ARTIFICIAL INTELIGENCE IN ORGANIC FARMING -GOOD PRACTICES

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Abstract: Organic farming has gained global prominence as a sustainable alternative to conventional agriculture, driven by increasing awareness of environmental and health concerns. Its growth is supported by evolving consumer preferences and a shift away from synthetic inputs such as antibiotics, chemical fertilisers, and growth promoters. Despite its ecological benefits, such as enhanced biodiversity and improved soil health, organic farming faces persistent challenges, including greater vulnerability to pests, diseases, and restrictions on antimicrobial agents, which can impact productivity and economic viability.

Recent advances in artificial intelligence (AI) present new opportunities to address these challenges. AI technologies have shown considerable potential in optimising pest and disease management, resource allocation, and automation of farm operations, enhancing both efficiency and sustainability in organic systems.

This paper explores the potential of artificial intelligence in enhancing organic production. It examines the basic definitions and principles of organic farming, as well as the differences between organic and conventional agriculture, with an emphasis on the advantages and challenges of organic production for the environment and human health.

Furthermore, it analyzes key AI technologies and their specific applications in organic agriculture, along with examples of successful AI implementations in organic production

Key words: organic farming, artificial intelligence, deep learning, sustainable agriculture

1. INTRODUCTION

Organic farming, also known as ecological or biological agriculture, has become a key component of modern agriculture due to growing awareness of the importance of environmental preservation and human health. The evolution of organic farming, innovative marketing systems, and consumer concerns about conventional agricultural practices, such as the use of antibiotics, chemical fertilisers, and growth promoters, have driven the rapid growth of organic agriculture. Ecological characteristics include high levels of plant and biota biodiversity and a positive correlation with species richness, which results from reduced or no use of chemicals in the soil (Bengtsson et al., 2005; Clough et al., 2007).However, organic farming faces numerous challenges, including an increased presence of harmful insects and pathogenic bacteria, which can result in economic losses. The ban on the use of antimicrobial growth promoters also presents an additional challenge (Hughes & Heritage, 2004).

Addressing these challenges is essential for the sustainability of organic farming, and modern science and technology can play a significant role.The application of Artificial Intelligence (AI) has shown promising results in optimising agricultural production. AI technologies can aid in pest and disease management, resource optimisation, and the automation of various farming practices. This paper explores the potential of AI in improving organic production. Furthermore, key AI technologies and their concrete applications in organic farming are analysed, along with examples of successful AI implementations in organic production [1], [5].

2. ORGANIC FARMING

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Ecological, organic, or biological farming is perceived as the production of "healthy food" without usage of agrochemicals such as synthetic fertilisers, pesticides, hormones, and similar substances. Although this definition captures part of the essence of organic farming, it is a more complex concept involving comprehensive management aimed at achieving sustainable and environmentally friendly production (Znaor, 1996). Organic farming is not merely the exclusion of chemicals but a system that seeks to fully utilise the potential of a given ecosystem, including autonomous management, stimulation, enhancement, and harmonisation of biological processes within various parts of the farm (Znaor, 1996).

Today, many governments subsidise the organic sector to reward the environmental performance of organic farmers and compensate for increased production costs or lower yields (Stolze & Lampkin, 2009). The International Federation of Organic Agriculture Movements (IFOAM) was established in 1972 as the global umbrella organisation for organic farming. IFOAM promotes ecologically, socially, and economically sustainable production of food and fiber, aiming to optimise quality in all aspects of agriculture and the environment. The core principles of IFOAM include promoting biological cycles, long-term soil fertility, mobilization of organic matter within closed systems, use of renewable resources, pollution avoidance, conservation of genetic diversity, enabling animals to express natural behavior, ensuring adequate income for producers, and producing high-quality food that is socially and economically acceptable (IFOAM, 2017) [6].

This perception is based on evidence that organic systems reduce negative environmental impacts such as greenhouse gas emissions, biodiversity loss, soil degradation, and water pollution (Foley et al., 2011). However, health benefits and challenges of organic production are complex and multifaceted. While organic farming offers many ecological and social benefits, challenges such as lower yields and higher requirements remain significant. Conventional agriculture, while offering high productivity, poses environmental risks due to the intensive use of synthetic inputs. Conventional agriculture is based on the assumption that agricultural land is homogeneous, meaning it has uniform physical, chemical, and biological properties. The same amount of input is applied across the entire field, which can lead to either excess or deficiency of nutrients in different parts of the soil. By introducing precision agriculture, it becomes possible to adjust agronomic practices in order to create uniform optimal conditions for crop or plantation growth and development across the entire area.

The future of sustainable development in agriculture requires integrating the best practices from both systems to strike a balance between food production and the preservation of natural resources (Seufert & Ramankutty, 2017; Foley et al., 2011).

3. ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) refers to the field of computer science dedicated to developing computer systems capable of performing tasks that require some form of intelligence. The term also refers to characteristics of non-living systems that demonstrate intelligence, known as intelligent systems.AI development is based on concepts such as machine learning and neural networks, enabling systems to process large amounts of data, communicate with humans through natural language or with other systems, learn from experience, draw conclusions, exhibit adaptive behavior, and perform complex planning. Although current intelligent systems still have specialised functions for a limited range of tasks—unlike humans, who can perform diverse functions simultaneously—their applications are broad and varied. These include machine translation, expert systems, robotics, computer games and simulations, text generation and chatbots, data mining, automatic programming, etc.Machine learning and deep learning are key technologies that allow systems to learn from data without explicit programming. Machine learning uses mathematical and statistical methods for analysis and prediction, while deep learning is a subset of machine learning that uses neural networks for complex classification and prediction tasks.

3.1. Machine and Deep Learning

Machine learning enables systems to learn from experience without the need for explicit programming, using mathematical and statistical methods to improve based on data. Various stages of image processing—including preprocessing, segmentation, feature extraction, classification, and prediction—can be implemented using different machine learning models.

Machine learning tasks are divided into supervised and unsupervised learning, depending on the learning signal. In supervised learning, data are presented with inputs and corresponding outputs to construct a rule that maps inputs to outputs. In some cases, inputs may be partially available, and some target outputs are missing or provided only as feedback in dynamic environments (reinforcement learning – RL). In a supervised setting, the acquired knowledge (trained model) is used to predict missing outputs (labels) for test data. In unsupervised learning, the data are unlabeled, and the goal is to discover hidden patterns.

4. APPLICATION OF ARTIFICIAL INTELLIGENCE IN ORGANIC FARMING

Artificial Intelligence (AI) in agriculture enables technological advancements, including advisory services, data analytics, the Internet of Things (IoT), and the use of cameras and sensors. AI provides improved predictive insights by analyzing data on weather, soil, crop performance, and temperature. Risks such as interoperability, security, data reliability, and unforeseen socio-ecological consequences have also been explored. AI can enhance crop management by identifying plant diseases and optimizing the application of agrochemicals. Machine learning can support plant phenotyping, crop monitoring, soil composition assessment, weather forecasting, and yield prediction. An increasing number of farmers are adopting AI, IoT, and other technologies to boost productivity. AI-based technologies promise significant changes in agriculture. Farms can use AI and cognitive technologies to improve decision-making, data analysis, task automation, and operational efficiency [4].

Large amounts of data can be leveraged to increase production and sustainability through advanced technology and trust in machine learning. The growing use of sensors, faster access to satellite imagery, lower costs of data loggers, drones, and improved access to government data facilitate the use of AI. Banks can use AI to assess farmers' creditworthiness and production history before approving loans, enhancing transparency and reducing risk. AI applications based on computer vision must be trained on large and diverse image datasets of pests. An AI model can learn from data and images using a network of experts and farmers, complementing their knowledge to support better decision-making. Data collection through community participation mechanisms could help gather richer contextual data, while various remote sensing technologies can provide localised information on rainfall and weather indicators [7], [8].

4.1. Examples of Artificial Intelligence in Organic Farming

4.1.1. Autonomous Tractors – Bear Flag Robotics Technology

Bear Flag Robotics integrates advanced autonomous technology into tractors, enhancing agricultural productivity. Their system can be installed on existing tractors, eliminating the need for purchasing new equipment. The system enables rapid field mapping and the generation of optimal paths, and it can be scaled to operate multiple tractors simultaneously. Operators can remotely monitor and control the tractors through a user interface that provides real-time data and 360-degree video views. The technology supports various agricultural implements and uses an advanced path generator to optimize field operations. This significantly contributes to the efficiency and adaptability of farming operations, allowing for better resource management and reduced labour hours.

Bear Flag Robotics' autonomous tractors use artificial intelligence to analyse and adapt to field conditions, including obstacle recognition and real-time operational adjustments. The technology is designed for continuous operation, reducing the need for human intervention and enabling farmers to focus on strategic aspects of farm management. Additionally, the system provides detailed analytics and reports, helping farmers make informed decisions in crop management.

4.1.2. Crop Monitoring Drones – Taranis

Taranis uses advanced high-resolution imaging technology for leaf-level crop analysis, applying artificial intelligence to detect various issues. This technology enables the identification of diseases, insect damage, nutrient deficiencies, as well as plant and weed counting. By using aerial high-resolution images and AI analysis, Taranis helps farmers optimize yields and reduce losses. The system can be applied to various crops such as corn, cotton, soybeans, and sugar beets, offering a detailed view of crop conditions.

Taranis technology uses drones and satellites to collect high-resolution images that enable detailed crop monitoring. Artificial intelligence analyzes these images to identify potential problems such as diseases, pests, and nutrient deficiencies at a microscopic level. This allows farmers to respond quickly and adjust their practices to ensure optimal growing conditions.

