

Sowing the Seeds of Change: Harnessing Artificial Intelligence for Sustainable Agriculture

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Abstract:- This scholarly investigation probes AI's profound impact on agriculture, tackling global food production and sustainability issues. AI's role in precision farming, resource optimization, and data-driven decision-making is underscored, incorporating agronomy, biotechnology, environmental sciences, economics, and ethics. Ethical oversight for data privacy, equitable access, and responsible AI deployment is deemed critical. Retraining strategies for the agricultural workforce and rural communities are emphasized. The study examines AI's contributions to crop management, resource conservation, environmental sustainability, and global food security, showcasing autonomous tractors, drones, UAVs, and gene-based approaches as promising solutions. It also assesses shifting labor dynamics, skill requisites, and ethical implications. Advocating responsible innovation, the work envisions an ethical and sustainable integration of AI in agriculture, shaping a resilient and food-secure future while proactively addressing upcoming challenges.

Keywords: Autonomous tractor, Drone, Machine learning, Gene-based algorithm, Artificial neural network.

1. Introduction

In the realm of modern agriculture, a quiet revolution is underway, driven by the relentless march of technology. At its forefront stands Artificial Intelligence, a potent force that promises to transform the age-old practice of farming into a highly sophisticated, data-driven enterprise. AI's emergence in agriculture is not just a trend; it is a necessity dictated by the urgent global need to feed an ever-expanding population while navigating the unpredictable challenges posed by climate change. Standing at the crossroads of agriculture's past and its future, this report ventures into the realm of AI's profound impact on farming. From the humble beginnings of automated irrigation systems to the present-day integration of machine vision, big data, and automation, AI is revolutionizing the very essence of agriculture. It offers solutions to optimize resource use, enhance crop yields, predict weather patterns, and mitigate the impact of pests and diseases. Delving into this transformative journey, the report explores the multifaceted dimensions of AI in agriculture, uncovering its promises, potential, and the challenges it brings, all in the pursuit of a more sustainable, efficient, and resilient global food supply. Agriculture is the cornerstone of global food production and a critical component of economies worldwide. The need for food is increasing as the world's population rises coupled with the effects of climate change and resource limitations, posing significant challenges to the agriculture industry. In this context, the integration of Artificial Intelligence into agriculture has emerged as a transformative solution with the potential to revolutionize how crops are grown, managed, and distributed. AI in agriculture refers to the application of advanced technologies like automation, machine vision, pattern recognition, and big data to handle the myriad issues that producers and the farming sector face. AI is a term used to describe a system that resembles a human being in terms of thought, behavior, or both [1]. In order to answer the question of whether a machine can

actually "think," Alan Turing developed the Turing Test concept in the 1950s [2]. A computer must be proficient in four areas in order to pass the Turing Test: machine learning, automated reasoning, knowledge representation, and natural language processing [1]. However, Turing's definition faced criticism for not distinguishing between knowledge and intellect, similar to the challenge of defining a computer while separating its hardware from its software [3]. Another definition of AI characterized it as "a program that can perform as well as a human in an arbitrary environment," implying that AI consists of programs with inputs and outputs that interact within an environment [3]. AI finds applications in various domains, including Robotics, automated programming and scheduling, theorem proving, sophisticated database retrieving, expert consulting systems, perception issues, and more [4].

2. Methods

Artificial intelligence is a type of intelligence that can carry out tasks that were previously only humanly possible, like communication, language processing, visual recognition, and comprehension. AI includes a wide range of methodologies, tactics, and techniques intended to imitate intelligent behavior [5]. It makes it possible to do complex activities and actions that other digital technologies are unable to [6]. AI often surpasses human capabilities in critical areas like thinking, planning, learning, and perception, contributing to more sustainable production methods. In agriculture, AI finds application through software programs and algorithms, manifesting in various forms such as drones, cars, and agricultural machinery. The distinction between intelligent and non-intelligent digital technologies, as well as AI and non-AI robots, is essential. While non-AI robots like milking robots have been used in agriculture, AI robots demonstrate human-like abilities such as context awareness and problem-solving. Despite being in their early stages, AI robots are already contributing significantly to tasks like crop scouting, pest control, and harvesting. Figure 1 outlines three distinct AI categories, with Artificial Narrow Intelligence (ANI) excelling in specific tasks like autonomous driving and disease identification. ANI has already shown success in a number of fields, and its use is anticipated to grow [7]. Artificial General Intelligence (AGI) is the term used to describe machines that have human-level intelligence and are capable of doing intellectual tasks that humans can [8]. According to Bostrom (2014) [9], Artificial Super Intelligence (ASI) anticipates a degree of intelligence that is well above human cognitive capability in almost every discipline. For the sake of this essay, shall continue to concentrate on artificial narrow intelligence because it is now being used whereas general and super intelligence are still in the research and development stages and have not yet found practical application. Additionally, will use Artificial Narrow Intelligence for specialized agricultural applications, dividing them into the management of crops and livestock. Despite the importance of AI in livestock management, this study focuses primarily on its applications in aspects of crop management [10], such as soil management, insect and weed killer, medical management, crop production, and water consumption control.

