation-driven growth. Continued collaboration and dialogue among policymakers, industry stakeholders, and civil society are essential to navigate the complex challenges and opportunities presented by AI adoption in Polish agriculture effectively.

5. AI Technologies & Applications in Agriculture Industry

Artificial intelligence (AI) technologies have emerged as transformative tools revolutionizing various facets of agriculture, offering innovative solutions to address a multitude of challenges faced by farmers and agricultural stakeholders. Across the agricultural landscape, AI-driven applications are being deployed to optimize processes, enhance decision-making, and ultimately increase productivity, efficiency, and sustainability in food production.

Precision agriculture stands out as one of the primary domains where AI technologies are making significant strides. Through the integration of AI-powered sensors, drones, and satellite imagery, farmers can collect vast amounts of data related to soil conditions, crop health, and environmental parameters. These data streams are then analysed using advanced machine learning algorithms to generate actionable insights. By leveraging precision agriculture methodologies augmented by AI, farmers can make informed decisions regarding irrigation, fertilization, and pest management. Such data-driven approaches enable farmers to optimize resource allocation, minimize input costs, and maximize crop yields, thereby fostering a more sustainable agricultural ecosystem. (Rensburg, 2023).

Predictive analytics is another area where AI technologies are driving transformative changes in agriculture. By harnessing historical data alongside real-time environmental indicators, AI algorithms can forecast crop yields, predict pest outbreaks, and anticipate weather patterns with remarkable accuracy. These predictive insights empower farmers to proactively implement preventive measures to safeguard crop yields and mitigate risks. Whether adjusting planting schedules, deploying targeted pest management strategies, or optimizing crop rotations, AI-driven predictive analytics enables farmers to make data-driven decisions that optimize production outcomes while minimizing the impact of external factors on agricultural operations. (Nayak, 2024).

In livestock farming, AI-driven monitoring and management systems are revolutionizing traditional husbandry practices. Through the deployment of AI-powered sensors and monitoring devices, farmers gain real-time insights into critical parameters such as feed intake, activity levels, and health indicators among their livestock. Machine learning algorithms analyse these data streams to detect anomalies and identify potential health issues early on, enabling farmers to intervene promptly and enhance animal welfare. Furthermore, AI-driven analytics are optimizing breeding programs, improving feed efficiency, and bolstering overall farm profitability in livestock operations. (ibid.).

The advent of autonomous farming machinery equipped with AI capabilities is gaining momentum across agricultural landscapes, ushering in a new era of labour efficiency and operational optimization. These AI-powered robots are capable of executing a diverse array of tasks, ranging from planting and weeding to harvesting, with precision and efficiency. By reducing the reliance on manual labour, autonomous farming machinery not only amplifies productivity but also addresses labour shortages within the agricultural sector, thereby fostering heightened farm efficiency and profitability. (ibid.).

Smart farming systems, underpinned by AI and the Internet of Things (IoT), are fostering seamless integration and interoperability of farm equipment, sensors, and data analytics platforms. This interconnectedness facilitates real-time monitoring and control of agricultural processes, optimizing resource utilization, enhancing decision-making, and elevating operational efficiency across the entire

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agricultural value chain. Additionally, AI-driven decision support systems provide farmers with invaluable insights and recommendations to fine-tune farm management practices, ensuring optimal yields, minimal risks, and enhanced profitability. (Dhanaraju, 2022).

Innovative AI technologies such as computer vision and natural language processing are also being leveraged to address specific challenges within the agricultural sector. Computer vision algorithms can analyse images captured by drones or cameras to identify crop diseases, assess plant health, and monitor crop growth stages. Natural language processing algorithms enable farmers to interact with AI-powered chatbots or virtual assistants to access real-time information, receive personalized recommendations, and streamline decision-making processes. (Nayak, 2024).

AI applications in agriculture have had a profound impact on agricultural productivity, revolutionizing traditional farming practices and enhancing efficiency, sustainability, and resilience within the sector. These AI-driven solutions leverage advanced technologies such as machine learning, computer vision, and predictive analytics to optimize various aspects of agricultural operations, resulting in improved yields, reduced resource inputs, and enhanced profitability for farmers. (Intellias, 2023). Here are some key examples of successful AI applications and their impact on agricultural productivity (GeoPard Agriculture, n.d.):

- Precision Agriculture

AI-powered precision agriculture technologies enable farmers to optimize resource management by precisely targeting inputs such as water, fertilizers, and pesticides based on real-time data and predictive analytics. By utilizing sensors, drones, and satellite imagery coupled with machine learning algorithms, farmers can accurately assess soil conditions, monitor crop health, and identify areas of inefficiency within their fields. This targeted approach to farming not only maximizes crop yields but also minimizes waste and environmental impact, leading to improved productivity and sustainability.

- Crop Monitoring and Disease Detection.