The advantages of the system include reduced need for physical field inspections, increased efficiency of treatments and resource management, and improved overall productivity and yield. Taranis technology also enables precise monitoring of crop development over time, which is crucial for making informed agricultural decisions.

4.1.3. Advanced Farm Management System – CropX

CropX is a comprehensive agronomic farm management system that uses advanced technologies to collect and analyze soil and atmospheric data. Through an intuitive user interface, farmers can manage multiple farms and fields, accessing customizable data views, remote monitoring and control, as well as graphical displays and satellite imagery of the fields [2].

This technology enables farmers to increase productivity and efficiency, reduce costs, and improve the sustainability of their practices.

4.2. Cereal Farm case study-Integrating AI with Traditional Knowledge in Northeastern India

Cereal Farm is a family-run agricultural enterprise located in the northeastern region of India, traditionally known for its fertile soils and abundant rainfall. However, in recent years, the effects of climate change have become increasingly apparent. The farm now faces irregular and unpredictable weather patterns, including droughts, delayed rainfall, and destructive hailstorms — all of which have negatively impacted crop yields and quality.To address these challenges, the farm adopted an AI-based crop advisory application. The app offers:

- Localised weather forecasts
- Recommendations for planting and harvesting schedules
- Early detection and treatment advice for crop diseases
- Fertiliser application suggestion

Based on the app's guidance, the farm also introduced drought-resistant hybrid maize varieties to cope with the increasing aridity and reduce crop failures.

Challenges and Farmer Feedback: Despite the potential of the AI solution, the farmers encountered several critical challenges:

Inaccuracy in weather forecasts

- Fertilizer application recommendations that did not suit local soil conditions
- Poor performance of hybrid seeds, which were not adapted to the region's microclimate
- Concerns about the loss of indigenous seed varieties

A farmer explained:

"Our ancestors saved part of the harvest to use as seeds next season. When the app recommended hybrid seeds, we tried them, but they didn't grow properly. So we went back to native seeds — and over time, these improved in quality again."

Hybrid Approach – Traditional Knowledge Meets AI:While the AI app added value, farmers did not abandon their traditional practices. Instead, they developed a hybrid approach that combined generational knowledge with digital tools.

"Traditional knowledge has its own importance, but to deal with climate change, we must use technology too. Both should go hand in hand," said one farmer.

The AI was particularly helpful in decision-making under uncertainty, such as forecasting rainfall and optimising market timing. Meanwhile, traditional knowledge informed practices like field preparation, seasonal planting decisions, and crop rotation strategies [3].

AI tools can complement but not replace traditional knowledge systems.Local adaptation and context-aware AI are essential — generic hybrid seed recommendations often fail in diverse agroecological zones.Farmer trust and feedback loops are crucial for refining AI tools.Blended approaches, where technology supports but doesn't dominate, offer the best outcomes for climate-resilient agriculture.Thus, the co-existence and co-evolution of AI and traditional knowledge represent a promising path toward resilient, climate-smart, and sustainable farming systems.

5. CONCLUSION

Organic farming represents a sustainable alternative to conventional agricultural practices, offering numerous benefits for the environment and human health. Although it faces challenges such as pest and pathogen management, restrictions on chemical fertilisers and antibiotics, and reduced yields, modern science and technology provide tools to overcome these issues. Artificial intelligence (AI) has emerged as a key technology that can significantly enhance organic production.

The integration of AI technologies such as machine learning, deep learning, and computer vision enables precise resource management, more effective pest and disease control, and automation of various agricultural operations. By using AI, farmers can optimise the use of water and nutrients, increase crop yields, and improve overall production efficiency.

In conclusion, the application of artificial intelligence in organic production represents a significant step toward more sustainable and efficient agriculture. Future research and development should focus on further integrating AI technologies to fully realise their benefits and enable organic farming that is both economically viable and environmentally sustainable.

Artificial Intelligence (AI) represents a new chapter in the evolution of agricultural technology, marked by its ability to make autonomous decisions and perform complex tasks without direct human supervision. Unlike traditional systems that merely provide recommendations, advanced AI systems actively interact with their environment, adapt to changing conditions, and independently manage operations such as soil analysis, crop monitoring, and pest control.

The emergence of AI is significant for modern agriculture, which faces the dual challenge of increasing productivity amid rapid global population growth and climate change. These intelligent systems continuously learn from their interactions with diverse agroecological environments, becoming increasingly efficient and adaptive.By integrating with Internet of Things (IoT) devices—such as sensors, weather stations, and drones, AI enables continuous data exchange and analysis. This level of precision is crucial for the development of regenerative and environmentally friendly agricultural practices, making agent-based AI a fundamental tool in shaping the agriculture of the future. Through a case study on the application of artificial intelligence in organic farming, this paper will showcase innovative implementations of these technologies, along with an analysis of the challenges and strategic approaches that highlight their transformational potential.

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