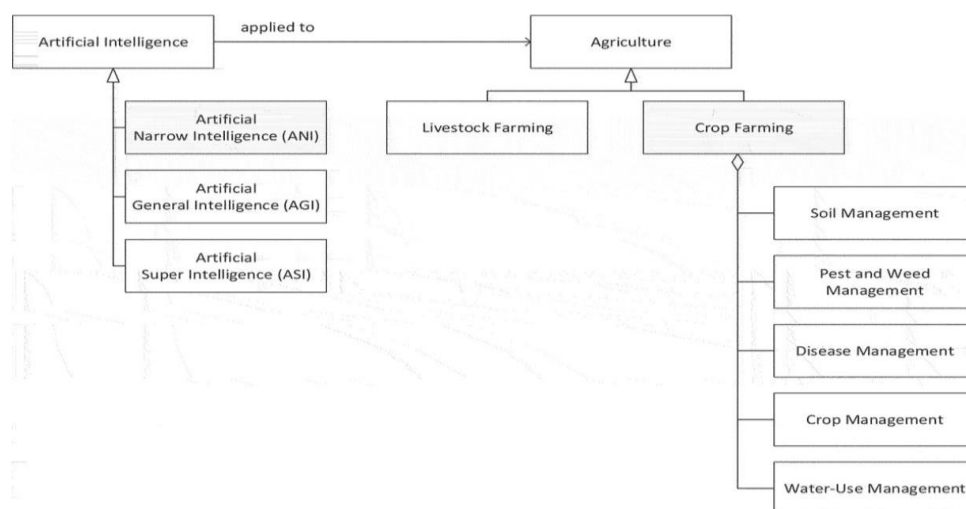


Figure 1. Shows the flowchart of the UML diagram of AI in agriculture

3. Domains

The management of livestock and the production of crops are two different aspects of agriculture, which is frequently referred to as the art and science of cultivating land. Managing this physical environment effectively to suit the biological requirements of the crop plant is the main problem in agriculture [11]. Soil productivity, water availability, climatic conditions, and the presence of pests and pathogens are important variables affecting crop yield [12]. By reducing procedures and optimizing resource use, AI is changing the agriculture industry. Water management aims to improve irrigation systems and water usage on farms, whereas crop management seeks to distribute resources [13], [14]. A key significant element of the location farming system is effective soil management which can also be achieved through Iot in Agriculture [15], [16]. Farmers should be concerned about the ecology and their bottom line while using chemicals in the right amounts [17]. Nitrification, which makes use of a chemical watering system, has proven to increase fertilizer effectiveness [18]. For effective and sustainable resource allocation, agricultural forecasting, particularly crop production forecasting, is essential [19]. Crop classification involves determining the varieties of crops being farmed and can make use of convolutional and image analysis techniques. Finally, effective control techniques have a considerable impact on agricultural productivity and quality, which considerably increases food security [20].

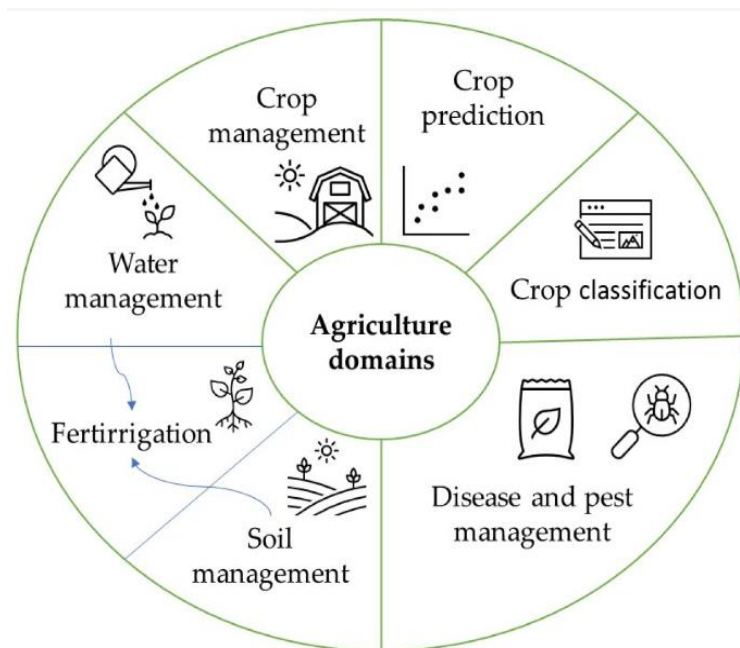


Figure 2. Shows the agriculture domains

3.1. Crop management

Crop management involves a comprehensive set of practices crucial for ensuring robust crop growth and maximizing yields. From the initial stages of land preparation, which includes plowing and leveling the soil, to the selection of the right seeds and their proper sowing techniques for uniform plant spacing, every step is vital. Implementing suitable irrigation systems and schedules, strategic fertilization based on soil testing, and effective weed, pest, and disease management are crucial to ensuring the health and productivity of crops [21]. Additionally, crop rotation plays a significant role in mitigating soil degradation and minimizing the buildup of specific pests and diseases. Timely harvesting techniques and careful post-harvest handling, including proper storage, transportation, and processing, are essential to maintain crop quality and prevent spoilage.