AI-based crop monitoring systems leverage computer vision and image recognition algorithms to analyse visual data captured by drones or cameras installed in the fields. These systems can detect early signs of crop diseases, nutrient deficiencies, and pest infestations, allowing farmers to take timely corrective actions. By identifying and addressing potential threats to crop health at an early stage, AI-driven crop monitoring systems help prevent yield losses and ensure the overall health and productivity of agricultural crops.

- Predictive Analytics for Yield Forecasting

AI-powered predictive analytics tools utilize historical data, weather forecasts, and other relevant variables to forecast crop yields with a high degree of accuracy. By analysing past yield trends and correlating them with environmental factors, machine learning algorithms can generate predictive models that enable farmers to anticipate yield fluctuations and plan their operations accordingly. This proactive approach to yield forecasting empowers farmers to optimize harvest timing, logistics, and marketing strategies, ultimately maximizing profitability and reducing market volatility.

- Autonomous Farming Machinery

AI-driven autonomous farming machinery, such as robotic harvesters and precision planters, automate labour-intensive tasks in the field, significantly improving operational efficiency and productivity. These intelligent machines utilize advanced sensors, GPS technology, and machine learning algorithms to navigate fields, identify crops, and perform tasks with precision and accuracy. By reducing the need for

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manual labour and streamlining field operations, autonomous farming machinery helps farmers increase productivity, minimize labour costs, and optimize resource utilization.

- Soil Health Monitoring and Management

AI-based soil health monitoring systems leverage sensor technology and data analytics to assess soil quality, fertility, and moisture levels in real-time. By continuously monitoring soil conditions and analysing data collected from sensors installed in the field, these systems provide farmers with valuable insights into soil health and nutrient management. This information enables farmers to make data-driven decisions regarding fertilization, irrigation, and soil conservation practices, leading to improved soil health, enhanced crop yields, and long-term sustainability.

- Supply Chain Optimization

AI technologies are increasingly being used to optimize supply chain logistics and distribution processes in agriculture. By leveraging predictive analytics and machine learning algorithms, companies can forecast demand, optimize inventory levels, and streamline distribution routes, resulting in more efficient and cost-effective supply chain management. This enables farmers to deliver their products to market more effectively, reduce waste, and improve profitability.

AI technologies are driving a paradigm shift in agriculture, offering transformative solutions to address complex challenges and unlock new opportunities for innovation and growth. By harnessing the power of AI, farmers can optimize resource utilization, minimize risks, and enhance productivity, ultimately contributing to the advancement of sustainable and resilient food systems. As AI continues to evolve and mature, its integration into agriculture holds immense potential to revolutionize the way food is produced, distributed, and consumed, shaping the future of agriculture for generations to come. AI applications in agriculture have had a transformative impact on agricultural productivity, enabling farmers to make more informed decisions, optimize resource utilization, and adapt to changing environmental conditions. (Javaid, 2023). As AI technologies continue to evolve and become more accessible, their role in driving innovation and sustainability within the agricultural sector is expected to grow, ultimately shaping the future of food production and global food security.

6. Pedagogical Practices and Training

Addressing the digital literacy gap among agriculture workers is a multifaceted endeavour that requires comprehensive pedagogical approaches and robust training programs. In response to the increasing digitization of agricultural practices, there has been a growing recognition of the importance of equipping agriculture workers with the necessary digital skills and knowledge to navigate and leverage digital technologies effectively in their work. To this end, various pedagogical approaches and training initiatives have been developed to bridge the digital divide and empower agriculture workers to thrive in the modern agricultural workforce. (Gow, 2023).

One effective pedagogical approach involves the implementation of targeted training programs that focus on practical, hands-on learning experiences. These programs often incorporate a blend of classroom instruction, workshops, and field demonstrations to provide agriculture workers with tangible opportunities to learn and practice using digital tools and technologies. By immersing participants in real-world scenarios and providing guidance and support from experienced instructors, these training programs help agriculture workers develop the confidence and proficiency needed to embrace digital technologies such as farm management software, GPS-enabled equipment, and data analytics platforms. (O'Donoghue, 2018).

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Moreover, integrating digital literacy training into existing agricultural education and extension programs is essential for ensuring that agriculture students and practitioners are adequately prepared to meet the demands of a technology-driven agricultural industry. By embedding digital literacy modules into curriculum offerings at agricultural colleges, vocational training centres, and extension programs, educators can ensure that learners acquire the fundamental digital skills and knowledge needed to succeed in their careers. These integrated approaches to digital literacy education provide learners with a solid foundation in digital literacy while also exposing them to the practical applications of digital technologies in agriculture. (FAO, 2023).

Collaborative learning initiatives and peer-to-peer knowledge sharing networks also play a crucial role in addressing the digital literacy gap among agriculture workers. By fostering a culture of collaboration and knowledge exchange within the agricultural community, these initiatives create opportunities for agriculture workers to learn from their peers, share best practices, and collectively build their digital literacy skills. Online forums, social media groups, and community workshops serve as valuable platforms for agriculture workers to connect, collaborate, and learn from one another, thereby strengthening their digital literacy skills and capacity to leverage digital technologies effectively in their work. (Molina, 2021).