3.2. Crop prediction

Crop prediction relies on the analysis of extensive data, encompassing factors like weather conditions, soil quality, historical yields, and pest and disease occurrences [22]. Advanced technologies, including satellite photography, weather forecasts, and soil sensors, provide crucial real-time statistics on various environmental

aspects. Machine learning algorithms and data analysis uncover patterns that might elude human observation, aiding in predicting insect outbreaks, disease vulnerability, and optimal planting times. Mathematical models, such as crop simulation models, amalgamate data and environmental variables to anticipate crop growth and yield under different conditions. Satellite and drone imagery facilitate remote sensing, enabling the monitoring of crop health, nutrient deficiencies, and pest or disease damage. Integrated farm management software platforms equip farmers with tools for data tracking, informed decision-making, and resource optimization. Government agencies and research institutions contribute to crop forecasts and guidance based on extensive data analysis. Moreover, farmer cooperatives and agricultural extension services play a vital role in disseminating crop prediction information and best practices to local farmers.

3.3. Crop classification

Crop classification is a vital process that involves grouping various crops based on distinct criteria, including plant species, growth habits, intended use, geographic location, and climatic adaptation. Categorizing crops by plant species encompasses different varieties, such as wheat, lentils, apples, and tomatoes. Understanding the growth habits of crops, whether they are annuals, biennials, or perennials, is crucial for implementing appropriate planting and harvesting methods [23]. Moreover, categorizing crops by their intended use, whether they are food crops, cash crops, forage crops, or industrial crops, aids in efficient resource allocation and market analysis. Geographic classification of crops helps in regional planning, market assessment, and the formulation of targeted agricultural policies. Additionally, considering crop classifications based on their adaptability to specific climates, such as tropical, temperate, or arid regions, is essential for optimizing cultivation practices and ensuring successful crop management strategies.

3.4. Disease and pest management

Infection and insect control in agriculture is a critical practice aimed at safeguarding crops from diseases and pests, thereby ensuring healthy growth and optimal yields while minimizing losses and the reliance on chemical interventions. To achieve this, farmers employ various proactive measures, including crop rotation, the selection of disease-resistant crop varieties, and maintaining proper field sanitation practices [24]. Regular monitoring of crops is imperative to identify early signs of disease or pest presence, often utilizing techniques such as scouting, trapping, and remote sensing for comprehensive crop health assessment. Interactive Insect Control (IIC) combines multiple strategies, including cultural measures and biological controls, with the judicious use of chemical pesticides as a last resort. Biotechnology offers an additional avenue through genetic modification, creating crops with inherent resistance to specific pests and infections, and reducing the dependence on artificial interventions. Emphasizing natural control techniques, organic farming practices integrate organic pesticides, beneficial insects, and crop rotation, while chemical control, when necessary, is executed with care to minimize environmental impact and pesticide resistance. Governments and agricultural organizations play a crucial role in educating and training farmers through extension services, equipping them with the knowledge and skills necessary for effective disease and pest management decisions.

3.5. Soil management

Soil management is vital for maintaining and enhancing soil quality and fertility, ensuring sustainable crop production and long-term agricultural viability. Regular soil testing is crucial to assess nutrient levels, pH, and other soil properties, guiding decisions about fertilization and soil amendments. Farmers apply fertilizers based on soil test results to maintain optimal nutrient levels for crop growth, avoiding over-application that could harm the environment [25]. Adding organic matter, such as compost or cover crops, improves soil structure, moisture retention, and nutrient availability, and enhances beneficial soil microorganisms. Crop rotation prevents soil depletion and the accumulation of crop-specific pests and diseases, mitigating soil nutrient imbalances. Practices like reduced tillage or no-till farming minimize soil erosion, compaction, and disruption of beneficial soil organisms. Erosion control measures, such as contour farming, terracing, and planting cover crops, prevent soil erosion, preserve topsoil, and prevent sediment runoff into water bodies. pH adjustment may be necessary to suit specific crops, achieved through adding lime to raise pH or sulfur to lower it. Moreover, soil conservation

practices, including agroforestry, buffer strips, and windbreaks, protect soil from erosion and degradation, contributing to sustainable soil management.

3.6. Fertirrigation

Fertirrigation, a technique combining fertilization and irrigation, employs water-soluble fertilizers delivered to crops through an irrigation system, ensuring precise nutrient application. Various irrigation systems, including drip irrigation, sprinklers, or flood irrigation, can facilitate fertigation [26]. Its key advantage lies in its precision, allowing farmers to supply nutrients directly to the root zone, optimizing nutrient uptake, and minimizing fertilizer wastage. Automated fertigation systems enable farmers to control the timing and frequency of fertilizer application, considering crop growth stages and nutrient requirements. By ensuring uniform distribution of nutrients across the field, fertilization promotes consistent crop growth and minimizes nutrient imbalances. Particularly valuable in regions with limited water resources, fertigation optimizes nutrient use efficiency while conserving water.

3.7. Water management

Water management in agriculture is essential for ensuring the sustainable and efficient use of water resources for crop production, addressing both water quantity and quality. Implementing effective water supply systems, such as drip and sprinkler irrigation, minimizes water wastage by delivering water directly to the plant roots and reducing evaporation. Farmers utilize water scheduling techniques based on crop growth stages, weather conditions, and soil moisture levels to determine appropriate irrigation timing and volume. Rainwater harvesting reduces reliance on groundwater and surface water sources, especially in regions facing water scarcity [27]. Planting drought-resistant crop varieties helps conserve water in water-scarce regions. Real-time monitoring of soil moisture levels through soil moisture sensors enables precise irrigation management. Ensuring the quality of irrigation water, free from contaminants and salinity issues, is vital for maintaining crop health. Adherence to water use regulations and permits is crucial to prevent over-extraction of water resources. Applying mulch to the soil surface aids in reducing water evaporation, maintaining soil moisture, and controlling weed growth, thus minimizing the need for frequent irrigation. Properly designed drainage systems and flood control measures, such as levees and dikes, prevent waterlogging and protect agricultural areas from the adverse effects of flooding.

4. AI-Powered Solutions

The 1950s saw the advent of artificial intelligence, which was motivated by cognitive functions and neurobiology [28]. Analyzing AI technology's use in agriculture to boost food production while coping with climate change was the main problem in this. Intelligent systems can be divided into four categories: those that act like humans, those that reason rationally, and those that think and act like humans [29]. These classifications deal with behavior and thought, evaluating success in terms of adherence to logic or human performance. An AI system has the ability to acquire, represent, and manipulate knowledge in addition to storing and manipulating data. The ability to infer new knowledge from previously known knowledge is a component of manipulation. The artificial intelligence technologies discussed in this section were cited in the SLR articles. The discovered technologies were divided into three major categories: applications for cognitive science, robotics, and natural interfaces. The technologies mentioned in the 176 publications that were examined are shown in Fig. 3 [30]. The deployment of particular AI techniques including computer vision, robotics, machine learning, augmented reality, and virtual reality was supported by IoT, big data, and cloud computing technologies (AR & VR). In, a disease and pest management application that gave an overview of the field and created an intelligent watering system stood out. Digital twins for agriculture were among the cutting-edge technologies examined. It is difficult for agricultural digital twins to accurately depict how biological systems interact with their surroundings.