Furthermore, mentorship programs can provide invaluable support and guidance to agriculture workers as they navigate the digital landscape. Pairing less digitally literate individuals with more experienced mentors who possess proficiency in digital technologies can accelerate the learning process and provide personalized assistance and encouragement. Mentorship programs can take various forms, including formal mentorship arrangements facilitated by agricultural organizations or informal peer mentoring relationships established within agricultural communities. By fostering mentorship opportunities, agriculture workers can gain valuable insights, receive tailored support, and develop the skills and confidence needed to embrace digital technologies in their agricultural practices. (Erazo, 2015).

Identifying best practices and successful training initiatives concerning AI in agriculture involves identifying programs that effectively address the unique challenges and opportunities presented by the integration of AI technologies into agricultural practices and the most recognizable are (ibid.):

- Tailored Training Programs

They are key to successful initiatives as they acknowledge the diverse needs and backgrounds of agriculture workers, offering a variety of training options such as workshops, seminars, online courses, and hands-on practical sessions. By providing flexible and accessible training opportunities, these programs ensure that agriculture workers can acquire the necessary AI skills and knowledge at their own pace and convenience.

- Collaboration and Partnerships

They are fundamental in successful training initiatives because these partnerships involve government agencies, agricultural organizations, educational institutions, technology companies, and industry experts. By leveraging the expertise and resources of multiple stakeholders, these initiatives offer comprehensive training programs covering various AI-related topics, from basic concepts to advanced applications.

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- Experiential Learning

It is prioritized in effective training initiatives due to providing opportunities for participants to engage in real-world projects, case studies, and simulations that simulate agricultural scenarios and challenges. Through practical learning experiences, participants develop practical skills and confidence in using AI technologies, ensuring they can apply their knowledge effectively in their agricultural work.

- Continuous Learning and Support

An integral way to successful training initiatives which offer access to online forums, communities of practice, mentoring programs, and technical support channels for ongoing guidance and support beyond the initial training period. By fostering a culture of continuous learning and support, these initiatives empower agriculture workers to continuously improve their AI skills and stay updated on emerging trends.

- Outcome-Oriented Evaluation

An essential factor for assessing key performance indicators such as knowledge acquisition, skills development, behaviour change, and impact on agricultural productivity and sustainability. Through data collection and participant feedback, these initiatives identify areas for improvement and make informed decisions to enhance the quality and relevance of their training programs.

- Scalability and Sustainability

They develop scalable training models and resources that can be easily replicated and adapted to different contexts and regions. Moreover, they seek to build local capacity and institutionalize AI training within existing agricultural education and extension systems to ensure long-term sustainability and impact.

Addressing the digital literacy gap among agriculture workers requires a holistic approach that encompasses targeted training programs, integration of digital literacy into agricultural education and extension initiatives, collaborative learning initiatives, and mentorship programs. By equipping agriculture workers with the digital skills and knowledge needed to thrive in today's technology-driven agricultural landscape, these pedagogical approaches and training initiatives contribute to building a more digitally inclusive and resilient agricultural workforce, ultimately driving innovation, productivity, and sustainability in the agricultural sector. On the other hand, best practices and successful training initiatives concerning AI in agriculture emphasize tailored programs, collaboration and partnerships, experiential learning, continuous support, outcome-oriented evaluation, scalability, and sustainability. By adopting these principles and strategies, training initiatives can effectively equip agriculture workers with the AI skills and knowledge needed to drive innovation, productivity, and sustainability in the agricultural sector. (Gow, 2023).

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7. Conclusions

The intersection of agriculture and technology is definitely multifaceted, particularly focusing on the integration of artificial intelligence (AI) in agricultural practices. Beginning with exploring Poland's agricultural policies the light was then shed on examining AI applications in farming, the transformative potential of technology in enhancing productivity, sustainability, and resilience within the agricultural sector.

Through initiatives such as precision farming, livestock management optimization, and supply chain innovation, AI is revolutionizing traditional farming methods and empowering farmers with advanced tools and insights. Moreover, Poland's commitment to research, innovation, and technology transfer underscores its dedication to driving agricultural advancement and addressing contemporary challenges such as climate change and market volatility.

When navigating into the evolving landscape of agriculture and technology, it's imperative to stay informed about the latest developments, policies, and initiatives shaping the sector. By embracing innovation, fostering collaboration, and prioritizing sustainability, stakeholders can harness the full potential of technology to build a more resilient, efficient, and inclusive agricultural ecosystem for generations to come.

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AI4Agri Project website: https://www.ai-4-agri.eu/

AI4Agri Project e-Learning Platform: https://ai4agri-elearning.eu/

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