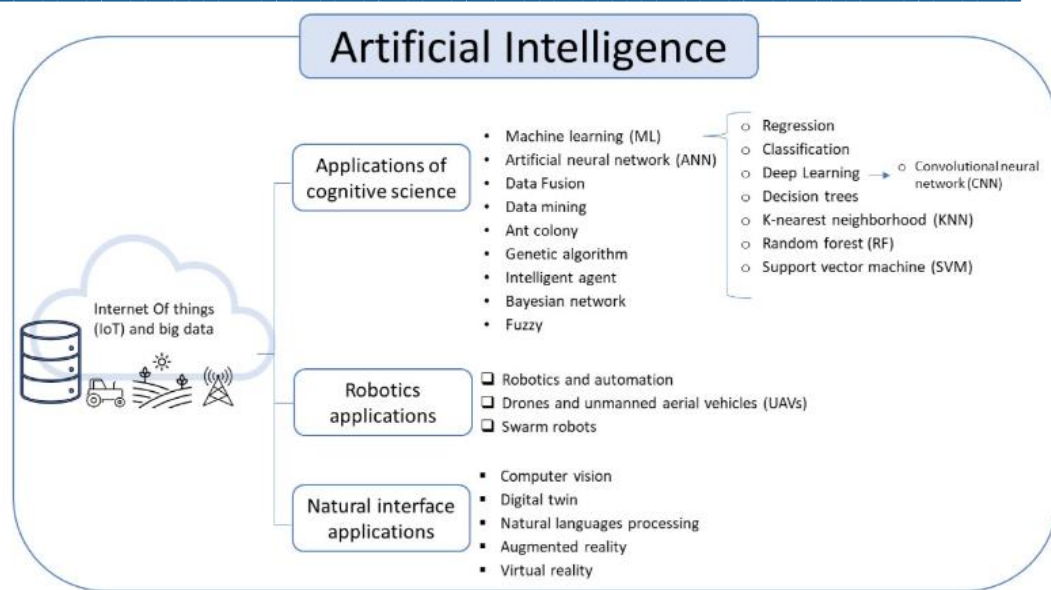


Figure 3. Shows the AI techniques to enhance agriculture

4.1. Robotics and automation in agriculture

In agriculture, robotics and automation have become integral for improving efficiency, productivity, and sustainability. These technologies are transforming traditional farming practices and addressing the difficulties of nourishing an expanding world population [31-33]. One prominent example of robotics and automation in agriculture is the use of autonomous tractors. These vehicles are equipped with advanced sensors, GPS technology, and computer systems that enable them to perform various tasks without human intervention [34]. Autonomous tractors are revolutionizing the agricultural landscape through their precision and efficiency. Equipped with advanced navigation systems, they can navigate fields with exceptional accuracy, following predefined paths or adjusting routes in real time using GPS and sensor data. This precision translates into optimized planting, fertilization, and harvesting. Their ability to operate round the clock enhances overall efficiency, reducing the time required to complete tasks. Additionally, they can function in adverse weather conditions that might pose challenges for human operators. One of the significant advantages of autonomous tractors is the reduction in labor costs, streamlining operations, and contributing to cost savings for farmers. This data empowers farmers to make informed decisions about crop management strategies. Furthermore, the use of autonomous tractors promotes sustainable farming practices by optimizing resource utilization and minimizing the over-application of fertilizers or pesticides, thereby reducing the environmental footprint of agricultural activities.

Example: **Autonomous tractors.**



Figure 4. Autonomous tractors

4.2. Machine learning

Machine learning in agriculture harnesses the power of data analysis and predictive modeling to optimize farming practices and enhance crop management [28], [31-33]. Problem: Farmers need to accurately predict the production of crops to make planning about planting, resource allocation, and marketing strategies. In the realm of agriculture, the utilization of machine learning involves a systematic approach. Farmers first gather diverse data on weather, soil, pests, and past yields. After preparing and structuring the data, relevant features influencing crop yields are selected. Machine learning models, including regression or advanced algorithms like Random Forest or Gradient Boosting, are then trained on historical data for yield prediction. Model validation ensures accuracy through techniques like cross-validation. Integrating real-time data sources like weather forecasts and soil sensors enables continual model updates for precise predictions.

Example: **Predictive Crop Yield Modeling.**



Figure 5. Benefits of machine learning

Machine learning in agriculture brings forth numerous benefits. Firstly, it aids farmers in predicting crop yields for upcoming seasons, facilitating better planning and efficient resource allocation. If the model forecasts a low yield, farmers can adjust planting densities or invest more in irrigation and fertilization to optimize production. Secondly, by anticipating potential yield variations attributed to weather conditions or other factors, farmers can implement risk mitigation strategies such as crop insurance or diversification, safeguarding their investments. Lastly, machine learning optimizes the use of crucial resources like water, fertilizer, and pesticides, minimizing waste and mitigating adverse environmental effects, ensuring sustainable agricultural practices.

4.3. Drones and UAVs in Agriculture

Drones and UAVs have gained widespread adoption in agriculture due to their ability to capture high-resolution aerial data quickly and cost-effectively. They provide valuable insights into crop health, soil conditions, and farm management [32]. Crop analysis and monitoring are two of the main uses of drones in agriculture. Drones with cameras and sensors may collect precise data and photographs from above the fields. The benefits of drones and UAVs in agriculture are depicted in Figure. 6. Drones are playing a pivotal role in modern agriculture through their diverse capabilities. Aerial imaging [35] allows farmers to gain comprehensive insights into their crops' health, growth, and potential issues, aiding in timely interventions. Some drones utilize multispectral cameras to capture data beyond human vision, revealing crucial information about plant health, nutrient levels, and stress factors. NDVI maps derived from drone data assist farmers in identifying areas that require special attention, distinguishing stress indicators from healthy vegetation. Moreover, drones contribute to pest and disease detection by analyzing crop images for unusual patterns or color changes, enabling early intervention. Equipped with specialized sensors, drones can also collect vital soil data, including moisture content and nutrient levels, facilitating optimized irrigation and fertilization strategies. This data-driven approach empowers farmers to practice precision agriculture, minimizing resource wastage and enhancing overall yield and quality.

Example: Crop Monitoring and Analysis.

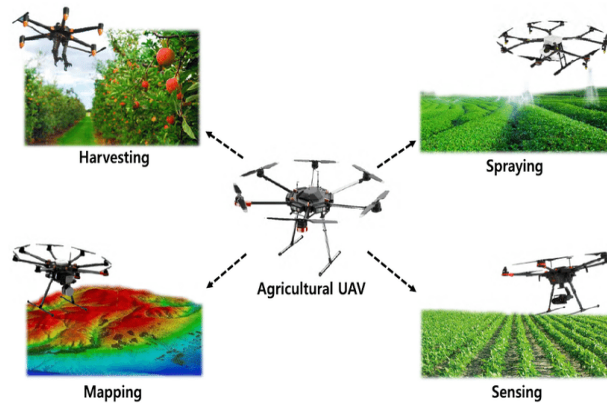


Figure 6. Benefits of UAV

4.4. Gene-based approaches

The ideas of natural selection and genetics serve as the foundation for genetic algorithms, which are optimization approaches [37]. Problem: Crop rotation is a critical practice in agriculture to maintain soil health and reduce the risk of pests and diseases. Farmers need to determine the best crop rotation plan for their fields to maximize yields and minimize soil degradation while adhering to specific crop rotation rules. Genetic algorithms offer a systematic approach to optimizing crop rotation plans. Initially, potential solutions are encoded as sequences of crops, each represented as a gene. An initial population of rotation plans is created, incorporating random or semi-random crop combinations. The evaluation of these plans relies on a defined fitness function, assessing adherence to objectives like maximizing yield, minimizing soil nutrient depletion, and adhering to crop rotation rules. The selection of individuals from the population is based on their fitness scores, favoring those that align more closely with the set objectives. Through crossover, pairs of selected individuals exchange segments of their crop sequences, generating new solutions that continue to be evaluated and refined based on the defined criteria. Genetic algorithms contribute significantly to agriculture, particularly in optimizing crop rotation. They aid farmers in identifying optimal crop rotation plans that maximize yields, foster soil health, and minimize the risk of pests and diseases. By strategically planning crop rotations, farmers can enhance resource efficiency, reducing the reliance on fertilizers, pesticides, and irrigation while maintaining productivity. Emphasizing sustainable crop rotations is crucial for ensuring the long-term viability of agriculture, as it prevents soil degradation and fosters biodiversity, promoting a balanced and resilient ecosystem.

Example: Crop Rotation Optimization.

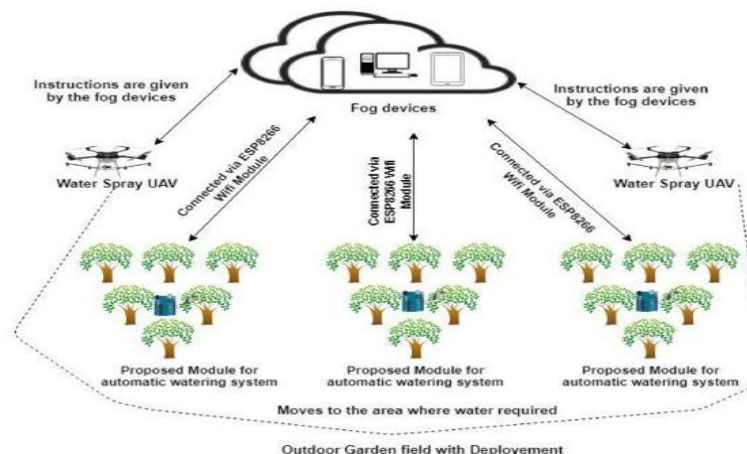


Figure 7. Generic algorithms based on IoPAT

5. Societal Implications of Agriculture Using Automation

The infusion of agro-automation in farming is ushering in a profound transformation with a myriad of social implications that touch upon various facets of society [38]. Foremost among these is the evolving landscape of agricultural labor. As AI-powered machinery and robotics automate a range of tasks, there is a potential reconfiguration of labor dynamics in farming communities. While this automation can boost productivity and reduce labor demands, it may simultaneously lead to job displacement, particularly for those engaged in manual and repetitive agricultural work. Such a shift necessitates a proactive approach to workforce adaptation, entailing investments in training and upskilling programs to equip agricultural workers with the digital literacy and technical know-how to manage and maintain AI-driven farming technologies. Simultaneously, it highlights the need for policies that address potential employment disparities stemming from automation.

6. Aggro-Tech Ethics

Transparency and accountability in AI systems are integral to maintaining ethical standards. Farmers must have a clear understanding of how AI algorithms make decisions and recommendations, especially when these technologies play a pivotal role in critical farming operations. Ensuring that AI systems are explainable and that farmers can comprehend the basis for AI-driven insights fosters trust and encourages responsible use.

Moreover, ethical considerations extend to the environmental impact of AI in agriculture. While AI holds the potential to optimize resource use, reduce waste, and promote sustainable farming practices, there is also the risk of overreliance on technology, leading to resource-intensive practices that harm ecosystems and biodiversity. Ethical agricultural AI should prioritize environmental sustainability, striving to strike a balance between technological advancement and ecological responsibility. Finally, ethical dilemmas may arise concerning the integration of AI and human decision-making [38]. Farmers must retain agency and autonomy in their operations, with AI technologies serving as valuable tools rather than replacing human judgment entirely. Ethical AI in agriculture should empower farmers by providing them with information and insights to make informed decisions while respecting their expertise and traditional knowledge.

7. Convergence of AI in Agriculture

It is a dynamic convergence of diverse fields, each contributing essential expertise to harness AI's transformative potential for the betterment of agriculture and food production. At the heart of this alignment is the synergy between AI and agricultural sciences. AI-driven data analytics, coupled with agronomic knowledge, enable precision farming practices that optimize crop yields, minimize resource use, and mitigate environmental impact. This interdisciplinary approach empowers farmers with data-driven insights to make informed decisions, leading to more sustainable and efficient farming practices. Biotechnology also plays a pivotal role in this alignment, as AI-driven genetic analysis and breeding techniques enhance crop resilience and nutritional value. Machine learning models can predict the genetic traits of plants with greater accuracy, expediting the development of crop kinds that are more suited to adjusting to changing environments and capable of addressing global food security challenges.

8. Conclusion

In conclusion, the combination of agriculture and artificial intelligence represents a pivotal moment in the ongoing quest to meet the challenges of a growing global population and an ever-changing climate. AI's infusion into agriculture has unlocked a wealth of opportunities, from precision farming and crop monitoring to sustainable resource management and predictive analytics. It has empowered farmers with unprecedented insights and tools to optimize their practices, reduce waste, and enhance yields. Moreover, this interdisciplinary alignment of AI with agriculture has underscored the importance of collaboration among experts in agronomy, biotechnology, environmental sciences, economics, ethics, and more. However, it's important to continue to be mindful of the ethical, social, and environmental implications as embrace the transformational power of AI in agriculture. In order to make sure that the advantages of AI are distributed widely and morally, data privacy, equal access, and responsible AI deployment must continue to be at the forefront of thinking. Additionally, must continue to address issues related to workforce displacement, particularly in rural communities, by offering

training and support for those affected by automation. AI's role in agriculture is a dynamic and evolving one, and as look to the future, it is clear that responsible innovation and thoughtful adaptation will be key. By embracing AI technologies while maintaining a commitment to ethical and sustainable practices, can build a more resilient and food-secure world, where agriculture not only meets current needs but also anticipates and addresses the challenges of tomorrow. The journey of AI in agriculture is a testament to the ability to leverage cutting-edge technology to overcome complex global issues and cultivate a brighter, more sustainable future for agriculture and food production.

References

- [1] Kok J N, Boers E J W, Kusters W A, et al, "Artificial Intelligence: definition, trends, techniques, and cases [C]", *International symposium on Southeast Asia Water Environment*, 2002.
- [2] Kevin Warwick, "Artificial Intelligence: The Basics[M]", *Routledge*, 2011.
- [3] Dobrev, D, "A Definition of Artificial Intelligence", arXiv preprint arXiv:1210.1568, 2012.
- [4] Nilsson, Nils J, "Principles of artificial intelligence", *Morgan Kaufmann*, 2014
- [5] Cook & O'Neill, Tekinerdogan, Bedir, Ryan, Mark "An interdisciplinary approach to artificial intelligence in agriculture", Article: 2168568, 2023.
- [6] T. Davenport, Tekinerdogan, Bedir, Ryan, Mark "AI composes a series of approaches, methods, and techniques to simulate intelligent behavior", Article: 2168568, 2023.
- [7] Albiero, D, "Agricultural robotics: A promising challenge", *Current Agriculture Research Journal*, 7(1), 1, 2019.
- [8] Almeria, S., Lopez-Gatius, F., Garcia-Ispuerto, I., Nogareda, C., Bech-Sabat, G., Serrano, B., Santolaria, P., & Yaniz, J. L, "Effects of crossbreed pregnancies on the abortion risk of Neospora caninum-infected dairy cows", *Veterinary parasitology*, 163, 323–31, 2021.
- [9] Aggarwal, N., & Singh, D, "Technology-assisted farming: Implications of IoT and AI", in IOP Conference Series: *Materials Science and Engineering*, IOP Publishing, p. 012080, 2021.
- [10] Madsen, E.L, "Impacts of agricultural practices on subsurface microbial ecology", In *Advances in Agronomy*; Elsevier: Amsterdam, The Netherlands; Volume 54, pp. 1–67. ISBN 978-0-12-000754-7, 1995.
- [11] Elavarasan, D.; Vincent, D.R.; Sharma, V.; Zomaya, A.Y.; Srinivasan, K, "Forecasting yield by integrating agrarian factors and machine learning models: A survey", *Comput. Electron. Agric.*, 155, 257–282, 2018.
- [12] Atzberger, C, "Advances in remote sensing of agriculture: Context description, existing operational monitoring systems and major information needs", *Remote Sens.*, 5, 949–981, 2013.
- [13] Kreuze, J.; Adewopo, J.; Selvaraj, M.; Mwanzia, L.; Kumar, P.L.; Cuellar, W.J.; Legg, J.P.; Hughes, D.P.; Blomme, G, " Innovative digital technologies to monitor and control pest and disease threats in root, tuber, and banana (RT&B) cropping systems: Progress and prospects", In *Root, Tuber and Banana Food System Innovations*; Thiele, G., Friedmann, M., Campos, H., Polar, V., Bentley, J.W., Eds.; Springer International Publishing: Cham, Switzerland; pp. 261–288. ISBN 978-3-030-92021-0, 2002.
- [14] Koech, R.; Langat, P., "Improving irrigation water use efficiency: A review of advances, challenges and opportunities in the Australian context", *Water*, 10, 1771, 2018.
- [15] Khanna, A.; Kaur, S, "Evolution of Internet of Things (IoT) and its significant impact in the field of precision agriculture", *Comput. Electron. Agric.*, 157, 218–231, 2019.
- [16] Carter, P.G.; Johannsen, C.J, "Site-specific soil management", In *Reference Module in Earth Systems and Environmental Sciences*; Elsevier: Amsterdam, The Netherlands, p. B978012409548910497X. ISBN 978-0-12-409548-9, 2017.
- [17] Karaşahin, M.; Dündar, Ö.; Samancı, A., "The way of yield increasing and cost reducing in agriculture: Smart irrigation and fertigation.", *Turk. JAF Sci. Tech.*, 6, 1370, 2018.
- [18] Vashisht, S.; Kumar, P.; Trivedi, M.C. "Improvised extreme learning machine for crop yield prediction.", In *Proceedings of the 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM)*, London, UK, 27–29 April 2022; IEEE: Manhattan, NY, USA; pp. 754–757, 2022.

- [19] Chen, K.-H.; Lin, C.-C.; Chen, C.-H.; Lee, J.-C.; Wu, C.-T, “Crop classification on deep learning.”, Proceedings of the 2022 IET International Conference on Engineering Technologies and Applications (IET-ICETA), Changhua, Taiwan, 14–16 October; IEEE: Manhattan, NY, USA, 2022; pp. 1–2, 2022.
- [20] Lucas, J.A., “Advances in plant disease and pest management.”, J. Agric. Sci., 149, 91–114., 2011.
- [21] Roland Ebel, “British Columbia - Edible Invasive Plants.”, Canada Responsible Forager, 2022.
- [22] Prajwala, T.R.; Ramesh, D.; Venugopal, H., “Modeling and Forecasting of Rainfall using IoT sensors and Adaptive Boost Classifier for a Region.”, SSRN Electron. J., 58–61, 2021
- [23] Zheng, W., Liu, X., Ni, X., Yin, L., and Yang, B., “Improving visual reasoning through semantic representation.”, IEEE Access 9, 91476–91486. doi:10.1109/access.2021.3074937, 2021.
- [24] Surendra K Dara, “Journal of Integrated Pest Management”, Volume 10, Issue 1, 12, 2019.
- [25] Dr. Vicente Serna-Escolano, Alicia Dobón-Suárez, “Effect of Fertigation on the Physicochemical Quality”, Agriculture13(4), 766; 2023.
- [26] Dover, “Department of Agriculture & Natural Resources”, Delaware State University, DE 19901, USA Soil Syst.,5(4), 61; 2021.
- [27] William J. Cosgrove, Daniel P. Loucks. “Water management: Current and future challenges and research directions”, First published: 20 June, 2015.
- [28] Ruiz-Real, J.L.; Uribe-Toril, J.; Torres Arriaza, J.A.; de Pablo Valenciano, J., “A look at the past, present, and future research trends of artificial intelligence in agriculture.” Agronomy, 10, 1839., 2020.
- [29] Russell, S.J.; Norvig, P., “Pearson Series in Artificial Intelligence”, Artificial Intelligence: A Modern Approach, 4th ed.; Pearson: Hoboken, NJ, USA; ISBN 978-0-13-461099-3., 2021.
- [30] Prof. Dr. Rosana Cavalcante de Oliveira and Dr. Rogerio Diogne De Souza E Silva, “Artificial Intelligence in Agriculture: Benefits, Challenges, and Trends”, Appl. Sci., 2023.
- [31] Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.-J. “Big data in smart farming—A review.”, Agric. Syst., 153, 69–80., 2017.
- [32] Talaviya, T.; Shah, D.; Patel, N.; Yagnik, H.; Shah, M., “Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides.”, Artif. Intell. Agric. 2020, 4, 58–73. 2020.
- [33] Williams, H.A.M.; Jones, M.H.; Nejati, M.; Seabright, M.J.; Bell, J.; Penhall, N.D.; Barnett, J.J.; Duke, M.D.; Scarfe, A.J.; Ahn, et al. “Robotic kiwifruit harvesting using machine vision, convolutional neural networks, and robotic arms.”, Biosyst. Eng, 181, 140–156. , 2019.
- [34] Connector Supplier (website), “Autonomous Tractors Take the Farmer Out of the Fields”, September 15, 2020.
- [35] CONSORTIO (website), “How farmers are using drones in agriculture”, 2020.
- [36] Ajitesh Kumar, “Agriculture Use Cases & Machine Learning Applications”, Analytics Yogi, September 30, 2021
- [37] Sayan Kumar Roy, Debashis De, “Genetic Algorithm based Internet of Precision Agricultural Things (IoT) for Agriculture Internet”, Volume 18, 100201, May 2022.
- [38] Mark Ryan1, “The social and ethical impacts of artificial intelligence in agriculture”, *mapping the agricultural AI literature*, 2021.